Hydrogeologic Assessment of Proposed Sand and Gravel Pit - Hamilton County, Indiana

September 3, 2021

Prepared for Beaver Materials

Prepared by

INTERA

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1 Executive Summary

Aggregate production from sand and gravel pits contributes significantly to Hamilton County's economy. In 2018, Indiana produced 17 million metric tons of sand and gravel, with a total value of $142 Million (USGS, 2021). New construction and upkeep of infrastructure require that sand and gravel aggregates be available at an economically acceptable cost within a 50-mile radius of the extraction site (Hill, 2021). Economically viable aggregate is only located within specific geological settings, which in Hamilton County is the outwash channel that roughly follows the White River. The White River outwash is the most productive aquifer in the County and supplies much of the County's population with drinking water. The dual use of this non-renewable resource requires cooperation and planning to minimize any potential negative effects, and thereby allow both mineral extraction and groundwater production to continue safely and sustainably.

A detailed investigation of the proposed Beaver Materials sand and gravel aggregate operation (the Site) north of Noblesville, Indiana was conducted to assess the potential risk to the hydrogeologic system that may be posed by the transformation of part of the Site from a low-lands soybean field to a gravel pit lake. In particular, risks to nearby public water supply wells, owned by Indiana American Water Company, were considered. The increased attention to these wells is due to their proximity to the Site, as well as the potential impact to the many Noblesville citizens that are served by Indiana American Water Noblesville Operation.

After compiling all the data and analyzing various scenarios, INTERA determined that with proper monitoring, the proposed sand and gravel pit is a low risk to negatively affect the local hydrologic system and nearby pumping wells.

2 Introduction

INTERA completed a hydrogeologic risk assessment for a proposed sand and gravel pit on Beaver Materials property (the Site). The Site is on an approximately 50-acre parcel located in Hamilton County, Indiana, on the north edge of the City of Noblesville as shown in Figure 1. The Site sits along the east bank of the White River, west of Allisonville Avenue and adjacent to Potters Bridge Park. The assessment was conducted to quantify the potential hydrologic risk associated with extracting surficial deposits from an area within the Site, defined as the estimated excavation area shown in Figure 1. Potential impacts to water quality and water quantity that may result from the proposed excavation were investigated. Specifically, impacts to nearby high-capacity public-supply wells were analyzed.

The risk assessment included:

- an analysis of previous studies at the Site,
- drilling three sonic boreholes to bedrock,
- detailed logging of unconsolidated sediment from the sonic boreholes,
- installation of two monitoring wells; one with a nested screen in the shallow and deep formations,
- data-logging probes deployed in the on-site and off-site monitoring wells,
- passive seismic geophysical survey,
- a detailed 3D conceptual geologic model,
- and a comprehensive regional groundwater flow model.

The following report details each section of the investigation and compiles each to form a risk assessment of various future scenarios.

3 Site Background

3.1 Study Area

A Study Area was selected to encompass the Site and surrounding areas that could influence the Site hydrologically, specifically delineated by a no-flow boundary in the groundwater model (Appendix B.2). The Study Area's boundary extends south to Conner St./Highway 38, north to Strawtown, west past Morse Reservoir, and east to Victory Chapple Road. The Study Area defines the extent of data gathering and analysis and is shown in the upper left inset to Figure 1. The Study Area also defines the domain of both the Three-Dimensional (3D) Conceptual Geologic Model (CGM) and the groundwater flow model. The proposed excavation area analyzed in this report was digitized form a preliminary concept map (Mader, 2020).

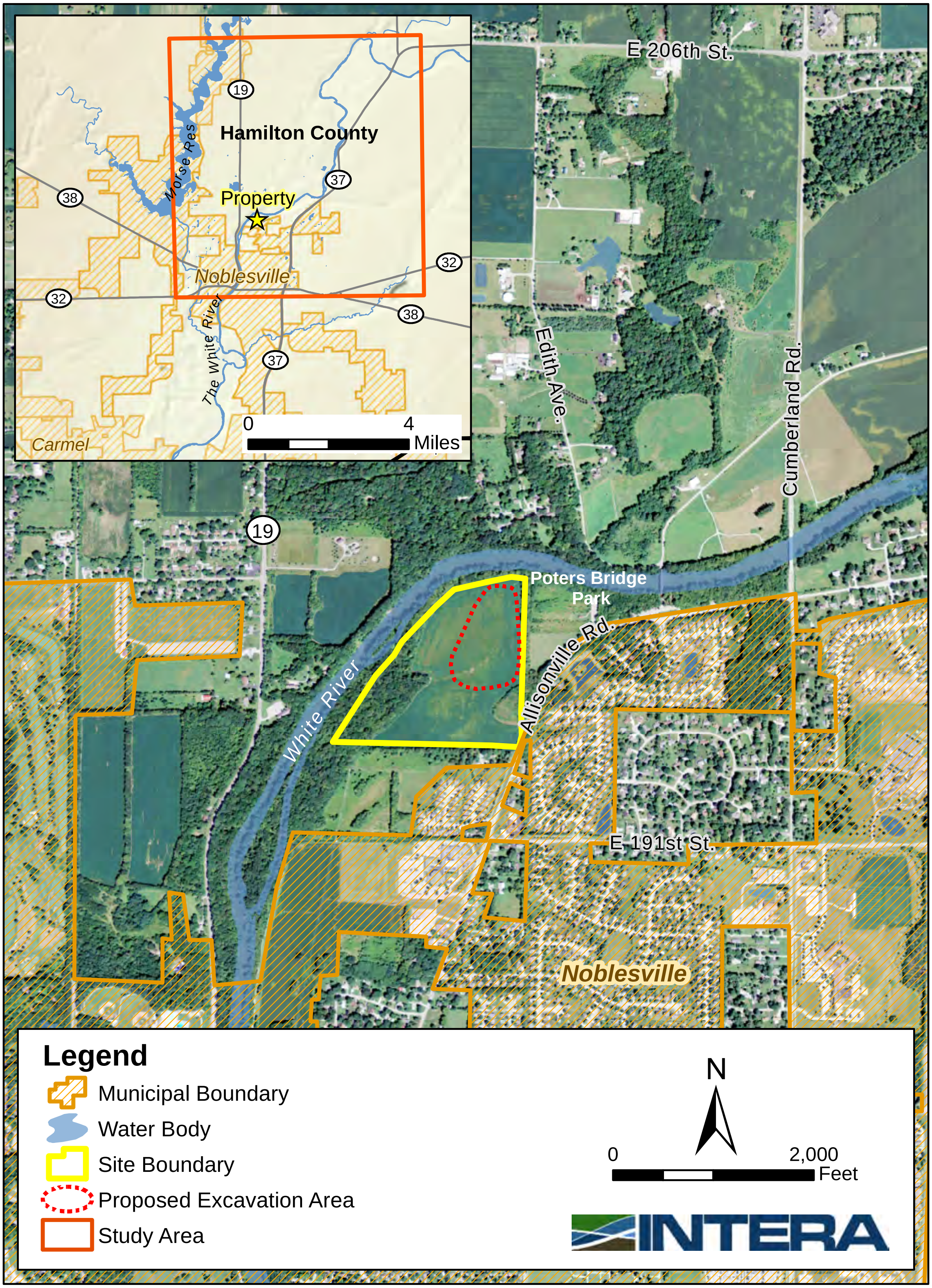


Figure 1: Location map showing the Study Area and Site boundary.

3.2 Current Land Use

The Site is located on a 50-acre parcel which currently utilized as a row-crop soybean field. The Site sits just outside of Noblesville city limits, with Potters Bridge Park bordering to the east, and the White River to the north and west (Figure 1). The Site contains some forested areas to the north, west, and south. There are multiple small alluvial terraces at the Site, and it lies mostly within the FEMA mapped 100-year floodplain as described in the preliminary environmental site assessment conducted at the Site (Spicer, 2020).

3.3 Unconsolidated Geology

The Site sits entirely within the glacial outwash valley, where sand and gravel deposits are prevalent. The outwash valley boundary is shown in Figure 2. The sand and gravel deposits, along with their associated aquifers, are vital resources that cover approximately 12% of Hamilton County. The resource often serves a dual purpose in the County: mining for construction material and pumping for drinking water. Figure 2 illustrates the location of the Site within the outwash, and in relation to the large groundwater pumping wells in the area. In particular, the proposed excavation area is within 0.5 miles of Indiana American Water Companies' (INAWC) White River North (WRN) Well Field and future Well Field at the INAWC Church Property (Figure 2).

3.4 Bedrock Geology

The bedrock in this area is comprised of the Silurian age Bainbridge formation, which is mainly limestone and dolomite (IGWS (2020)). Some wells in the area utilize the bedrock as a source of supply, such as at the INAWC Forest Park Well Field south of the Site, and possibly some homeowner wells within the Study Area. It is highly unlikely that the bedrock aquifer will be affected by proposed aggregate extraction (Appendix B.9). The bedrock surface in the area ranges from about 595 to 787 ft amsl with a total relief of about 190 ft (Figure 3). Bedrock valleys are shown in a blue shade, the areas with the lowest elevation shown on Figure 3. Most notably, the bedrock valley that roughly parallels the White River contains the sand and gravel aquifer that is utilized by three current INAWC well fields and the future Church Property Well Field. Depth to bedrock values in the area range from less than 20 to over 140 ft (Figure 4).

3.5 Homeowner Wells

INAWC service area covers much of the Study Area. The closest location with potential homeowner wells is the neighborhoods surrounding Heather Lane and Wagon Trail Drive, south of the White River, east of Cumberland Road, and north of Allisonville Avenue. Although these residences are relatively close to the Site (0.75 miles), they are even closer to large groundwater public supply wells (Figure 5). The groundwater model shows that water originating at the

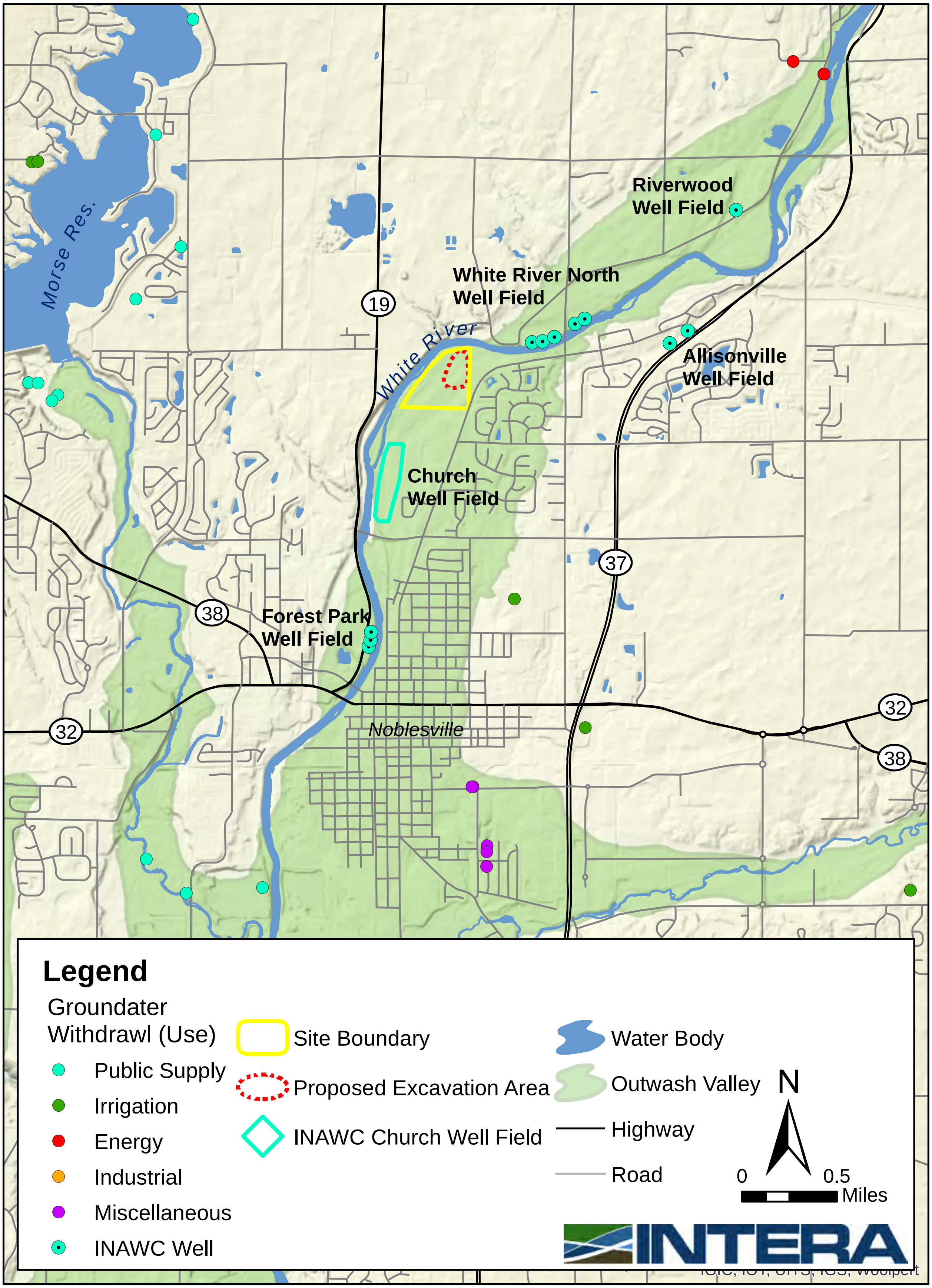


Figure 2: Outwash aquifer map.

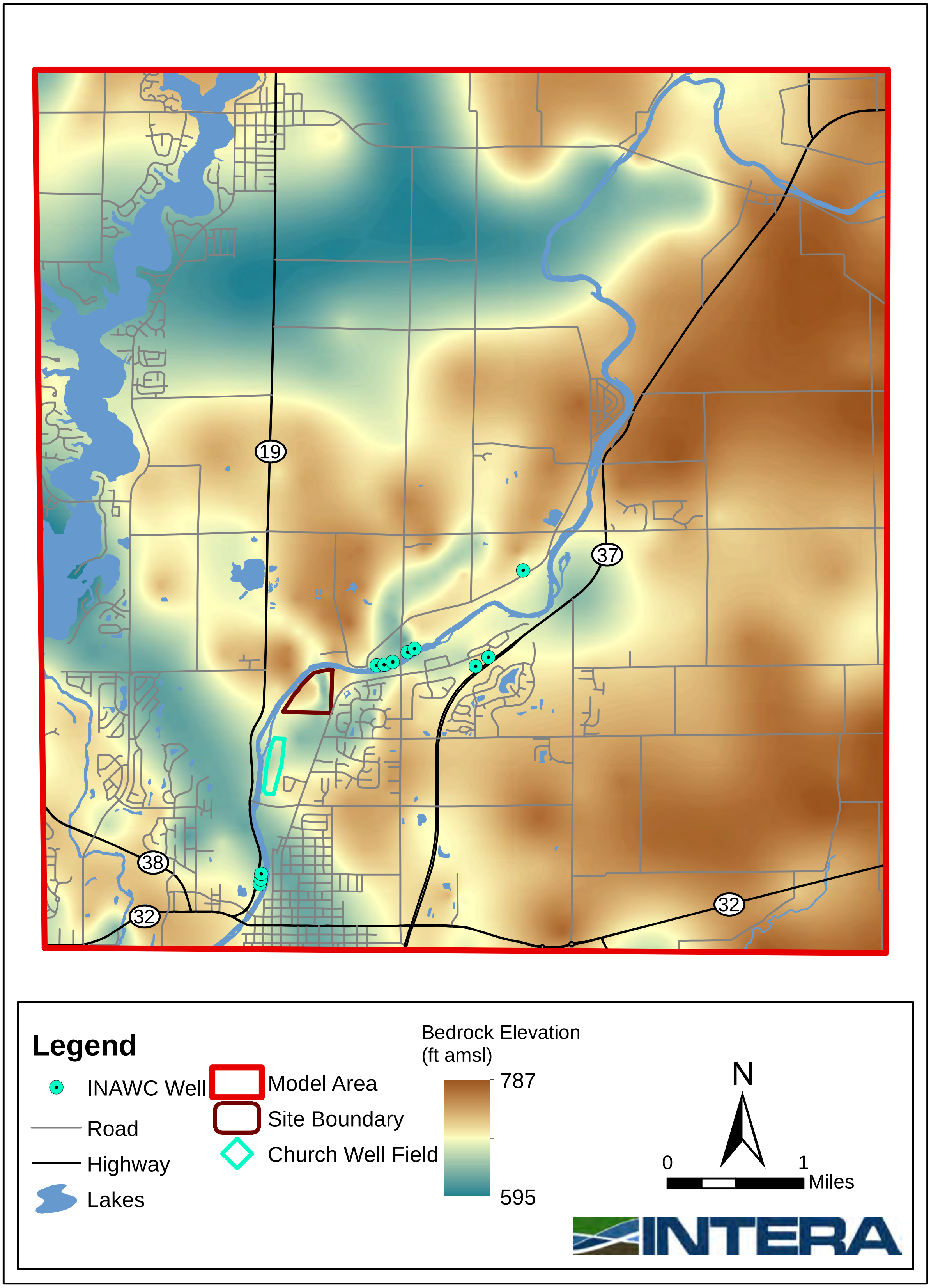


Figure 3: Bedrock elevation map of the Study Area.

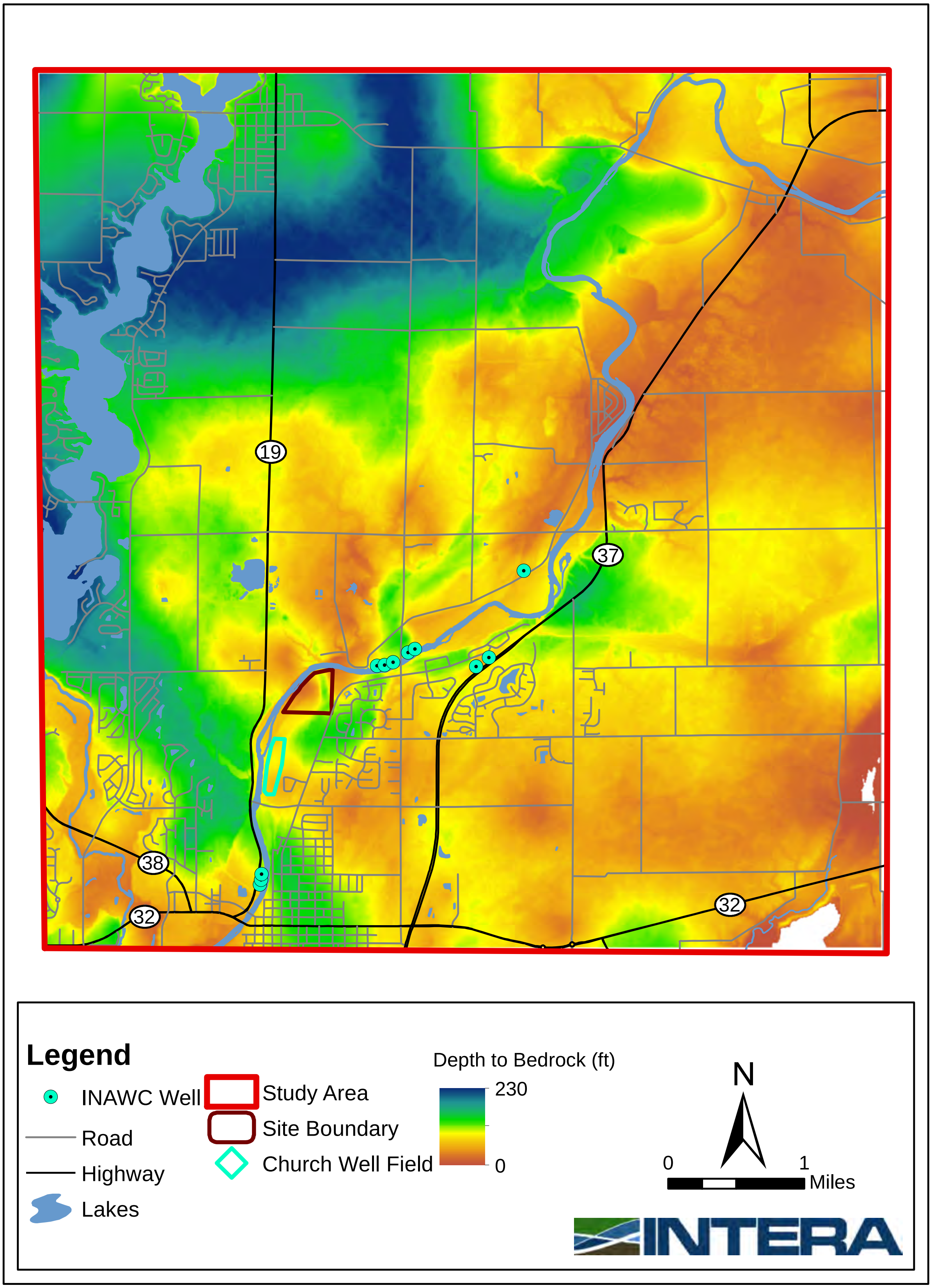


Figure 4: Depth to bedrock map of the Study Area.

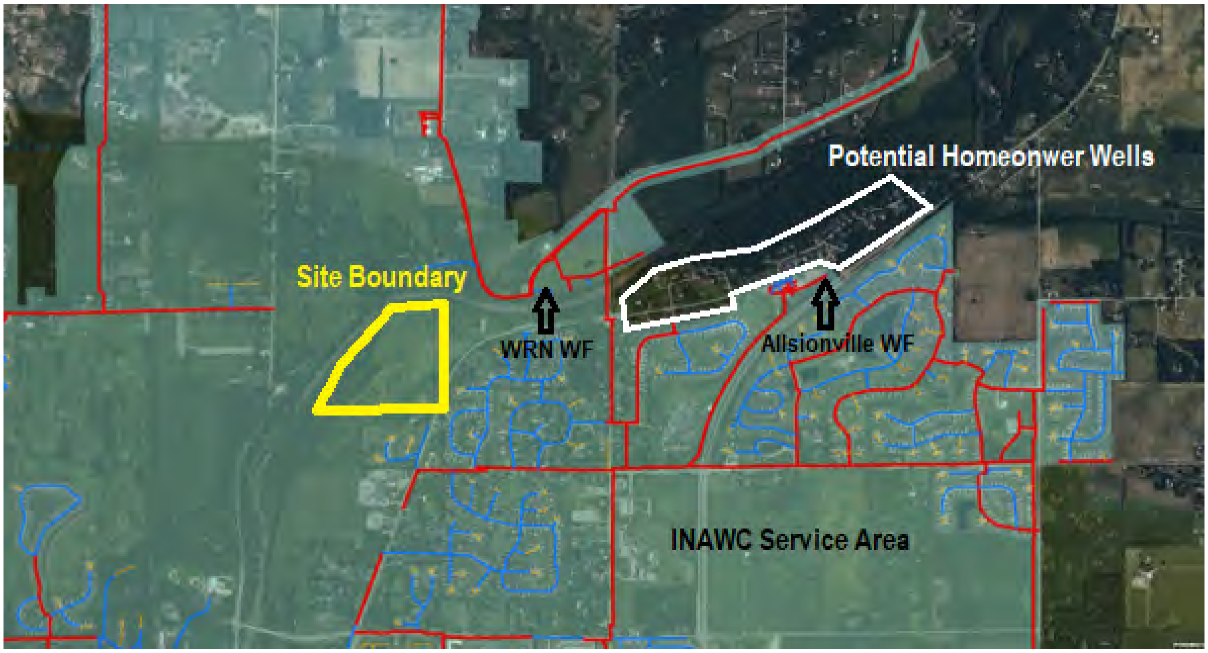


Figure 5: INAWC service area map showing area of potential homeowner wells.

Site is largely captured by the River with any a small amount going to the White River North (WRN) Well Field (Section 8).

3.6 Significant Water Withdrawals

Currently INAWC operates four well fields int he Study Area: White River North (WRN), Allisonville, Riverwood, and Forest Park. Although their pumping data was used in the groundwater flow model, Allisonville, Riverwood, and Forest Park Well Fields fall outside of the area of influence of the Site and are not included in the risk assessment. A fifth nearby well field, south of the Site, is in the process of being developed. The well field, located behind the White River Christen Church, will be referred to in this report as the Church Well Field. The Church Well Field and the WRN Well Field are both within a half mile of the Site (Figure 1). There are no other significant water withdrawal facilities that are within the Site's area of influence (Section 8).

4 Field Work

The objective of the field program was to collect high-resolution data to further characterize the Site and the surrounding area's hydrogeology. This effort involved installation of data logging probes in multiple monitoring wells, drilling three sonic boreholes, installation of three monitoring wells within two of the sonic boreholes, and a passive seismic survey.

Prior to field work, INAWC allowed access to their property to install pressure transducers in three monitoring wells surrounding the Site to monitor and record local background groundwater levels. The location of these monitoring wells is shown in Figure 6. The transducers recorded water levels every 5 minutes at each location.

4.1 Sonic Borehole Drilling and Lithologic Logging

Three sonic boreholes were drilled to bedrock at the Site between May 3rd and 5th, 2021. Location of these boreholes is shown in Figure 7. The boreholes were drilled by Cascade Environmental. Sonic drilling is a form of drilling which employs the use of high-frequency, resonant energy to advance a core barrel and casing into the subsurface. When the core barrel is retrieved from the subsurface, it produces a relatively undisturbed sample with near 100% core recovery. The recovered core sample was then classified and logged according to the unified soil classification system (USCS), which is used to describe the soil texture and grain size. Lithology for each hole (TH-1, TH-2, and TH-3) is shown in Appendix A. These test holes were drilled to supplement previous drilling at the Site (Ladish, 2020) and to add higher resolution lithologic data that could be used to extrapolate throughout the Study Area. The borehole locations were selected to fill in lithologic data gaps in previous drilling campaigns.

Two of the test holes were finished as monitoring wells (TH-1 and TH-2), one of which (TH-2) was installed with two monitoring wells, screened at different depths (Figure 7). Locations of the monitoring wells was selected to avoid areas of the potential excavation, as well as being proximal to INAWC WRN Well Field.

TH-1, located at the northeast corner of the Site, about 100 ft south of the White River, was drilled to a total depth (TD) of 40 ft below ground surface (bgs), reaching limestone bedrock at 39 ft bgs. TH-1 was used to construct a monitoring well (MW-1) with a screened interval between 25-30 ft bgs.

Located near the southeast edge of the property, TH-2 was drilled to a TD of 108 ft bgs, intercepting hard competent limestone at 97 ft bgs. TH-2 was used to construct a nested monitoring well system with two separate casings and screens: MW-2S (shallow) and MW-2D (deep). MW-2S has 10 feet of screen from 45-55 ft bgs. MW-2D has 10 feet of screen from 75-85 ft bgs. This nested system was installed to further examine the hydraulic connection between the deeper aquifer formation and shallower aquifer formation.

