

Chapter 4.

Physical design concepts of the geodatabase

4.1. Implement, prototype, review and refine the design

A geodatabase have been created, compiled of different feature classes, tables and entities. This section describes the implementation of the different features provided in the geodatabase and are presented in three phases.

Subsequently to the conceptual and the logical design of the geodatabase, the physical design was established. The conceptual and logical design concentrated on defining, identifying and specifying all the data components that would contribute to the general structure of the geodatabase. The physical design contains the physical execution of the conceptual and logical design, combining all the components of the geodatabase in one central place of storage.

4.1.1. Phase 1

Within the ArcCatalog environment a new file geodatabase named “PUK_Kampus5” were created with a storage capacity of up to 1TB. The application and purpose of the geodatabase had to be stipulated to ensure the correct compilation of the participating features. With the latter confirmed a feature dataset named “Water” were created. Prior to any other step executed in the geodatabase design, the Universal Transverse Mercator, WGS 1984 UTM Zone 35S co-ordinate system were specified which were imported from the QuickBird image (2008) referred to in Chapter 2. The QuickBird image (2008) already had the same co-ordinate system defined which also matched the chosen co-ordinate system for the feature dataset. Following the creation of the feature dataset and based on the current data provided, relevant feature classes were created within the “PUK_Kampus5 geodatabase as represented in Figure 4.1. Serving an “organized set of files” within the geodatabase, the feature classes are represented as layers that are used throughout the geodatabase and also contain spatial data that could visually be represented in ArcMap and ArcScene.

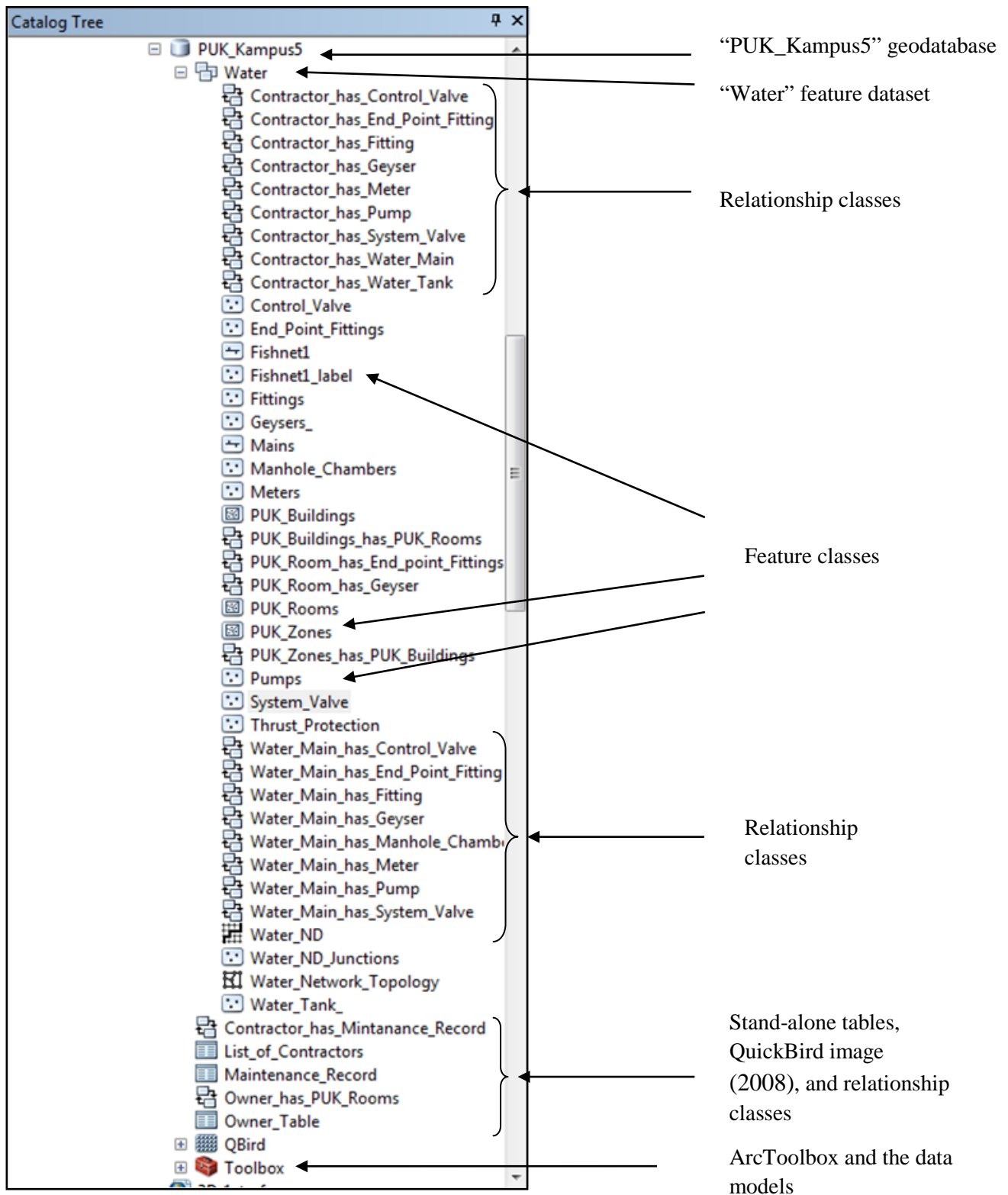


Figure 4.1. The water feature dataset

With the creation of each feature class, specifying attribute fields for the features that each layer represents were created inside of each feature class. It is also necessary to select the tick box “Co-ordinates include Z values” used to store 3D data under “Geometry Properties” with the onset of every new feature class created. This way 3D elevation values could be added to

the features. With reference to Chapter 3, a holistic view of the geodatabase and the feature classes contained within were examined. A set of predefined information values in the form of domains was created based on the nature of each feature class. Serving as additional information bearing components to the feature classes, stand-alone tables were also created. The relationship classes, together with the network dataset and the topological dataset were created as supportive mediums for the features participating in the model. Subsequently, the feature dataset, the stand alone tables and the QuickBird image (2008) are located followed by the ArcToolbox created specifically for the model. The layout of the geodatabase is, indicated in Figure 4.1.

The amount and nature of information that are created or imported into the geodatabase should be examined throughout the design especially whenever the need for a new table or field arises. Domains, subtypes and default settings are all subjected to the nature and behaviour of the data as well as the way it need to be represented. Whenever a default value is created for a field inside a feature class, the newly created object in that field would take on the default value specified for that field. However, when deciding between the creation of an extra table or creating a domain or subtype the amount and value of information that would be represented by each of these motivates the decision. With reference to Chapter 2, domains are created directly in the geodatabase and could be applied in more than one field for more than one feature.

Subtypes and domains are both created for the benefit of the data specified for the geodatabase. In order to ensure the correct application of either a subtype or domain, the question should be to what extent data regarding to the feature should be provided. Whenever a specification should be available for more than one feature throughout the geodatabase, it should be advised rather to create a domain for the specified selection. Subtypes are feature specific, created for a single feature indicating different types of that feature. Considering the prospect of being visualized according to specific values and symbology, applying subtypes provides a great advantage in the representation of data. Using subtypes also entails the option of selecting and representing the different types according to the specified value fields that selected features consists of. Subtypes and domains simplify the editing of attributes after the data were created. Domains and subtypes promote data integrity within the fields of the feature classes and are accompanied by stand-alone tables which provide additional sets of information for a specific feature.

Placing the points representing the fittings in the system, there had to be decided how and what each point would represent. After looking at the system holistically, there were decided to create two separate feature classes, each representing the fittings in the network and the endpoint fittings. The reason for this division was to accommodate the two different feature classes. Because each of these feature classes has specific features with specific functions in the system, it was better to separate the features from each other in order to ensure that each feature type could have its own subtypes defined for it. Each of these endpoint fittings also represents the location of the endpoint features in the network such as the basin taps, the urinals, toilets, bath tubs etc. It is also necessary to symbolize these features differently. The grouping of different features together in one feature class also promotes the management of the different features. However for the same reason, the amount of feature classes should also be limited.

With the creation of every feature class and every field defining the attributes thereof, possible relations between the different features were constantly considered. Extremely careful planning was done in order to ensure that the fields will be correctly created in the geodatabase with the focus on creating effective relationships between the participating features. Microsoft Access contributed greatly to the ease and effectiveness in the planning process which includes modelling the proposed relationships. Within this environment, feature classes were created, subtypes added and the relations between the features easily resembled. Access also provided the possibility to arrange the feature classes as desired and grouping the ones related together. Feature classes were able to be moved and organized in order to find the most suitable way of relating the features. This way, it would also be much easier to see whether a field is related more than once and the relationship could then neatly be deleted.

Eventually the application of Microsoft Access promoted visual representation of the planning process between the features. In comparison with executing this phase of the project on paper, utilizing Microsoft Access provided an editing environment that could be adjusted without having to erase many lines and entities on paper. Both, time effectiveness and simplicity in design were promoted. This process also modelled a complete layout view of all the features classes with their relationships in a single scene as indicated in Figure 4.2.

4.1.2. Phase 2 - Importing CAD and digitizing in ArcMap

Regarding the physical design of the geodatabase, it was necessary to create a standard geodatabase that could serve as a platform to work from. However, at the onset of the project the feature classes and the tables were still empty with no data. The importance of having a structure in place is of utmost importance. CAD data were copied to a secure location on the hard drive from where it was easily accessed. The drawings, created in a “dwg” or “dgn” format, were viewed in ArcCatalog and analyzed in order to look for ways to apply it in the design. The visual representation of the project started off with the QuickBird image (2008) that served as the key frame of reference for the CAD data due to its predefined projection. Working with electronic CAD data simplified the process by importing the drawings into GIS from where it was digitized in ArcMap.

The first attempt to reference and adjust the CAD drawings according to the QuickBird image (2008) was to apply the “Spatial Adjustment” procedure. This process entailed the importation of the CAD data into ArcMap, together with the QuickBird image (2008). In order to align the CAD drawings according to the reference format of the QuickBird image (2008), the “Spatial Adjustment” toolbar were added to the editing window. Firstly the CAD drawings were exported to a “shapefile” format in order to make the drawings more usable for the purposes required in the “Spatial Adjustment” environment. The editing of the drawings started right after “Start Editing” was selected and end snapping enabled. In the “Spatial Adjustment” toolbar the “New Displacement” link were selected. A corner on the CAD drawing was chosen and the corresponding corner on the QuickBird image (2008) was also selected. More than one of these reference points was selected in order to accurately align the CAD drawing with the points matching the QuickBird image (2008). These steps were followed by spatially adjusting the CAD drawing and selecting “Set Adjust Data” and managing to the “Adjust” selection provided. The result of this procedure is indicated in Figure 4.3.

The disadvantages of this process are that confusion could occur whenever a building plan was exported as a shapefile. The data lines that the shapefile consists of are represented in one colour which makes it hard to distinguish between the different features represented in the shapefile. The actual complication occurs whenever the features in the shapefile have to be related with the features in the QuickBird image (2008). The images have to be aligned by means of reference lines connecting the relevant reference points between the two images.

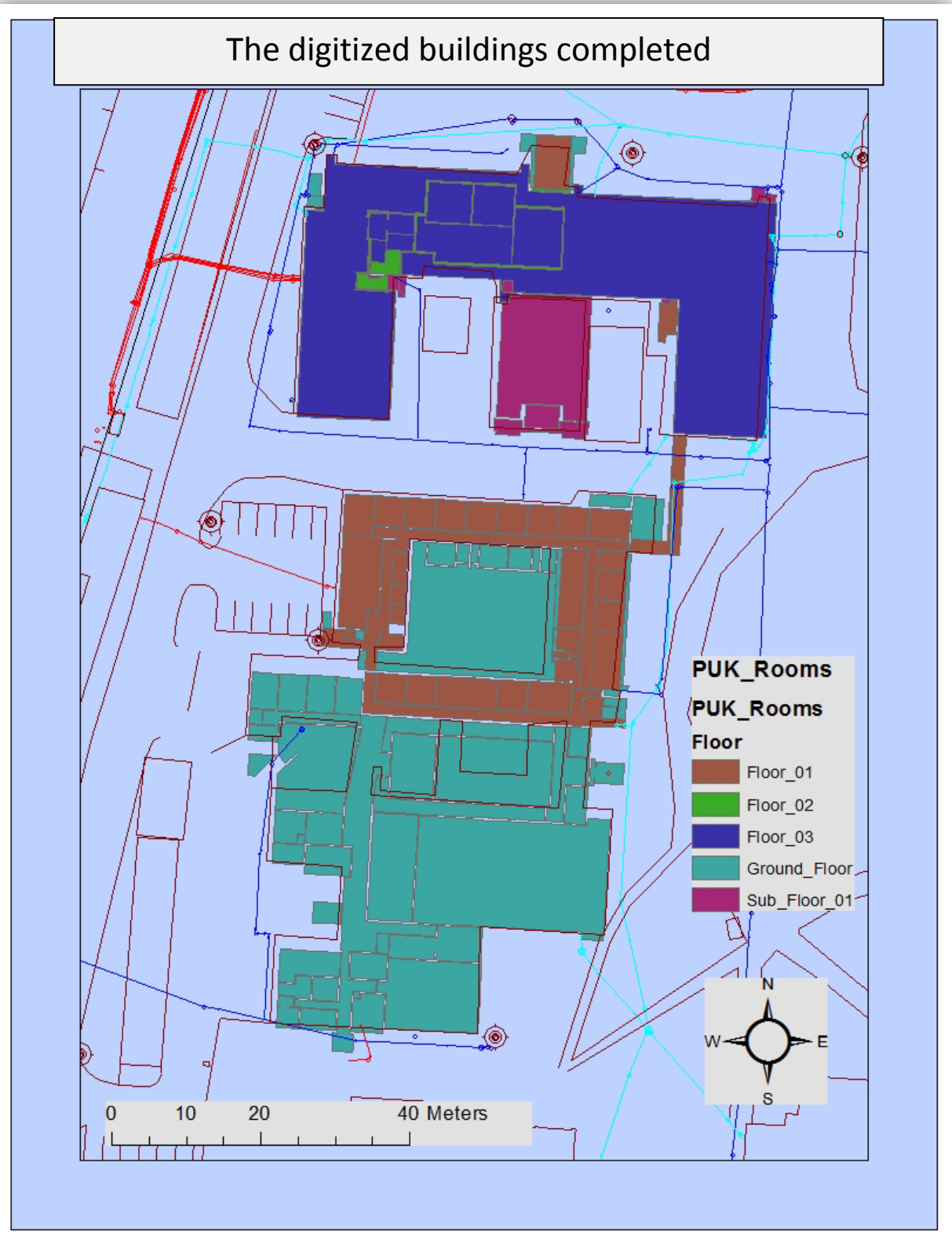


Figure 4.3. A design representation of the room polygons

However the execution of this procedure could not be applied effectively if the different polylines representing the shapefile image could not be distinguished from each other. Another disadvantage that could generally not be avoided and might influence the accuracy of the adjustment is the shadows present on the QuickBird image (2008), which are created by natural features covering some sections of the buildings. The fact that more selected reference points need to be placed to ensure greater accuracy of the adjusted CAD drawing is a valid point that should be stressed. However, this process is extremely time intensive and have to be executed with great accuracy to avoid an inaccurate spatial adjustment of the CAD drawings.

A positive remark to this process is that the adjusted CAD drawing could be adjusted, aligned, shifted and scaled to suite the backdrop reference image more accurately afterwards. The risk of deskewing the adjusted reference drawing could however occur in this process. In the light of the aforementioned, it was found that the “Scaling” tool was not the most user friendly application to be used in this instance which contributes to the disadvantages of the spatial adjustment process.

With the help of the georeferencing toolbar the “Add Control Points” function were selected and the CAD drawings were aligned according to the location of the buildings in the QuickBird satellite image (2008) which served as the medium of reference for the CAD drawings. After the control points were created for referencing the CAD drawing, the co-ordinates and alignment information were accessed by clicking on the “View Link Table” tab. A table displayed the co-ordinates and the location information of the new referenced CAD drawing and the information were saved in the “wld”. format. This “wld. file” that were created for the CAD drawings were saved and served as the source of reference for the rest of the CAD drawings. After a “wld. file” have been created it could easily be recalled for adjusting and referencing another CAD file. The process is indicated with the following steps:

The QuickBird image (2008) is added to ArcMap followed by the addition of the polylines version of the CAD data located inside a folder containing all the relevant CAD drawings. At first a warning message could be presented stating that the CAD drawing does not contain any form of spatial reference. However, due to the georeferencing procedure executed on a previous CAD drawing the saved “wld. file” could now be applied to the newly imported CAD drawing without having to repeat the georeferencing procedure again. By right clicking

on the CAD drawing next to the tick box the properties of that drawing could be accessed. The transformations tab within the properties window was selected and the “World File Name” for the drawing could be specified. The “Enable Transformations” box should be ticked followed by selecting the “Browse” button. Managing the location where the “wld. file” is saved, it could now be recalled and applied to the current CAD drawing (Figure 4.4). The newly CAD drawing would then be located exactly over the QuickBird image (2008) according to the georeferenced procedure earlier executed and represented in Figure 4.5. The image represented in Figure 4.5 also indicates that the QuickBird image (2008) and the CAD drawing are not perfectly aligned and shadows created by natural features obstruct the visual accuracy.

