Identification of Failing Septic Systems

Final Report

Prepared for:

Huron River Watershed Council

10/2/12

Prepared by:
Andrew Brenner - Photo Science
Matt Vernier - Sanborn

Huron River Watershed Council

Identification of Failing Septic Systems

Table of Contents

1 Acknowledgements

The project team would like to acknowledge the financial support of the Michigan Department of Environmental Quality under the section 319 grant program for this project, Tracking Code #2010-0044. We would also like to recognize the support and sponsorship of the Washtenaw County Environmental Health Department (WCEHD) and its Director Richard Fleece and Supervisor Leon Moore.

The visits to the field would not have happened without the tireless work of Mike Gebhard of the WCEHD and the work of volunteers and staff at the Huron River Watershed Council contacting homeowners for access to their properties. We would also like to thank the homeowners who allowed field samples to be taken on their properties. Support for the GPS and geospatial work came from Anthony Bedogne of the Washtenaw County Water Resource Commissioner's Office.

This project was funded by the USEPA through a grant to Michigan Department of Environmental Quality (MDEQ) that provided a grant to Huron River Watershed Council (HRWC).

2 Executive Summary

The Huron River Watershed subbasins of Honey Creek and Mill Creek have been identified as having an issue with e-coli bacterial pollution and providing a phosphorus load to the middle Huron River. One of the potential causes of these problems is failing septic systems. Since failing systems are hard to predict the extent of the problem is better quantified by some form of measurement. The objectives of this project were to develop a protocol to identify potential failures of septic systems preferably before they become an ecological and human health risk. The project evaluated both thermal and color infrared (CIR) imagery collected in the spring. Signatures were extracted from both thermal and color infrared imagery and although thermal signatures did indicate areas of anomalies those anomalies were also visible in the CIR imagery. Therefore the additional information provided by the thermal imagery did not appear to add sufficient information to justify its expense. The advantage to this conclusion is that many spring imagery collects are now available for analysis for septic failure at no addition cost to a health agency.

Prior to the image analysis, a GIS analysis was conducted to see if failure rates can be associated with environmental and property variables. Using the Washtenaw County Time of Sale database, it was not possible to determine a significant relationship that would allow the modeling of potential failure of the septic system.

What the project was able to show was that using the ancillary data the potential location of the septic fields was identified. This was important in the identification of signatures since it limited the area required to be reviewed by an analyst looking for failure signatures. The spatial models were developed with the support of the Health Department staff.

As the project progressed, project analysts were able to identify characteristics of failure signatures and differentiate them from other anomalies. Not all signatures indicate failures, some indicated a thinner than usual soil depth covering the field or the tank. Imagery was manipulated to improve the analyst's ability to identify the signatures. By dividing the signatures into three main Failure Classes, it was possible to develop a classification of properties into those that require special attention and those that do not. Field verification showed that the worst situations were identified into the Failure Class 1. Many of the systems that were moving to failure were include in Failure Classes 1 and 2. Some systems that were moving to failure were found in Failure Class 3. Although this indicates that the methods are reasonable at picking up failures, the false positives (i.e. where a positive signature is identified, but there is no problem) is high. The number of false positives can be reduced by better signature definition and checking the location of the signatures with written location information from permits.

In summary, this project has developed and tested a protocol for focusing resources to address failing septic systems that can be applied across Michigan and the nation. Focusing these resources will lead to more efficient enforcement of existing rules and effective education of property owners. Increased awareness among property owners should lead to improved maintenance of systems and, ultimately, reduced environmental and human health risks.

3 BACKGROUND

The overall project goal was to 1) reduce the quantity of phosphorus and bacteria entering the middle Huron River, and 2) develop a cost-effective approach for monitoring and rectifying problems with septic systems for County Health Departments.

The specific project objectives were to:

1) Demonstrate in an operational context how imagery and spatial analysis can rapidly and accurately identify septic systems that are in the process of failing or have failed;
2) Use the information created by these analyses to optimize the use of resources in the Washtenaw County Environmental Health Department (WCEHD) for rectification of these issues;
3) To design, implement and assess a campaign to educate households in high probability failure areas to take actions to prevent failures;
4) To enforce existing regulations in locations where severe problems are identified; and
5) To assess a) the accuracy of the monitoring system, b) the effectiveness of the education and enforcement activities, and c) the impact on phosphorus and bacteria in the tributaries leading to the middle Huron.

These objectives were met by:

1) **Identifying failing septic systems**: The project identified signatures of failure using digital image analysis in conjunction with spatial analysis. These signatures vary depending on soil and weather conditions, but relate to the impact on vegetation of saturation of soil with nutrients and water. Imagery from a camera that collects 2 thermal bands and a camera that collects 4 visible and infrared wavelengths, in combination with elevation and GIS datasets was analyzed to determine the probability of failing septic systems within Mill and Honey Creeks, tributaries of the middle Huron. This assessment was calibrated and verified with field observations with WCEHD.

2) **Integrating information into WCEHD operations**: The project team can use these data to analyze current WCEHD operations and discuss how to incorporate the project results into their work flow. Operational costs and productivity (number of locations assessed, failures found etc.) can be assessed and compared against current operational costs and productivity of the WCEHD staff.