TH-3 was drilled near the center of the proposed excavation area as shown in Figure 7. This borehole encountered competent limestone bedrock at 115 ft bgs, with a TD of 116 ft. This well was not outfitted with a monitoring well due to its location within the proposed excavation area. TH-3 was filled and abandoned after drilling was completed. Well construction details and lithologic information for each well and borehole is in Appendix A.

Pressure transducers were installed in MW-1, MW-2S, and MW-2D. These transducers recorded groundwater levels in 5-minute intervals. Response of the water levels to pumping at nearby WRN Well Field (Well I monitoring well) was analyzed and is shown in Figure 8.

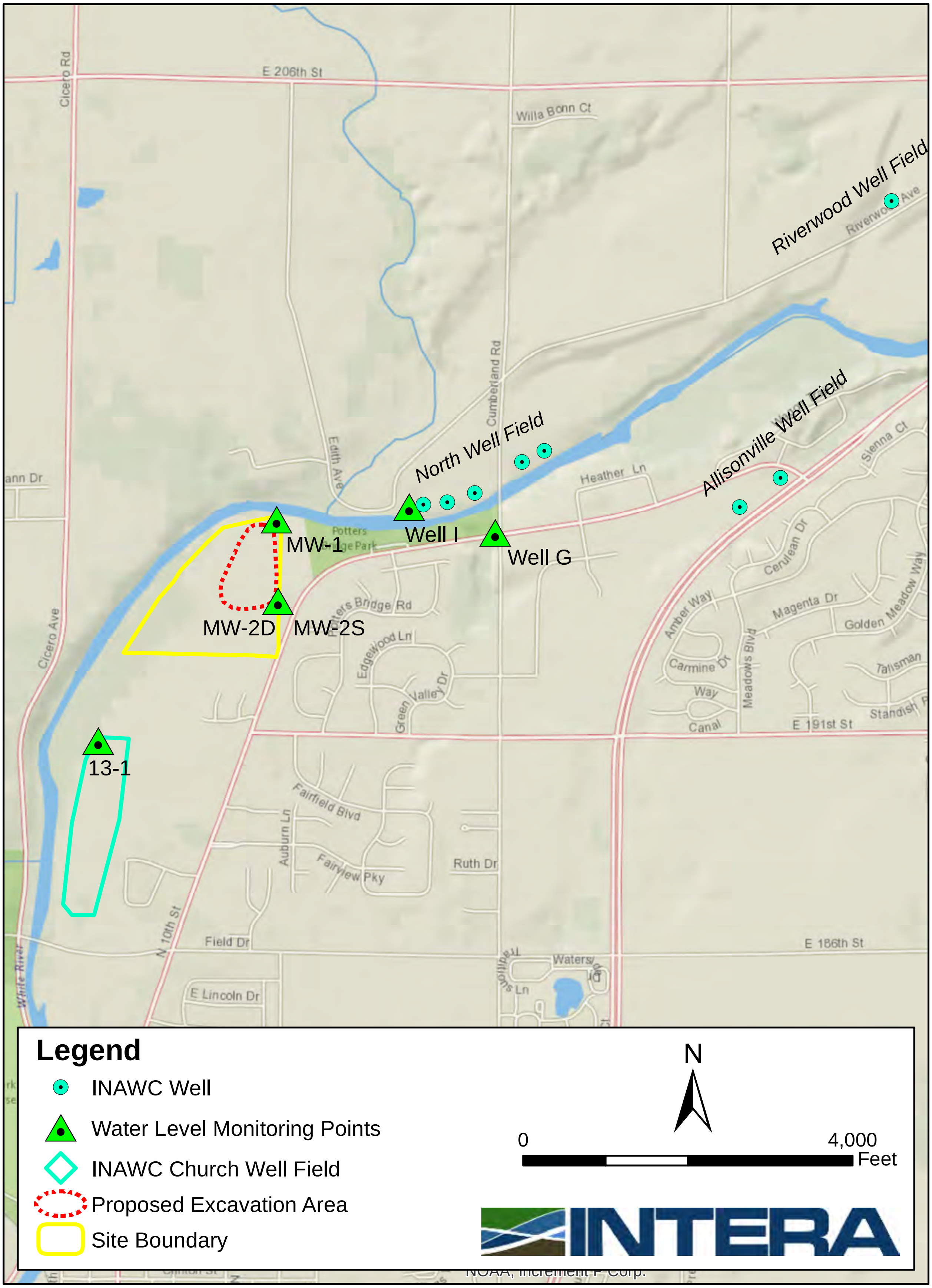


Figure 6: Monitoring well location map.

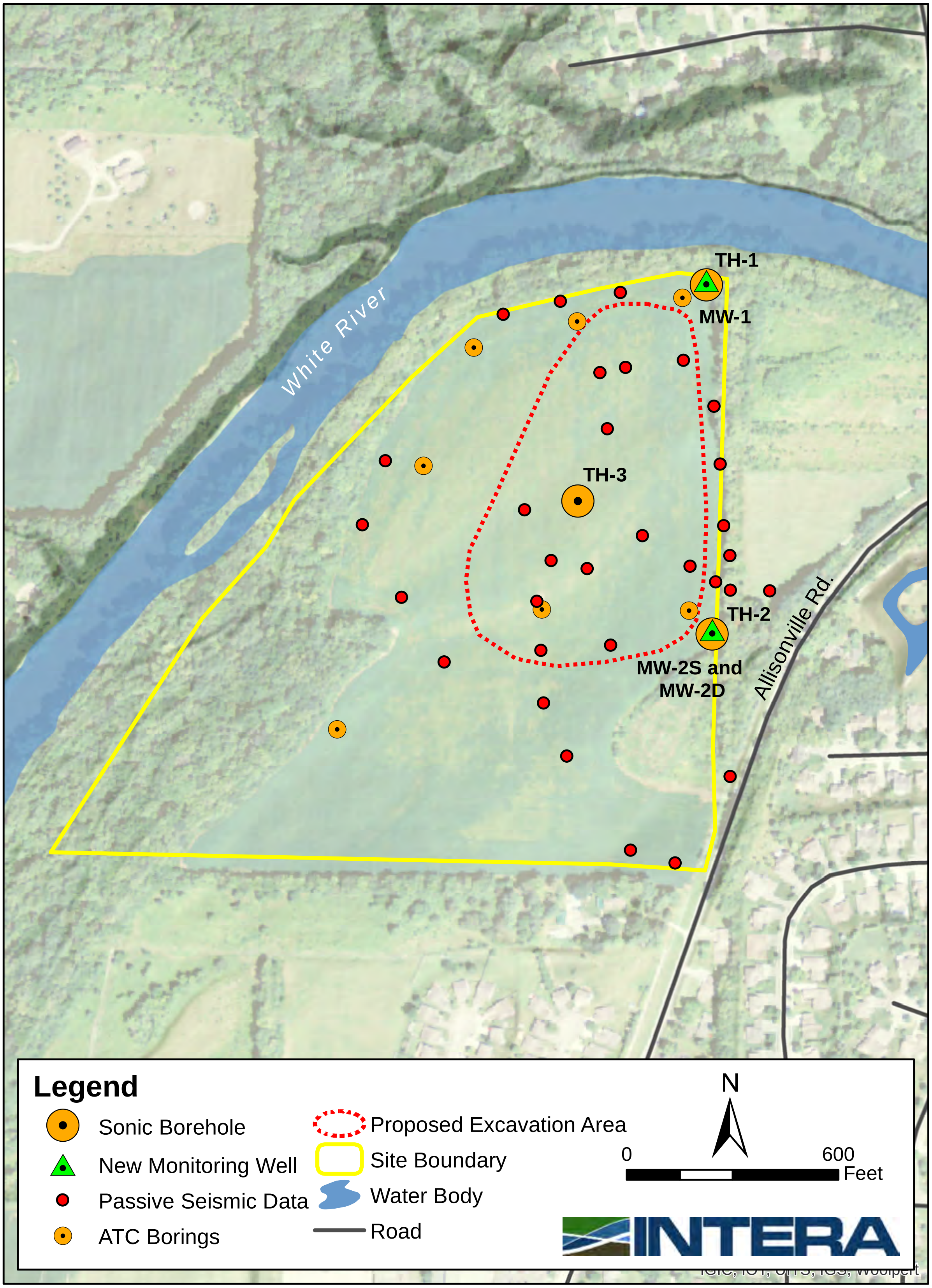


Figure 7: Field data location map.

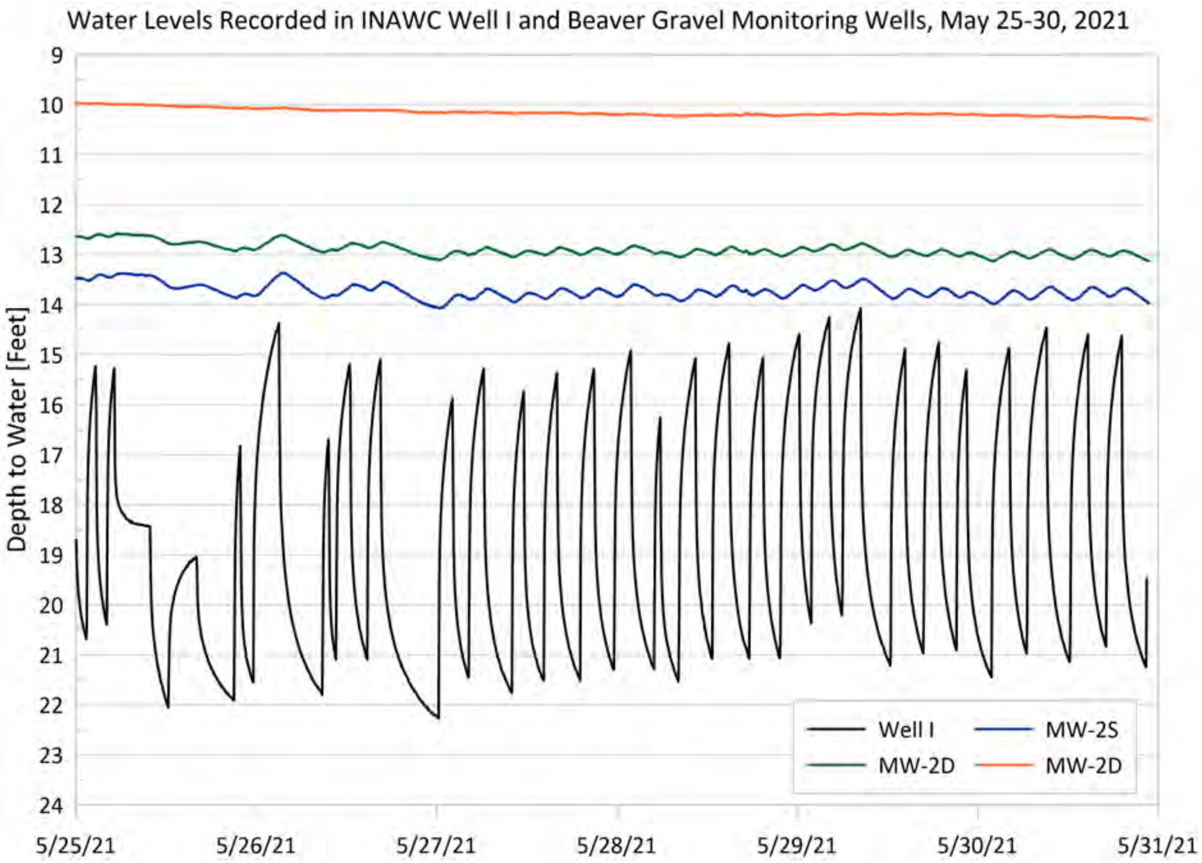


Figure 8: Response of monitoring wells to pumping.

4.2 Passive Seismic Survey

A passive seismic survey was conducted across much of the Site to collect high-resolution bedrock elevation data. The survey was conducted between May 3rd and 5th, 2021 using a Tromino 3G device (Tromino). A total of 33 data points were collected. The location of these data points can be seen in Figure 7. Data collection locations were selected to specifically define the area surrounding the proposed excavation area. Details of each data point is shown in Table 1.

The passive seismic method utilizes the fact that surficial shear waves (S-waves) naturally resonate and develop in a soft shallow layer which overlies a hard layer with a much higher seismic impedance. The resonance of this upper layer (unconsolidated thickness) produces a peak resonant frequency that can be extracted using the passive seismic HVSR method. The HVSR method compares the horizontal to vertical spectral ratio (H/V) of these passive seismic waves to determine a peak resonant frequency of the soft unconsolidated layer above the harder bedrock layer (Nakamura, 1989, 2000). The Tromino and associated software extract the peak H/V frequency at each recorded data point. The peak resonant frequency that is extracted from the H/V method is directly related to the thickness of the upper soft layer and the S-wave velocity of the material by the following equation:

Equation 1: $f0 = \frac{Vs}{4h}$,

where $f0$ = peak H/V frequency (Hz), Vs =S-wave velocity of upper layer (m/s), and h =thickness of layer (m).

The relationship between peak resonant frequency recorded at a point and the S-wave velocity at that point is not linear, so an exponential curve is calculated using multiple control points within an area. Using Equation 1, S-wave velocities are calculated for each control point, where values for depth (h) and frequency $f0$ are known. Five control points were used in this investigation. Plotting the calculated S-wave velocities (Vs) versus the peak frequency values ($f0$) recorded at each control point and fitting a trendline results in the following equation:

Equation 2: $Vs = 735.57e^{-0.081f0}$

where Vs =S-wave velocity of upper layer (m/s) and $f0$ =peak H/V frequency (Hz)

Equation 2 can then be applied to the rest of the recorded frequency data points ($f0$) to determine an approximate average S-wave velocity (Vs) at each point. These (Vs) and ($f0$) values are then inserted into Equation 1 to calculate an approximate depth to bedrock (h) value at each point.

5 3D Geologic Model

A 3D Conceptual Geological Model (CGM) was constructed to better visualize and define the shape of the bedrock surface and unconsolidated lithology within the Study Area. The model was constructed using Leapfrog Works version 2.4 software (Leapfrog). Leapfrog enables fast, detailed visualization and analysis of geologic features. A Leapfrog Viewer file of this area will

Table 1: Tromino data points

Data Point	**Bedrock Elevation (ft)**	**Latitude**	**Longitude**
1	626	40.069006	-86.005235
2	661	40.072770	-86.006366
3	638	40.072700	-86.006973
4	650	40.072597	-86.007551
5	612	40.072147	-86.006570
6	704	40.071888	-86.005413
7	666	40.070080	-86.005385
8	720	40.072858	-86.005434
9	585	40.070621	-86.006691
10	593	40.070878	-86.006134
11	602	40.071709	-86.006492
12	594	40.072188	-86.006310
13	711	40.072245	-86.005725
14	688	40.071437	-86.005349
15	690	40.070959	-86.005311
16	684	40.070725	-86.005246
17	659	40.070641	-86.005650
18	687	40.070453	-86.004841
19	596	40.070025	-86.006451
20	666	40.069983	-86.007156
21	653	40.069573	-86.007128
22	627	40.069161	-86.006890
23	735	40.071454	-86.008740
24	735	40.070955	-86.008971
25	724	40.070391	-86.008571
26	709	40.069889	-86.008136
27	686	40.070365	-86.007200
28	666	40.070456	-86.005241
29	664	40.070520	-86.005390
30	648	40.071137	-86.006835
31	700	40.071076	-86.007328
32	620	40.068332	-86.005790
33	628	40.068429	-86.006241

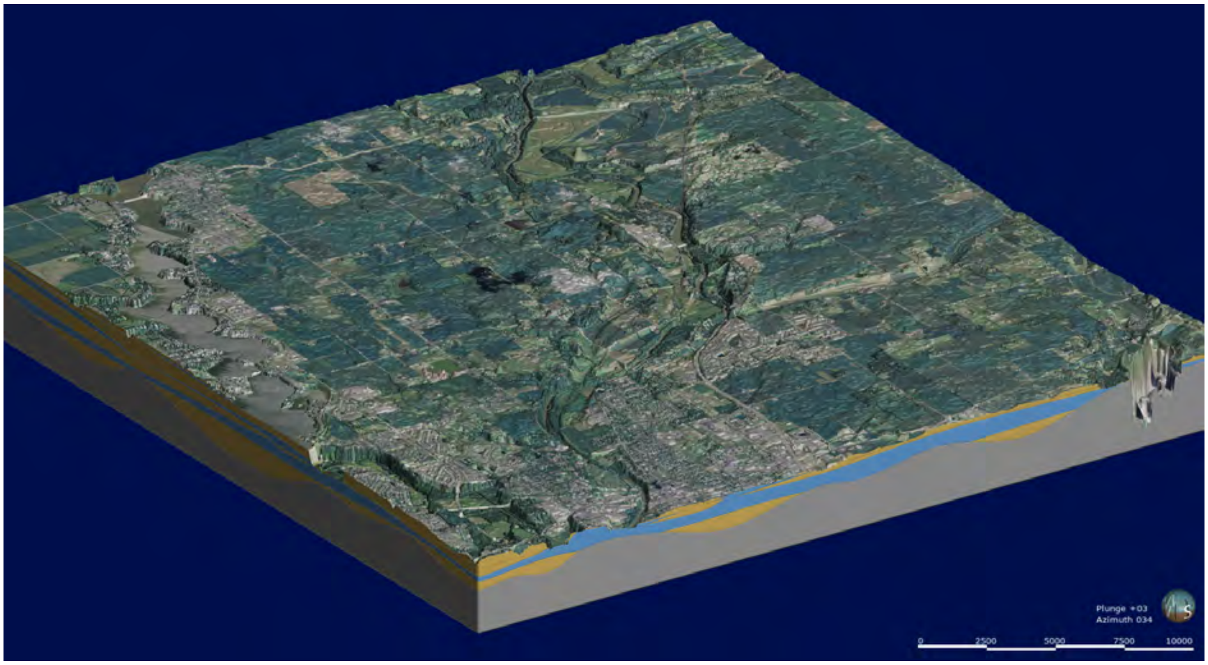


Figure 9: Leapfrog model.

be available upon request, where the user may freely manipulate and explore the 3D model.

5.1 Model Inputs

The domain of the CGM was delineated to match the model domain selected for the groundwater flow model. The domain reaches south to Conner St./Highway 38, north to Strawtown, west past Morse Reservoir, and east to Victory Chapple Road (Figure 1).

5.1.1 Topography

Topography in the 3D CGM was imported from USGS 1/3 arc-second DEM files (USGS, 2019). The topography represents the land surface and is also the top bounding surface for the CGM. The topography in the Study Area is mostly flat, with the major feature being the White River and outwash valley. An example image of the entire Leapfrog model is shown in Figure 9.

5.1.2 Bedrock Elevation

Preliminary bedrock elevation data was imported into the model from the IGWS Bedrock Topography 100-M DEM dataset (IGWS, 2015). This data was refined and enhanced, particularly at the Site using the new data points from the sonic boreholes, previous drilling campaigns, and passive seismic survey. Bedrock elevation data immediately surrounding the Site, from the WRN Well Field to the Church Well Field, is shown in Figure 10. The Site sits above a narrow bedrock valley that runs approximately north-south and connects with the larger bedrock valley that runs northeast-southwest. The larger bedrock valley is the site of both the WRN Well Field and the potential future Church Well Field. An apparent bedrock ridge separates the deep valley that lies below the Site from the aquifer where the WRN Well Field is located as seen in Figure 10. Well log data from the Indiana Department of Natural Resources (IDNR) well log database were also identified and added to the model area to increase accuracy at a regional scale. Bedrock elevation for the entire Study Area is shown in Figure 3.

5.1.3 Well Logs

Along with lithologic data from the new sonic boreholes and previous drilling at the Site, approximately 200 well logs were added to the CGM from the IDNR water well database. Locations of well logs are shown in Figure 11. A higher density of well data was used close to the Site, as shown in Figure 11. Lithologic data from these logs were grouped into three main categories based on their aquifer characteristics: Clay, Sand and Gravel, and Bedrock. Fine grained materials such as clay, silt, or till were grouped into the Clay category, coarse grained material such as sand, gravel, or cobbles were grouped into the Sand and Gravel category, and hard bedrock material were grouped into the Bedrock category.

5.2 Model Development

The 3D CGM was in large part developed to delineate in detail the size and extent of various lithologic layers throughout the Study Area that greatly effect how water moves through the system. The first step in this process was to consider the relative age of each of the large scale depositional and erosional features. These features, from oldest to youngest, are the bedrock, till, outwash, and alluvium.

The bedrock is the oldest feature and represents the lower most bounds of the productive sand and gravel aquifers. Some wells in the Study Area pump from the bedrock aquifer, but they usually do not produce much water and are sparsely located. The next oldest feature is the till. Till covers most of the Study Area and is largely composed of fine-grained sediments. Although the till is mostly made up of unsorted fine-grained material, there are layers and lenses of well-sorted sand and gravel deposits that serve as confined and semi-confined aquifers. The next youngest layer is the outwash. The outwash channel is well delineated and visable within the topography. The outwash channel was cut into the underlying till and the deposits within the channel are largely well sorted sands and gravels. The youngest feature to be delineated was the alluvial channel. This represents the earliest erosional and depositional process that has occurred since the deposition of the outwash. The alluvial material was These channel boundaries are shown in Figure 12.

Within each of the three unconsolidated features (till, outwash, and alluvium) layers and pockets of clay, as defined by the well logs, were delineated. First a top clay layer was delineated within each feature. Next, three separate basal clay units that sit on top of the bedrock, within bedrock valleys, were delineated. Then, working from bottom to top: 11 clay layers and lenses

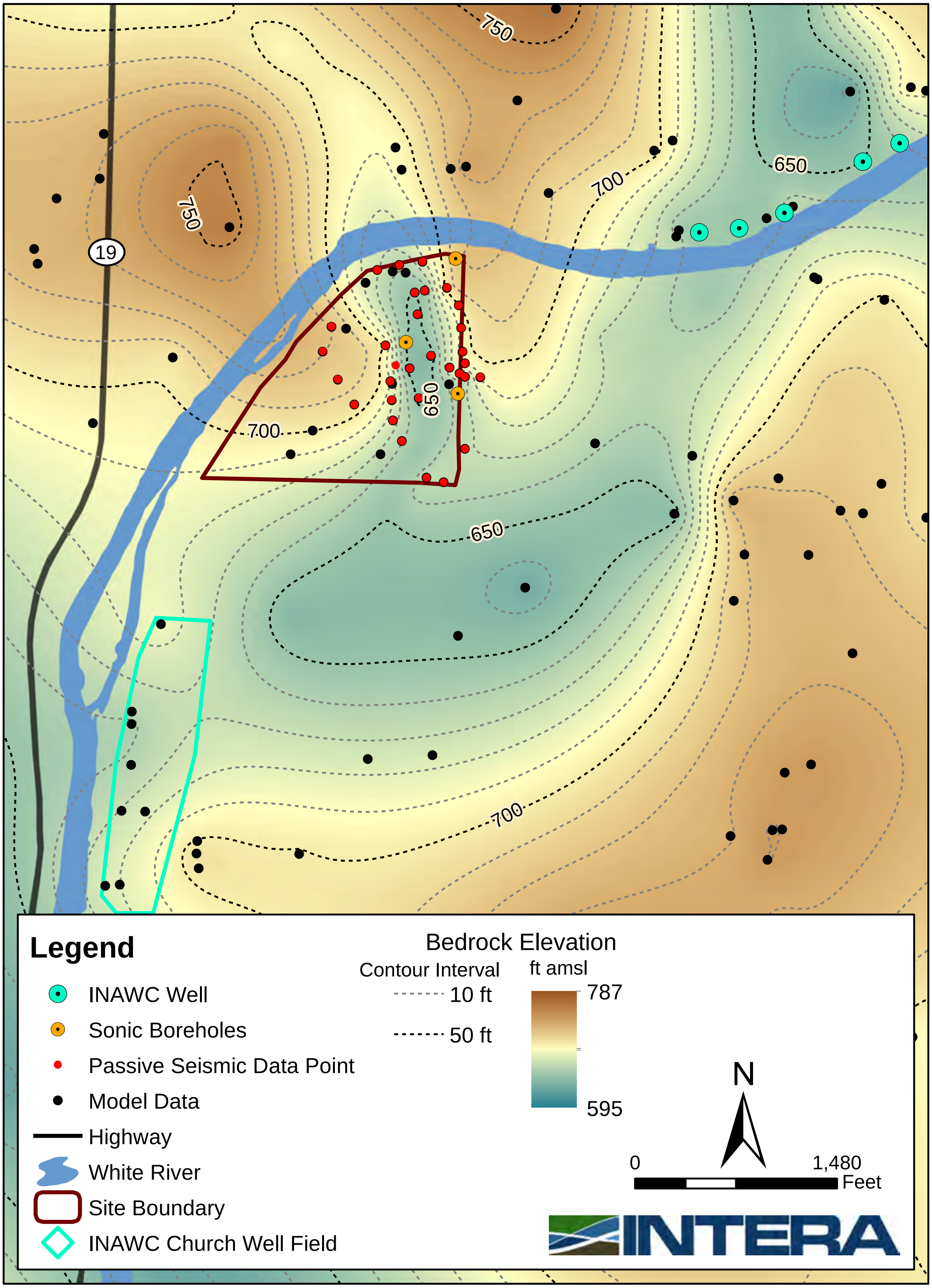


Figure 10: Bedrock elevation surrounding the site.