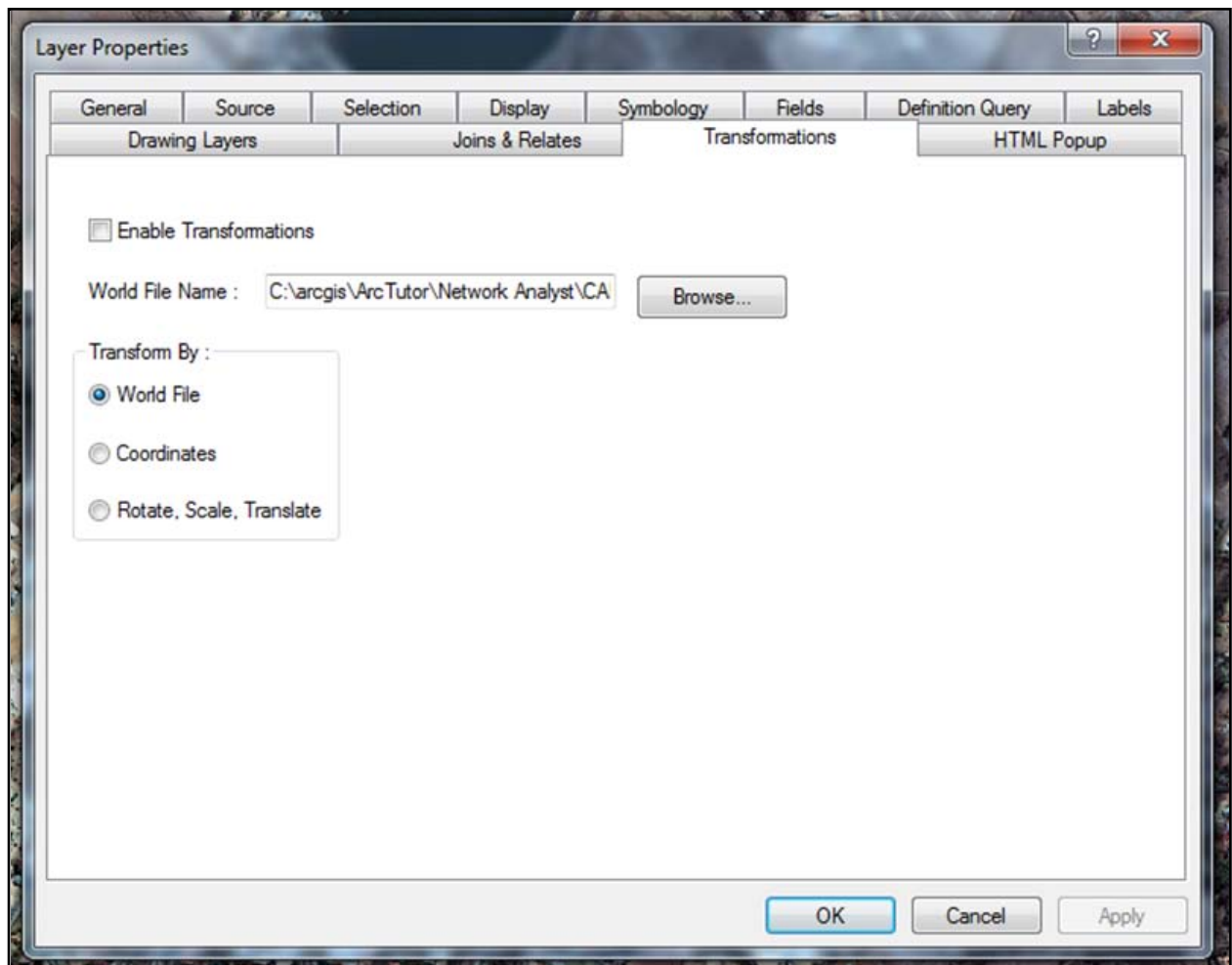


Figure 4.4. The “Transformations” environment

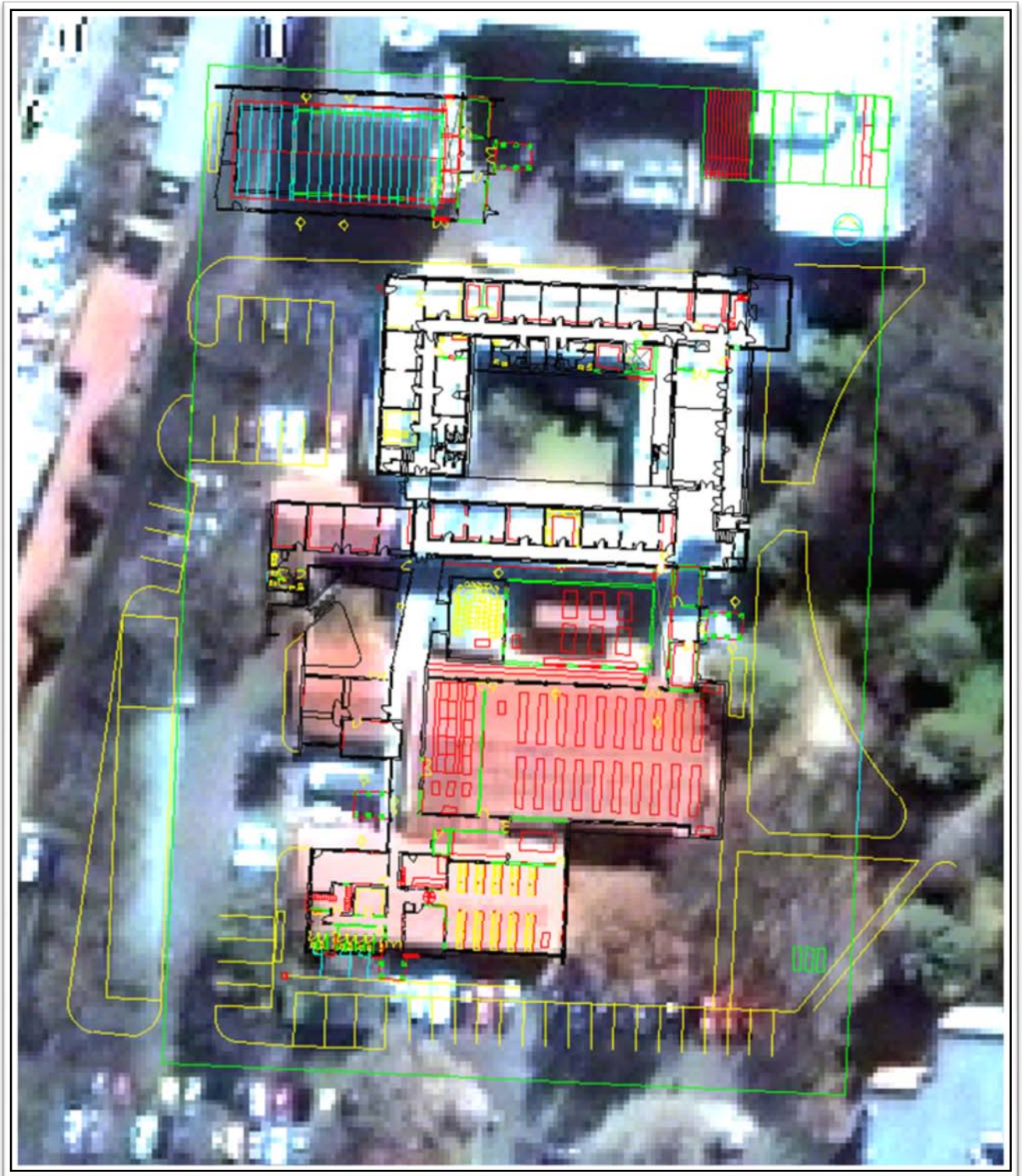


Figure 4.5. The CAD drawing referenced over the QuickBird image (2008)

Primarily the “PUK_Zones” that represent the management zones for the campus were digitized in order to provide a holistic representation of the study area within the campus. This process was followed by digitizing the building outlines of buildings E4 and E6 that serves as the focus of the study area. In general the “PUK_Zones” (Figure 4.6.), and “PUK_Buildings” (Figure 4.7) mainly serve as mediums of orientation for the location of the network features and the components thereof. The layout of the “PUK_Zones” after it has been digitized is indicated in Figure 4.6. The purple polygon in Figure 4.6 represents zone two which are the focal polygon of the study area.

The digitized building outlines also serve as “containers” for the network that forms the focus of the study and are indicated in Figure 4.7. Following the digitizing of the “PUK_Zones” (also known as the management zones) and the buildings it was the next logical step to digitize each room in the two proposed buildings for the study area. The rooms however are not situated in one level only but four separate floors which includes a “Sub-level”, “Ground-level”, “First-level”, “Second-level” and “Third-level” as represented in Figure 4.8.

Referring to the 3D view of the rooms, the walls within the buildings had to be modelled too. Executing the digitizing process entailed digitizing of the rooms within the walls which means that the walls would automatically be created without having to create a separate feature class for it. This way the “empty spaces” between the rooms represents the walls which were also the most effective and uncomplicated way of representing the true reality of the rooms with the walls in between.

Whenever a point had to be placed, the selection “Point at end of line” was chosen, the first click of the placement resembles the selection of the base height which is the position in the floor level and could be placed anywhere in the editing environment. However, the second click had to be exactly on the correct spot relative to the point indicated on the building plan which is termed true height. This means that the height of the second point also had to correspond to the height of the floor level or the height level of e.g. the inlet for a basin, geyser, shower head, tap, or urinal. Referring to the lines in the network, these had to be created at a certain height as well. Although line features differ slightly from the creation of points in the network, they also have their specification on how each line section should be created. Referring to Table 4.1, line elevations exists either as a horizontal line in 3D space or as a vertical line in 3D space.