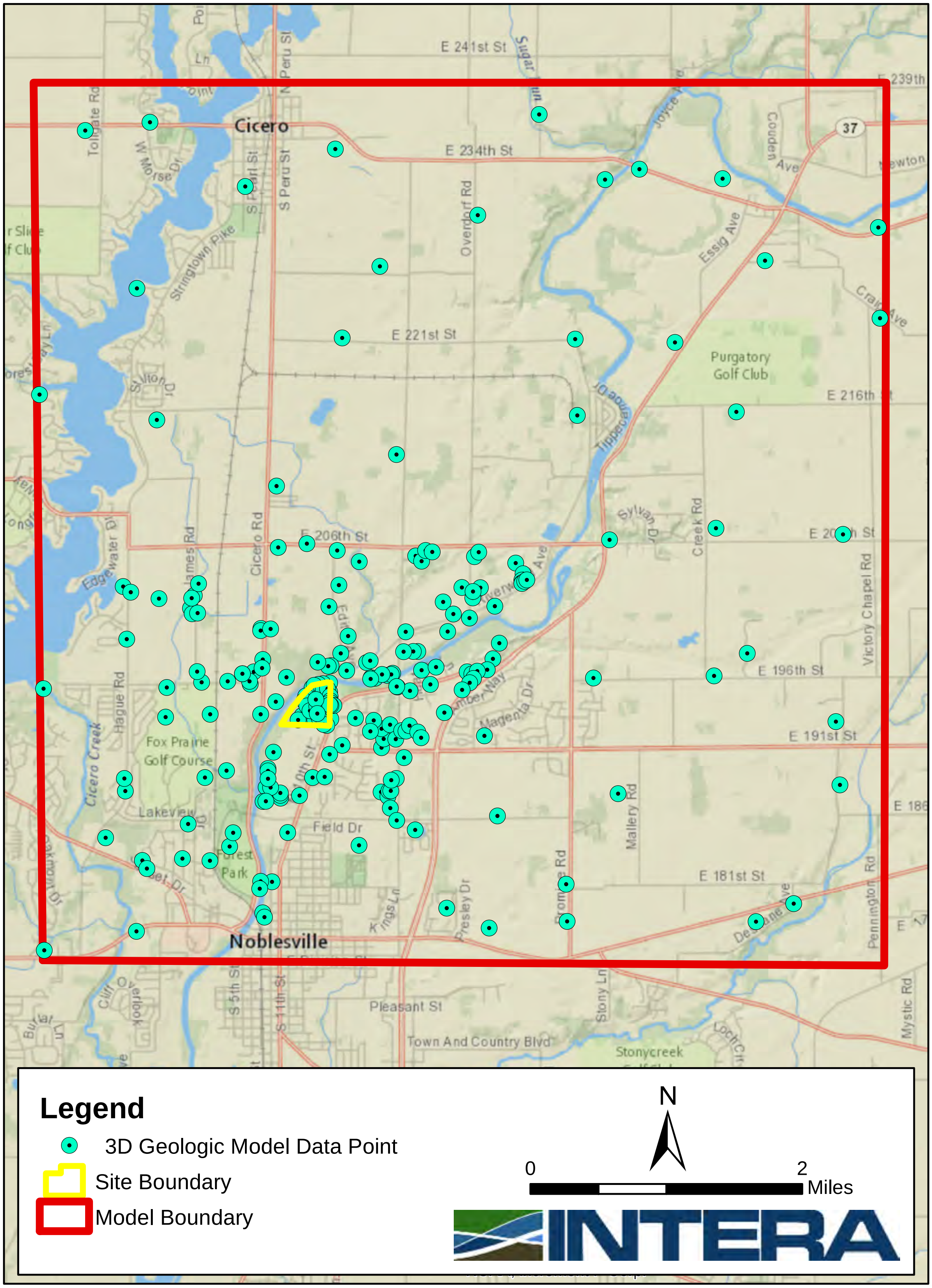


Figure 11: Well log locations used in Leapfrog 3D CGM.

were delineated within the till, 4 within the outwash, and an additional clay layer within the alluvium.

5.3 Geologic Cross-Sections

Three geologic cross-sections were developed from the CGM. The location of the cross-sections is shown in Figure 13. These cross-sections show the lithologic information contained within the CGM. Cross-section A-A' runs from northeast to southwest, perpendicular to the outwash channel, crossing through the proposed excavation area (Figure 14). Cross-section B-B' depicts a section that runs southwest to northeast, parallel to the White River, and through both the proposed excavation area and the INAWC WRN Well Field (Figure 15). Cross-Section C-C' shows a section that runs from southwest to northeast, crossing through the proposed excavation area and the INAWC Church Well Field (Figure 16).

5.4 Export to Groundwater Model

To properly transfer the detailed information contained in the CGM to the groundwater flow model, ten continuous layers were delineated across the CGM that represent either bedrock, clay, or sand and gravel. These layers utilized pinch out geometries to accurately portray lenses where present. The ten layers used in the groundwater flow model are labeled from bottom to top as: Bedrock Aquifer, Basil till overlying bedrock, Basal sand and gravel, Till unit A, Lower sand and gravel, Till unit B, Middle sand and gravel, Till unit C, Top sand and gravel, and Surficial unit (Table 3).

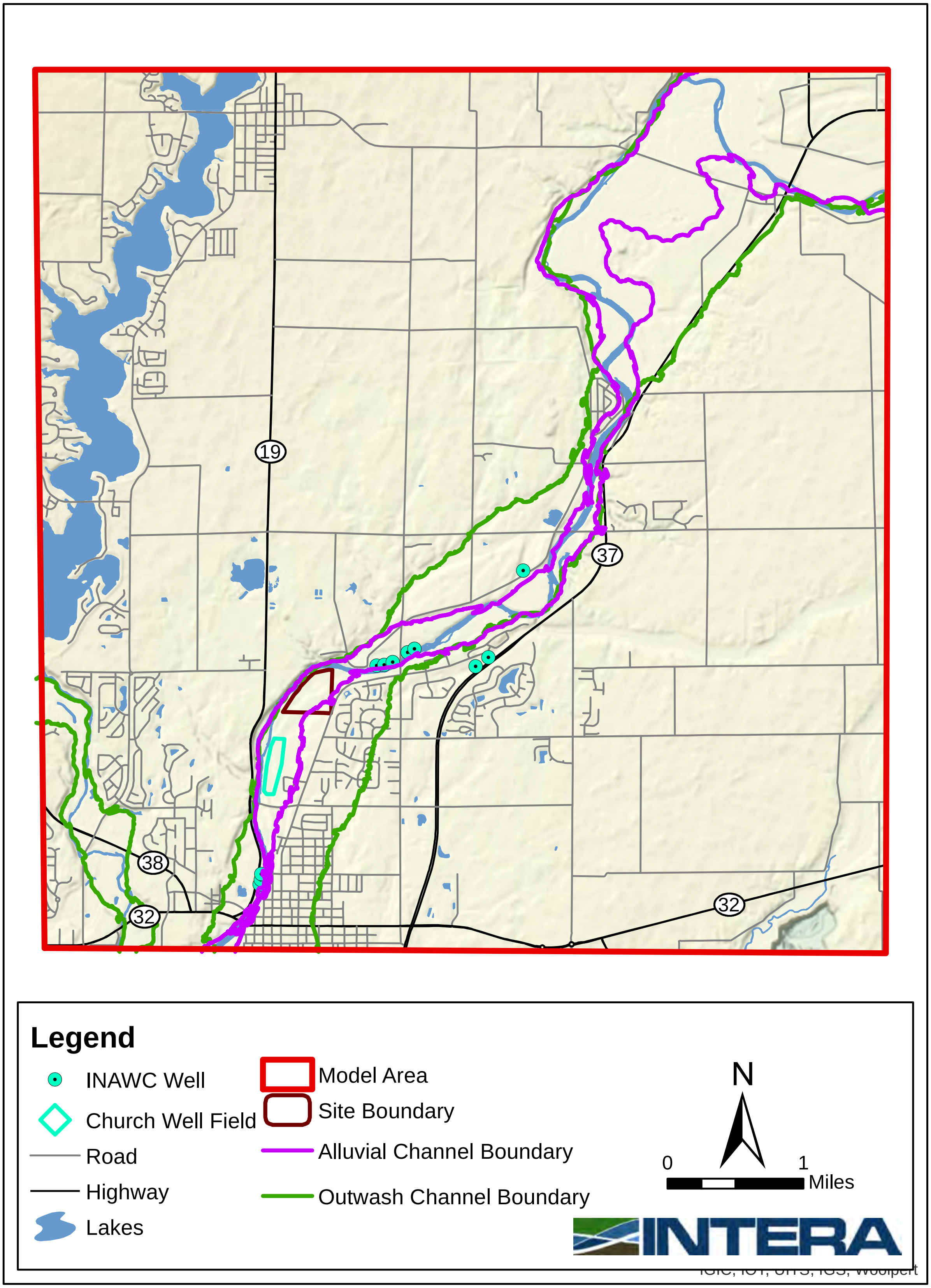


Figure 12: Map showing outwash and alluvial channels.

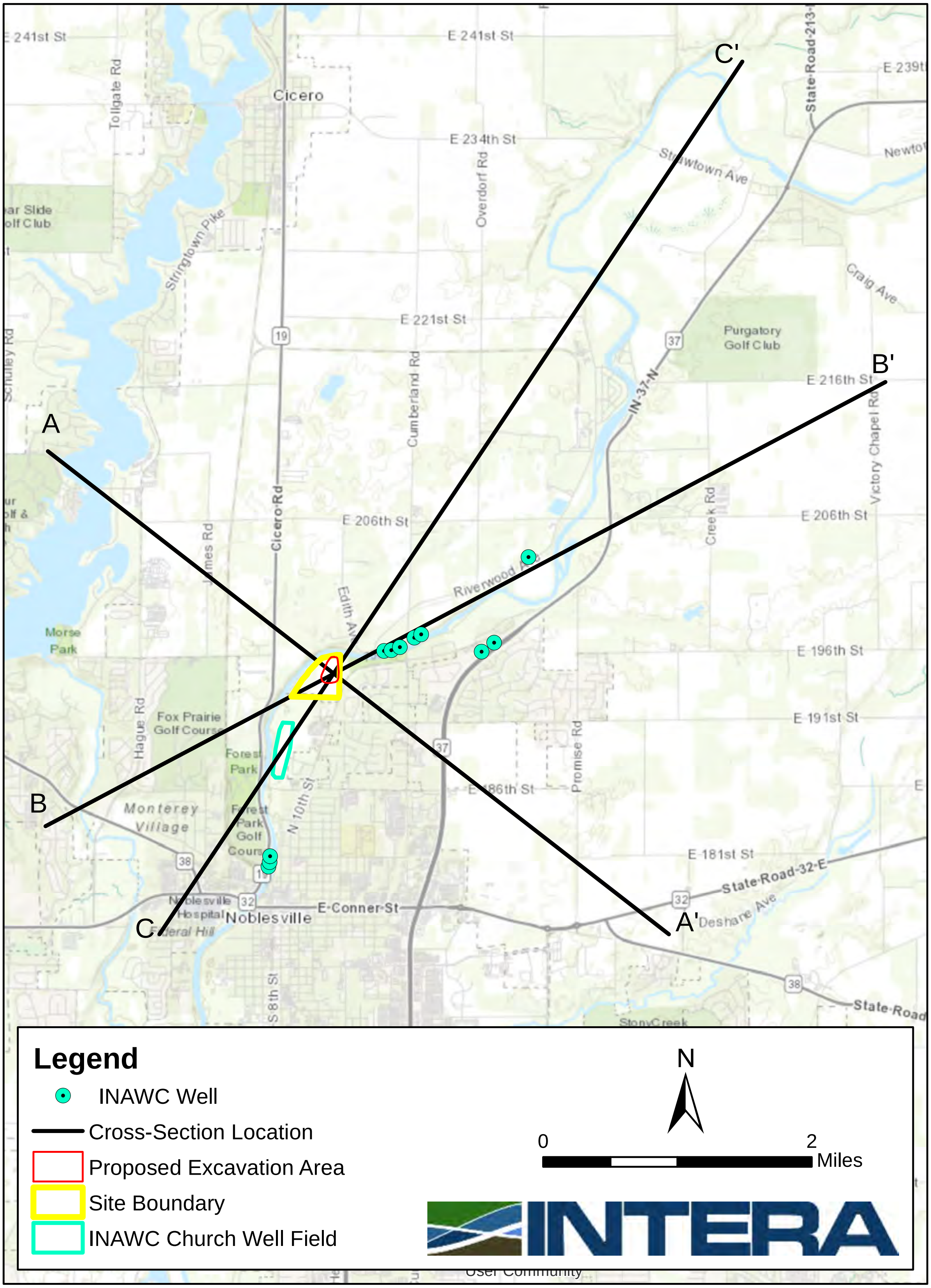


Figure 13: Cross-section location map.

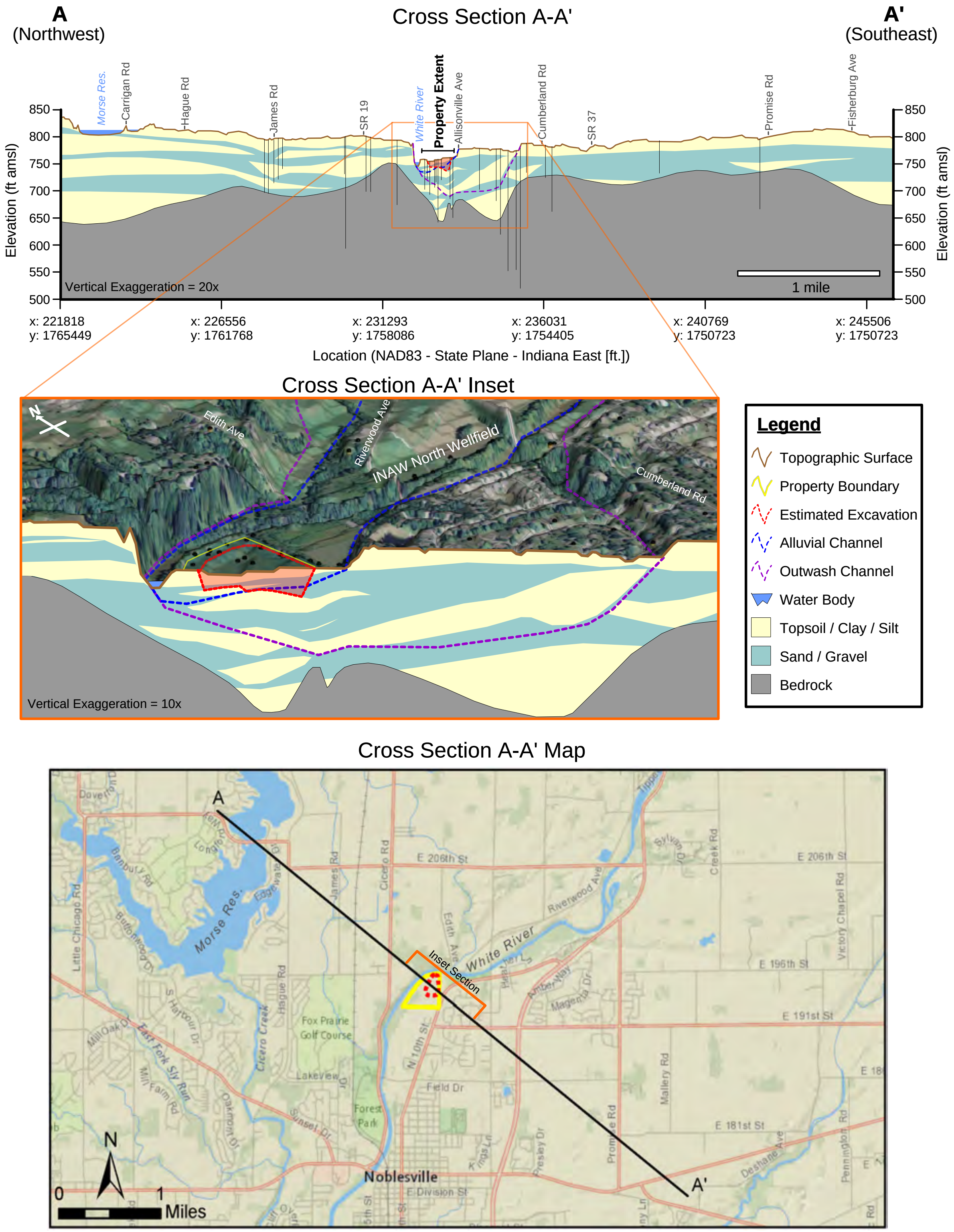


Figure 14: Cross-section A-A'.

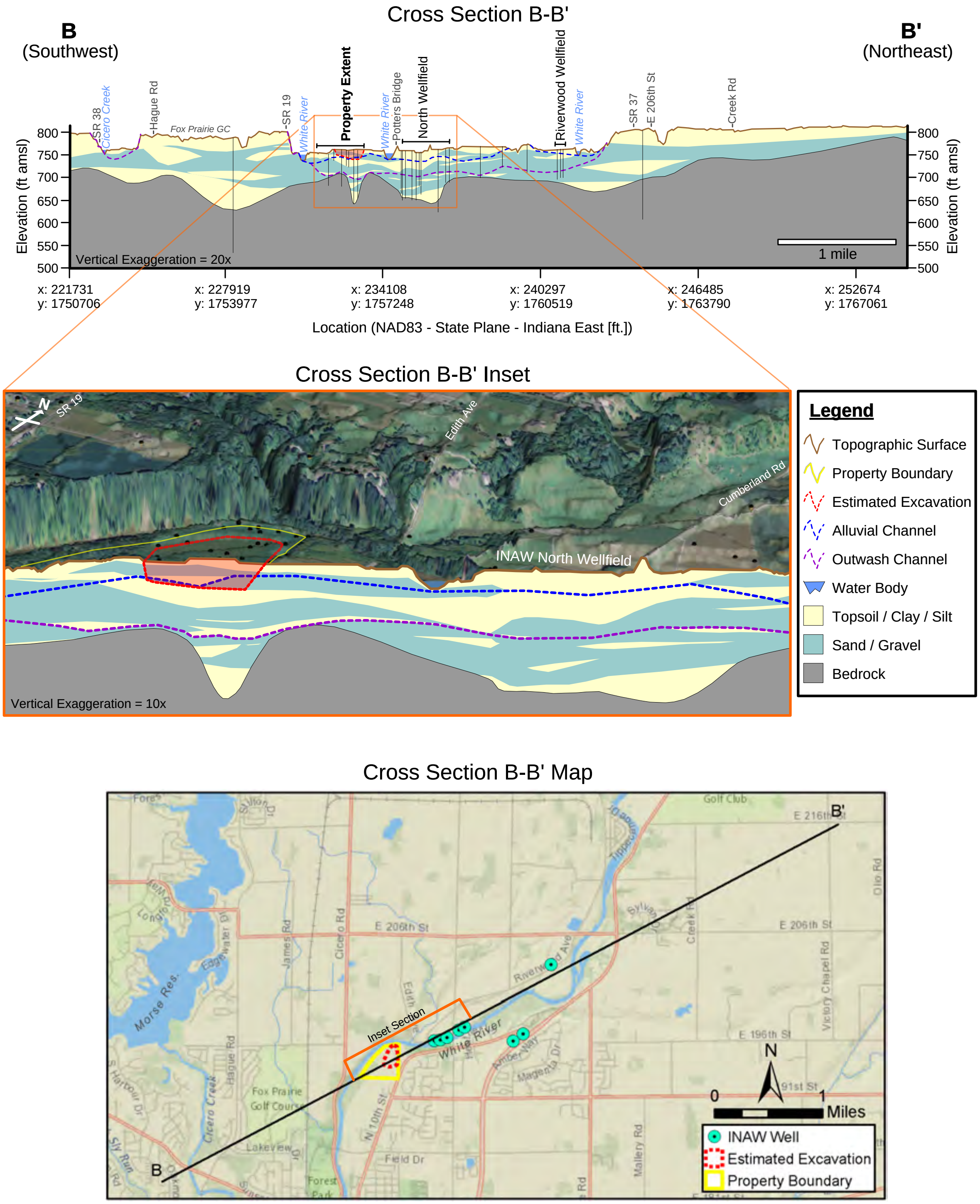


Figure 15: Cross-section B-B'.

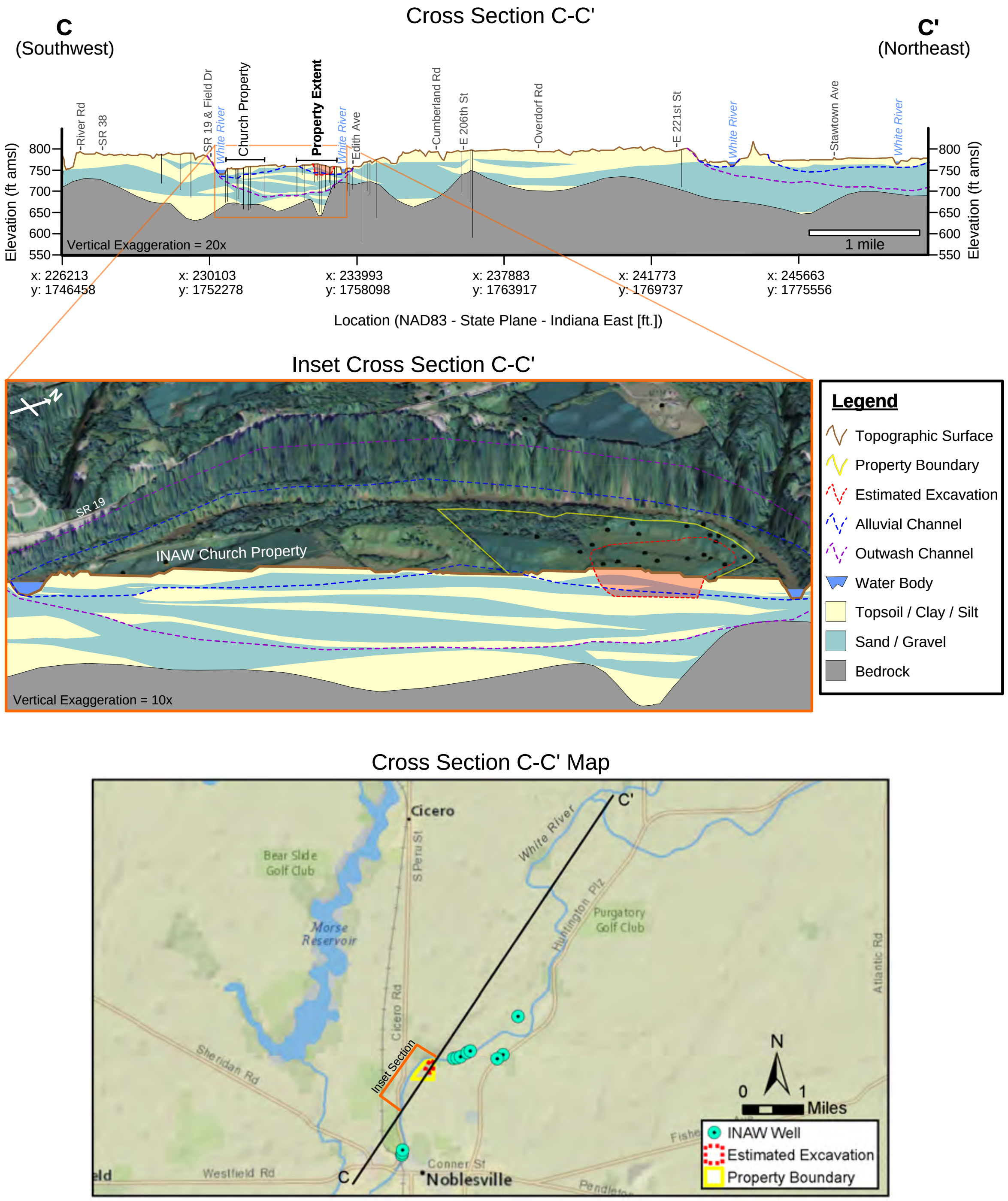


Figure 16: Cross-section C-C'.

6 Groundwater Flow Model

A groundwater flow model was developed to quantify the potential risks of the proposed sand and gravel pit at the Site on nearby production wells and any potentially nearby homeowner wells. Details of model construction are presented in Appendix B. Figure 17 shows the model domain, selected to investigate the potential hydraulic interaction between the Site and INAWC wells in the area. INAWC operates three well fields near the Site: the White River North (WRN), Riverwood, and Allisonville Well Fields. A forth nearby well field, south of the Site, is in the process of being developed. The well field site, located behind the White River Christian Church, is referred to in this report as the Church Well Field. In 2014, INAWC constructed a production well approximately 1,800 ft south of the parcel boundary within the Church Well Field (Champa, 2014). The well has not been placed into service, but plans include connecting this well to the system and potentially adding a second well in the future.

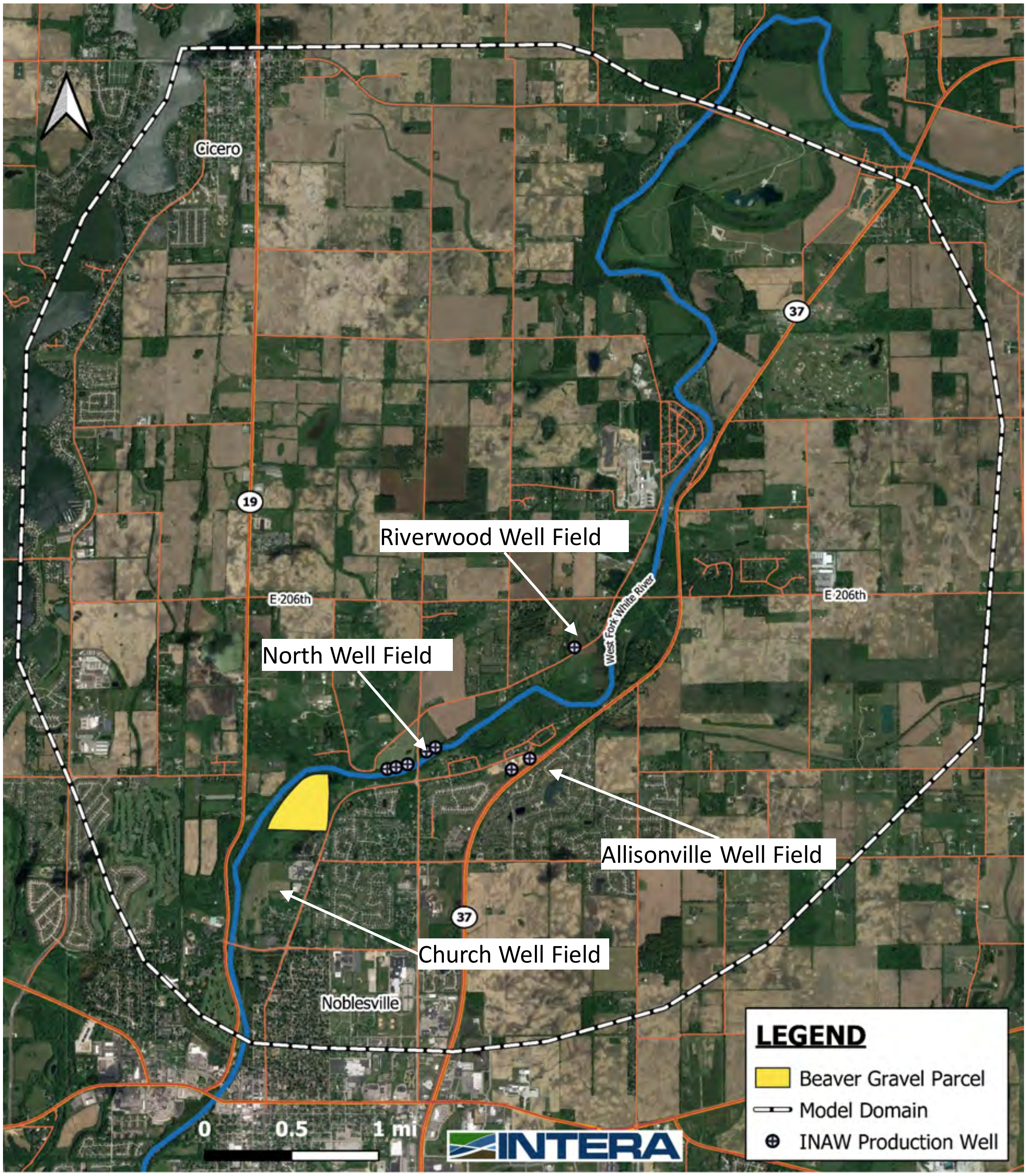


Figure 17: Model domain.

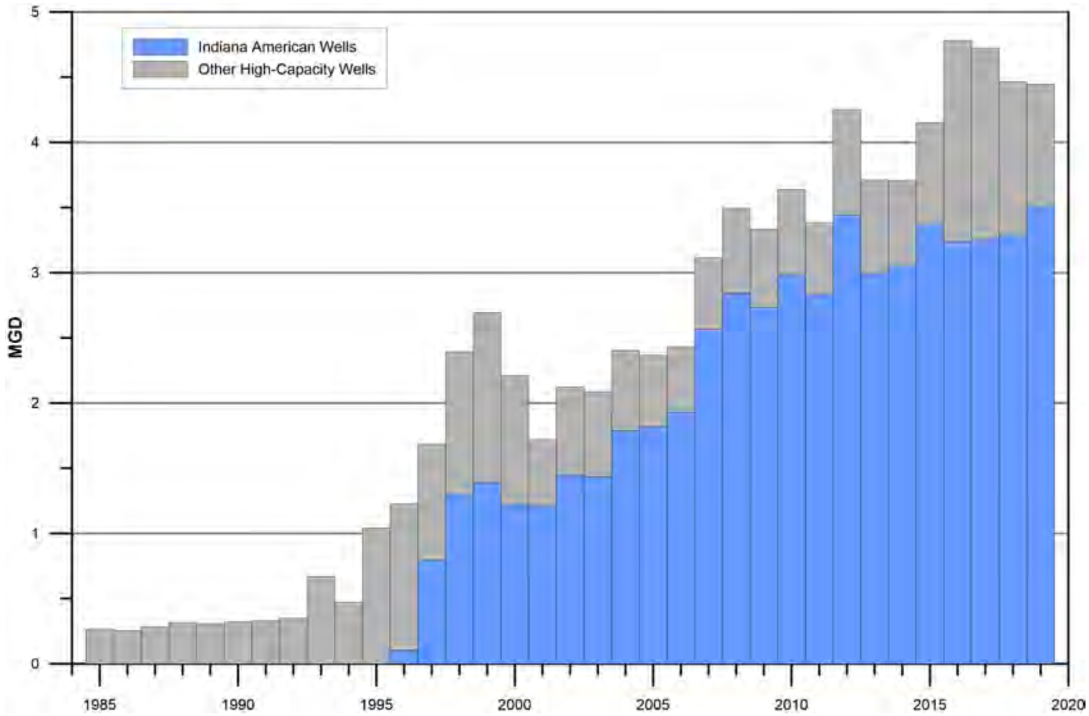


Figure 18: Significant water withdrawals by high-capacity wells in the model domain, 1985-2019 (IDNR, 2021).

7 Groundwater Use within the Model Domain

Growth in the area of the model domain has resulted in a significant increase in groundwater use since the IDNR started tracking withdrawals in 1985 (Figure 18). The most recent year of withdrawal available from IDNR is 2019. Since 2015, total withdrawals from the model domain have been between 4 and 5 MGD. The overall increase in groundwater withdrawals seen in Figure 18 is due to an increase in pumping high-capacity pubic-supply wells within the White River valley outwash aquifer.

INAWC's production has increased steadily since the mid-1990's to support an increasing population and new industrial and commercial customers, beginning with one well pumping an average of less than 1 MGD at the North Well Field in 1996, to approximately 3 MGD or higher every year since 2012 (Figure 18). INAWC began pumping from two new wells that make up the Allisonville Well Field in 2020, shifting some of the supply load from the other two well fields. Newly reported withdrawals from the three well fields in 2020 shows an all-time high of 3.62 MGD (Stefanich, 2021).

8 Predictive Modeling Analysis

Hydraulic interactions surrounding the proposed excavation area were quantified using particle tracking. Particle tacking was conducted with MODPATH-7, a post-processor designed to work with output from MODFLOW (Pollock, 2016). Forward particle tracking was used to estimate the time-of-travel of water from the proposed excavation area to nearby INAWC production wells. Backward tracking from the affected wells was used to estimate the fraction of water originating from or passing beneath the proposed excavation area. Model runs were conducted using a model-wide value of 0.25 for porosity.

8.1 Predictive Scenarios

A predictive analysis was conducted using multiple scenarios with varying particle release locations and varying pumping schemes to estimate potential future conditions. The scenarios are summarized in Table 2. These scenarios were selected to evaluate the hydraulic interaction between the proposed excavation, the North Well Field, and the Chruch Well Field, which

Table 2: Summary of predictive analysis scenarios.

			Pumping Scheme		
Scenario #	Location of particle release	Trace Direction	Existing Wells Current Rates	Church Well 1	Theoretical Church Well 2
	North Well Field				
1A	East side of mine parcel, L2	F	X		
1B	East side of mine parcel, L6	F	X		
1C	East side river reach, L1	F	X		
1D	North WF, Well 1, L8	B	X		
	Church Well Field, 1 Well				
2A	South side of mine parcel, L2	F	X	1 MGD	
2B	South side of mine parcel, L6	F	X	1 MGD	
2C	South side river reach, L1	F	X	1 MGD	
2D	Church WF, Well 1	B	X	1 MGD	
	Church Well Field, 2 Wells				
3A	South side of mine parcel, L2	F	X	0.5 MGD	0.5 MGD
3B	South side of mine parcel, L6	F	X	0.5 MGD	0.5 MGD
3C	South side river reach, L1	F	X	0.5 MGD	0.5 MGD
3D	Church WF, Theor. Well 2	B	X	0.5 MGD	0.5 MGD

Notes: F- Forward, B- Backward

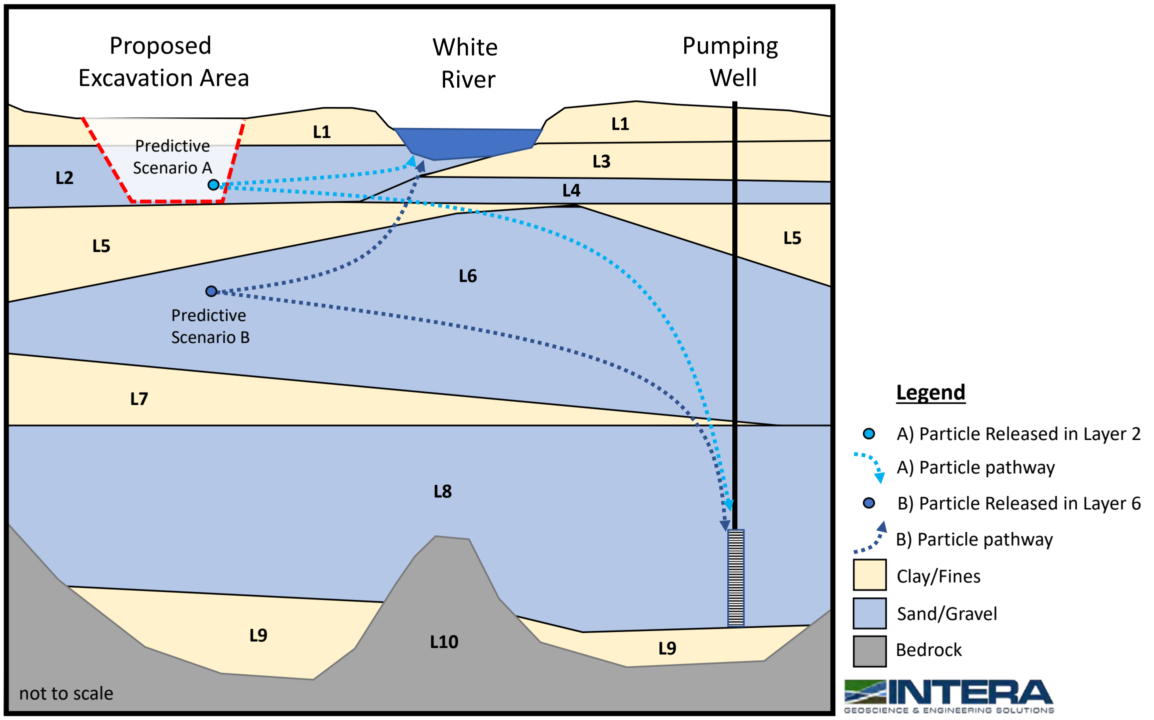


Figure 19: Conceptual cross-section of predictive modeling analysis.

incorporates two different development possibilities. Scenarios 1A through 1D were defined to analyize the hydraulic interactions between the North Well Field, the Site, and the White River (the River). Scenarios 2A through 2D address potential interactions between Church Well Field with 1 active well (Well 1), the Site, and the White River. Scenarios 3A through 3D address potenial interaction between the Church Well Field with 2 active wells (Well 1 and Well 2), the Site, and the River. For each scenario set (1, 2, and 3), particles were:

A) forward-traced from within the propsed excavation layer (L2) to existing and potential INAWC production wells,

B) forward-traced from below the propsed excavation layer (L6) to existing and potential INAWC production wells,

C) forward-traced from the river to the wells, and

D) back-traced from affected wells.

Figure 19 shows a conceptual cross-section that illustrates the predictive scenarios A) and B). The cross-section also illustrates the discontinuous nature of the model layers and the potential pathways to affected wells and the River.

8.1.1 A) Forward-tracing from the Site within Layer 2

Forward particle tracing was used to identify which wells could produce water originating at the proposed excavation. This was also done to quantify the time it would take for water to move from the excavation to the well. Beaver Materials plans to extract the unconsolidated sand and gravel deposits within the excavation area represented by Layer 2 (L2). Due to discontinuities and intervening layers, the base of the proposed excavation layer (L2) is Layer 5 (L5) as shown in Figure 19. For this set of scenarios (A), residence-time distributions were calculated for particles released from the proposed excavation layer (Layer 2). This assumes Layer 5 remains contiunous and unperforated through the area.

8.1.2 B) Forward-tracing from the Site within Layer 6

The residence-time distributions were also calculated for particles released from below the confining clay layer (Layer 5) to provide a worst-case scenario that the confining unit is perforated or if there are currently unknown opeings or “windows” that would provide a more direct pathway to the underlying Layer 6, and in turn, the production wells.

8.1.3 C) Forward-tracing from the White River

The extraction of sand and gravel at the Site will eventually create a pond due to the infiltration of groundwater when mining below the water table. The puporse of this set of scenarios is to evaluate the potential for the proposed excavation to alter the current surface and ground water system and potentially require IDEM to re-classify a well as Groundwater Under the Direct Influence of Surface Water (GWUDI). The GWUDI designation is triggered by key water-quality and temperature indicators in wells that pump near surface-water bodies that suggest the source water is characteristsic of surface water and needs additional treatment above and beyond what is required for groundwater. Requirements for treating groundwater to a potable standard are less stringent because aquifers typically provide natural filtration of particulates and generally long subsurface residence times that inactivate pathogens.

A GWUDI designation would be an undesirable outcome, requiring additional treatment for the source water. Short residence times from the Site to any production well would be a cause for concern. Long residence times equates to higher filtration and chemical evolution from surface water to groundwater. Residence-time distributions for particles forward-traced from the river were compared with residence time-distributions from the Site to nearby INAWC wells.

8.1.4 D) Back-tracing from affected wells

Using the class A scenarios, INAWC wells were identified that could potentially produce water that originated at the Site: the North Well Field - Well 1, Church Well Field - Church Well 1, and Church Well Field with theortical Church Well 2. Capture zones for the affected wells were delineated by back-tracing 200 particles for a 10-year time-of-travel. For each affected well, the volume of water passing beneath the parcel was estimated by tabulating the number of particles originating or passing through the proposed excavation layer, opposed to particles passing beneath proposed excavation layer.

8.2 North Well Field

Scenario 1A – Forward tracing from the Site to WRN Well Field, within the proposed excavation layer

One-hundred particles were released within the proposed excavation layer (Layer 2) along the eastern edge of the Site and forward-traced to a simulated termination point. Particles originating on the northern edge of the excavation boundary terminate in the river (61%), while particles originating on the southern edge of the excavation boundary terminate at North Well Field Well 1 (39%), the closest production well to the parcel (Figure 20).

The base layer of the proposed excavation, Layer 5, is mapped as thin or absent in areas between the Site and Well 1. This provides a pathway for particles at the southeastern portion of the parcel to migrate from Layer 2 to Layer 8, where Well 1 pumps as shown in Figure 19.

Despite the pathway from the Site to Well 1, the simulated time-of-travel is relatively long for particles released from the proposed excavation (Layer 2). Figure 21 shows the residence-time distribution of particles terminating at Well 1 for the case where particles are released from the proposed excavation layer (Layer 2). The earliest calculated arrival time for particles released at the eastern boundary of the Site within Layer 2 is 7.4 years, with a median arival time of 9.1 years.

Scenario 1B – Forward tracing from the Site to WRN Well Field, below the proposed excavation layer

As expected, particles released from below the underlying clay, within Layer 6, arrive sooner. The earliest simulated arrival time for a particle in this scenarios is 2.6 years, with a median arrival time of 5.8 years.

Scenario 1C – Forward tracing from the White River to Well 1

The distribution of residence times of particles originating at the River has a similar spread as the predicted residence times from the Site. However, the early and median travel times are much shorter. The earliest simulated arrival time for water from the River is on the order of 0.084 years (30 days), with a median arrival time of 1.03 years.

Scenario 1D – Back tracing from WRN Well 1

To estimate the fraction of water at Well 1 that originates from or passes beneath the Site, two-hundred particles were released from Well 1 and backward traced for a 10-year time period

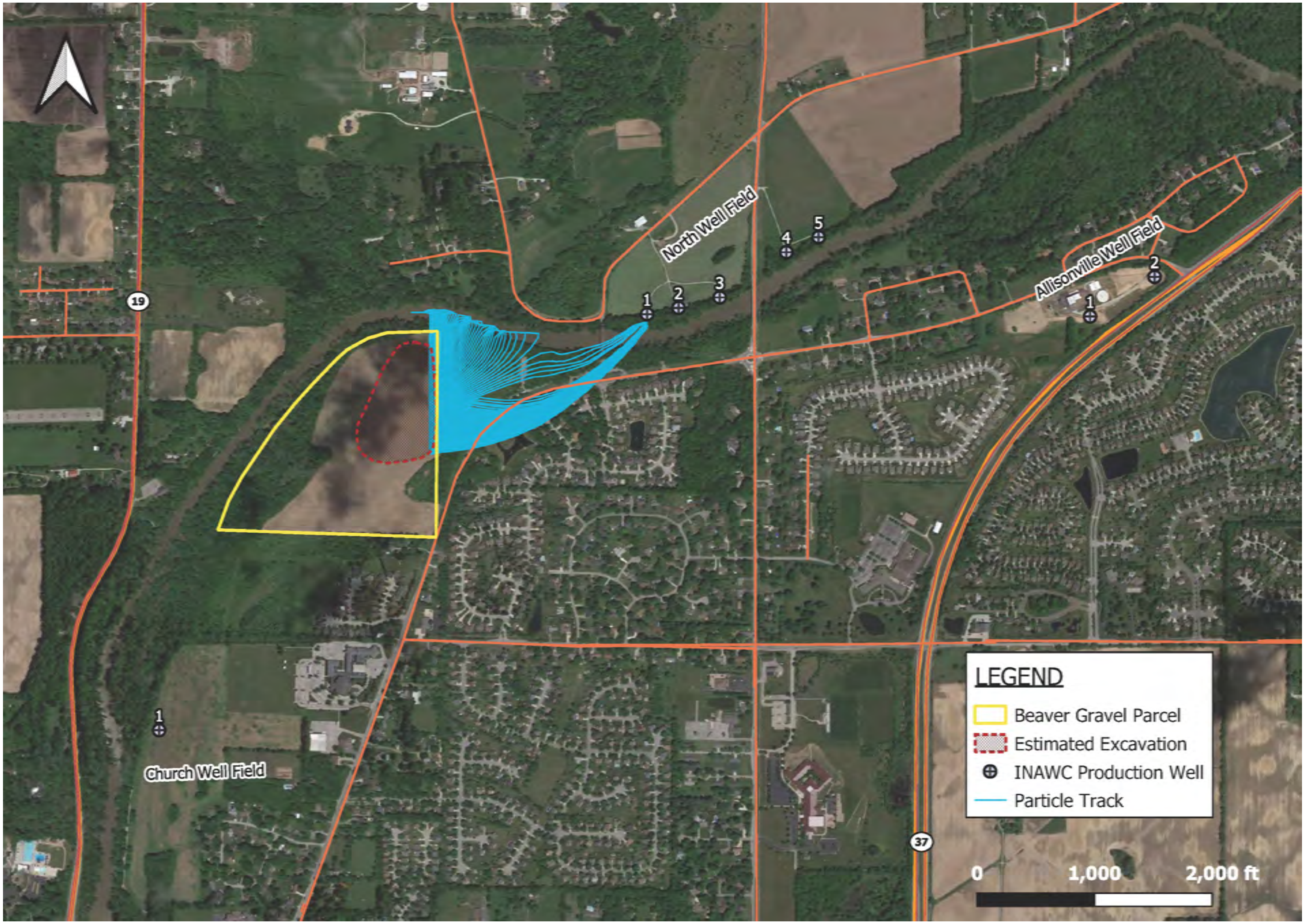


Figure 20: Simulated particle tracks released from eastern boundary of parcel terminate in the river and at Well 1.

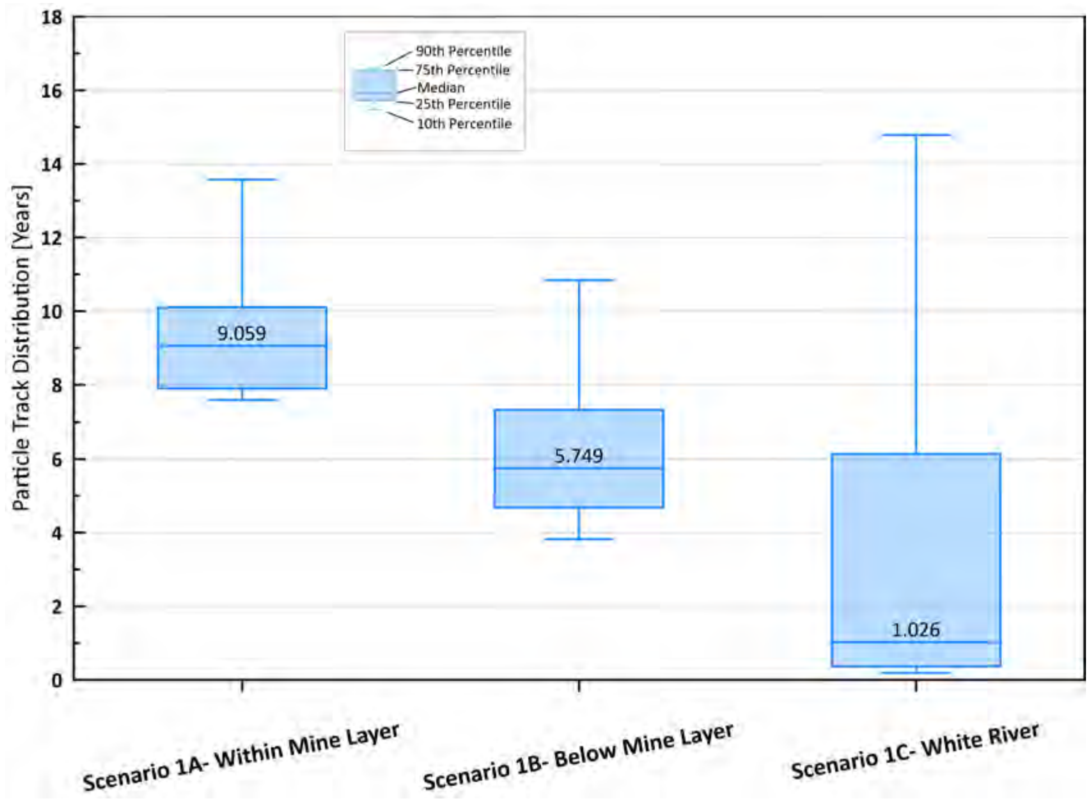


Figure 21: Residence-time distribution of particles arriving at North Well Field Well 1, released from A) the eastern boundary from within the mine layer, B) the eastern boundary of parcel below the mine layer, and C) the White River.

(Figure 22). Of the two-hundred particles, 1 particle (0.5%) originated in the proposed mine layer and 10 (5%) particles passed through or originated beneath the clay layer (Layer 5) underlying the proposed excavation layer (Layer 2).

Given these results, water which is pumped by Well 1 includes a small fraction (0.5%) of water that originated at the Site within the proposed excavation layer (Layer 2). Any potential contamination that originates at the Site within the proposed excavation layer and captured by Well 1 would be highly diluted. Water pumped by Well 1 includes a larger fraction (5%) of water that originates or passes through the permeable layers beneath Layer 2. However, even assuming that the clay layer beneath the excavation is perforated or is discontinuous, potential contamination originating at the Site and captured by Well 1 would still be highly diluted.

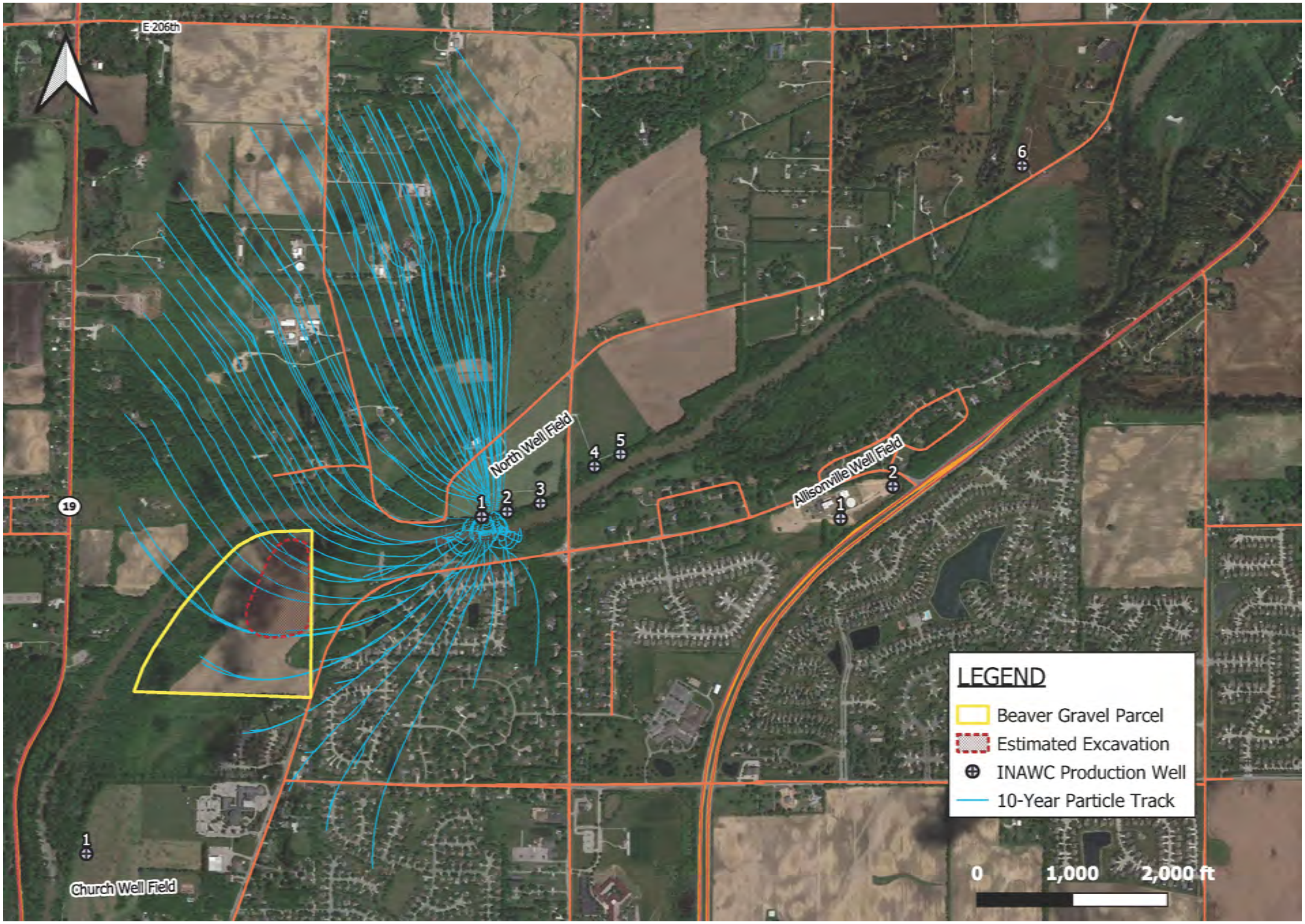


Figure 22: Simulated 10-year time-of-travel particle tracks backward traced from Well 1 at the North Well Field.

8.3 Church Well Field

The Church Well Field Well 1 was added to the predictive model to assess the potential risk of the proposed excavation on the future water production from this property. In the model, Church Well 1 was set to pump at 1.44 MGD, the recommended safe yield Champa (2014). An additional model run was conducted to asses a scenario where the Church Well Field has an additional well (Well 2). The theoretical new Well 2 was placed north of the existing Well 1, with both wells pumping at the recommended safe yield of 1 MGD each Champa (2014).

8.3.1 Church Well 1

Scenario 2A – Forward tracing from the Site to Church Well 1, within the proposed excavation layer

One-hundred particles were released in the proposed excavation layer (Layer 2) along the southern edge of the Site and forward-traced to a simulated termination point. In this scenario, 100% of the particles terminate at Church Well 1. (Figure 23).