PUK_Zones

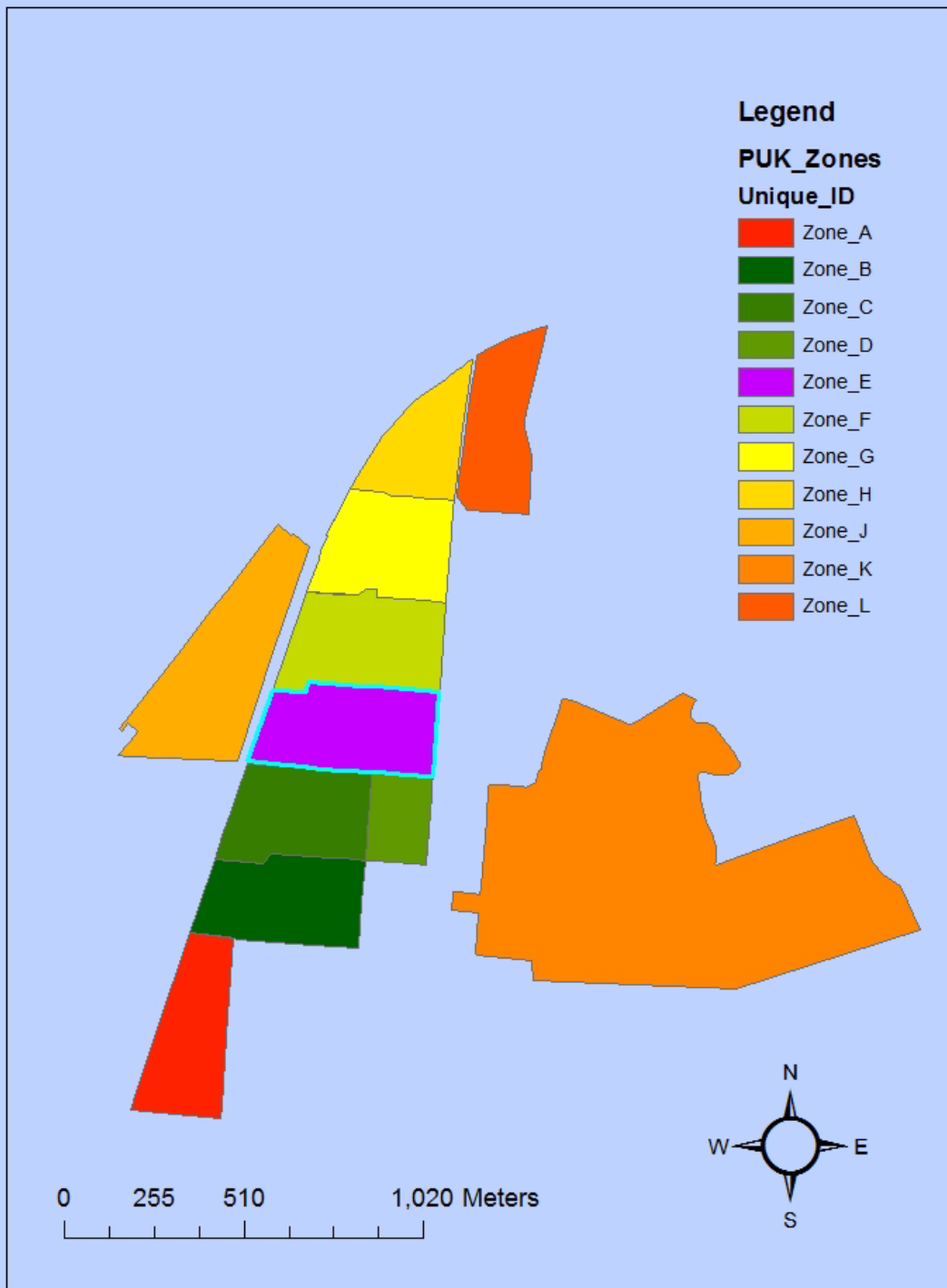


Figure 4.6. The layout of the PUK_Zones

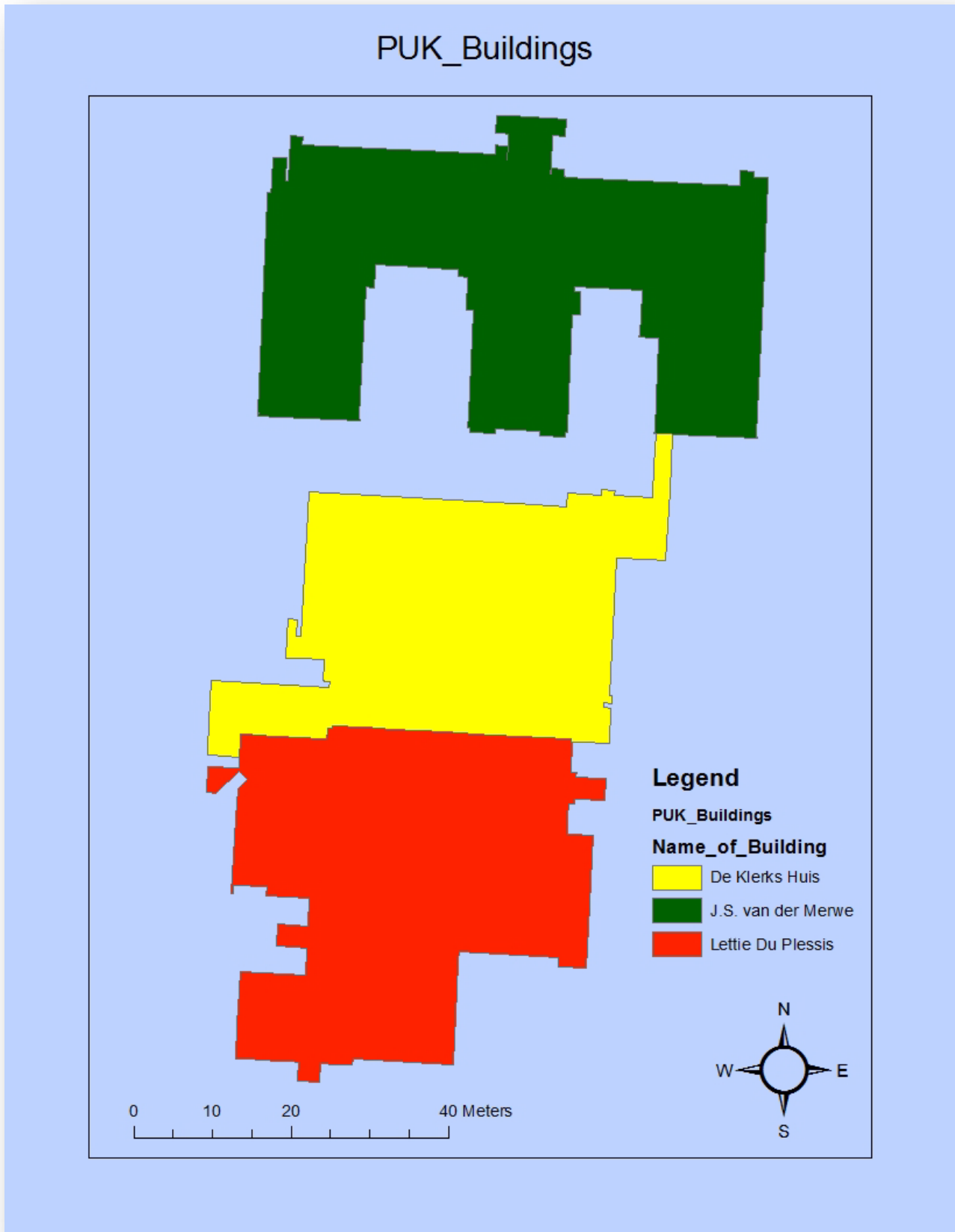


Figure 4.7. The layout of the PUK_Buildings after the digitizing process

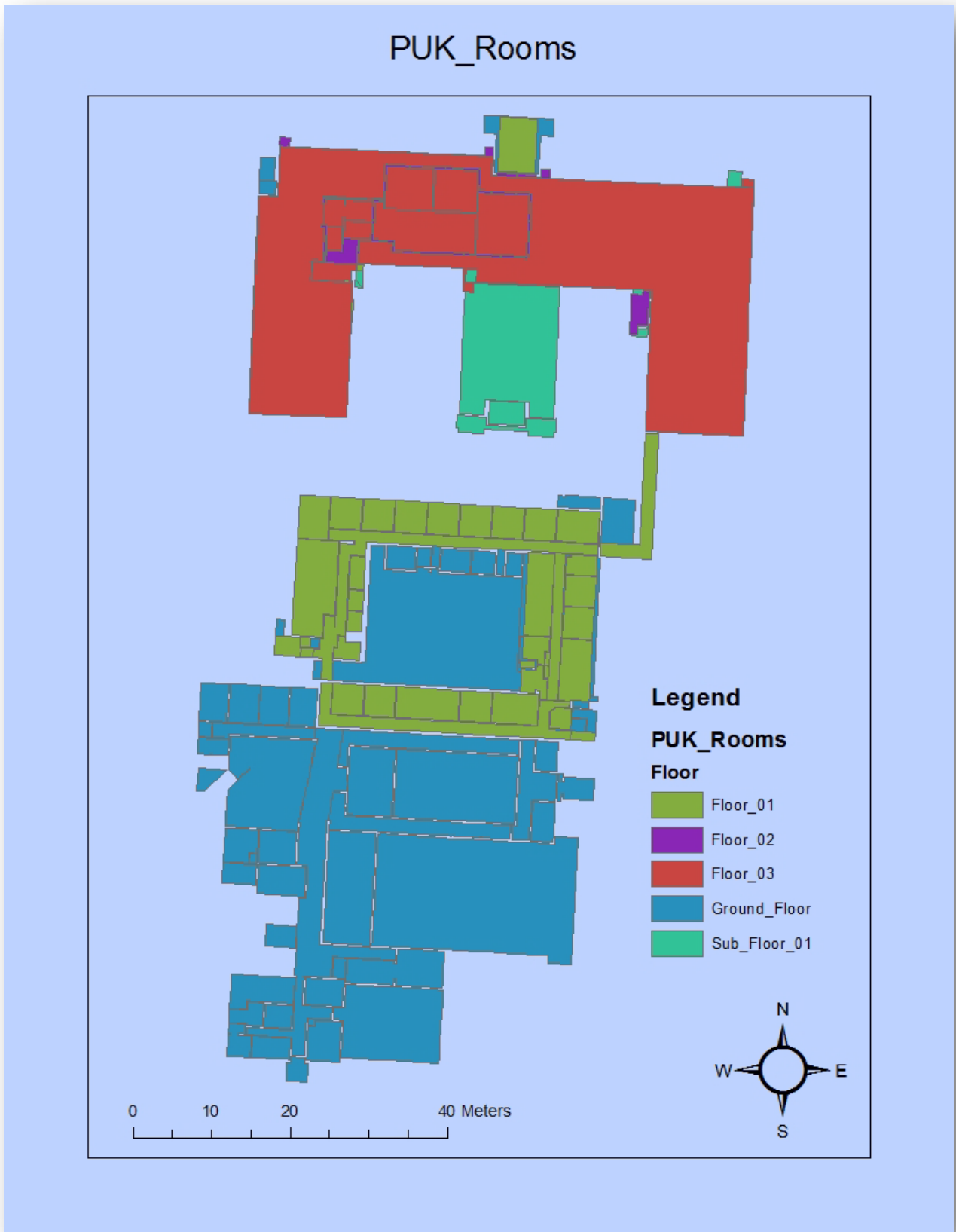


Figure 4.8. The PUK_Rooms after the digitizing process

Figure 4.9 represents the digitized PUK_Rooms (Figure 4.8) in a 3D view. The resemblance of the “PUK_Buildings” in ArcScene was executed by extruding the building outlines. The “Extrusion” tab was selected and subsequently the “Extrude features in layer” box selected adding an expression by which the digitized PUK_Buildings (Figure 4.7) were extruded as represented in Figure 4.10. The expression by which the buildings were extruded were done in the “Expression Builder” and were added as “[Number of Floors]*4”. Although the height of each floor was stipulated with a height of 5, the expression is multiplied by 4 which resemble the most accurate representation of the buildings. With the creation of the features, working and creating features in a logical order is one of the most important things that should be applied in order to ensure accurate editing of the data.

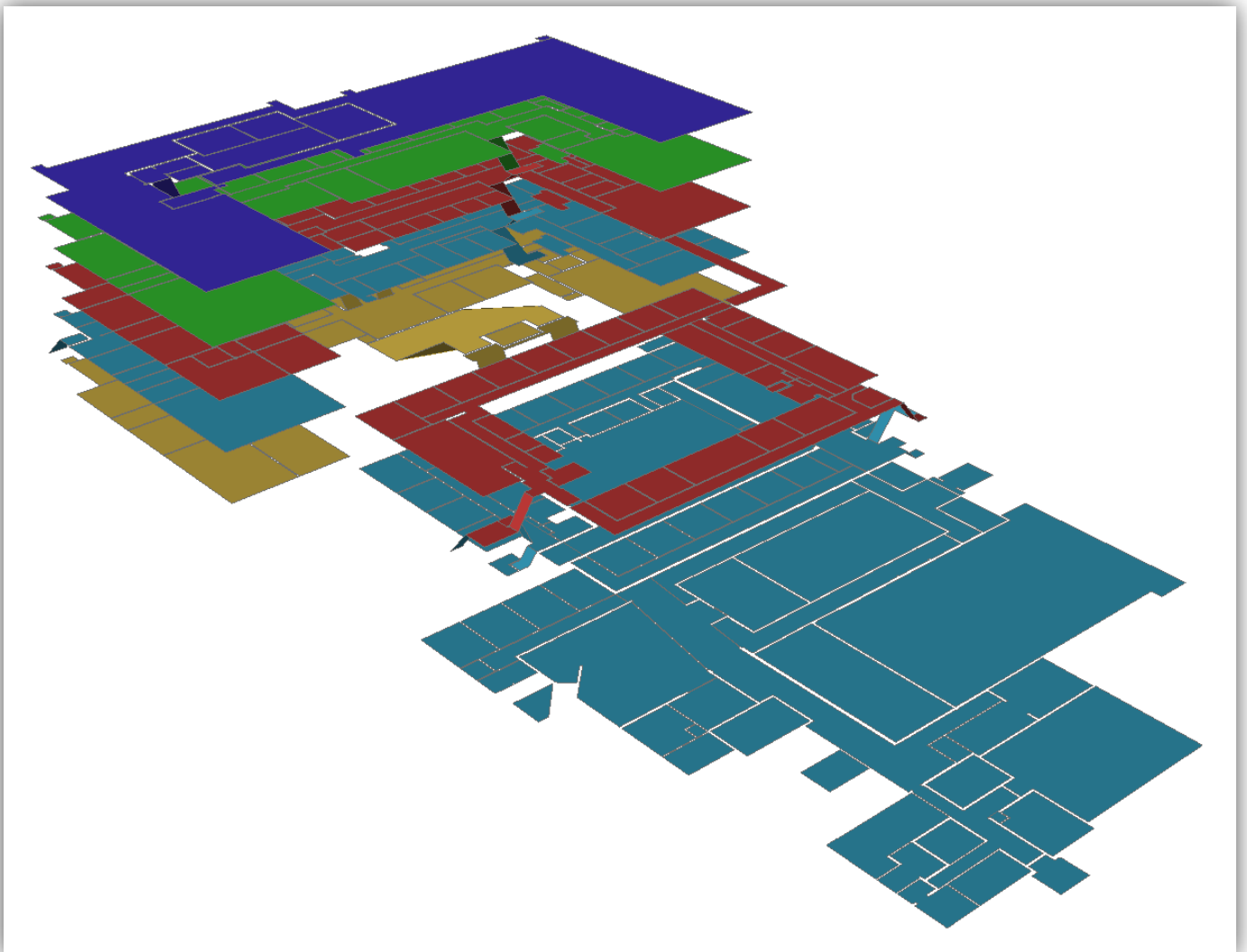


Figure 4.9. A 3D representation of the digitized PUK_Rooms

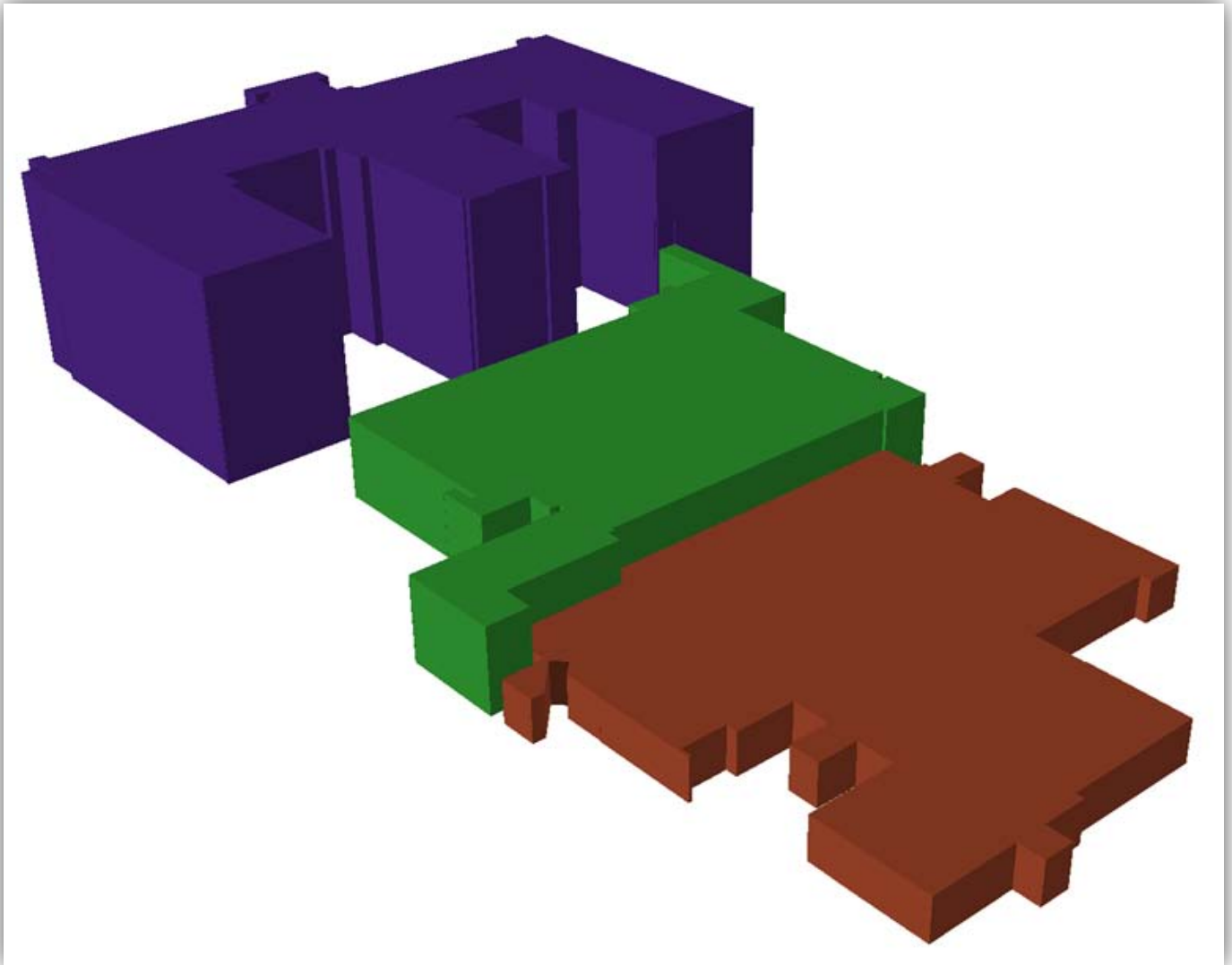


Figure 4.10. Resembles the digitized PUK_Buildings in a 3D view

4.1.3. Phase 3 - The editing of lines segments

A horizontal line in 3D space needs to have the two end points of the line located on the same elevation height. An error in this instance could result in a line tilted in space and most probably not able to connect to the corresponding fitting. In addition to the horizontal placement the vertical placement of the lines have a slight different approach. The first end point of placement requires to be connected to the point of origin (e.g. a fitting) and should therefore have the same height specifications as the point it originates from. The second selection for the point would be one specified for the initial height required for the line segment (e.g. a basin tap inlet).

Floor Level	Floor Elevation (meters)	Point Elevation	Line Elevation (horizontal)	Line Elevation (vertical)
Sub-Floor 1	-5m	-5m (placement at base height, position in floor level) -5m (placement at location, true height)	-5m (placement at base height and true height) -5m (placement at base height and true height)	-5m (placement at base height and true height) (?m) placement at extruded height
Ground-Floor	0m	0m (placement at base height, position in floor level) 0m (placement at location, true height)	0m (placement at base height and true height) 0m (placement at base height and true height)	0m (placement at base height and true height) (?m) placement at extruded height
Floor 1	5m	5m (placement at base height, position in floor level) 5m (placement at location, true height)	5m (placement at base height and true height) 5m (placement at base height and true height)	5m (placement at base height and true height) (?m) placement at extruded height
Floor 2	10m	10m (placement at base height, position in floor level) 10m (placement at location, true height)	10m (placement at base height and true height) 10m (placement at base height and true height)	10m (placement at base height and true height) (?m) placement at extruded height
Floor 3	15m	15m (placement at base height, position in floor level) 15m (placement at location, true height)	15m (placement at base height and true height) 15m (placement at base height and true height)	15m (placement at base height and true height) (?m) placement at extruded height

Table 4.1. A representation of the different floor levels and the utilities based on those levels

**Placement at base height is the placement of the point anywhere on the drawing indicating the base height of the selected point. Placement at true height is the placement of the point on*

the height indicated on the drawing. When placing a point, both height selections should be the same. When placing points for a line the height selections would differ.

In this model the height levels have been applied to fit intervals of 5 meters each in order to avoid unnecessary errors but also to represent the floor levels in intervals that would promote ease of editing. The focus of this prototype model is to indicate the application of the network within the buildings and the rooms and not so much the aesthetical representation of the buildings itself. Each level and each phase of the design contributes in its own unique way to the project as whole (Table 4.1).

With the infrastructural elements in place, a foundation for the development of the water network was established and the creation of the network was executed. The process entailed the placement of points at junctions and ends of lines strictly according to the building plans provided. Each point represents a certain feature in the network with attribute data describing the feature as an entity of the network. Starting off at the existing 50mm diameter water lines, the points relative to the water lines were placed. Every point had to be connected to a line and vice versa in order to complete the network without any spaces resulting in a successive line sections connected by means of points. The accuracy of the points snapping to the water main sections were supported by the “End Point Snapping” selection provided in ArcMap. The water network represented here models an “origin-to-end-point” network and not a circular network. Therefore, water provision flows from the origin to the end point which could be the inlet of a basin or toilet. In other words the model doesn’t need to have any directions modelled whenever a network dataset are created.

Referring to section 2.1, GIS are applied for understanding and displaying geographical referenced information. It is a software system that is applied for collecting and storing vast amounts of spatial information which could then be retrieved, analyzed and displayed (Zhu et al. 2009). GIS also represents information at the hand of layers creating interactive representations of those layers. The focus of GIS is therefore mainly on data storage and management and consists of the ability to represent the data graphically with descriptive information located within each feature. The focus of the CAD on the other hand is based on the aesthetical and creative design of building plans. GIS also proposes more than just an accurate representation of the building plans in a creative way but also provides the ability to visualize the plans and utilities in a two- and three-dimensional environment with the functionality to execute analyses on the participating features.

With the capabilities of GIS as an environmental management system, many of the development challenges for the network model were abridged. The 3D environment offers advanced real-life representations of the study area and the features within. It also promoted the ease in which the attribute data were created for each and every object in the model as represented in Figure 4.11. With the selection of a feature, the corresponding attribute information is automatically selected, which simplifies the procedure of obtaining the attribute information for that specific feature.

4.2. Design work flows for building and maintaining each layer

Figure 4.12 indicates the approach towards placing and creating a point in ArcMap. The editing environment was accessed with the selection of the “Start Editing” tab under “Editor” in ArcMap (1). The “Create Features” tree immediately opened and the feature to be edited was selected (2). Followed by the “Point at end of line” selection (3) and managed to the area proposed for the placement of the point, the first reference for the point feature was placed (4). As previously mentioned, the first selection only indicates the base height and the second selection need to be exactly on the required area of location (4). Inserting elevation heights as indicated in (5) provided the features with the correct elevation and enabled the features to be viewed correctly in ArcScene. After specifying the correct elevation heights the sketch were finished off by selecting “Finish Sketch”. The same procedure was followed with editing the other participating features.

ArcScene offers many advantages such as the reality in which features and models could be represented. It is also easier to retrieve feature specific data when the feature is viewed in ArcScene. It does however contain a few disadvantages as well that intensified the 3D editing process. The fact that many editing functions underperformed while creating features in 3D is among these disadvantages. It was found that the creation of features in ArcMap ensured a more accurate way of editing than within ArcScene. For the purpose of this study and projects that have similar requirements for 3D editing, it would be advised to apply the functionalities provided by ArcScene solely for attribute editing and visualizing the features created in ArcMap.



Figure 4.12. In the process of placing a point in ArcMap

4.2.1. Establishing relationship classes

Relationships in the model were created at the hand of corresponding fields in two related feature classes. These relationships had to be created among features that are related in a certain way by means of a field within each feature's attributes. Working with relationship classes Microsoft Access was also utilized for the creation of the feature classes as well as creating relationships between them. This approach enables the user to create and define the relationship classes and also have the possibility to create and edit the feature classes with their relationships before the feature classes are created in GIS.

It was found that great care should be taken with the preparation of the tables whenever the need for the creation of relationships arises. That is to ensure that specific fields would be able to link with each other and to ensure that the data types for those specific fields would also correspond with each other. For example, an attribute field with a “Long Integer” data type specified could only be related to another field in another feature class if that field also have a “Long Integer” specified for the values within.

With the finalization of the prototype relationship model created in Microsoft Access and all the features digitized and created within ArcMap the relationship classes were established. A few prototype relationship models were created to test and refine the design. Primarily all the attributes within the feature classes were validated to ensure that they are error free and complete. Starting off with the many-to-many relationships between the water mains and the fittings an intermediate table were automatically created once the cardinality of the relationships between the two fittings was specified. A “simple” (peer to peer) relationship was specified and the selected direction of the messages between the related objects in both directions. Figures 4.13, 4.14 and Figure 4.15 partially indicate some of the steps followed in creating the many-to-many relationships.

Figure 4.13 indicates that the primary feature class's name is the name that is selected to be represented first in the creation of the relationship. Any other feature class's name that is selected first would serve as the primary feature class for the many-to-many relationship. Figure 4.14 indicates that a cardinality have to be chosen in order to verify which relationship (one-to-one, one-to-many or many-to-many) would be created. Figure 4.15 indicates the creation of the two corresponding fields for the many-to-many relationship in this regard. Figure 4.16 represents the final relationship table between the main sections and the fittings.

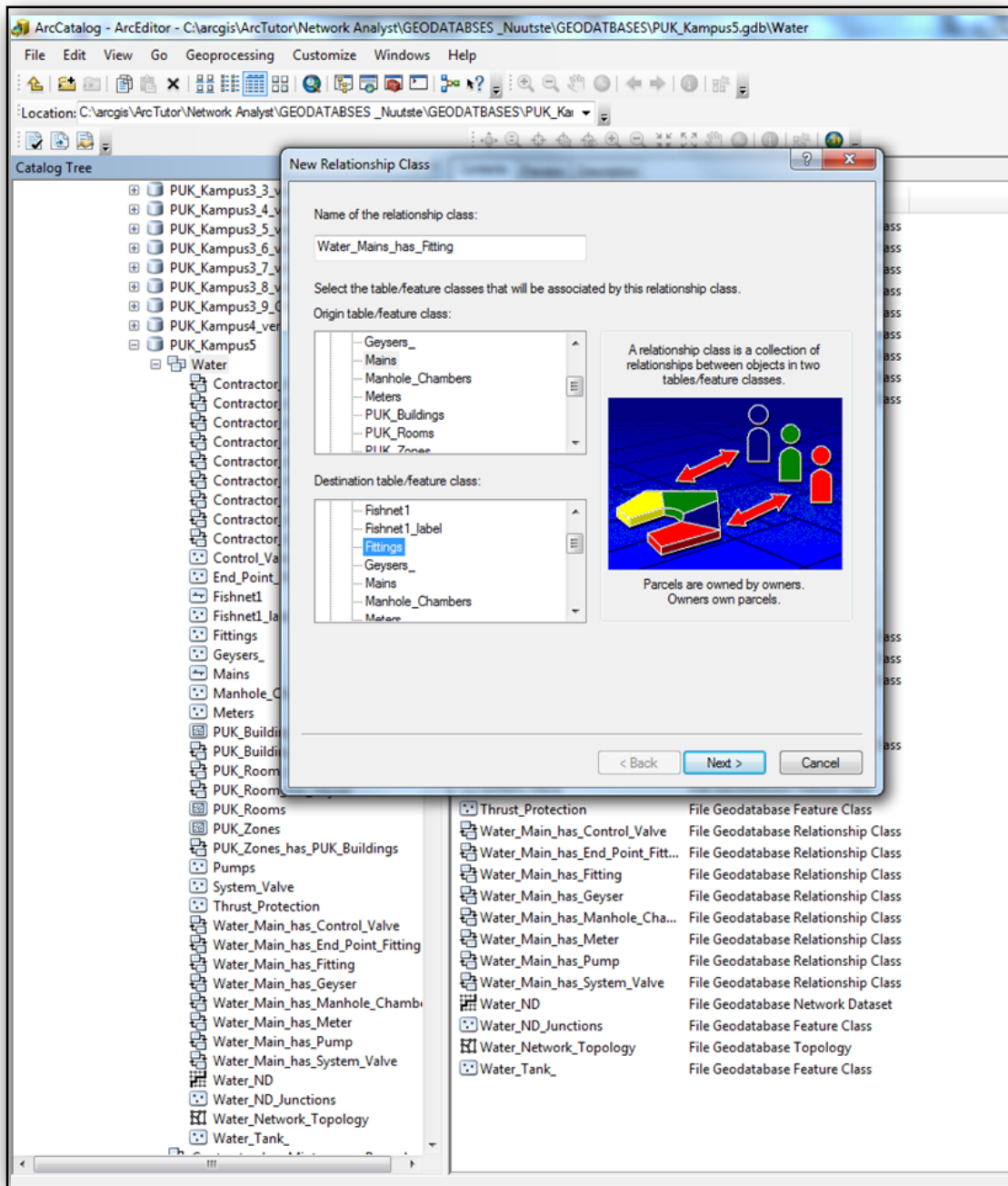


Figure 4.13. The onset of a many-to-many relationship

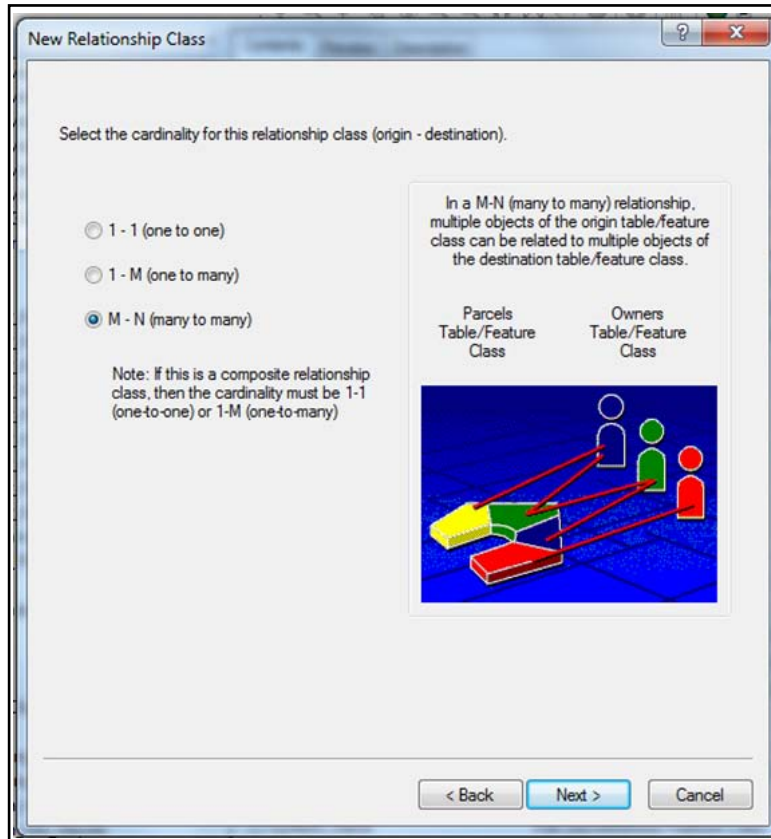


Figure 4.14. The choice of a relationship cardinality

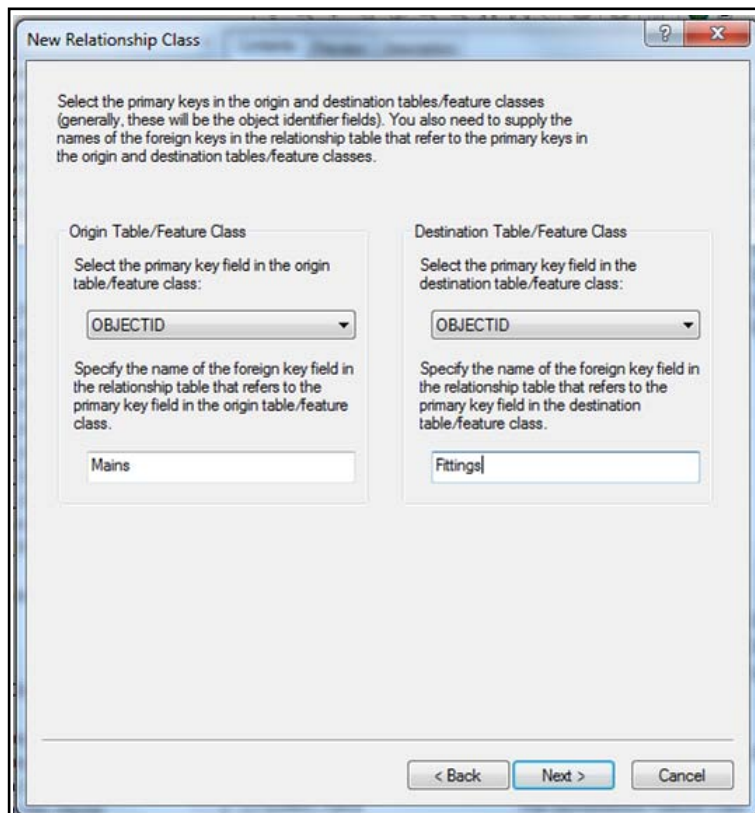


Figure 4.15. Two fields created in the many-to-many relationship

With reference to Figure 4.16 a good indication of the two tables that were created for the corresponding values between the “Main_Sections_Connected” and the “Fittings” are provided.

The screenshot shows the ArcSDE 5.6.8 - ArcScene - ArcEditor interface. The 'Table' window displays the following data:

RID *	Main_Sections_Connected *	Fittings *
1	2	77
2	2	78
3	3	74
4	3	77
5	4	74
6	4	75
7	5	75
8	6	66
9	6	79
10	7	144
11	7	79
12	8	69
13	8	79
14	9	80
15	9	69
16	10	80
17	11	70
18	11	69
19	12	70
20	12	71
21	13	71
22	13	72
23	14	72
24	15	83
25	15	82
26	16	85
27	16	82
28	17	83
29	17	86
30	18	85
31	19	86
32	20	84
33	21	82
34	22	87
35	23	89
36	24	89
37	24	90
38	25	90
39	26	59
40	26	66
41	27	84

Figure 4.16. The many-to-many relationship table between the main sections and fittings

The process in adding the values and finding a result represented in Figure 4.16 were executed by opening the attribute tables of the two features that are related to each other (in this instance the “Mains” and the “Fittings”). It was also necessary to add an additional table that were created for the many-to-many cardinality between those two tables. Selecting each and every line segment and the corresponding fittings connected at either point of the line ensures that the features are added to the table. In order to simplify these processes two columns were drawn on paper - each representing a line and a point. The values of each water line with its corresponding points (fittings) were written down and in the process a validation of all the connections were also executed. After a line feature and two point features were selected, the “Attribute” tab on the editing toolbar (Figure 4.17) were selected and the selected attributes were displayed. Right clicking on the “Mains” layer provides the option of adding the feature as a layer which is executed accordingly (Figure 4.18). Unfortunately, this process could only be executed in ArcMap not ArcScene.