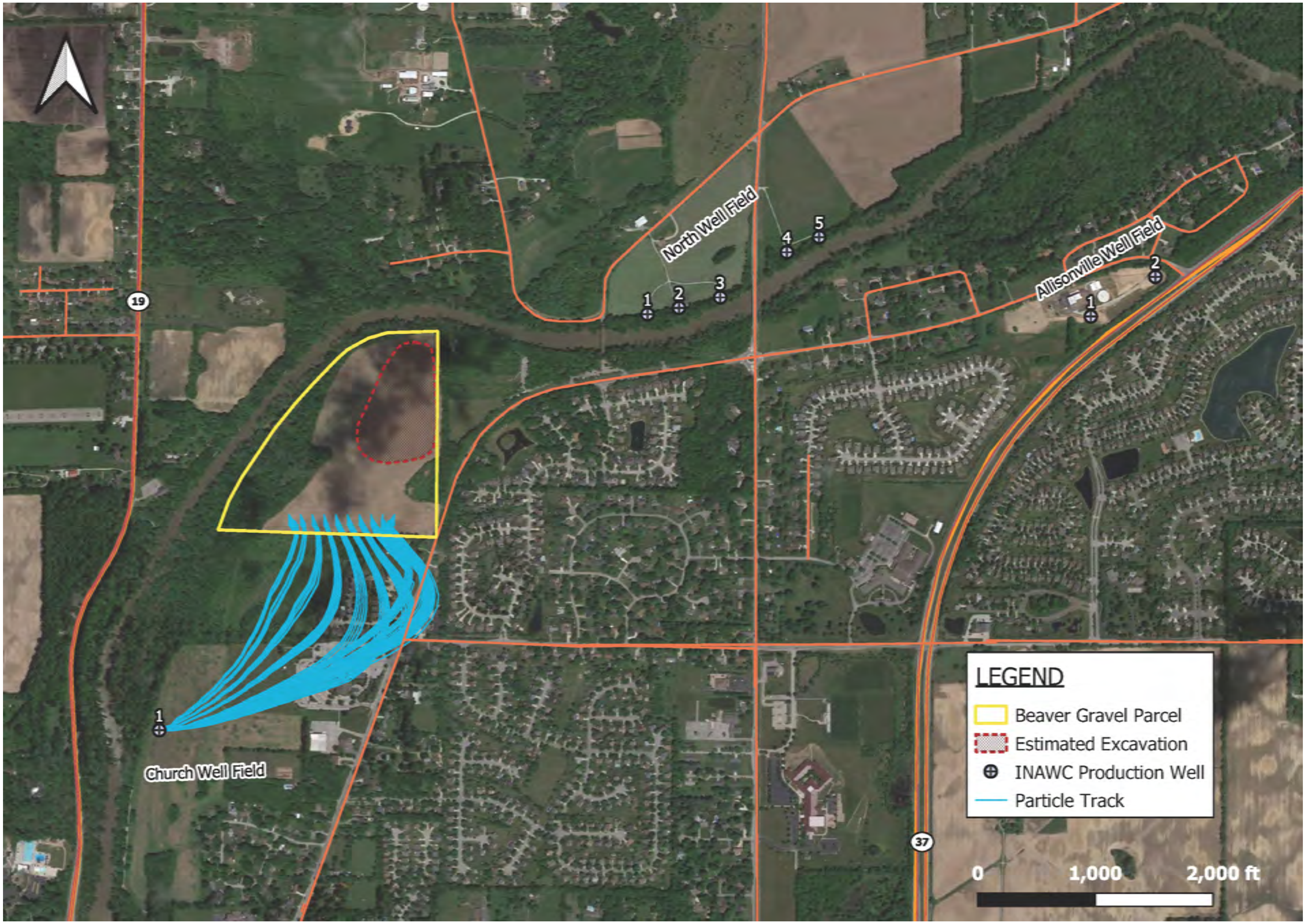
Similar to the area on the east edge of the Site, the base layer of the proposed excavation (Layer 5) is mapped as thin or absent in areas between the southern edge of the parcel and the Church Well Field. In the model, this gap in Layer 5 provides the pathway for particles to migrate from Layer 2 to Layer 8, where the Church Well Field wells would be pumping as shown in Figure 19. Figure 21 shows the residence-time distribution of particles terminating at Church Well 1 for the case where particles are released from the proposed excavation layer (Layer 2). The shortest arrival time for particles released from along the southern edge of the Site, within the proposed excavation layer is 4.5 years with a median arrival time of 10.8 years.

Scenario 2B – Forward tracing from the Site to Church Well 1, below the proposed excavation layer

One-hundred particles were again released from the southern edge of the Site, this time from within Layer 6, below the propsed excavation. The particles were traced to their termination point, which again was Church Well 1. As expected, these particles arive sooner than when released within Layer 2. The earliest arrival time was calcualted to be 2.6 years, with a median of 7.4 years.

Scenario 2C – Forward tracing from the White River to Well 1

The distribution of residence times of particles originating at the River and terminating at the Church Well 1 has a tighter spread than the predicted residence times from the parcel. The earliest simulated arrival time for water from the River is on the order of 0.12 year (30 days), with a median arrival time of 0.47 years as shown in Figure 24.



5.

Figure 23: With Church Well 1 pumping rate of 1.44 MGD, simulated particle tracks released from southern boundary of the parcel terminate at Well 1.

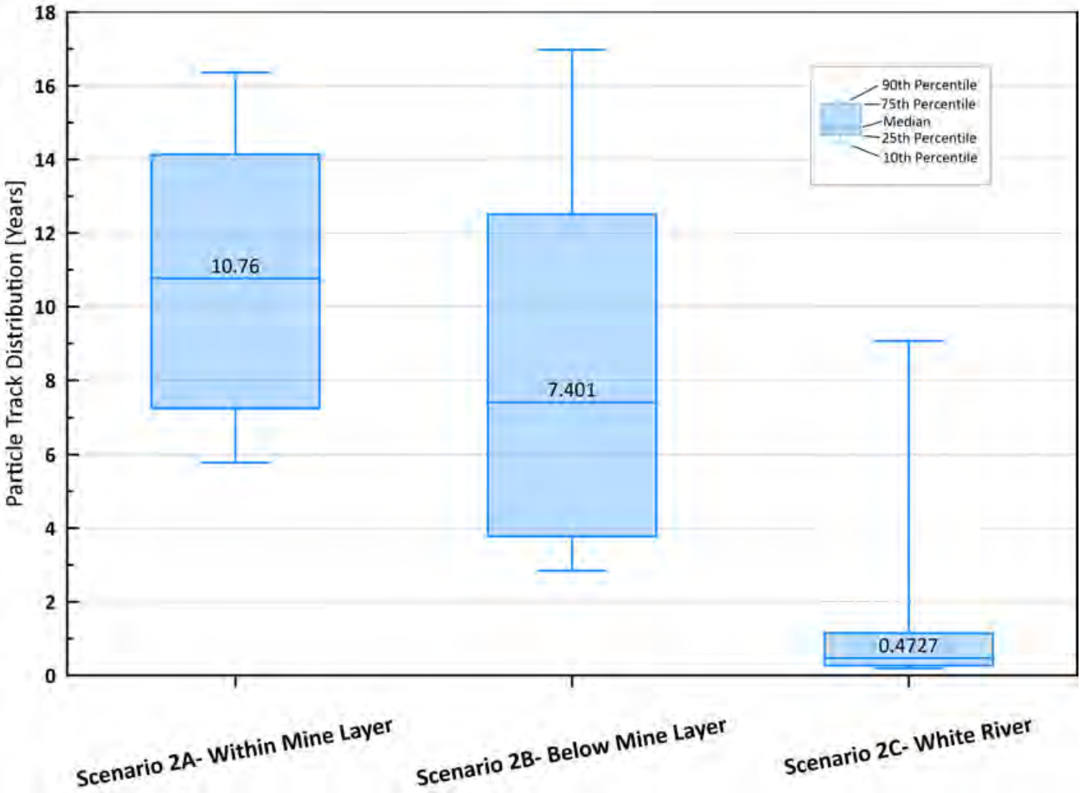


Figure 24: Residence-time distribution of particles of particles arriving at INAWC Church Well 1, released from A) from the southern boundary of parcel within the mine layer, B) from the southern boundary of parcel below the mine layer, and C) the White River. Church Well 1 is pumping at rate of 1.44 MGD.

Scenario 2D – Back tracing from Church Well 1, 10 Year Time-of-Travel

To estimate the fraction of water at Church Well 1 that would originate from or pass beneath the Site, two-hundred particles were released from Church Well 1 and backward traced for a 10-year time period (Figure 25). Of the two-hundred particles, two (1%) originate in or above the proposed mine layer and 17 (8.5%) pass through or originate beneath the clay layer underlying the proposed excavation layer. None of the particles pass though or beneath the proposed excavation layer, mainly due to pumping effects of the North Well Field. Given these results, water pumped by Church Well 1 would include a small fraction (1%) of water originating in the excavation layer. This indicates that any potential contamination originating in the proposed excavation layer and captured by the well would be highly diluted. Water pumped by Church Well 1 would include a larger fraction (8.5%) of water originating or passing through the permeable layers beneath the proposed mine layer. However, even assuming that the clay layer beneath the excavation is perforated or is discontinuous, potential contamination originating at the Site and captured by Church Well 1 would still be highly diluted.

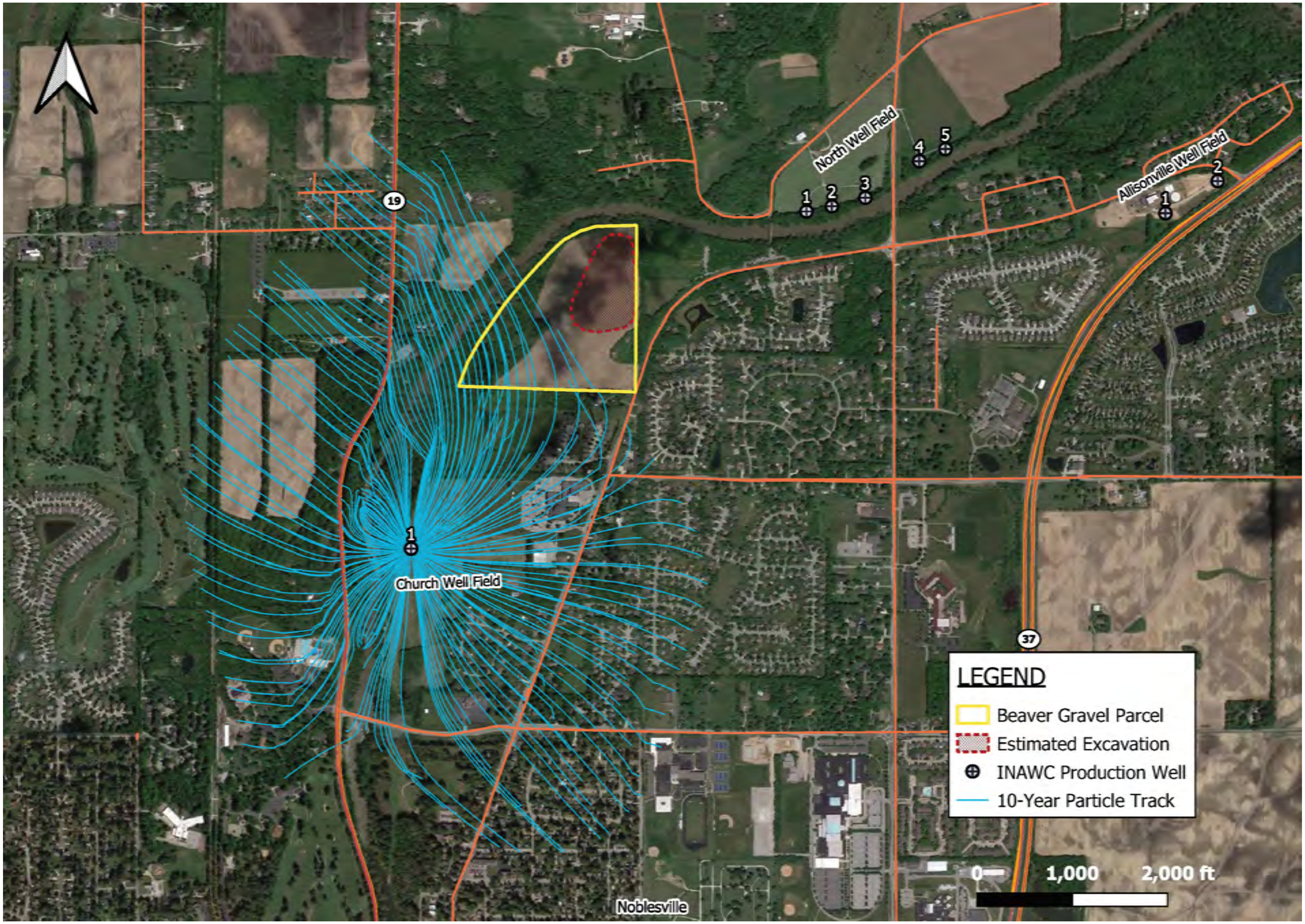


Figure 25: Simulated 10-year time-of-travel particle tracks backward traced from Well 1 at the Church Well Field.

8.3.2 Two Wells - Church Well 1 and Church Well 2

Scenario 3A – Forward tracing from the Site to the Church Well Field, within proposed excavation layer

Adding a second production well (Well 2) north of existing Church Well 1 results in shorter travel times due to the shorter distance between Well 2 and the Site. This simulation suggests that a well placed approximately 700 ft north of existing Well 1, at the northern edge of the Church Well Field, will capture all of the water originating at the southern edge of the Site (Figure 26). In this scenario, the shortest time-of-travel for particles released within the proposed excavation layer was 2.7 years with a median of 5.8 years (Figure 27).

Scenario 3B – Forward tracing from the Site to the Church Well Field, below proposed excavation layer

One-hundred particles were again released from the southern edge of the Site, this time from within Layer 6, below the proposed excavation. The particles were traced to their termination point, Church Well 2. As expected, these particles arive sooner than when released within Layer 2. The earliest arrival time was calcualted to be 1.0 years, with a median of 2.9 years.

Scenario 3C – Forward tracing from the River to theoretical Well 2

The distribution of residence times of particles originating at the River and terminating at the theoretical Church Well 2 has a similar spread as the predicted residence times from the parcel. However, the early and median travel time are much shorter. The earliest simulated arrival time for water from the River is 0.14 year (51 days), with a median arrival time of 1.3 years (Figure 27).

Scenario 3D – Back tracing from theoretical Well 2

To estimate the fraction of water at Church Well 2 that would originate from or pass beneath the Site, two-hundred particles were released from Church Well 2 and backward traced for a 10-year time period (Figure 28). Of the two-hundred particles, 6 (3%) originate in or above the proposed excavation layer and 32 particles (16%) pass through or originate beneath the clay layer underlying the proposed excavation layer. None of the particles pass though or beneath the proposed excavation layer, mainly due to the pumping effects of North Well Field. Given these results, water pumped by Church Well 2 would include a small fraction (3%) of water originating in the excavation layer. This indicates that any potential contamination originating in the proposed excavation layer and captured by the well would be highly diluted. Water pumped by Church Well 2 would include a larger fraction (16%) of water originating or passing through the permeable layers beneath the proposed excavation layer. However, even assuming that the clay layer beneath the excavation is perforated or is discontinuous, potential contamination originating at the Site and captured by Church Well 2 would still be diluted.

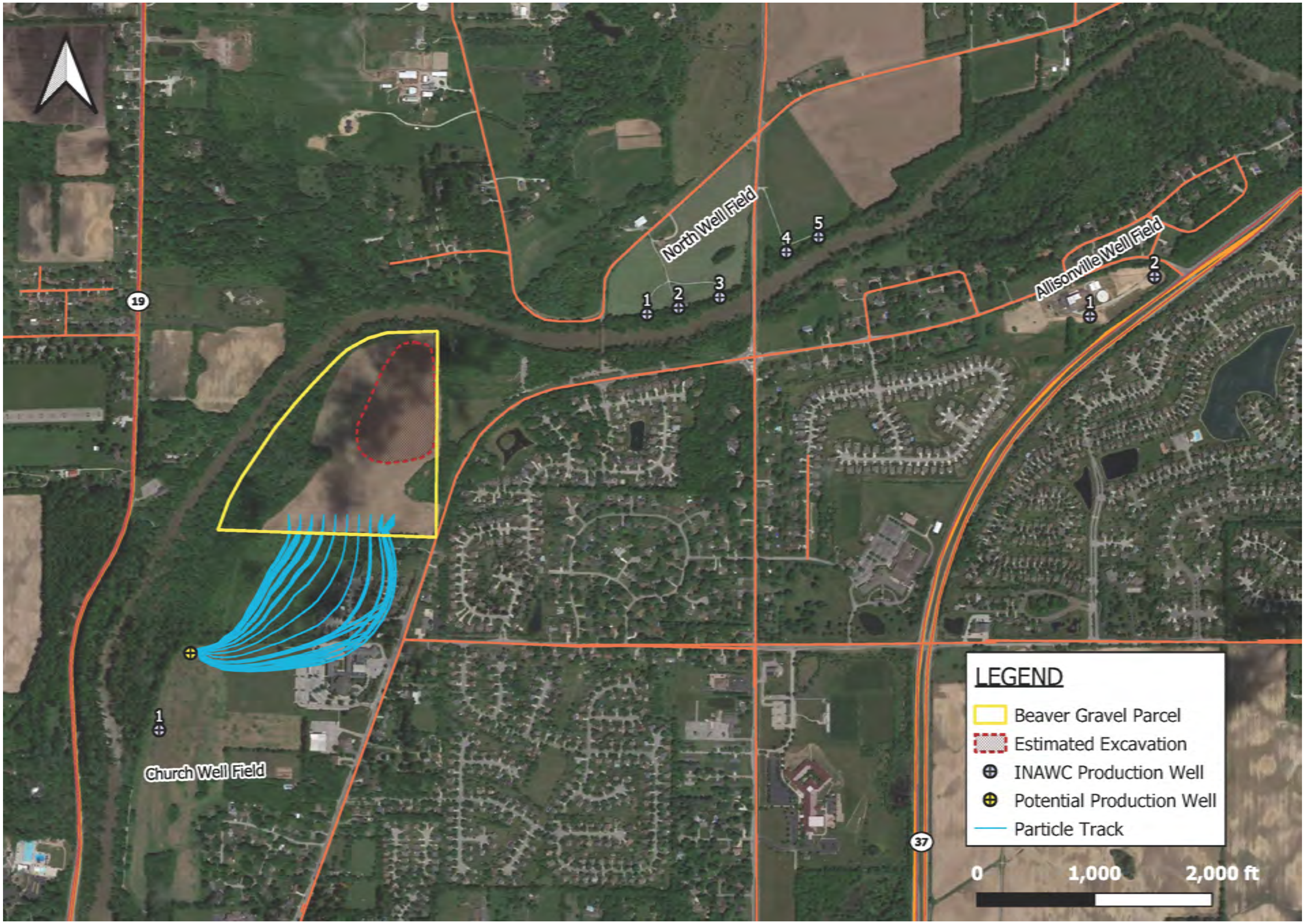


Figure 26: With Church Well 1 and theoretical new Well 2 each pumping at a rate of 1 MGD, particles released from eastern boundary of parcel terminate at Well 2 .

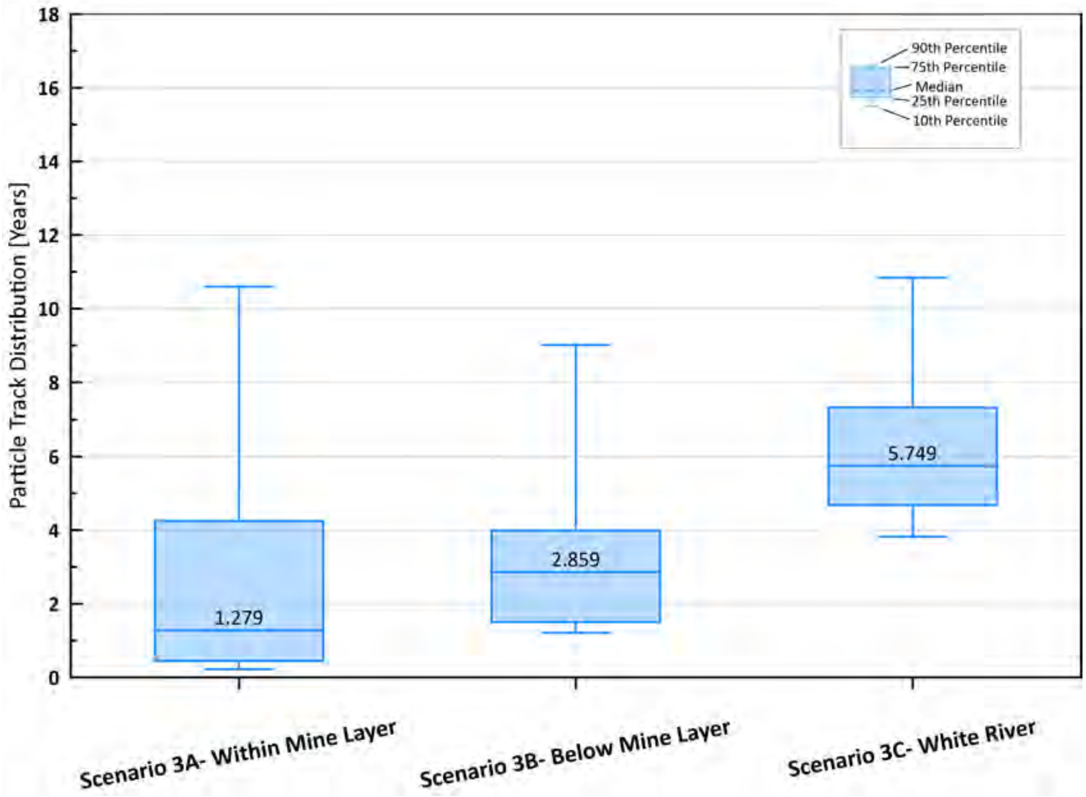


Figure 27: Residence-time distribution of particles arriving at a theoretical new Church Well 2. Particles released from A) from the southern boundary of parcel within the mine layer, B) from the southern boundary of parcel below the mine layer, and C) the White River. Church Well 1 and a theoretical new Well 2 are each pumping at a rate of 1 MGD.

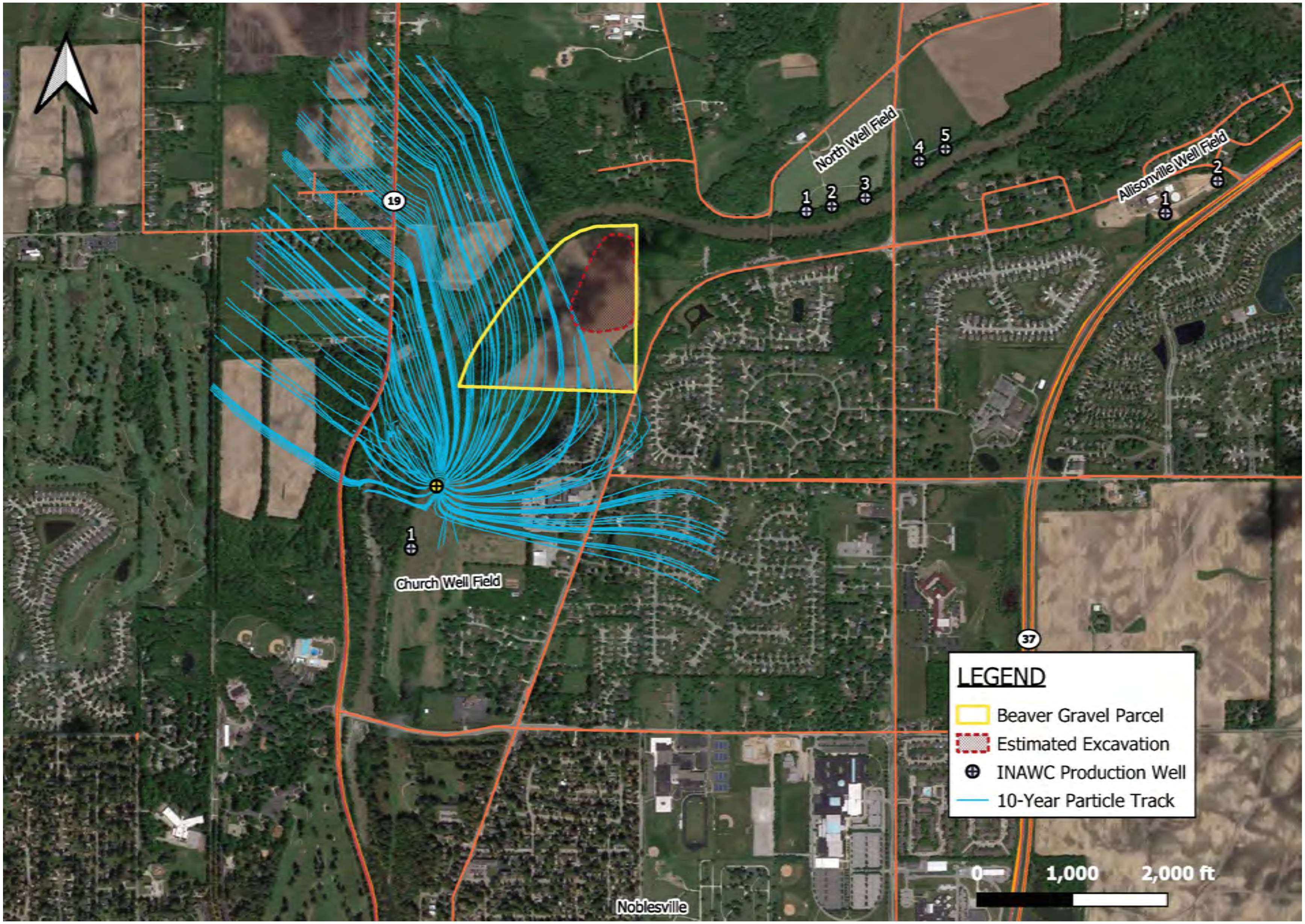


Figure 28: Simulated 10-year time-of-travel particle tracks backward traced from theoretical new Well 2 at the Church Well Field.

8.4 Conclusions

- Water beneath the mine parcel could be induced to move into production wells.

- Based on proximity to the Site and historic production rates, water could migrate from the east edge of the proposed excavation, beaneath the White River, and into WRN Well 1.
- If Church Well 1 is set into operation at the recommended safe yield, water could migrate from the south side of the Site into Church Well 1.
- With the addition of second well at the Church property, with both wells pumping at the recommended safe yield, water could migrate from the south side of the Site into theoretical Church Well 2.

- Only one active production well could be producing some water sourced from the Site.

- If the Church Well Field is set into operation, it would also potentially produce some water sourced from the Site.

- The earliest predicted time-of-travel bewteen the Site and potentially affected wells is 1-3 years based on conservative assumptions.

- Assuming that the clay layer beneath the proposed excavation remains uncompromised and is in fact continuous, as indicated in the 3D CGM, the earliest time of arrival of particles released from the proposed excavation layer (10th percentile) increases to a range of 3 to 7 years.
- The most conservative estimate of time-of-travel of 1 to 3 years, assumes that the clay layer beneath the Site becomes compromised, or is not in fact locally continuous. The earliest arrival (10th percentile) of particles released from beneath the proposed excavation layer is approximately one year for theoretical Church Well 2, three years for Church Well 1 (without Church Well 2), and three years for WRN Well 1.

- The risk that the proposed excavation will affect the groundwater (GWUDI) status of nearby production wells is extreemly low.

- For the three potentially affected production wells, the proposed excavation will not alter existing surface-water residence times.
- The residence times from the White River to affected wells are much shorter than from the Site.

- Any potential contamination originating in the proposed excavation and captured by a well would be highly diluted.

- Assuming that the clay layer beneath the Site is continuous, as represented in the 3D CGM, and is not compromised, the predicted volume of water captured by the affected wells from the proposed excavation layer ranges from 0.5% to 3%.
- With the most conservative assumptions, the predicted volume of water captured by the affected wells from the proposed excavation layer ranges from 5% to 16%.

- An effective monitoring program at the Site could mitigate risk that a production well could be contaminated as a result of the proposed excavation

- Based on predicted arrival times from the proposed excavation and the dilution effect, a monitoring program utilizing sentinel wells located at the east and south boundaries of the parcel could siginificantly reduce the risk of contamination moving from the Site to a well.

9 Risk Assessment

This report addresses the hydrologic risks associated with the act of physically extracting the sand and gravel, and the long-term risks associated with the presence of a gravel pit lake (GPL). Potential impacts to water quantity and water quality are addressed. It is important to note that the proposed excavation activities at the Site do not include the most common sources of groundwater contamination associated with sand and gravel mining: sorting and washing, concrete or asphalt plant operations, onsite fueling, waste sludge/spoils pits, vehicle maintenance, and machine shops. Any of these activities or any other associated activity will occur off site. The only activities that are proposed at this site are: extraction of the material using an excavator or dredge, and removal and transportation of the material from the Site using dump trucks. This operation will not require any water extraction or de-watering.