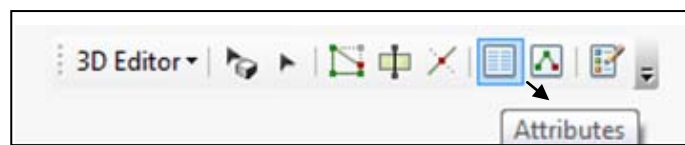


Figure 4.17. The “Editor” toolbar with the “Attributes” tab

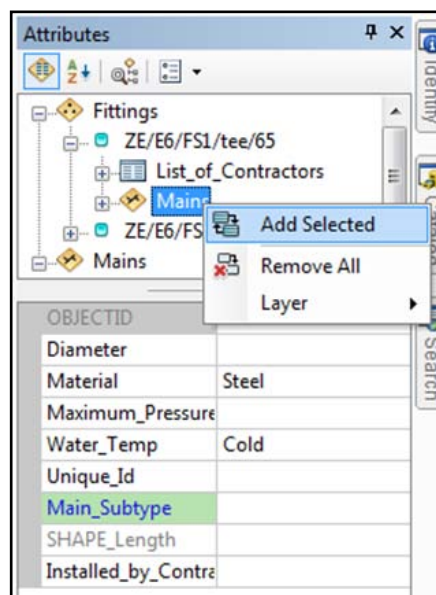


Figure 4.18. The attributes after opened by the “Attributes” tab in Figure 4.17

With reference to Figure 4.19, following the procedures executed in Figures 4.17 and 4.18 a single feature within the model could be selected and the information of that specific feature could be derived. After the relationships were created a feature such as a specific room could be selected and the information of that room could be derived together with all the other features located within

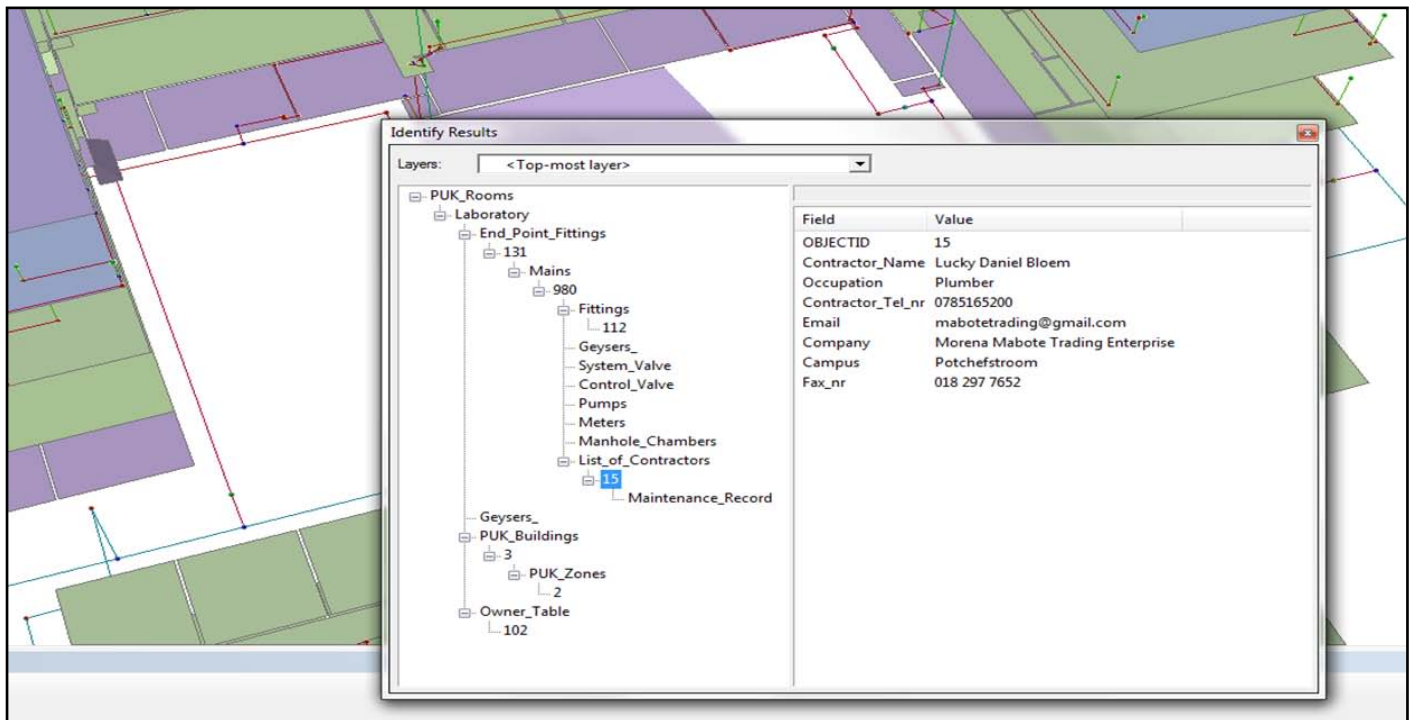


Figure 4.19. The “Identify” tool applied

With reference to Figure 4.20, a water main has been selected. According to the relationship created for the features the selection indicates that the water main has two fittings connected to it at either sides of the main section. Furthermore, each of these fittings was installed by a certain contractor with all his information indicated in the right side of the “Identify Results” window. It is also indicated that the same contractor, C.J. du Preez, have executed work on other features along the water network with a “+” next to it. This means that C.J. du Preez also worked on another section of the water mains and a geyser that is connected to the water main initially selected. The information could now be obtained by selecting the “+” button next to the features. The features without the “+” symbol next to it does not have any information relevant to the specified selection.

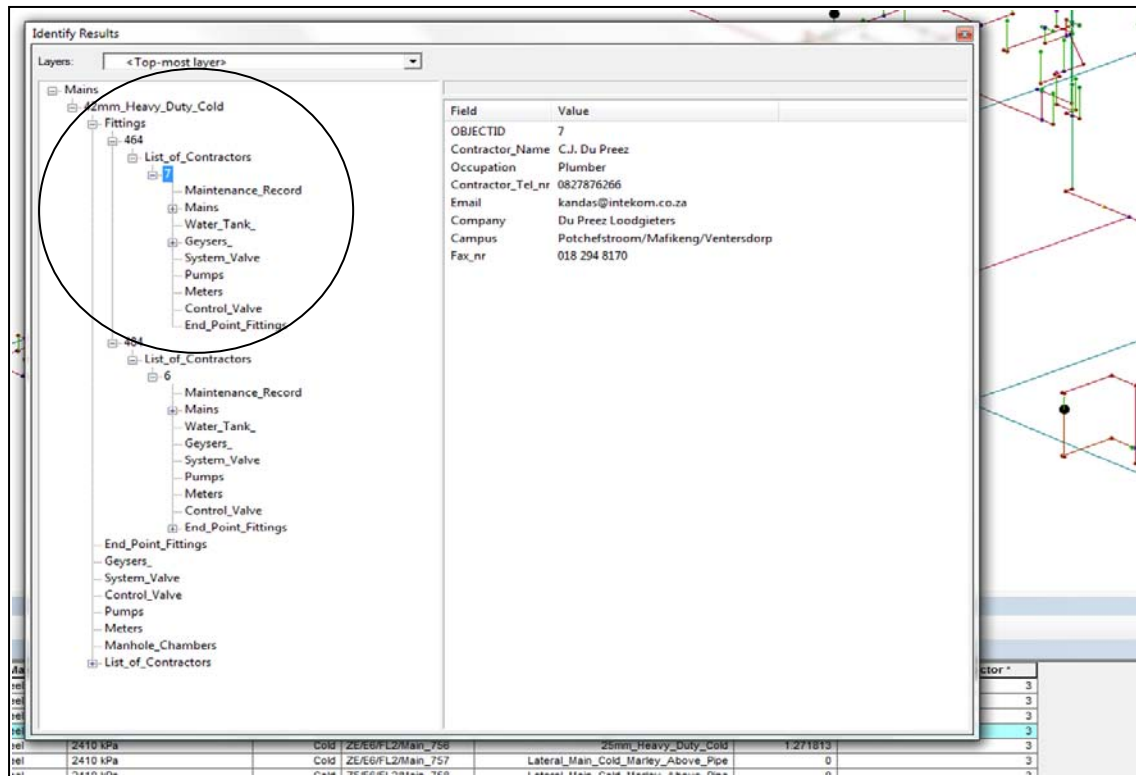


Figure 4.20. A water main selected

Originally a one-to-many relationship between “PUK_Rooms” and the “Fittings” as well as a one-to-many relationship between the “PUK_Rooms” and the “Mains” were proposed. Unfortunately there were found that many of the point fittings are not situated in a defined space which is the same phenomena that occurred for the water mains that crossed through certain rooms and walls. During the creation of the relationships it was found that the point features sharing two or more lines could have a one-to-many relationship created for them. These features include the geysers, system valves, control valves, pumps, meters and manhole chambers. However, it was found that if any of those relationships had to be created as a one-to-many relationship, a field for the relating feature within the water main feature class would have to be created and in turn would mean that an increased amount of fields would contain a “Null” value defined for it.

Generally the amount of “Null” values has to be limited to ensure a complete robust geodatabase. The solution to the problem was to apply the many-to-many relationship technique in order to have those features related to the water mains. The one-to-many relationship cardinality does however work perfectly for features connected to each other without those features connected to only a few selected entities along the network. A very important concept came forth from this encounter and it would therefore be advised to create

a many-to-many relationship between features that only have a few selected features it relates to. An example of such an encounter is the system valves along the water network. Table 4.2 represents the scenario with regard to the excess <<Null>> values that could be prevented when applying many-to-many relationships in cases when one-to-many relationships cannot be applied without the delivering unnecessary <<Null>> values in the tables.

OBJID	Unique_ID	Geysers	System_Valves	Pumps	Meters
1	ZE/E6/FS1/Main_1	<<Null>>	1	<<Null>>	<<Null>>
2	ZE/E6/FS1/Main_2	<<Null>>	2	<<Null>>	<<Null>>
3	ZE/E6/FS1/Main_3	<<Null>>	<<Null>>	2	<<Null>>
4	ZE/E6/FS1/Main_4	1	<<Null>>	<<Null>>	<<Null>>
5	ZE/E6/FS1/Main_5	2	<<Null>>	<<Null>>	<<Null>>
6	ZE/E6/FS1/Main_6	<<Null>>	<<Null>>	<<Null>>	1
7	ZE/E6/FS1/Main_7	<<Null>>	3	<<Null>>	<<Null>>
8	ZE/E6/FS1/Main_8	3	<<Null>>	<<Null>>	<<Null>>
9	ZE/E6/FS1/Main_9	<<Null>>	<<Null>>	<<Null>>	2
10	ZE/E6/FS1/Main_10	4	<<Null>>	<<Null>>	<<Null>>
11	ZE/E6/FS1/Main_11	5	<<Null>>	<<Null>>	<<Null>>
12	ZE/E6/FS1/Main_12	6	<<Null>>	<<Null>>	<<Null>>

Table 4.2. The creation of one-to-many relationships among the fields indicated

With regard to the relationships established between the “PUK_Zones” and the “PUK_Buildings” a one-to-many cardinality was selected. One zone contains more than one building and more than one building is situated within a zone. The same one-to-many relationship was established between the “PUK_Buildings” and the “PUK_Rooms” because one building contains more than one room. Unlike the water mains and the fittings along the water network the “End_Point Fittings” however, are located within the rooms and every room contains more than one “End_Point Fitting”. For this reason a one-to-many relationship

between the “PUK_Rooms” and the “End_Point Fittings” were established. Every room within the PUK buildings has one owner occupying it which means a one-to-one relationship was created between the “PUK_Rooms” and the “Owner” table. Each water main eventually ends up at a certain point and each of these points are known as the “End_Point Fittings” from which the one-to-one relationship between the “Mains” and the “End_Point Fittings” were established. A one-to-many cardinality was established between the “List_of_Contractors” and the “Maintenance_Records” tables because each contractor could have more than one maintenance operation executed on a certain facility. The same cardinality were established between the “List_of_Contrctors” the “Mains”, “End_Point Fittings”, Geysers, Fittings, “System_Valves”, ”Control_Valves”, Pumps, Meters, Manholes and the “Water_Tank”.

Unlike a many-to-many relationship cardinality, one-to-one or one-to-many relationship cardinality has their corresponding fields located within the feature class. The primary key values would therefore be inserted into the corresponding foreign key field within the related feature class. These cardinalities are therefore much simpler than the many-to-many relationship classes, although, the many-to-many relationship cardinalities are much more flexible than the one-to-one or one-to-many relationship cardinalities.

4.2.2. Topology

The topology rules proposed in Chapter 3 were created and validated. Figure 4.21 represents the topology rules specified for each feature within the water network model.

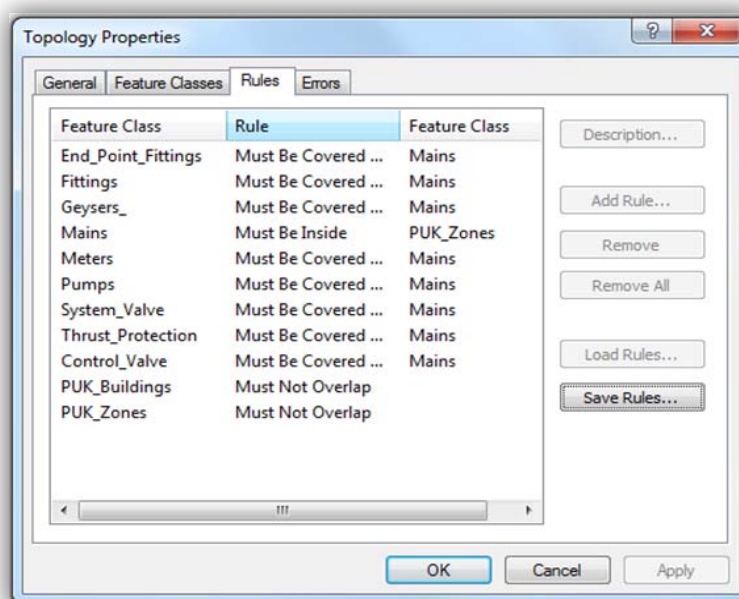


Figure 4.21. A representation of the features participating in the topology rules

Once the topological rules were established for the water network any form of editing that does not conform to the rules were indicated in red as represented in Figure 4.22. A problem exists with the “End_Point_Fittings” not connected to the “Mains” at a certain point and a section of the “PUK_Zones” that overlap. The topology rules provided by ArcGIS supported the data integrity of the data created.

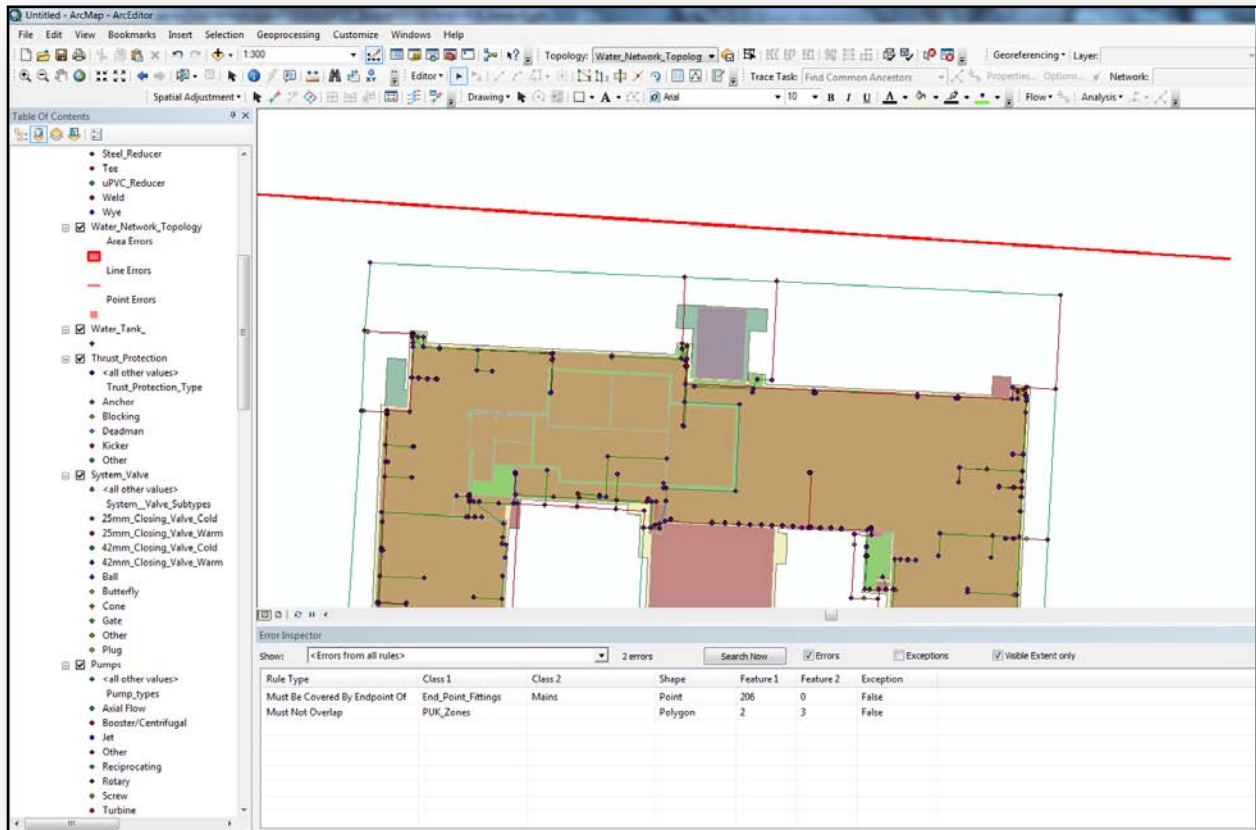


Figure 4.22. A representation of the topology rules applied indicating two errors in red

4.2.3. Network dataset

A network dataset was created after topology rules were specified for the features. The purpose of the network dataset was to store the connectivity of the source features. It therefore keeps track of the source features in the network and basically serves as a verification tool indicating whether any features are not connected. Furthermore, the network dataset also enabled the model of finding the shortest route between two or more points in the network. The network dataset therefore served as the “tracks” for the shortest route model to “run” on.

Within every feature dataset, only one network dataset could be created containing the source features participating in the network dataset. The network dataset does not need to contain all the features within the feature dataset, only those participating in the network and therefore

the fishnet and the thrust protection feature classes were excluded. The network dataset also comprises of points and lines and therefore the water mains serves as the edges connected to all the junctions (points) in the network. With all the elements contained inside the network dataset a connectivity policy has to be created for the features to participate in. The “mains” have “end point” connectivity specified for connecting with the points in the network and therefore the points have to “honor” that policy in order to connect to the water mains validly. In order to have elevation specified for the features the “Using Z Co-ordinate Values from Geometry” were selected. Unlike a street network, the flow direction of commodities within the pipelines of the water network consists of one direction only and therefore no turns were specified for the network dataset.

With the existence of a network dataset created and operating within the feature dataset, new features could be created and edited. However, any existing features could not be updated and neither could any of their attribute data be adjusted. Whenever a scenario like this occurs a warning message would be given stating that there is an error updating an attribute and that the logical network is of an older version and does not support the requested functionality. This would require that a new network dataset would have to be created after deleting the previous one. Even though, the shortest route model would still be able to operate with the new network dataset.

4.2.4. “ModelBuilder” and the shortest route model

Following the network dataset, a model for the water network was created with the focus on solving the shortest route between two or more points along the network. This model is based on the network dataset created for the system. Firstly and foremost, situated within the main toolbar the “ModelBuilder” window were opened. Located within the ArcToolbox (Figure 4.23) under “Network Analysis Tools” and under “Analysis” the “Make Route Layer” tool were dragged into the “ModelBuilder” window. By double clicking on the “Make Route Layer” the network dataset previously described were added. Within the same toolbox, the “Add Locations” tool was added to the “ModelBuilder” window. Right clicking the “Add Locations” tool a menu opened which provided the option of selecting “Make Variable”, followed by selecting “From Parameter” and “Input Locations”. Right click and opening “Input Locations” the first feature that would participate in the model are selected, e.g. the “Fittings” feature (Figure 4.24). The “Fittings” would be situated in a blue bubble which

should be right clicked and the property settings adjusted, managed to “Data Type” and selecting “Feature Set”.

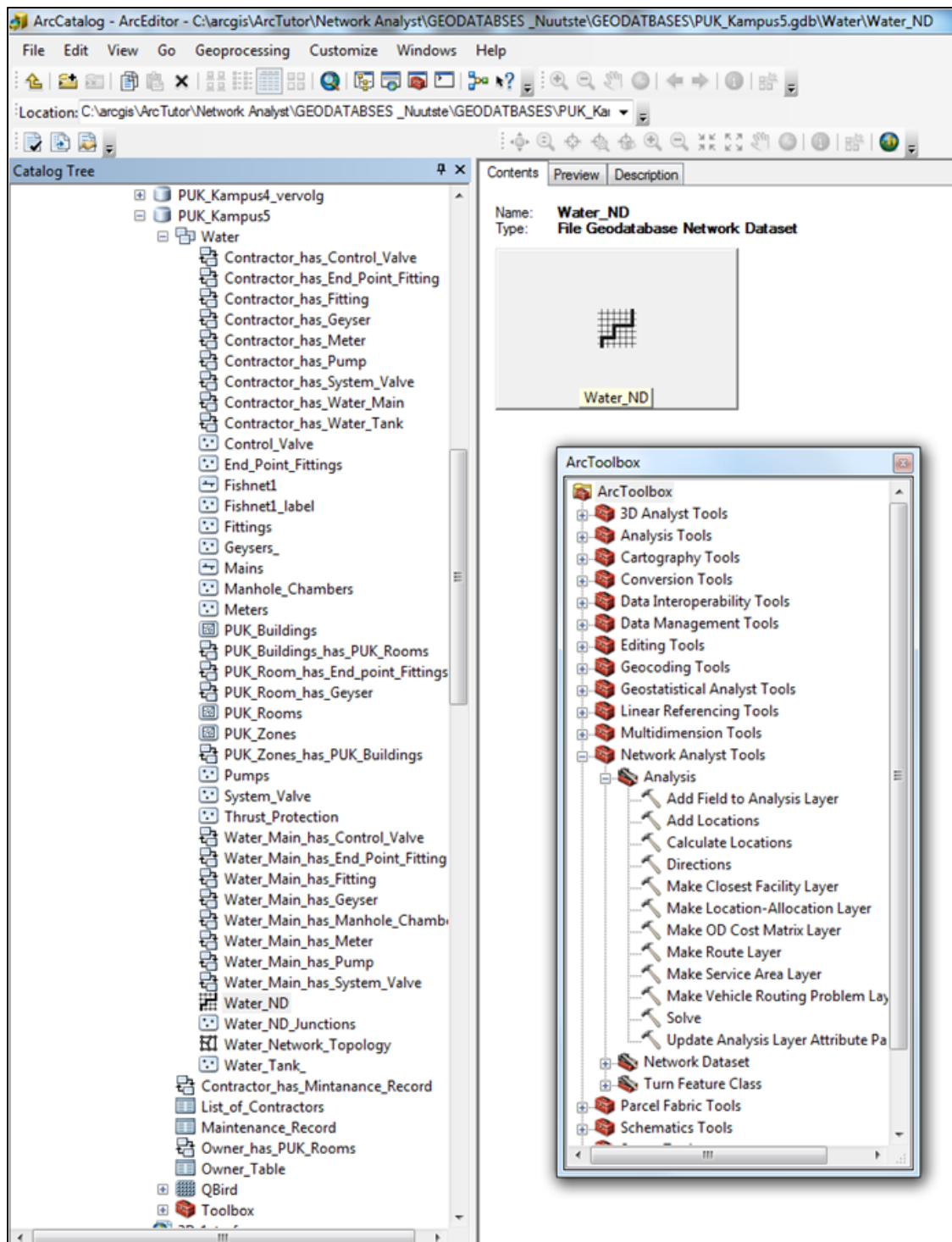


Figure 4.23. The shortest route model within the toolbox created

Next it was necessary to select “Add Locations” and selecting “Open” in order to input a network analysis layer in the drop-down list. The layer would be visible as the first route

created in the model up till now (Figure 4.25). The shortest route model was executed for the following features:

- Water_Tanks;
- Geysers;
- System_Valves;
- Pumps;
- Meters;
- Manhole_Chambers;
- Control_Valve;
- Fittings; and
- End_Point_Fittings.

Once each of these features were added to the model, the next step was to insert the “Solve” tool, right click and selecting the final route under the “Input Network Analysis Layer”. Managing to the “Data Management Toolbox” the “Layers and Table Views” toolbox was opened from which the “Apply Symbology from Layer” tool was added to the “ModelBuilder” window (Figure 4.26). Once opened, the “Input Layer” of the last route could be added and the same for the “Symbology Layer” too. The “Symbology Layer” however, had to be created or imported from a previous symbology layer. In this instance a symbology layer were imported from a previous model and were applied for the current model. The symbology layer contains unique symbology that would be applied for the current model and is imperative for the visual representation of the created model. A new toolbox was created in which the newly created tool was added. Every feature except for the symbology feature bubble was selected as a parameter including the water network and the last route (in green).

It would however also be recommended to validate and run the model after each section were added. This way any error within the composed model would more easily be located and could then be corrected accordingly. Whenever an error message occurs during the running phase of the model read the error and ensure that all the elements within the network are connected. A solution might also be to open the “Solve” tool in the “ModelBuilder” window and deselect both the tick boxes “Ignore invalid locations” and “Terminate on solve error”. Validate and run the model again.

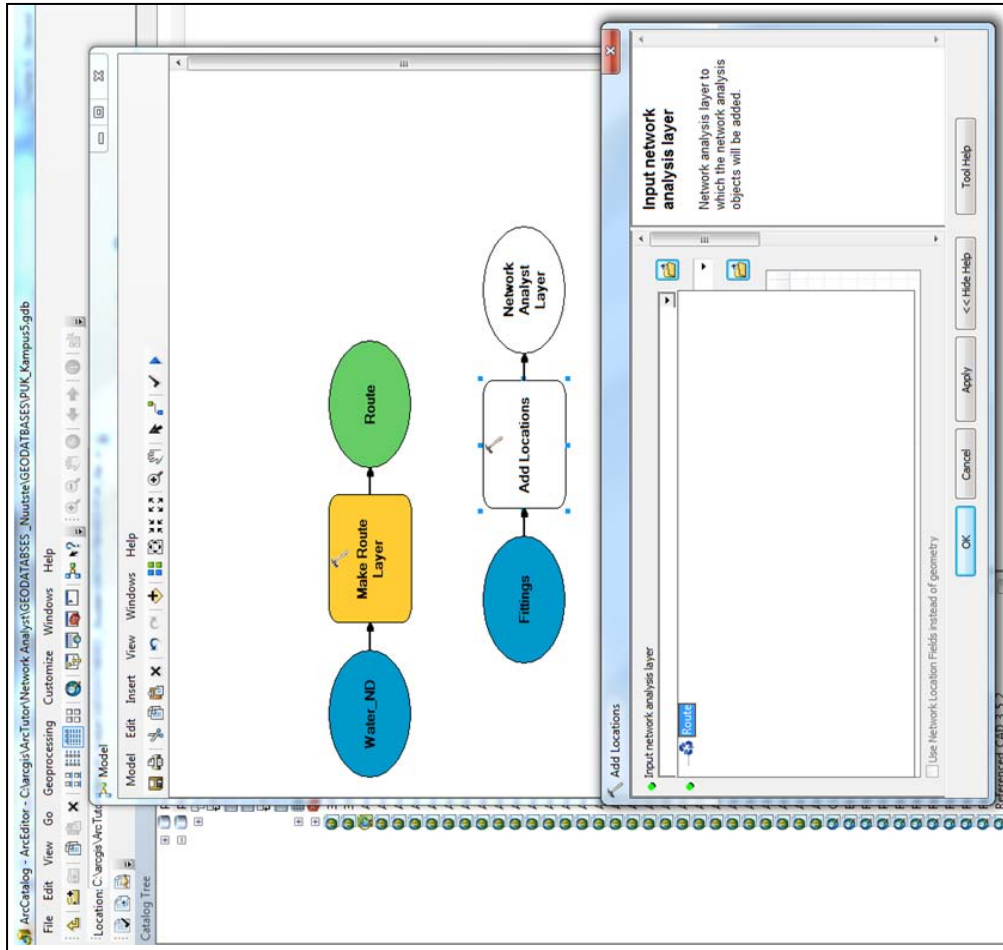


Figure 4.25. The “first route” layer

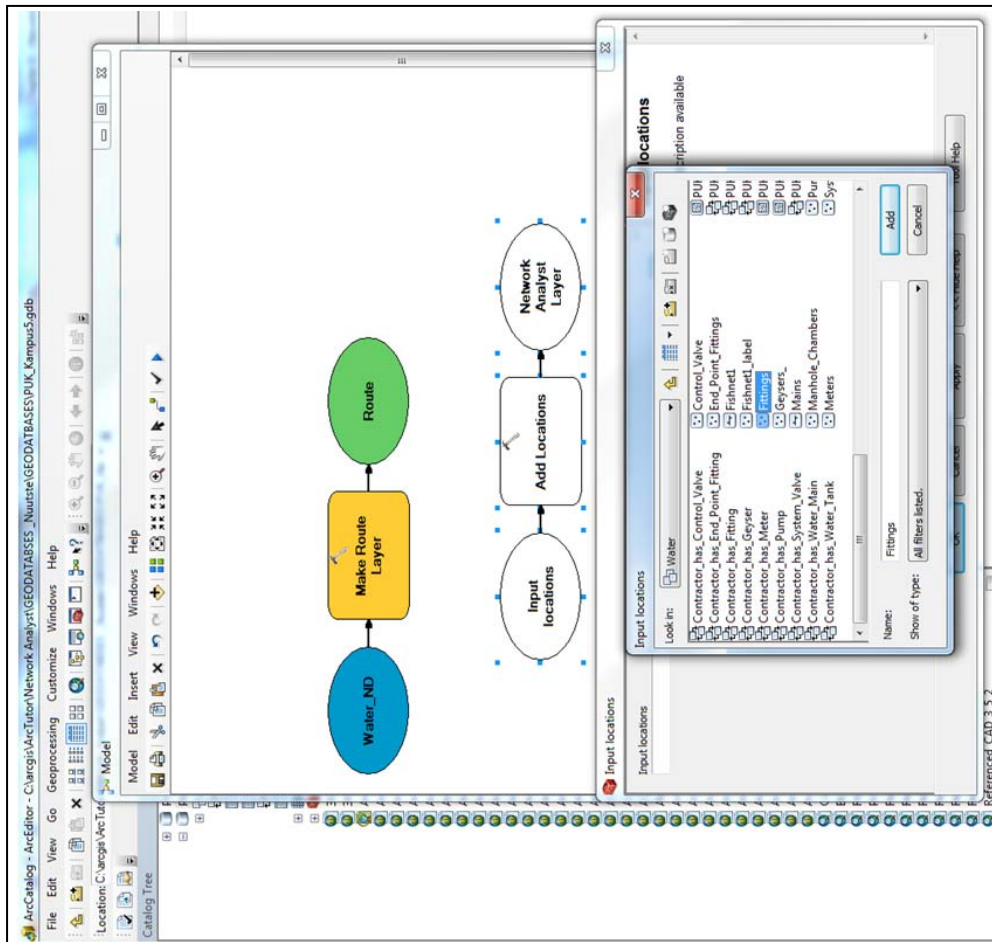


Figure 4.24. The “Fittings” layer

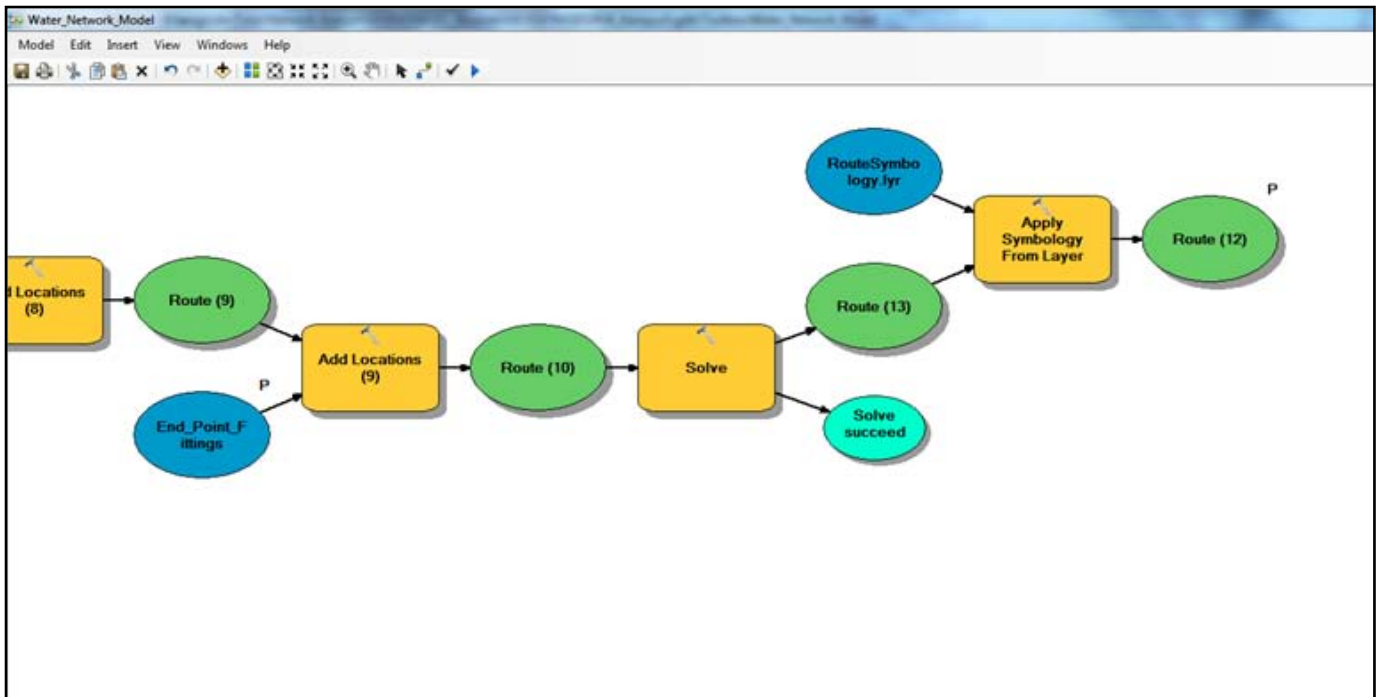


Figure 4.26. The shortest route model is finished off

Following the creation of the shortest route model the application thereof provided the ability to indicate the shortest route between two or more points as represented in Figure 4.27 and Figure 4.28.