9.1 Water Quantity

Since there will be no water directly removed from the Site during or after sand and gravel extraction, the only effect on water quantity will be changes in evapotranspiration due to the exposure of the water table within the proposed excavation area. Evapotranspiration rates vary with changes in temperature, relative humidity, wind and air movement, and soil-moisture availability. The proposed excavation area is approximately 12 acres. With a conservative estimate of 500 mm per year rate of evapotranspiration for a soybean field (Irmak et al., 2014), the current 12 acres loses approximately 20,000 gallons per day. An open lake of the same size would lose about 50,000 gallons per day (USGS, 1956). This means that after completion of the GPL, the site will lose an additional 0.03 million gallons per day (MGD) to evapotranspiration. This is a negligible amount within the large outwash aquifer system.

After extraction of the material off-site has finished, the effect will be to increase the storage capacity (coefficient of storage) around the GPL (Landberg, 1982). This is due to the porosity increasing from approximately 25-40% for sand and gravel to 100% for open water. For a relatively small area such as the proposed excavation area the increase in storage capacity will be negligible. Both identified methods of changing the local water budget are insignificant and water quantity will not be affected by the proposed sand and gravel extraction operation.

9.2 Water Quality

Potential effects on water quality can be analyzed within three settings based on the activity at the Site: pre-excavation, active excavation, and the post-excavation. The first setting, pre-excavation, is the baseline scenario that other settings can be compared to. The second setting is active excavation, which represents the period of time that aggregate is being extracted and transferred from the Site. The third setting considers the finalized GPL, with no active operations on site. Also, two categories of risks are examined: anthropogenic sources and physical changes to the hydrogeologic system. Anthropogenic sources included any contamination that would be introduced to the Site due to human activity. Physical changes to the hydrogeologic system include any changes to the system due to the extraction and removal of material from the Site.

9.2.1 GWUDI Status of Pumping Wells

The risk of the GPL affecting the groundwater (GWUDI) status of nearby production wells was assessed using the groundwater model (Subsection 8.1.3). For all potentially affected production wells, the GPL will not alter existing surface-water residence times, as the residence times from the White River to any affected wells are much shorter than from the Site.

9.2.2 Active Excavation

When activity begins at the Site, there will be an increase in human activity that includes the use of trucks and other equipment, which introduces potential contaminants such as oil, gas, and hydraulic fluids. The risk of contamination caused by fluids introduced by the operation of heavy machinery can be mitigated using varrious engineering controls and best practices.

When extraction of material begins, the fist thing to be altered is the removal of the top layer of clay/soil (L1 in Subsection B.1). This removal of surficial material is the first change to the physical system. This will be a dry extraction process that is above the water table. The top clay/soil layer provides a buffer to any potential contamination released at the site. In the scenario of a release of contamination at the Site, the surficial clay/soil layer would greatly slow the migration of contamination downwards towards the water table.

The next step is the extraction of the underlying sand and gravel ore unit, shown as L2 in Subsection B.1. This will bring the pit below the water table and begin the wet extraction process. Once the water table is breached and groundwater is exposed to the atmosphere, a potential release of contamination would enter the groundwater systemat a faster rate. Physically disturbing the aquifer materials via the extraction process will increase the turbidity of the water within the GPL. The increase in turbidity would most likely not be detectable off Site. Gravel washing operations, which will not occur at this Site, are more likely to produce turbidities that can migrate a significant distance.

Since sand and gravel deposits are the ore body that is being extracted, the clay mapped under the L2 layer (L3) will remain and serve as the bottom of the GPL, which would provide a partial hydrologic barrier from the underlying aquifer material (L8) where INAWC WRN Well Field and future Church Well Field pump water. Although, if the underlying clay (L3) is either not continuous beneath the pit, or is breached during the excavation process, the travel times will become shorter for contaminiation originating at the site, as shown in the groundwater model (Section 8).

Groundwater modeling showed that even in the worst-case scenario of an incompetent or breached underlying clay layer, travel times to affected wells (WRN Well 1, and Church Well 1) is approximately 1 to 3 years. If the clay layer remains uncompromised and is in fact continuous, as indicated in the CGM, the earliest time of arrival of water from the excavation area increases to a range of 3 to 7 years. Groundwater modeling also showed that any potential contamination origination in the proposed excavation and captured by an affected well would be highly diluted (Section 8).

9.2.3 Post-Excavation Gravel Pit Lake

Once the material is extracted from the Site, the GPL will remain. At that point, risks associated with the operation of heavy machinery would cease. Anthropogenic sources of contamination would be limited to unknown events. These potential anthropogenic sources could be mitigated depending on the end use of the property.

The water that sits within the GPL will be part of the hydrologic system and will include inflowing and outflowing water from the GPL into the groundwater and vice versa. Groundwater-fed GPLs affect the biological, organic, and inorganic parameters of inflowing groundwater through combined effects of bank filtration at the inflow, reactions within the lake, and bank filtration at the outflow (Muellegger et al., 2013).

Some of these affects may include:

- reduction in Nitrate (NO^3) and Phosphate (PO^4) concentrations as groundwater passes through the lake ecosystem (Muellegger et al., 2012),
- biomass accrual that may induce clogging of the GPL and the successive hydrodynamic isolation from the adjacent groundwater (Muellegger et al., 2012),
- precipitation of metal oxides, calcite and other composite minerals including phosphorus (P), calcium (Ca) and carbon (C) (P. Mollema, 2016),
- an increase in biodiversity (P. Mollema, 2016), and
- changes in groundwater temperature due to the exposure of water to the atmosphere, limited to and area of several hundred feet downgradient of the GPL due to the high thermal inertia of aquifer material and the effects of dilution (Hansen, 2018).

The long travel times presented in the groundwater model would support a monitoring plan that could mitigate risk involved with any potential contamination originating at the Site reaching a pumping well. In addition to monitoring wells MW-1, MW-2S, and MW-2D on the east edge of the Site, monitoring wells could be installed along the southern boarder of the Site to act as sentinel wells that could be sampled prior to work at the Site for a baseline, and then at some determined interval. This could be done along with sampling water directly from the GPL. A monitoring program would significantly reduce the risk of contamination moving from the Site to a pumping well, as the contamination could be detected and intercepted using various environmental remediation methods.

9.3 Risk Matrix

A risk matrix was developed to quantify the risk associated with each presented scenario. Each scenario was assigned a Potential Impact and Likelihood category: Very Low, Low, Medium, High, or Very High. These values were plotted against each other, within a matrix, to identify a risk category: Low, Moderate, High, or Very High. This matrix is shown as Figure 29. Below is a brief summarization of each scenario.

9.3.1 Pre-Excavation Scenario

This scenario represents the current conditions at the Site.

- (PRE) Pre-Excavation, no monitoring – LOW RISK. This scenario was assigned a likelihood of Very Low due to the lack of potential contaminant sources at the Site. This was assigned a Potential Impact of Medium due to current unmonitored nature of the current Site. If there were a release of contaminants at the current Site, it would likely go unnoticed until it was intercepted by a pumping well.

9.3.2 Active Excavation Scenarios

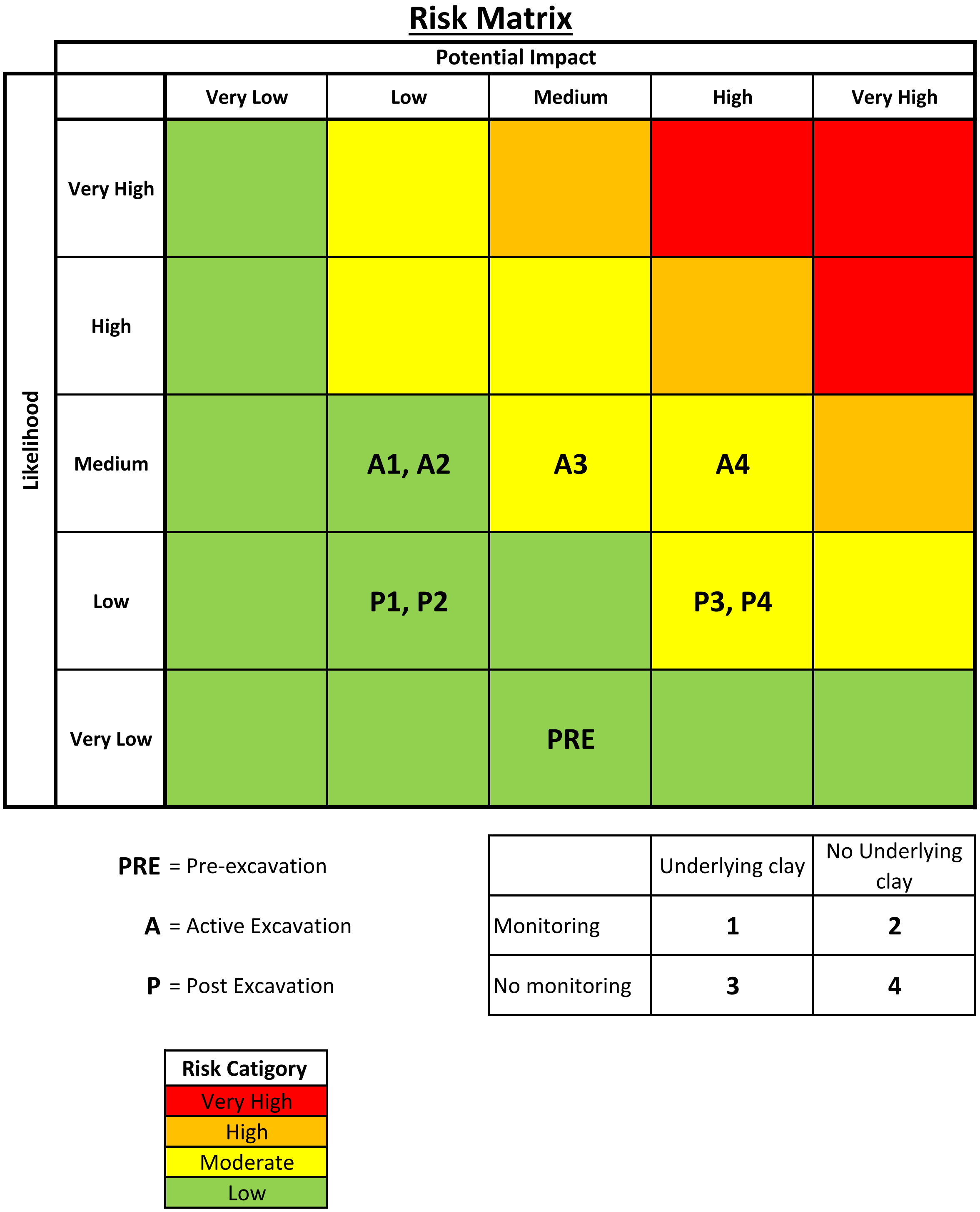
The following scenarios represent conditions at the Site when active extraction and transportation of materials are occurring. These scenarios were all assigned a likelihood of Medium due to the increased activity and anthropogenic potential sources of contamination during excavation.

- (A1) with monitoring, underlying clay intact – LOW RISK. This was assigned a potential impact of Low assuming a sufficient monitoring program is implemented with regular sampling.

- (A2) with monitoring, underlying clay not intact – LOW RISK. This was assigned a potential impact of Low assuming a sufficient monitoring program is implemented with regular sampling. Even though in this scenario the intervening clay layer may not be intact, groundwater modeling showed that travel times were still significant and would allow for sufficient monitoring and remediation.

- (A3) without monitoring, underlying clay intact – MODERATE RISK. This was assigned a potential impact of Medium since a release of contamination in this scenario would likely go unnoticed until it was intercepted by a pumping well. Even when the underlying clay intact, a release of contamination could reach one of the affected wells with due time.

- (A4) without monitoring, underlying clay not intact – MODERATE RISK. This was assigned a potential impact of High since a release of contamination in this scenario would likely go unnoticed until it was intercepted by a pumping well. Also, with the underlying clay not intact, the potential contamination would reach an affected well in a shortened amount of time with greater concentration.



Risk Matrix

Likelihood	Potential Impact					
		Very Low	**Low**	**Medium**	**High**	**Very High**
	Very High	🟩	🟨	🟧	🟥	🟥
	High	🟩	🟨	🟨	🟧	🟥
	Medium	🟩	🟩 **A1, A2**	🟨 **A3**	🟨 **A4**	🟧
	Low	🟩	🟩 **P1, P2**	🟩	🟨 **P3, P4**	🟨
	Very Low	🟩	🟩	🟩 **PRE**	🟩	🟩

PRE = Pre-excavation

A = Active Excavation

P = Post Excavation

	Underlying clay	No Underlying clay
Monitoring	**1**	**2**
No monitoring	**3**	**4**

Risk Catigory
🟥 Very High
🟧 High
🟨 Moderate
🟩 Low

Figure 29: Risk Matrix

9.3.3 Post-Excavation Scenarios

The following scenarios represent conditions at the Site after extraction and transportation of materials has occurred. These scenarios were all assigned a likelihood of Low since there will no longer be heavy machinery operating at the Site. These scenerios assume a slightly higher likelihood rating of Low from the Pre-Excavation scenario of Very Low since anthropogenic activities may increase if trails or parks are extended to the Site.

- (P1) with monitoring, underlying clay intact – LOW RISK. This was assigned a potential impact rating of Low assuming a sufficient monitoring program is implemented with regular sampling.

- (P2) with monitoring, underlying clay not intact – LOW RISK. This was assigned a potential impact of Low assuming a sufficient monitoring program is implemented with regular sampling. Even though in this scenario the intervening clay layer may not be intact, groundwater modeling showed that travel times were still significant and would allow for sufficient monitoring and remediation.

- (P3) without monitoring, underlying clay intact – MODERATE RISK. This was assigned a potential impact of High since a release of type contamination in this scenario would be unknown and would likely go unnoticed until it was intercepted by a pumping well. Even when the underlying clay intact, a release of contamination could reach one of the affected wells with due time.

- (P4) without monitoring, underlying clay not intact – MODERATE RISK. This was assigned a potential impact of High since a release of type contamination in this scenario would be unknown and would likely go unnoticed until it was intercepted by a pumping well. Also, with the underlying clay not intact, the potential contamination would reach an affected well in a shorted amount of time, and with greater concentration.

9.4 Conclusions

Overall, risk remains Low in all cases if an effective monitoring program is implemented, as shown in scenarios A1, A2, P1, and P2 (Figure 29). During active excavation, the likelihood of contamination to the aquifer is slightly increased due to the operation of heavy machinery. This likelihood could be reduced using various engineering controls and best practices while operating the equipment. The true impact of a potential contamination release at the Site during excavation would depend on the type, amount, and duration of contamination released. Known contaminants that will be on Site include fuel, oil, and hydraulic fluids associated with the operation of heavy machinery. The volume of these known contaminants at any one time would be very low and limited to operating machinery. Any other contaminants would have to be introduced from an unknown origin.

After excavation has completed, and heavy machinery is no longer on Site, the likelihood of contamination would return to pre-excavation conditions. This post-excavation likelihood could vary depending on the end use of the property. The likelihood of contamination at the post-excavation GPL could be further reduced by limiting or restricting access to the GPL. There will be no known contaminants at the Site so any contamination would have to be introduced from an unknown origin. The potential impact of any unknown release would be greatly reduced with an effective monitoring program.

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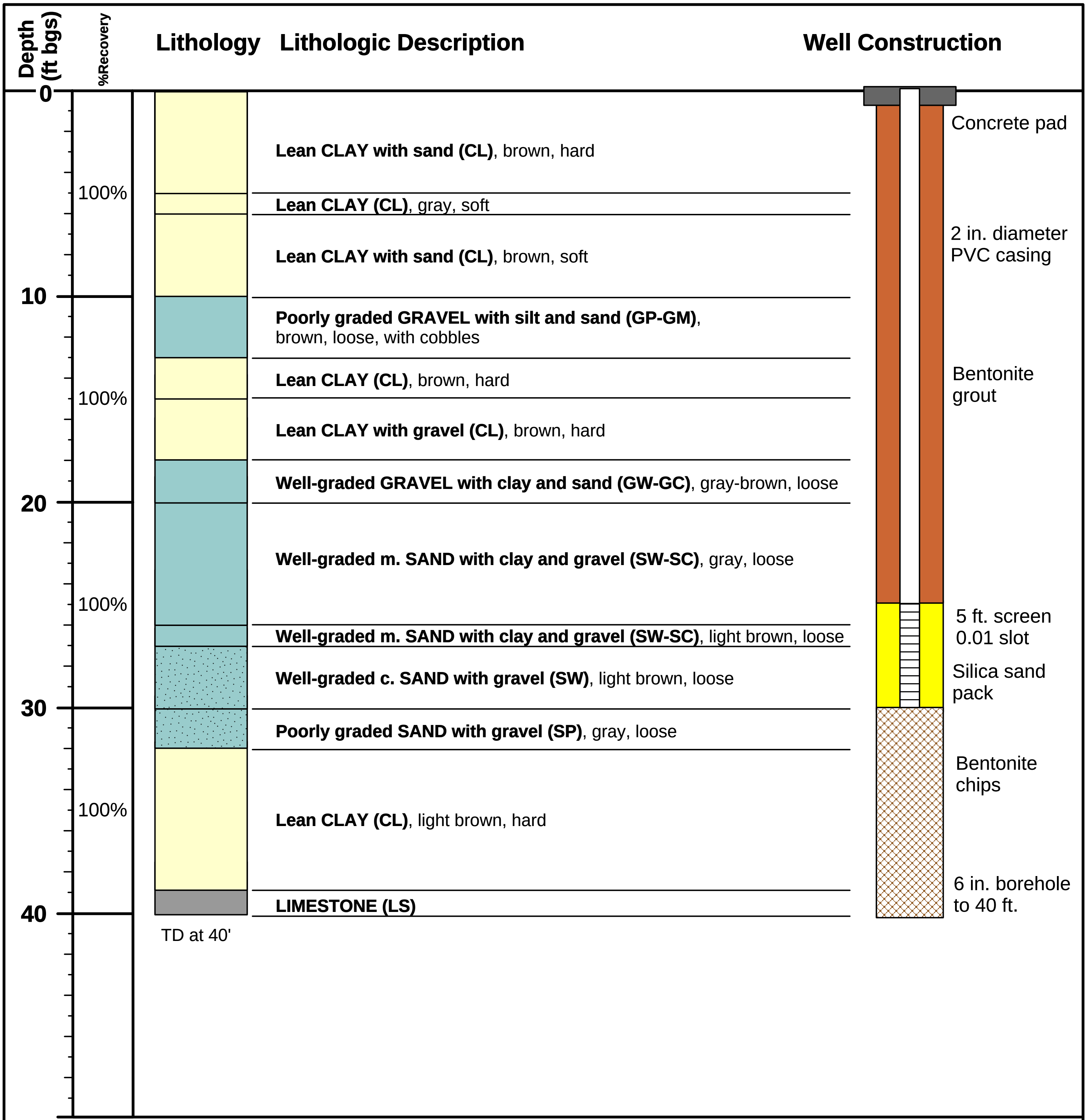
A Well Logs

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS	**Well: TH-1 (MW-1)**	**Site:** Noblesville, IN Beaver Materials
Date: 5/3/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.072842° **Long:** -86.005515°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~759 ft amsl



Lean CLAY with sand (CL), brown, hard

Lean CLAY (CL), gray, soft

Lean CLAY with sand (CL), brown, soft

Poorly graded GRAVEL with silt and sand (GP-GM), brown, loose, with cobbles

Lean CLAY (CL), brown, hard

Lean CLAY with gravel (CL), brown, hard

Well-graded GRAVEL with clay and sand (GW-GC), gray-brown, loose

Well-graded m. SAND with clay and gravel (SW-SC), gray, loose

Well-graded m. SAND with clay and gravel (SW-SC), light brown, loose

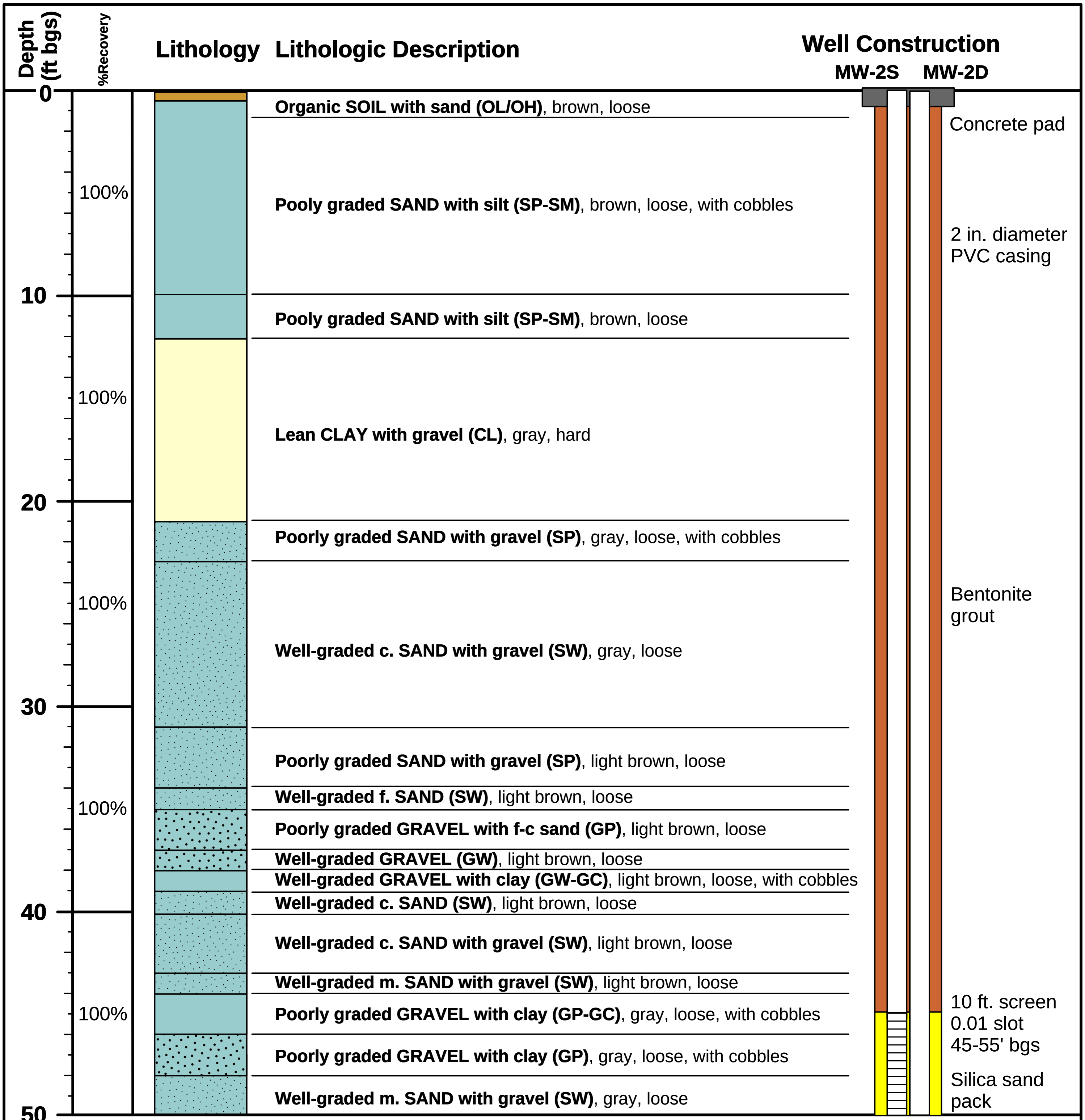
Well-graded c. SAND with gravel (SW), light brown, loose

Poorly graded SAND with gravel (SP), gray, loose

Lean CLAY (CL), light brown, hard

LIMESTONE (LS)

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS	**Well: TH-2 (MW-2S, MW-2D)**	**Site:** Noblesville, IN Beaver Materials
Date: 5/4/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.070131° **Long:** -86.005419°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~762 ft amsl



Lithologic Description

Well Construction

Organic SOIL with sand (OL/OH), brown, loose

Pooly graded SAND with silt (SP-SM), brown, loose, with cobbles

Pooly graded SAND with silt (SP-SM), brown, loose

Lean CLAY with gravel (CL), gray, hard

Poorly graded SAND with gravel (SP), gray, loose, with cobbles

Well-graded c. SAND with gravel (SW), gray, loose

Poorly graded SAND with gravel (SP), light brown, loose

Well-graded f. SAND (SW), light brown, loose

Poorly graded GRAVEL with f-c sand (GP), light brown, loose

Well-graded GRAVEL (GW), light brown, loose

Well-graded GRAVEL with clay (GW-GC), light brown, loose, with cobbles

Well-graded c. SAND (SW), light brown, loose

Well-graded c. SAND with gravel (SW), light brown, loose

Well-graded m. SAND with gravel (SW), light brown, loose

Poorly graded GRAVEL with clay (GP-GC), gray, loose, with cobbles

Poorly graded GRAVEL with clay (GP), gray, loose, with cobbles

Well-graded m. SAND with gravel (SW), gray, loose

Continued on next page

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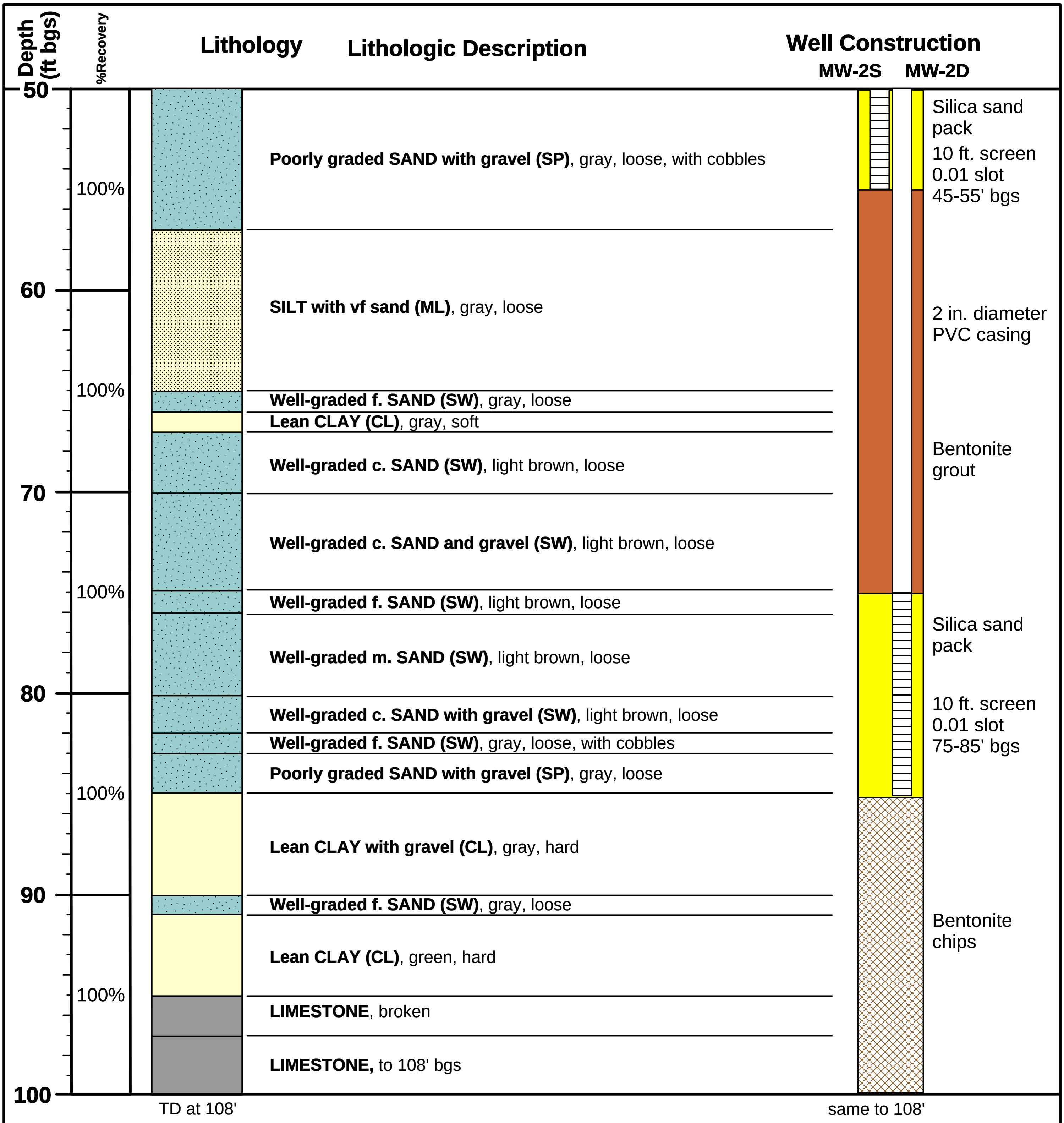
	Well: TH-2 (MW-2S, MW-2D)	**Site:** Noblesville, IN Beaver Gravel
Date: 5/4/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.070131° **Long:** -86.005419°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~762 ft amsl



Lithologic Description

Poorly graded SAND with gravel (SP), gray, loose, with cobbles

SILT with vf sand (ML), gray, loose

Well-graded f. SAND (SW), gray, loose

Lean CLAY (CL), gray, soft

Well-graded c. SAND (SW), light brown, loose

Well-graded c. SAND and gravel (SW), light brown, loose

Well-graded f. SAND (SW), light brown, loose

Well-graded m. SAND (SW), light brown, loose

Well-graded c. SAND with gravel (SW), light brown, loose

Well-graded f. SAND (SW), gray, loose, with cobbles

Poorly graded SAND with gravel (SP), gray, loose

Lean CLAY with gravel (CL), gray, hard

Well-graded f. SAND (SW), gray, loose

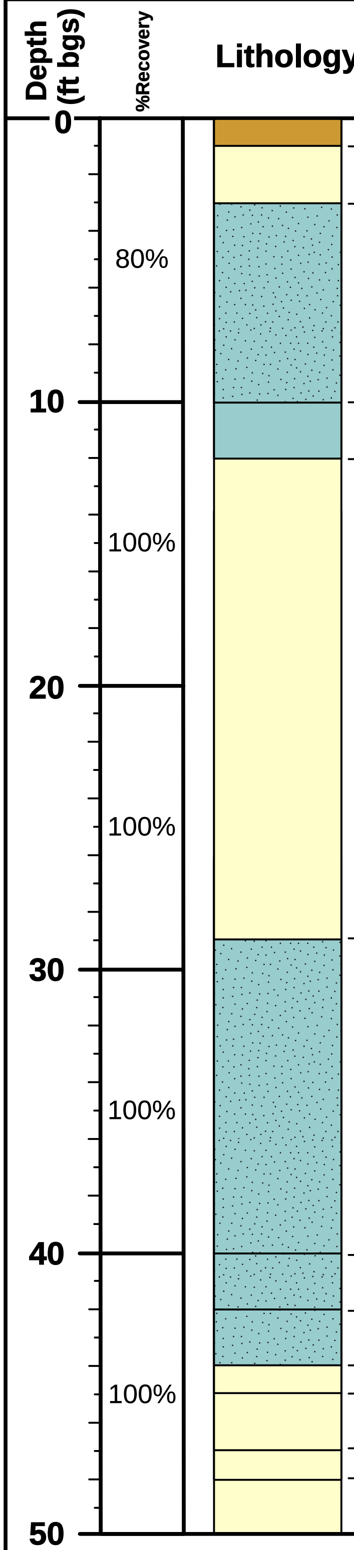
Lean CLAY (CL), green, hard

LIMESTONE, broken

LIMESTONE, to 108' bgs

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS	**Well: TH-3**	**Site:** Noblesville, IN Beaver Materials
Date: 1/25/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.071137° **Long:** -86.006803°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~758 ft amsl

Depth (ft bgs) | **%Recovery** | **Lithology** | **Lithologic Description**



Organic SOIL (OL/OH), dark brown, hard

Lean CLAY with sand (CL), brown, hard

Poorly graded SAND with gravel (SP), brown, loose

Well-graded GRAVEL with clay (GW-GC), brown, loose, with cobbles

Lean CLAY with gravel (CL), gray, hard, with cobbles

Poorly graded SAND with gravel (SP), gray, loose

Poorly graded SAND with gravel (SP), brown, loose

Well-graded c. SAND (SW), brown, loose

Lean CLAY (CL), brown, loose

Lean CLAY (CL), gray, hard

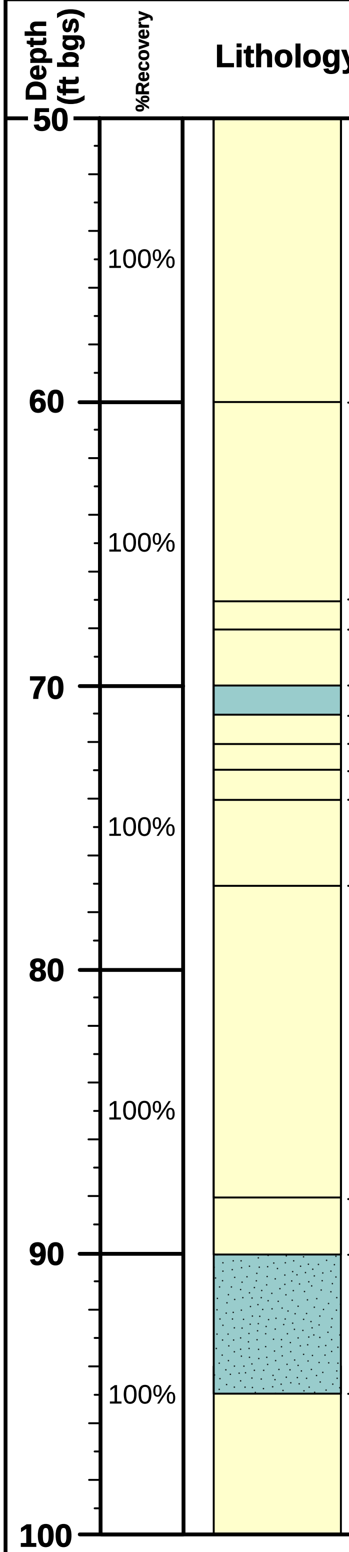
Lean CLAY with sand (CL), gray, medium hard

Lean CLAY (CL), gray, hard

Continued on next page

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS	**Well: TH-3**	**Site:** Noblesville, IN Beaver Materials
Date: 5/5/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.071137° **Long:** -86.006803°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~758 ft amsl

Depth (ft bgs) **%Recovery** **Lithology** **Lithologic Description**



Lean CLAY with gravel (CL), gray, hard

Lean CLAY (CL), gray, hard

Lean CLAY (CL), gray, soft

Lean CLAY (CL), gray, hard

Poorly graded SAND with clay (SP-SC), gray, loose, with cobbles

Lean CLAY (CL), gray, hard

Lean CLAY (CL), gray, loose

Lean CLAY (CL), gray, hard

Lean CLAY with gravel (CL), gray, hard

Lean CLAY with sand (CL), gray, hard

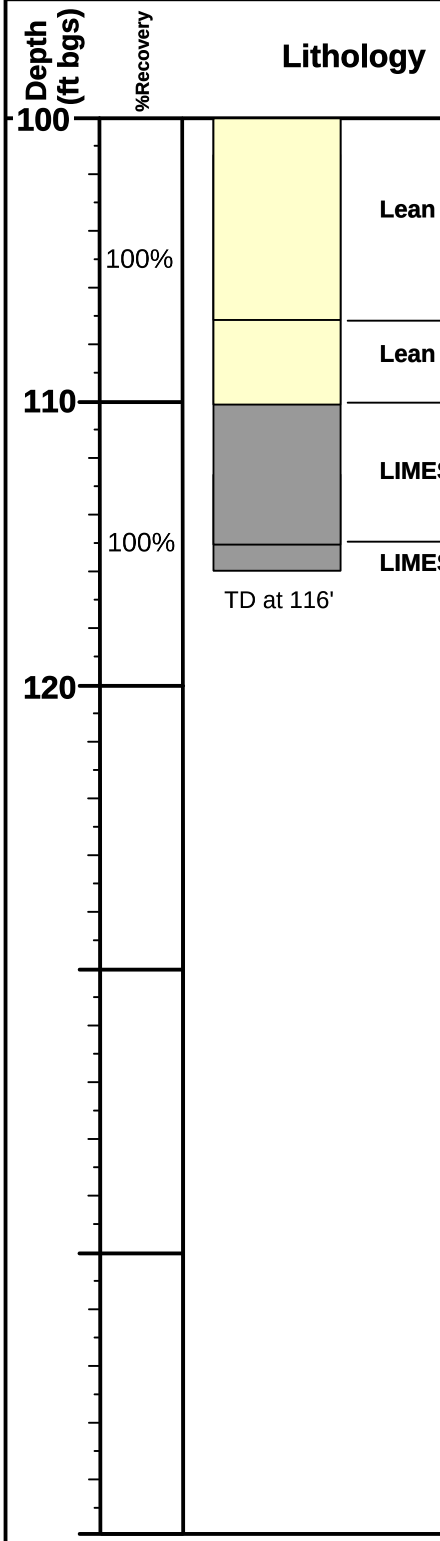
Lean CLAY (CL), gray, hard

Well graded m. SAND with gravel (SW), gray, loose

Lean CLAY (CL), brown, hard

Continued on next page

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS	**Well: TH-3**	**Site:** Noblesville, IN Beaver Materials
Date: 5/5/2021	**Location:** Hamilton Co. Indiana	**Lat:** 40.071137° **Long:** -86.006803°
Logged by: Oliver Wittman, P.G. Geologist, INTERA	**Drilling Method:** Sonic **Drilled by**: Cascade	**Elevation:** ~758 ft amsl



Lithologic Description

Lean CLAY with gravel (CL), gray, hard

Lean CLAY (CL), green, hard

LIMESTONE, broken

LIMESTONE

B Groundwater Flow Model

The groundwater flow model was developed using the USGS code MODFLOW-6 (Langevin et al., 2017) and facilitated by the use of the pre- and post-processing package Model Muse (Winston, 2009). A base model was calibrated to steady state (i.e., average) conditions representative of the years 1997 through 2006. This time period was selected to make use of recent water levels reported on well logs to IDNR that have been field located by the agency. The model was refined in the local area based on a transient analysis of a pump test conducted at the Site, prior to buildout of the WRN Well Field (Eagon, 1996). The model was created to quantify the varrious hydraulic interactions surrounding the Site, and to assess the potential risk involved with the proposed sand and gravel operation to the current hydraulic system.

B.1 Grid and Layering

The model layering was exported from the CGM developed using the Leapfrog software package (Section 5). Grid cell sizes were set to 200 x 200 ft. in the model and further reduced to 100 x 100 ft for the predictive analysis in order to provide sufficient detail in local flow patterns between the Site, the White River, and production wells. The various clay and sand/gravel units comprising the unconsolidated deposits were grouped into nine layers (Table 3), with a tenth layer representing bedrock. These layers are refered to as Layer 1 through Layer 10 (or L1 through L10) with Layer 1 representing the surfical clay down to Layer 10 representing the bedrock. For Layers 1 through 9, odd numbered layers represent clay deposits and even number layers represent sand and gravel deposits.

Figure 30 shows an east-west cross section of the flow model, looking north at the general location of E. 206th Street. The layers representing the unconsolidated deposits were based on modeled surfaces exported from the CGM as described in Subsection 5.4. The bedrock was modeled with a constant thickness of 100 ft thick.

Some of the model layers are discontinuous within the domain (Figures 31-33). For example, Layer 3 represents a clay unit that is only present on the west side of the model domain (Figure 31). The discontinuous portions of model layer were represented as “vertical pass-through” cells using the IDOMAIN capability of MODFLOW-6 (Langevin et al., 2017).

B.2 Boundary Conditions

The model boundary extends from Strawtown to Noblesville, covering an area of approximately 27 square miles. The model was created using natural flow boundaries. The domain extent was defined using a no-flow boundary to the north, east, south, and southwest of the Site (Figure 34). The no-flow boundary was delineated by connecting stagnation points from a generalized potentiometric contour map developed by IDNR (Grove, 2012b). The western boundary of the domain was defined as a hydrologic feature representing Morse Reservoir.

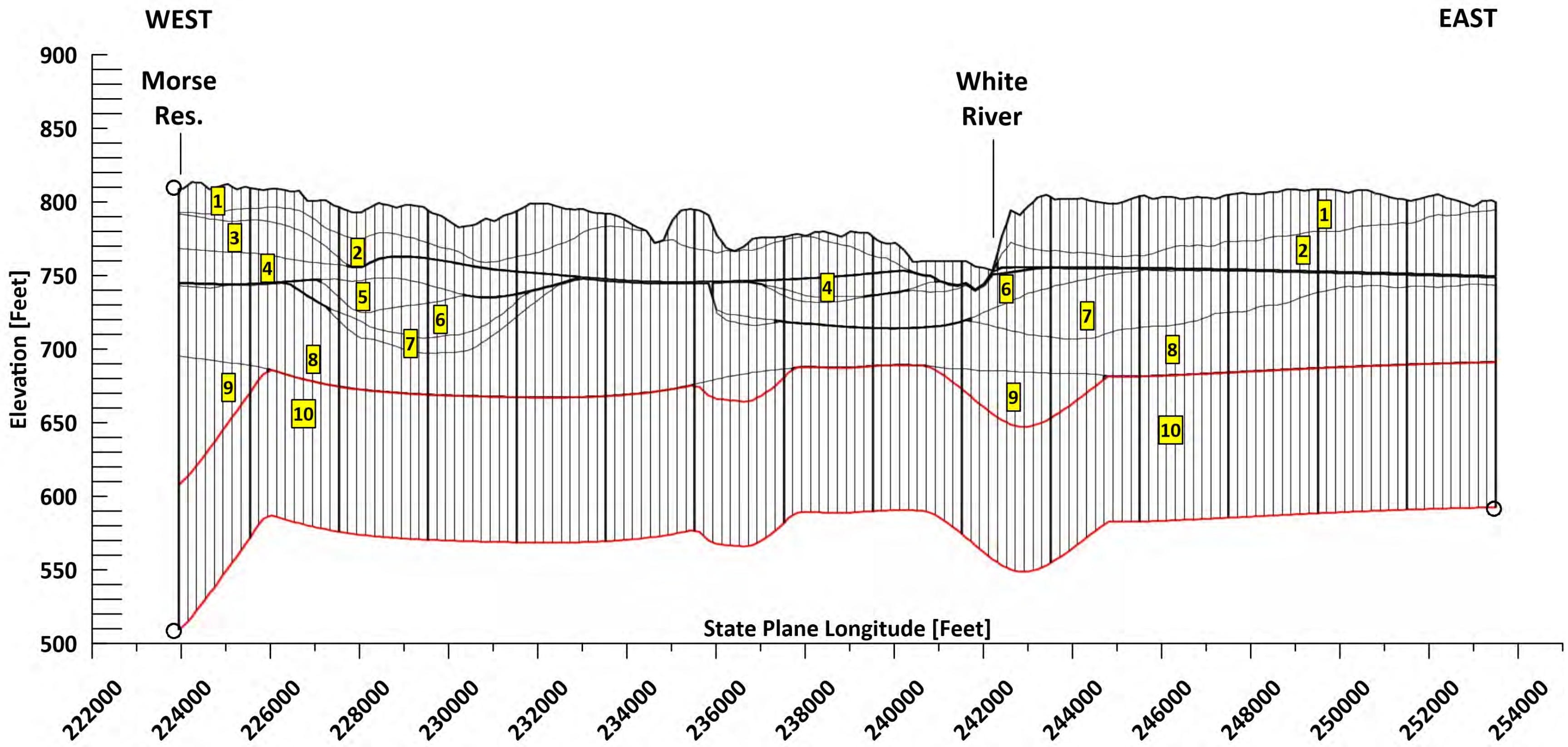
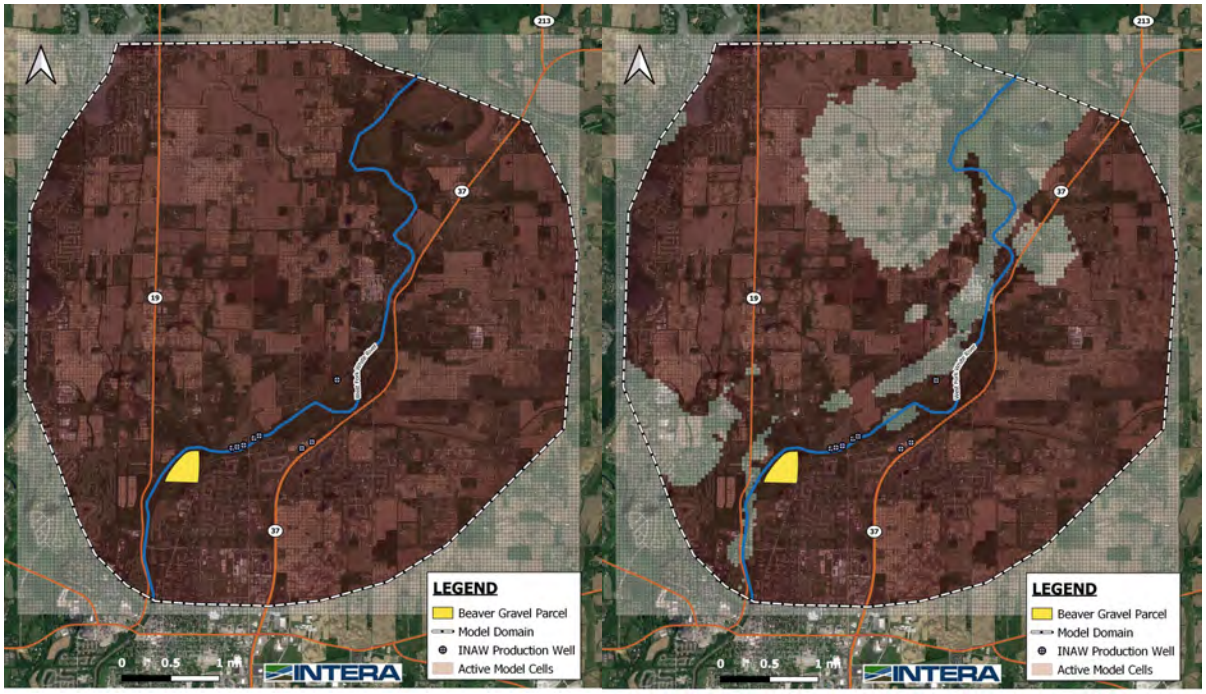
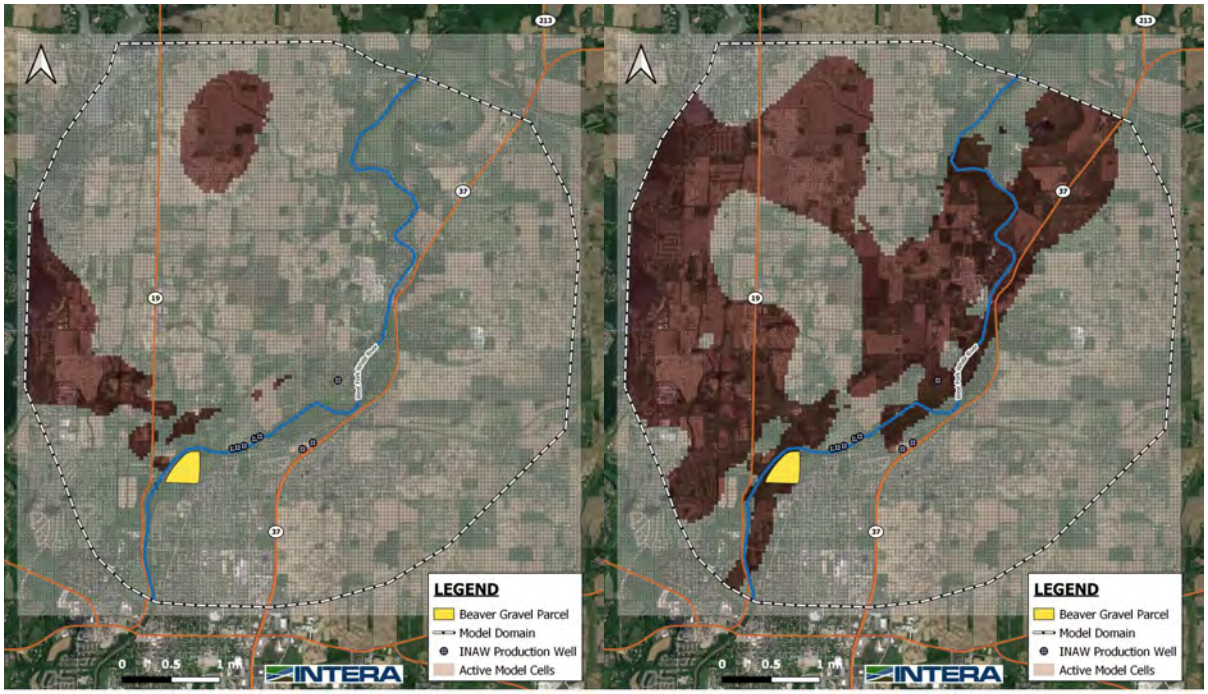


Figure 30: Cross section of MODLFOW model. Yellow boxes denote model layer number. Vertical exaggeration = 40.

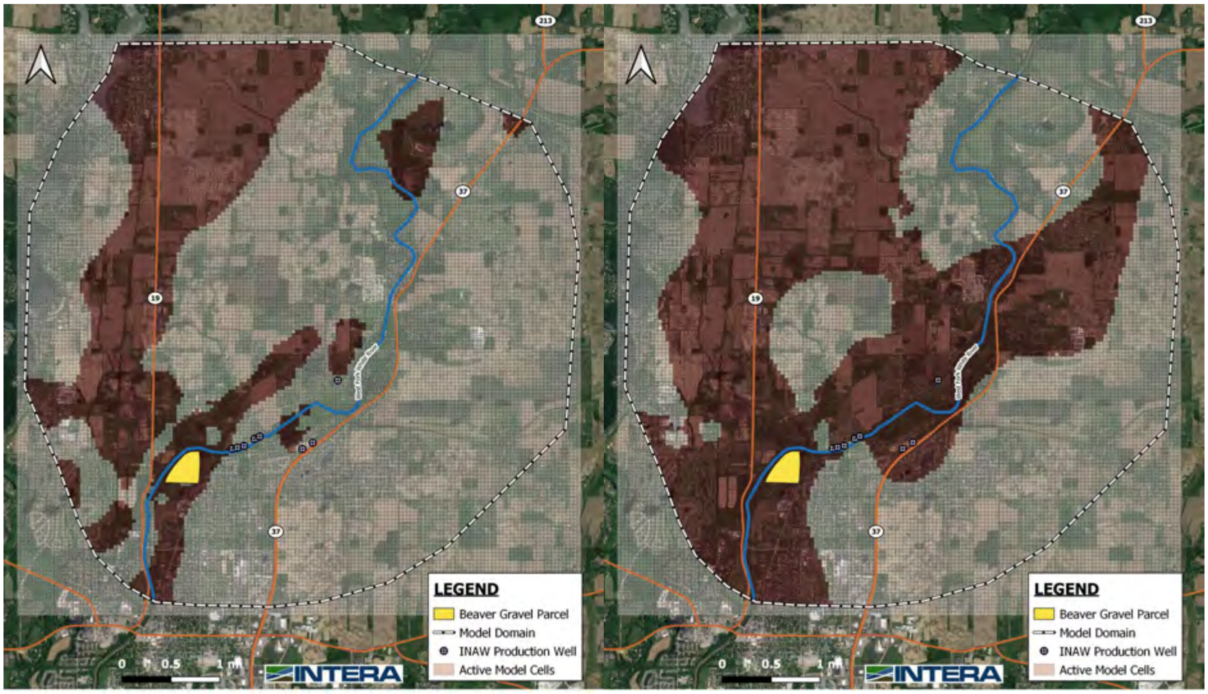


Layer 1 **Layer 2**

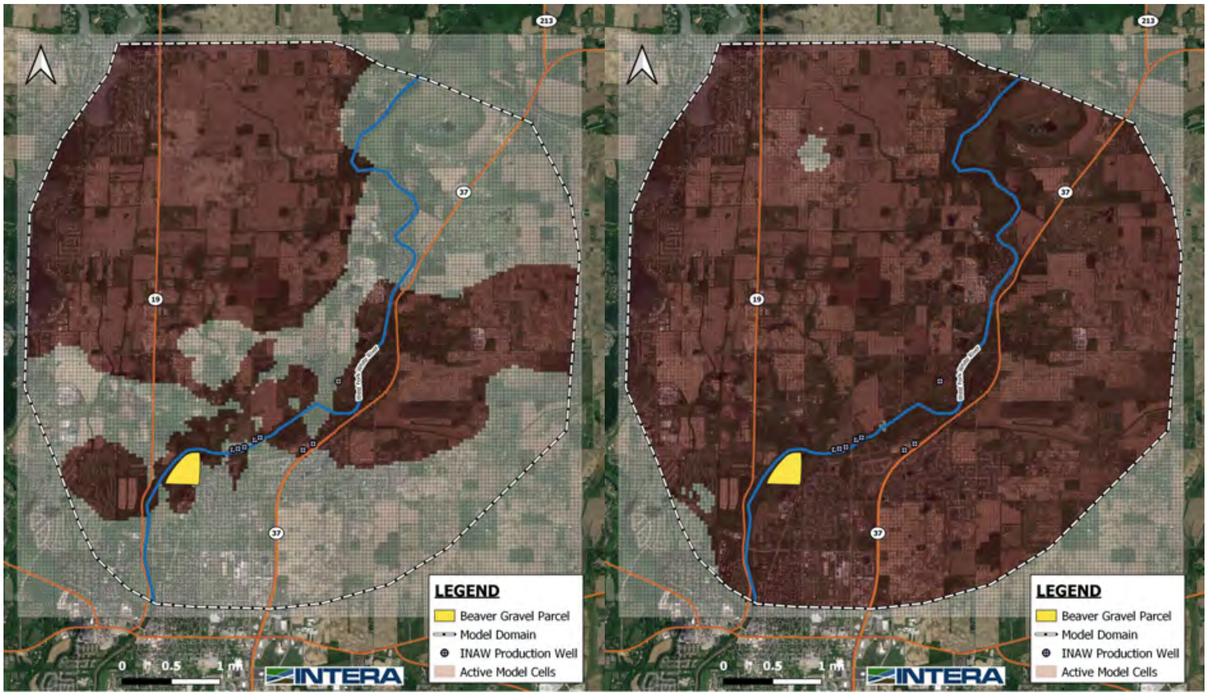


Layer 3 **Layer 4**

Figure 31: Spatial distribution of active cells in Layers 1-4.