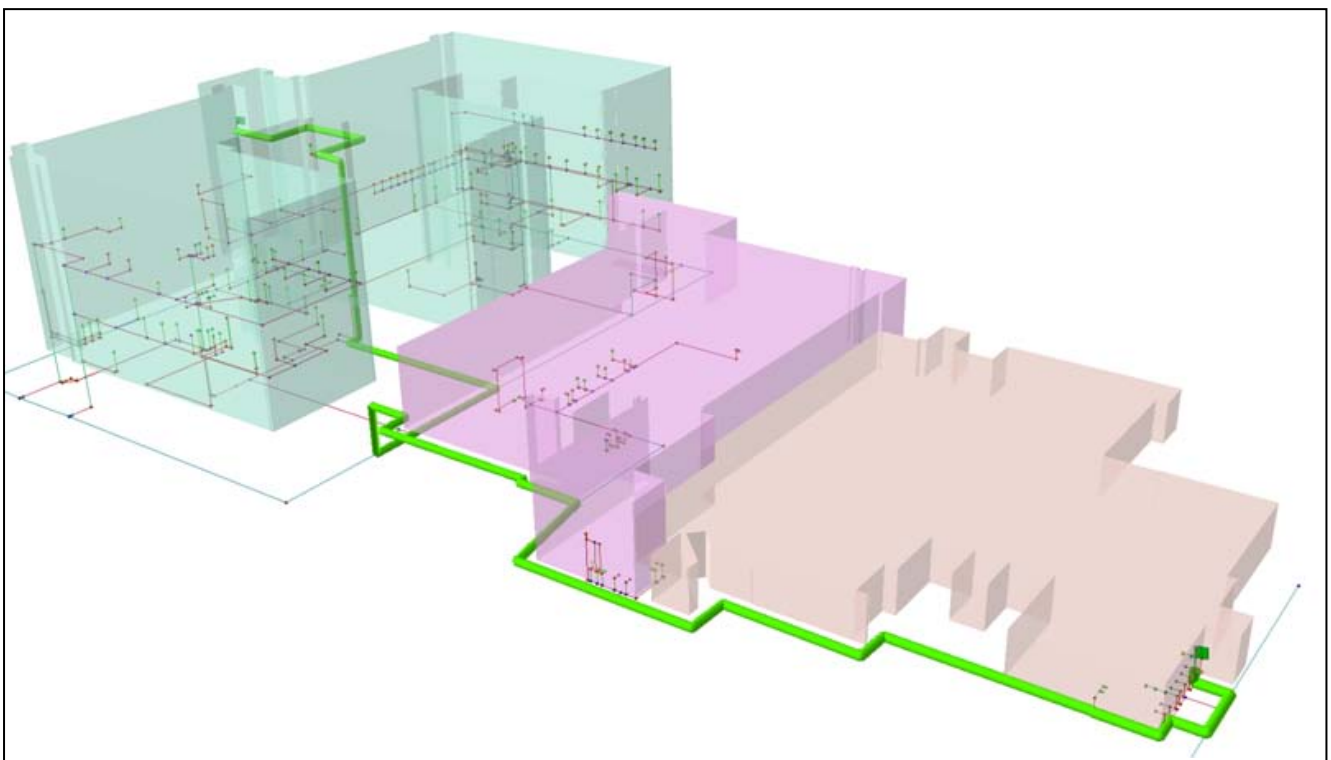


Figure 4.27. A representation of the shortest route between two points

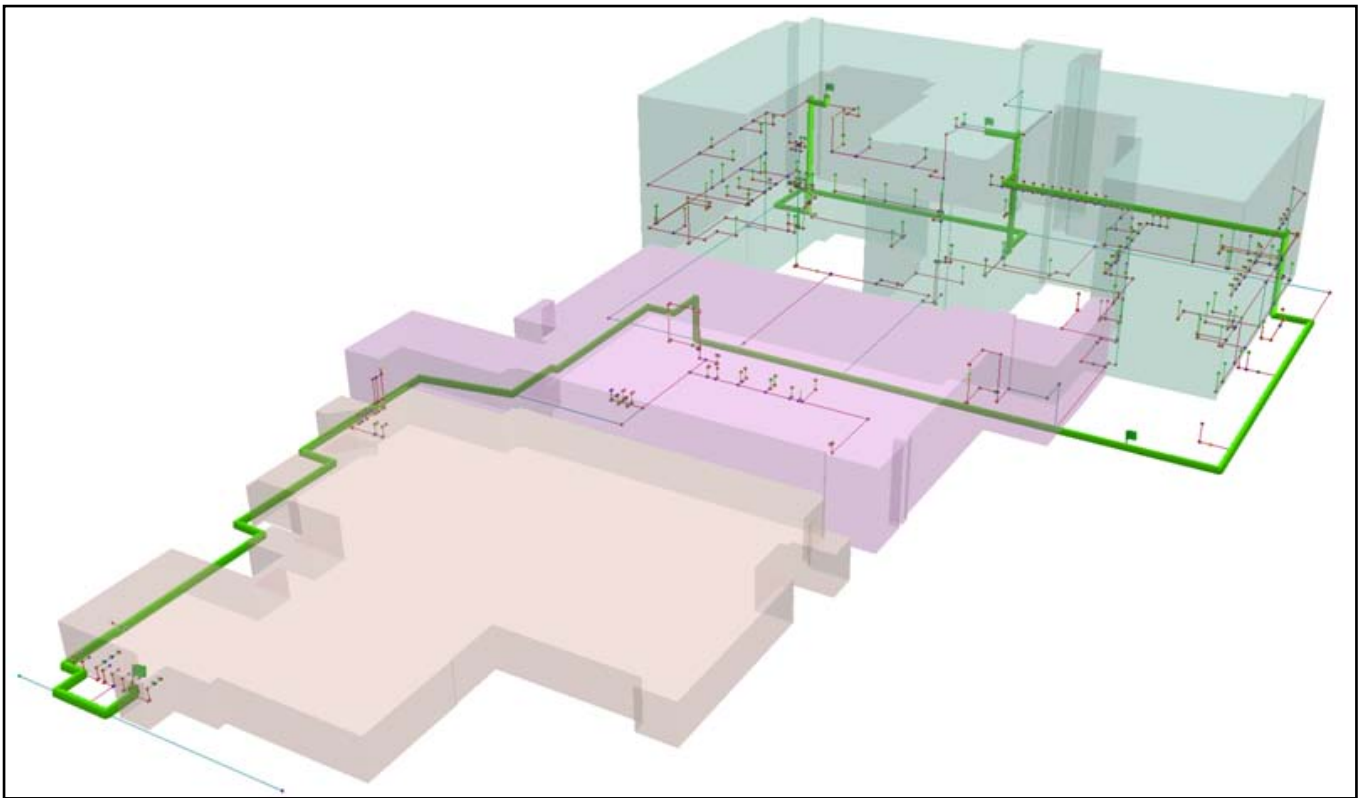


Figure 4.28. A representation of the shortest route between more than two points

The model could be explained at the hand of a real life scenario. In the water network presented a major leak could appear at any point in any given time. For example a leaking pipe section located within a bathroom. If a person recognizes the leak that stem from the bathroom or any other room in the building, the maintenance department of the university should be informed. The operator standing by could then request the room number the leak is originating from. Immediately the operator could open ArcScene, move to the rooms feature class, select the specific room with the “Select by Attributes” tool and locate the room. With the help of the relationship classes it would be possible to derive a good indication of all the facilities within the selected bathroom as well as the facilities connected to each other. All possible pipeline sections in the extent would also be visible. With all the information at hand and easy to be located with the click of a button, the process of finding or locating a feature is simplified. It would be possible to find or locate the closest water system valve in order to close it down for maintenance procedures.

With the shortest route model, the shortest route towards the system valve could be located and more than one “stop” along the network line could be selected. In that way, the operator would be able to look at all the possible pipe line sections and facilities that will be influenced by the leaking pipe or the closing of the water system valve. A report could also be sent to the contractor that was involved in previous operations executed on the facilities at

hand. After any maintenance procedures were executed the “Maintenance Record Table” could be updated and in that way record could be held of the maintenance procedures in the network.

The application of the model and the network are fairly simple to use, however the procedure is currently more based on a manual cartographic way of executing the results required. The facilities and the features along the network could be identified visually with the help of the “Select by Attributes” selection, however, the rest of the analysis are in the hands of the user. The shortest route could be located between the points selected, but from there on the user would have to indicate the rest of the features that would be influenced by the interruption on the network. More than two points could also be selected and with the application of the shortest route model and indication of the lines or facilities that would be influenced by the closing of certain valves, could be provided. Even though, the placement of the points would have to be executed manually.

4.2.5. The fishnet

In order to have the features outside the buildings referenced with a procedure more accurate than looking at the closest tree or natural element, the fishnet model were added to the layout of the map representation in ArcMap. This fishnet model is not operational in ArcScene and could only be applied in ArcMap. From a 2D point of view, the fishnet could be applied for enhancing the orientation of features located on ground level outside buildings. This is therefore more of a cartographic approach for locating features and contributed to the orientation of the features located on the QuickBird image (2008). Its functionality is therefore discussed.

The fishnet model is compiled by a series a cells which are assembled by a series of rows and columns. In order to have the correct settings for the creation of the fishnet it is required to have a proper observation of the QuickBird image (2008) that serves as the backdrop reference image for the map. Primarily the measurable units in which features are represented need to be determined e.g. meters or centimetres. Subsequently the extent of the area covered by the fishnet needs to be calculated (Figure 4.29). Depending on the cell size selected for the fishnet the process of building the model might take up to 20 minutes.

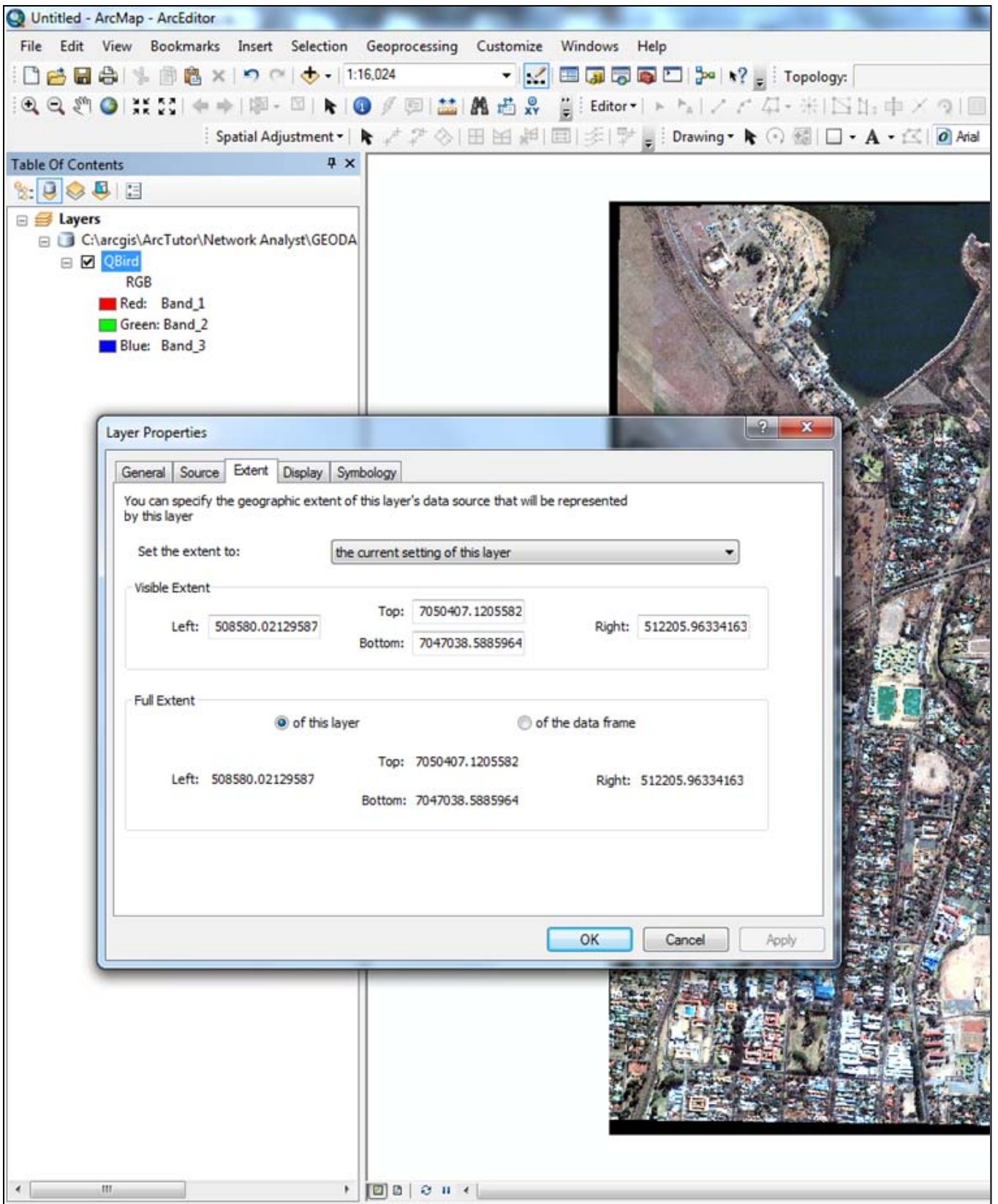


Figure 4.29. A representation of the extents of the QuickBird image (2008)

The formula used for this calculation: Subtract the bottom extent from the top extent and the left extent from the right extent in order to derive an indication for the values that the rows and columns need to be divided into.

$$\text{Top} - \text{Bottom}: 7050407.1205582 - 7047038.5885964 = 3,368.535 \approx 3369$$

$$\text{Right} - \text{Left}: 512205.96334163 - 508580.02129587 = 3,625.9421 \approx 3626$$

Because the units that are currently selected for the QuickBird image (2008) are meters, the rest of the calculation is fairly simple. If cells of 1meter x1 meter are required the amount derived at each of the extents subtracted need to be divided by 1 in order to have the rows and the columns defined.

$$(\text{Rows}) \text{ Top} - \text{Bottom} = 3369/1 = 3369 \text{ rows to be created}$$

$$(\text{Columns}) \text{ Right} - \text{Left} = 3626/1 = 3626 \text{ columns to be created}$$

By opening the ArcToolbox and managing to the “Data Management Tools” the “Feature Class” toolbox are opened and the “Create Fishnet” tool selected as indicated in Figure 4.30. The “Output Feature Class” is specified as well as the “Template Extent” and then the “Cell Size Width”, “Cell Size Height”, “Number of Rows” and “Number of Columns” are added.

With the development of an accurate fishnet model, four main entities are adjusted with reference to the map. These entities are indicated in Figure 4.30 and are:

- cell size width;
- cell size height;
- number of rows; and
- number of columns.

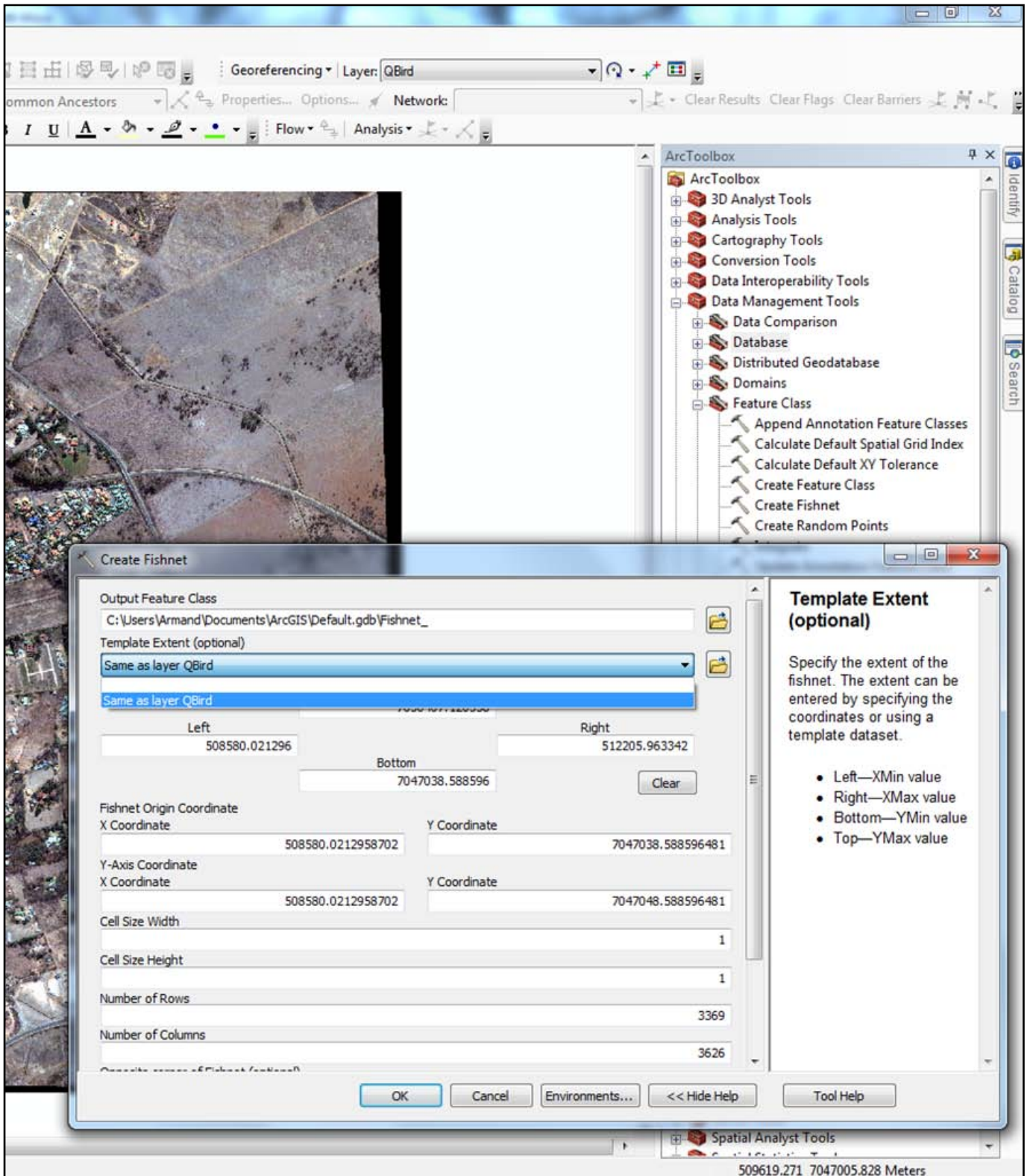


Figure 4.30. A representation of the cell sizes for the creation of the fishnet

4.3. The final product

The final product of the design is represented in the Figures 4.31, 4.32, 4.33 and 4.34. Figure 4.31 represents the proposed buildings and the floor levels in ArcScene. Figure 4.32 represents the proposed buildings and also indicates the proposed water network system. The floor levels altogether with the water network system are represented from a different angle in Figure 4.33. Figure 4.34 represents the final layout of the floors, the building outline and the water network contained within.