Layer 5 **Layer 6**



Layer 7 **Layer 8**

Figure 32: Spatial distribution of active cells in Layers 5-8.

Table 3: Model layers.

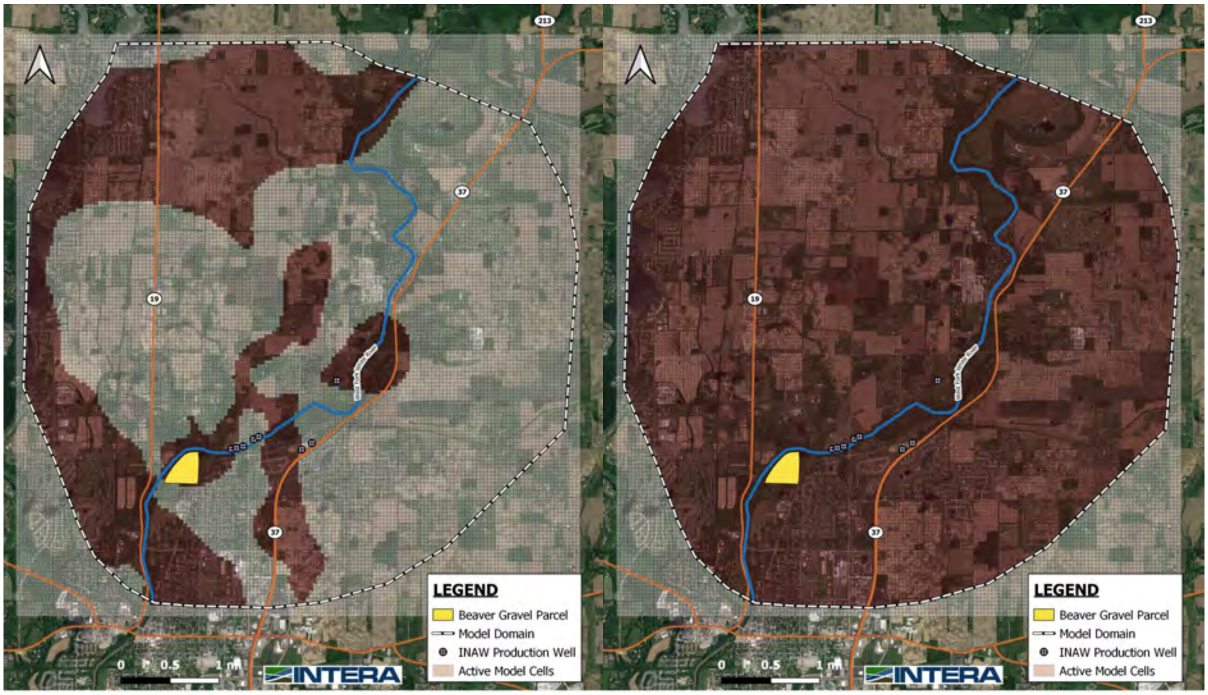
Layer Number	Description	Active Cells Base Model	Active Cell Predictive Model
1	Surficial Unit	18,756	75,035
2	Top sand and gravel	14,536	58,179
3	Till unit C	1,657	6,634
4	Middle sand and gravel	7,590	30,351
5	Till unit B	5,184	20,722
6	Lower sand and gravel	10,273	41,108
7	Till unit A.	10,150	40,566
8	Basal sand and gravel	18,562	74.234
9	Basal till overlying bedrock	6,684	26,769
10	Bedrock Aquifer	18,756	75,035

Both the West Fork of White River and Morse Reservoir were simulated with the MODFLOW RIV (river) package. River stage data at the northern boundary of the model domain were set based on the USGS stream gage located north of the Site, in Strawtown. Water levels at Morse and throughout the lower reach of White River were derived from a USGS DEM (USGS, 2020).

B.3 Aerial Recharge

In general, precipitation that does not runoff as surface water either percolates through the unconsolidated sediments and recharges the groundwater, or is lost through evapotranspiration. Rechage rates are variable depending on multiple factors, such as: soil type, vegetation type and cover, elevation, slope, temperature, and solar radiation. Within the domain, two general geological landscapes are present: the outwash system and the surrounding glacial till. In order to represent these two systems accurately, two recharge rates were applied to the model domain, one for the area representing the outwash/alluvial aquifer system and one for the rest of the model.

The outwash aquifer system is recharged by precipitation and inflow from till aquifer systems east and west along the outwash valley perimeter. In the model, recharge was applied to the outwash at a set rate of 14 in/yr. This rate is consistent with previous IDNR estimates of recharge within the outwash aquifer. In this area, IDNR estimated a range of recharge of 10.5 to 14.7 in/yr (IDNR, 2002). Recharge to the rest of the model was set to 4 in/yr. This is consistent with previous estimates of recharge to glacial till. Arihood (1982) suggests a range of 2.0 to 4.5 in/yr for till aquifers in Hamilton County. IDNR (2002) reports an estimated range of 3.15 to 4.73 in/yr for till aquifers in the West Fork of the White River Basin.



Layer 9 **Layer 10**

Figure 33: Spatial distribution of active cells in Layers 9 and 10.

B.4 High-Capacity Wells

High-capacity well locations and historical water withdrawals were obtained from the IDNR Significant Water Withdrawal Facility (SWWF) database (IDNR, 2021) (Figure 34). The total combined rates for public utilities and other major sectors for the base model and predictive scenarios are summarized in Table 4. The model was calibrated using the reported average annual withdrawal rate for each well between 1997 and 2006 (IDNR, 2021). Total withdrawal for the base scenario was 2.2 MGD, with 1.4 MGD of the total being pumped by INAWC production wells.

The predictive scenario representing current average conditions was based on the most current information available. Average rates for INAWC wells were based on data from 2016 to 2020. All other rates were based on data from 2016 through 2019. The predictive scenario included a total withdrawal rate of 5.8 MGD, with 4.5 MGD of the total being pumped by INAWC production wells.

B.5 Water-Level Observations

Water levels reported on well logs obtained from IDNR were used for calibration of regional flow in the model. The IDNR well log data set is derived from static levels that are reported when a well is drilled. The model was calibrated to steady state (i.e., average) conditions representative

Figure 34: Boundary conditions.

of 1997 through 2006. This time period was selected to make use of more recent water levels reported on well logs to IDNR that have been field located by the agency. Figure 35 shows the location of 64 water-level observations reported to the State.

Generally, the water-level data reported to the IDNR database are of poor quality; the data are reported by various drillers, using different methods, and representing different times of the year when water levels are naturally variable. In addition, the IDNR data are not based on strict vertical control of the measuring point elevation. Despite the uncertainties, the IDNR data is the only data available for calibration beyond the area of interest, and is still useful when analyzing regional trends. This data was incorporated into the calibration to estimate specific model parameters. The calibration is used to fit of modeled results in the "middle" of the observed data.

B.6 Surface Water/Groundwater Interaction

The degree of hydraulic connection between surface water bodies and groundwater can have an significant effect on flow patterns created by wells that pump groundwater adjacent to rivers, similar to the wells at the WRN Well Field. The hydraulic connection is modeled with conductance, a lumped term that governs the modeled exchange between groundwater and surface water. Specifically, conductance (C) is a factor that relates the difference in head in a river cell to the rate of flow. In MODFLOW, C generally has units of L^2/T and is equal to KLW/M, where:

K = the hydraulic conductivity of the sediment in the boundary condition such as a river or drain,

L = the length of the boundary condition in the cell,

W = the width of the boundary condition, and

M = the thickness of the sediment in the boundary condition perpendicular to flow between the boundary and the cell.

Model Muse provides a function that can automatically calculate the length term above. In this case, C is treated as KW/M instead of KLW/M, making the units L/T. This is the units of the conductance terms reported here. The conductance term for the White River was set at 50 ft/day for the base model and increased to 100 ft/day for the refined grid in the predictive model. These values are based on previous field testing and groundwater flow modeling of the region [REF]. The conductance for Morse Reservoir was set at 10 ft/day.

B.7 Calibration

The base model was calibrated manually by adjusting four hydraulic conductivity values, applied to the layers as shown in Table 5. Due to a lack of observations in the bedrock aquifer, Layer 10 parameters were adjusted to generally match bedrock potentiometric contours published by IDNR (Grove, 2012a). The parameters for Layers 1 through 9, which represent the unconsolidated deposits, were adjusted until the model adequately simulated the behavior of

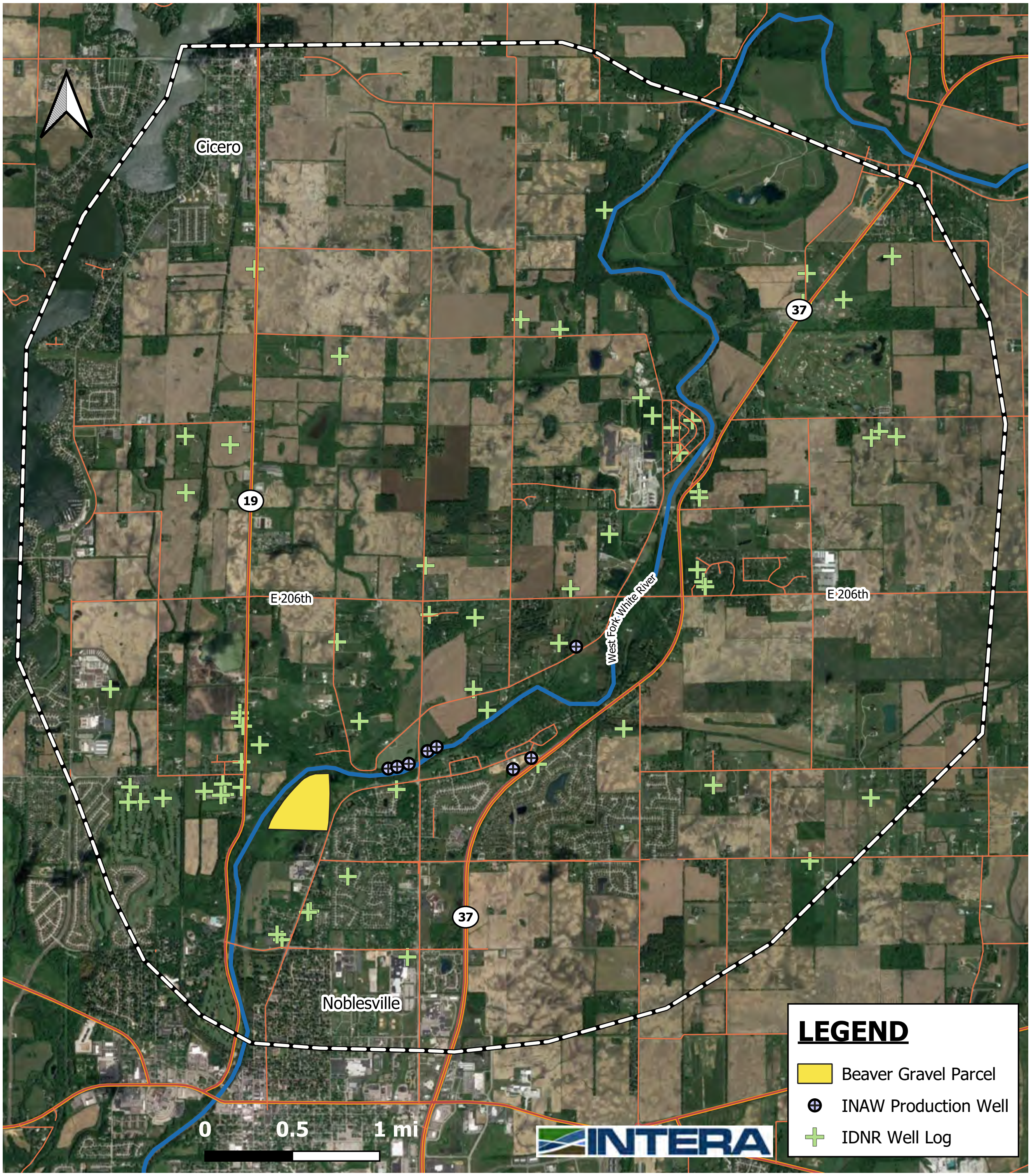


Figure 35: Location of water-level observations used in base model calibration (IDNR, 2020).

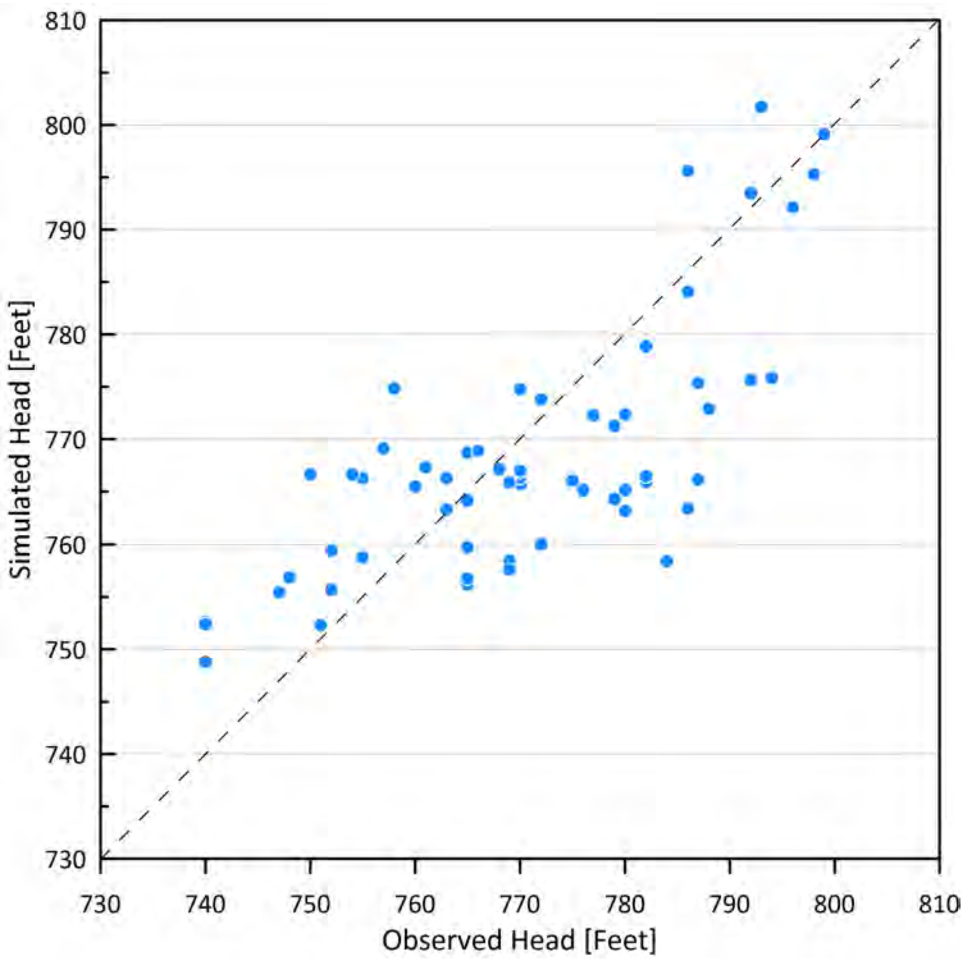


Figure 36: Simulated vs. observed values, base model calibration.

the system in the model domain. Figure 36 shows simulated values plotted against observed heads. The root mean square residual was 10.8 ft. Potentiometric contours for the calibrated base model are shown in Figure 37.

B.8 Local Refinement

As part of development of the WRN Well Field, a 72-hour pumping test was conducted with what is now Well 2 (Eagon, 1996). The response to pumping was recorded in multiple monitoring wells (Figure 8). INTERA performed a transient analysis of the test results to confirm and refine local aquifer properties. Particular attention was paid to a Well I, a monitoring well located between the pumping well (Well 2) and the Site. Based on results of this analysis, the vertical hydraulic conductivity was adjusted locally for Layer 7 (Till Unit A).

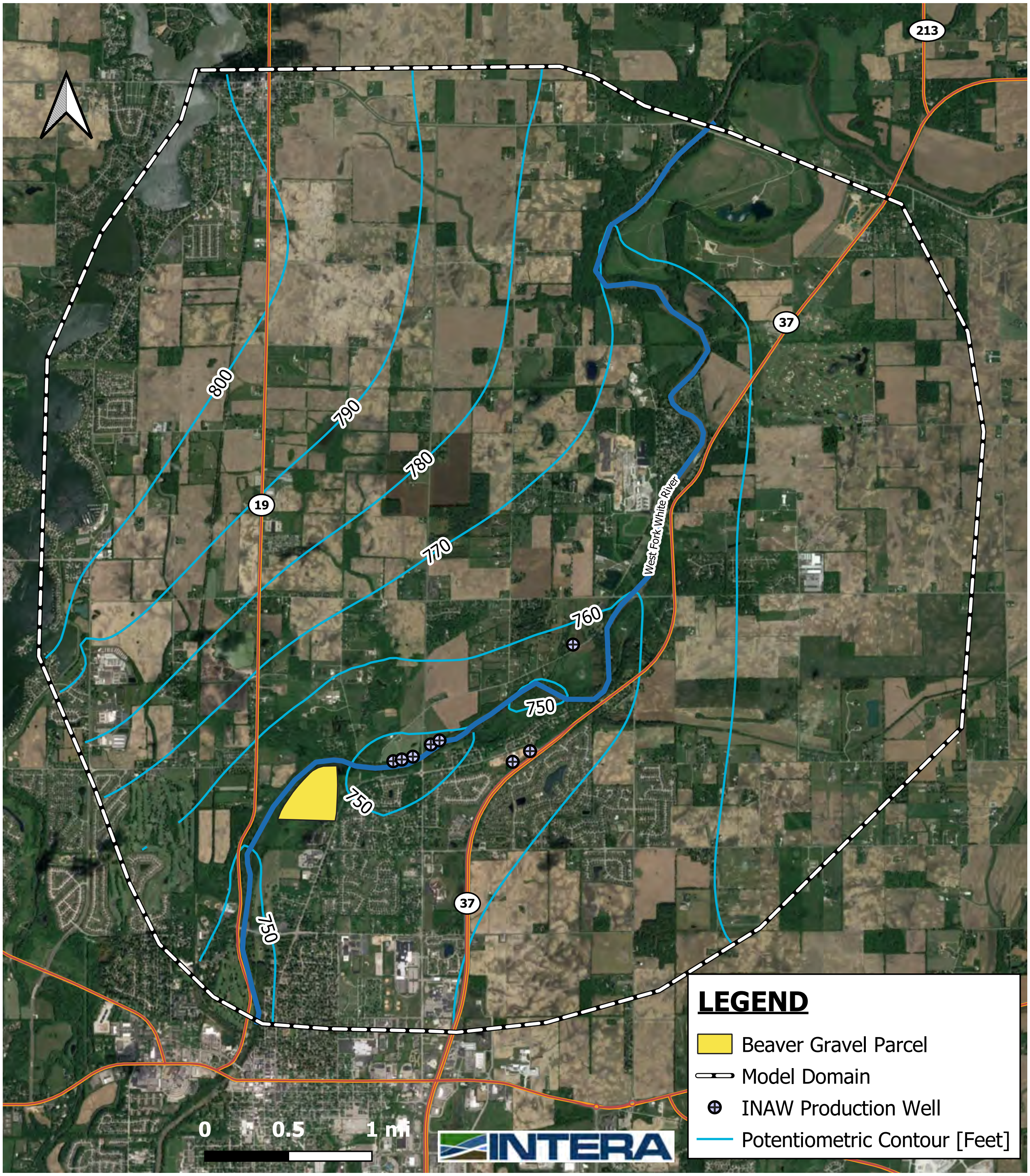


Figure 37: Simulated potentiometric contours for Layer 8, calibrated base model.

B.9 Final Model Parameters

Final model parameters based on calibration and local refinement are summarized in Table 6. The horizontal hydraulic conductivity (Kx) of 200 ft/day derived for the outwash aquifer is consistent with previous work in the region and specifically at the WRN Well Field. Arihood (1982) reported a range of K values for the outwash aquifer (based on aquifer material) to be from 40 to 415 ft/day. IDNR (2002) reports a transmissivity (T) range of 2,000 to 20,100 ft^2/day for the outwash aquifer system in the West Fork White River Basin. Assuming a saturated thickness of 50 ft, this translates to a K range of 40 to 400 ft/day. Based on the results of the 72-hour constant rate test at the North Well Field, Eagon (1996) derived a T range of 6,565 to 11,784 ft^2/day for the outwash deposits. Assuming a saturated thickness of 50 ft, this translates to a K range of approximately 130 to 235 ft/day.

Hydraulic parameters for the bedrock are not as available as the unconsolidated deposits due to high local variability and a lack of quality pumping tests. Well drillers report some variability of hardness, fracturing, and solution features in the bedrock but overall, it is relatively impermeable and is only an important water resource at select locations. Based on a constant thickness of 100 ft, the hydraulic conductivity (Kx) of 10 ft/day derived for the bedrock aquifer equates to a regional T value of 1,000 ft^2/day. This value is consistent with previous work in the region. Herring (1976) reports T values for the Silurian-Devonian aquifer in Marion County in the range of 60 to 1,300 ft^2/day. Arihood (1982) reported a general value of 1,000 ft^2/day for the model area with isolated sites along the White River as high as 10,000 ft^2/day.

The permeable layers within the unconsolidated deposits are separated by the confining clay layers and lenses of variable thicknesses. There is little existing information regarding the hydraulic properties of the low permeable clay units. The values used to represent clay layers are consistent with previous work in the Hamilton County and work at the north WRN Well Field site. For a regional model of the County, Arihood (1982) reports a range of Kv values from 7 x 10^{-4} to 7 x 10^{-2} ft/day. Using a leaky aquifer model to analyze the original pumping test from Well 2 at the WRN Well Field, Eagon (1996) derived a Kv range of approximately 3 x 10^{-3} to 8 x 10^{-1} ft/day for clay overlying the outwash deposits.

B.10 Water Budget

The water budget for the base and predictive models are shown in Tables 7 and 8, respectively. Pumping rates for high-capacity wells are discussed in Section B.4.

Table 4: Withdrawal rates for high-capacity wells in the base model (average 2009-2013) and the predictive scenario (average 2016-2018) .

Facility	Source ID	MWU Code	Modeled Pumping Rate Base Scenario '97-'06 Average [MGD]	Modeled Pumping Rate Pred. Scenario '16-'20 Average [MGD]
Noblesville Soccer Club	1	IR	0.004	–
Duke Energy	1	EP	0.009	0.016
Duke Energy	2	EP	–	0.003
Duke Energy	3	EP	–	0.002
Purgatory Golf Course	6	IR	–	0.180
Purgatory Golf Course	8	IR	–	0.076
Citizens Energy Group	7	PS	–	0.562
Town of Cicero Utilities	1	PS	0.079	0.076
Town of Cicero Utilities	2	PS	0.077	0.083
Town of Cicero Utilities	3	PS	0.139	0.160
Town of Cicero Utilities	4	PS	0.119	0.108
INAWC North Well Field	1	PS	1.400	1.718
INAWC North Well Field	2	PS	–	0.246
INAWC North Well Field	3	PS	–	0.525
INAWC North Well Field	4	PS	–	0.457
INAWC North Well Field	5	PS	–	0.379
INAWC Allisonville Well Field	1	PS	–	0.600
INAWC Allisonvile Well Field	2	PS	–	0.600
Noblesville Schools	2	IR	0.003	–
Meadows Property Owners	1	IR	0.023	–
Meadows Property Owners	2	IR	0.019	–
Indianapolis Dept. of Waterworks	7	PS	0.305	–
		TOTAL	**2.2**	**5.8**

Notes; MGD- million gallons per day, MWU- Major Water Use, IR-Irrigation
PS- Public Supply, EP- Energy Production

Table 5: Model parameter scheme.

Layer Number	Description	Kx [ft/day]	Kz [ft/day]
1	Surficial Unit	K_Till	K_Till/10
2	Top sand and gravel	K_SnG	K_SnG/4
3	Till unit C	K_Till	K_Till/10
4	Middle sand and gravel	K_SnG	K_SnG/4
5	Till unit B	K_Till	K_Till/10
6	Lower sand and gravel	K_SnG	K_SnG/4
	Outwash Area	K_Outwash	K_Outwash/4
7	Till unit A.	K_Till	K_Till/10
8	Basal sand and gravel	K_SnG	K_SnG/4
	Outwash Area	K_Outwash	K_Outwash/4
9	Basal till overlying bedrock	K_Till	K_Till/10
10	Bedrock Aquifer	K_Bed	K_Bed/10

Table 6: Final aquifer parameters.

Layer Number	Description	Kx [ft/day]	Kz [ft/day]
1	Surficial Unit	0.5	0.05
2	Top sand and gravel	25	6.25
3	Till unit C	0.5	0.05
4	Middle sand and gravel	25	6.25
5	Till unit B	0.5	0.05
6	Lower sand and gravel	25	6.25
	Outwash Area	200	50
7	Till unit A.	0.5	0.05
	Local Refinement	5	0.5
8	Basal sand and gravel	25	6.25
	Outwash Area	200	50
9	Basal till overlying bedrock	0.5	0.05
10	Bedrock Aquifer	10	1

Table 7: Water balance for base model.

	INFLOW	INFLOW	OUTFLOW	OUTFLOW
	[ft^3/day]	[MGD]	[ft^3/day]	[MGD]
Wells	–	–	295,622	2.21
Recharge	950,022	7.11	–	
River Leakage	218,597	1.64	873,003	6.53
Total	1,168,619	8.74	1,168,626	8.74

IN - OUT = 6.1 ft^3/day*; Error = 0.00%*

MGD = million gallons per day

Table 8: Water balance for predictive model.

	INFLOW	INFLOW	OUTFLOW	OUTFLOW
	[ft^3/day]	[MGD]	[ft^3/day]	[MGD]
Wells	–	–	775,867	5.80
Recharge	950,260	7.11	–	–
River Leakage	462,258	3.46	636,688	4.76
Total	1,412,517	10.57	1,412,554	10.59

IN - OUT = 36.0 ft^3/day*; Error = 0.00%*

MGD = million gallons per day