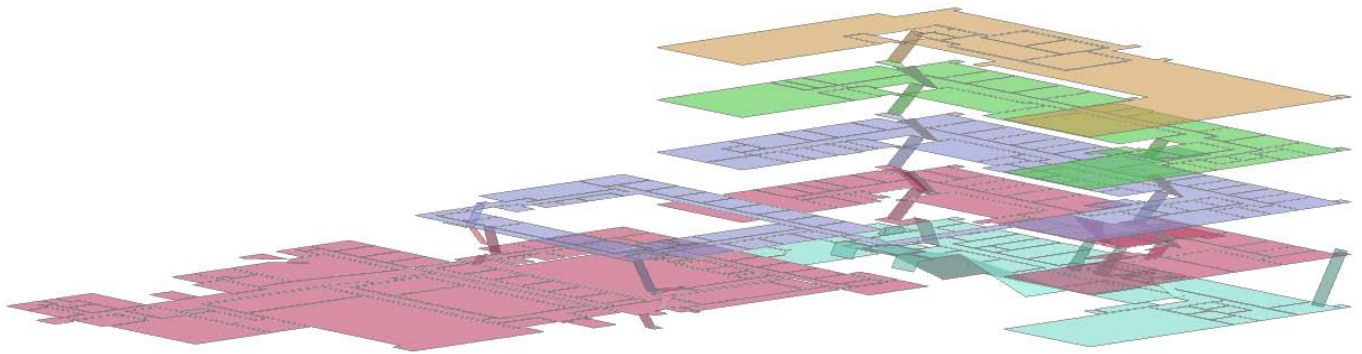


Figure 4.31. A representation of the proposed buildings and the four floor levels in 3D

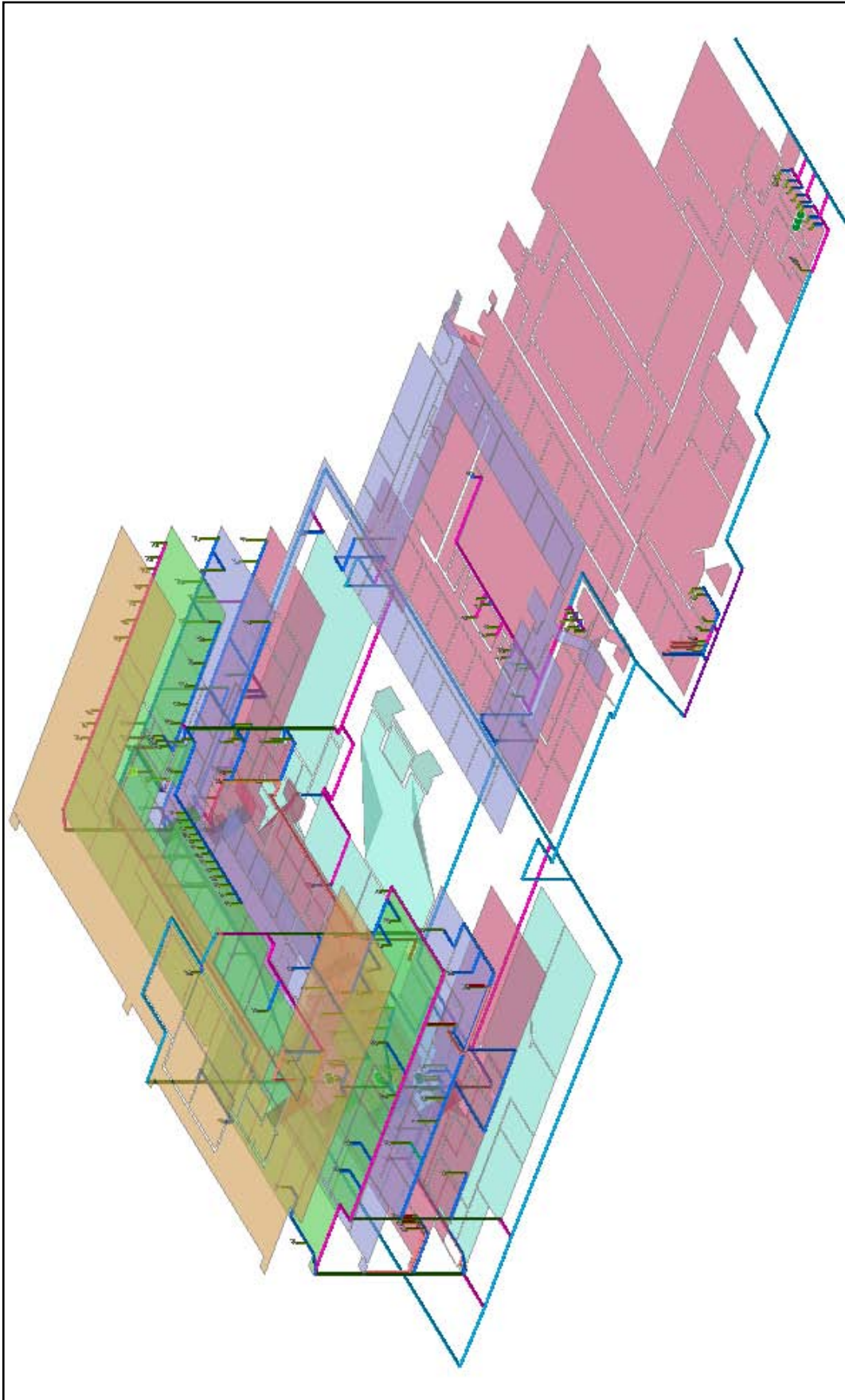


Figure 4.32. A representation of the rooms and facilities in 3D

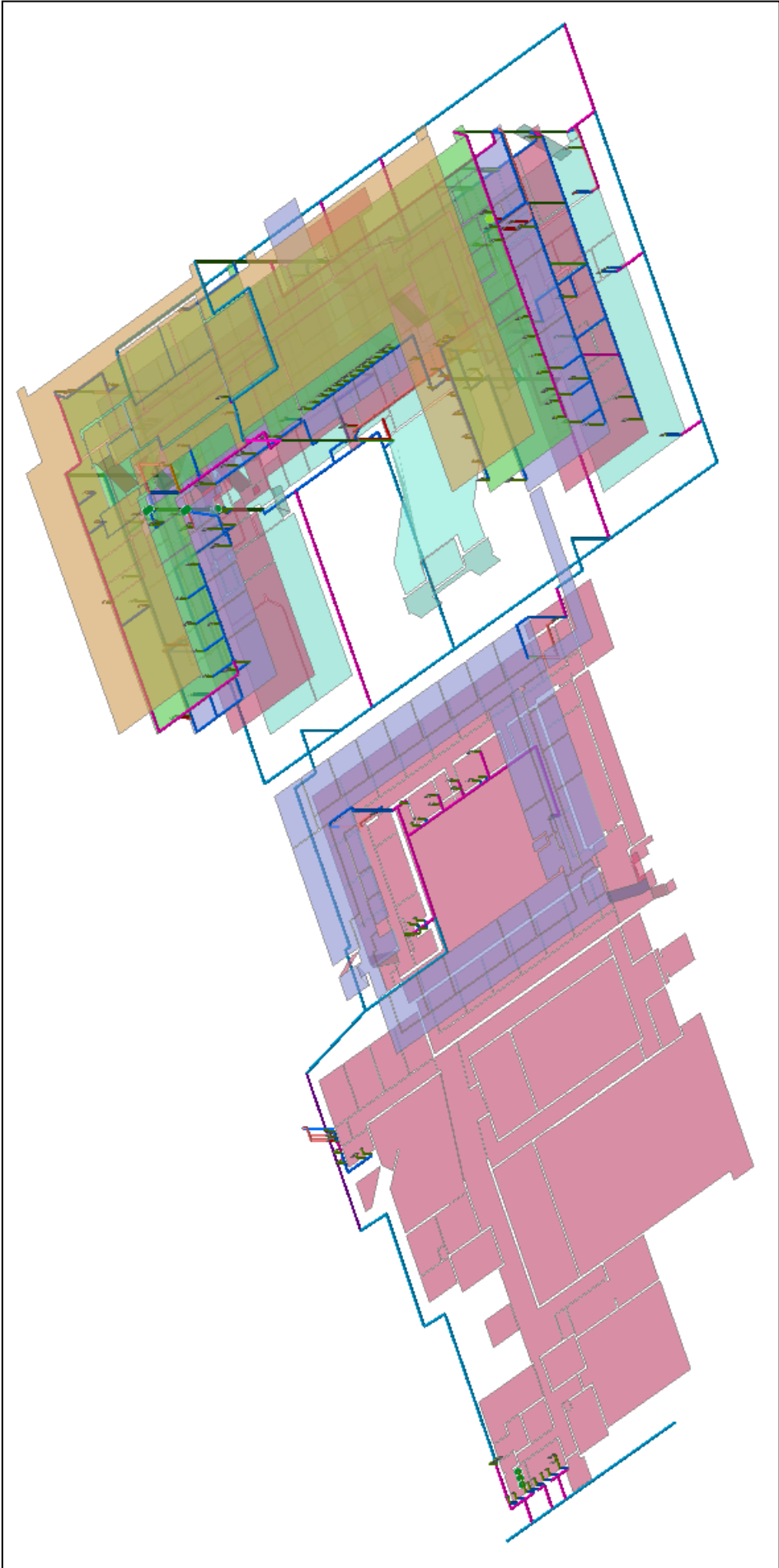


Figure 4.33. A different angle of representation regarding Figure 4.32

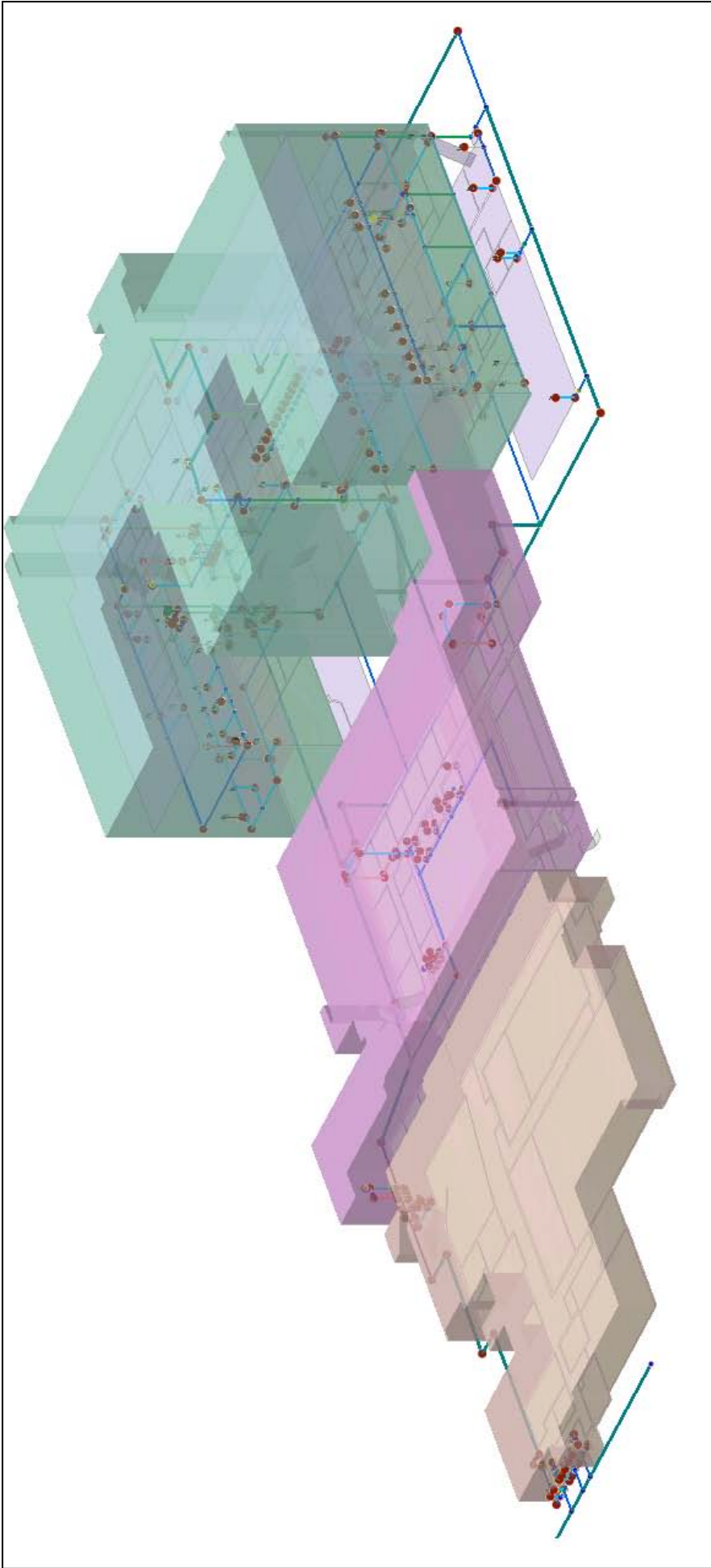


Figure 4.34. The layout of buildings E4 and E6

4.4. Documenting the design

Documenting the design serves as the final step of the physical design. ArcGIS provides the result of the project to be represented in two ways. The physical design could be represented by means of a physical demonstration in ArcScene or ArcMap. This way a clear indication of the project and the operational features within the geodatabase could be represented. The representation also entails a more administrative way by representing the design of the geodatabase together with its operational features, layer diagrams, schema diagrams and specified rules by means of a summarized diagram.

The design of the diagram was created in conjunction with Microsoft Visio and ArcCatalog. The software for the extension was derived from the “ArcGIS Resource Center”. Following the revision of a few forums with the focus on the “Geodatabase Diagrammer” a link for the software were obtained. In conjunction with Microsoft Visio 2007 the 2010 version of the “Geodatabase Diagrammer” were installed (ESRI, 2011b). At the hand of the “readme” file provided with the diagrammer software a summarized diagram of the geodatabase were created. The implementation of the steps provided by the “readme” file served a key role for creating the diagrammer correctly and is added as Addendum C. The creation of the geodatabase diagram offers a layout of all the components of the geodatabase and the various relationships, domains, subtypes etc. and is not automatically assembled with the creation thereof. Once Microsoft Visio 2007 have been installed together with the extension for the geodatabase diagrammer the layout of the diagram was created without any features yet connected. The final product of the diagram is manually executed by connecting the different feature classes and relationships with each other manually. Even though this is also a very time consuming process, the end result could be represented according to the preferences of the user. Addendum C represents the final result of the geodatabase diagram. Addendum D represents a summary of Addendum C. For a more distinct version of the geodatabase diagram please refer to the electronic format additionally provided.