3) **Educating the target audience:** HRWC is developing an educational campaign, building on their existing materials to inform homeowners in high risk areas about the functioning, maintenance, and rectification of

issues associated with septic systems. The target audience will be contacted to determine success of implementing corrective measures or suggested best practices.

4) **Enforcing existing regulations**: WCEHD will be able to take actions on households where systems are identified as failing and causing a public hazard with respect to leaking of untreated sewage into the middle Huron River. These activities are within WCEHD current mandate but are not covered in this report.

This report only covers the activities of Sanborn and Photo Science outlined in Objective 1 in the list above.

4 DETAILED DESCRIPTION OF PROJECT

This section contains a description of what was completed to meet Objective 1 and the results that were found. This section discusses the elements of the project that proved effective as well as those found to be ineffective.

4.1 Overview of process

The approach involved the following tasks:

- Task 1: Collect and analyze existing septic failure data
- Task 2: Collect aerial imagery and conduct initial analysis of imagery to produce draft failure map
- Task 3: Verify results
- Task 4: Finalize failure map and develop protocols for the future analysis of failure

4.2 Collect and analyze existing septic failure data

The first phase of the septic failure identification project was to gather existing data, both spatial and tabular, and to learn if there were any aspects of the data that might be predictive of the likelihood of failure. Prior to data analysis, several possible predictors were suggested, such as:

- Soil type
- Soil hydric regime
- Number of occupants
- Number of baths
- Age of home

The approach involved analyzing data contained in the Washtenaw County Environmental Health Department's (WCEHD) Time-of-Sale (TOS) database, looking for correlations between septic failure indicators and environmental and property variables. The failure indicator was Saturation Class (Table 1), a categorical variable expressed by the following rating scheme. The Time-of-Sale database contains reports on septic and well conditions at a property when it is sold. This database includes an assessment of the drain field using the same protocols as were used on this project.

The key element to the healthy functioning of a drain field is that the water can easily drain downwards first being filtered by the drain field and then by the soil before entering the water table. When a field stops draining as designed, anaerobic conditions occur and septage stops breaking down the way it is supposed to. There are a couple of reasons for the drain field to stop working: (1) it could be under too much water flow, or (2) the field may be getting blocked with particulate matter. Both factors will cause the field to become saturated and eventually stop draining so that liquid will start moving upwards to the surface of the ground and becoming an ecological and health hazard. Therefore the degree of septic saturation indicates how close the field is to failing and posing a health risk.

Saturation Class	Degree of Septic Saturation
A	None
B	<50% saturation of field below tile holes
C	50 - 100% saturation of field below tile holes
D	<50% saturation of field above tile holes
E	50 - 100% saturation of field above tile holes

Table 1: Description of saturation definitions

The dependent variables were primarily from the TOS data (Table 2), as well as commonly available GIS datasets, such as soils and elevation. The soils data were derived from the Soil Survey Geographic Database (SSURGO) (NRCS, 2010), and the elevation-related data were derived from 3 m resolution National Elevation Dataset (NED) data.

Variable	Description
Year built	Year of construction of house
Age of home	Age of home (as of 2011)
Date Inspection	Date of last inspection
No baths	Number of baths
No bdrms	Number of bedrooms
No months vac	Number of months house has been vacant
No residents	Number of residents
Bed area	Drain (Septic) field area
Biomat	Degree of biomat present (A-E) A: None B: <50% of field below tile holes C: 50 - 100% of field below tile holes D: <50% of field above tile holes E: 50 - 100% of field above tile holes
DF cover	Inches of cover over drain field
DF cover max	Maximum cover on drain field
DF Dist SW	Distance of drain field to nearest surface water
DF Type	Type of drain field
Eff distrib	Method of effluent distribution to drain field
Eff exposed	Is there exposed effluent? (Y,N)
Final App	Date of final construction approval
Last Pump	Date of last pumping
Sand Stone	Sandy soil present under drain field (Y,N)
SW Diverted	Surface water diverted from drain field (Y,N)
Wood Veg	Is woody vegetation present on drain field? (Y,N)

Table 2: TOS data variables included in the model

For the purposes of this study, the soil type was crosswalked to a rating class, proposed by the WCEHD septic specialists. These ratings were:

1. High suitability for septic systems – 90% likelihood of soil type suitability
2. Med-high suitability for septic systems – 60% likelihood
3. Med-low suitability for septic systems – 30% likelihood
4. Low suitability for septic systems – 10% likelihood

The ratings are based on several factors, including sand component, slope, and flooding tendency. Using these ratings, the soil variable is correlated with the slope variables derived from elevation data. Percent slope was calculated from the NED data and averaged over a parcel.

Washtenaw County's parcel database was obtained from the Washtenaw County GIS department for the purposes of the project in December 2010. The usage for these data is twofold:

1. Property owner and address identification, in order that the owners could be contacted if their property was chosen for a site visit.
2. To limit the search area for the septic signature. According to the TOS database, the overwhelming majority of septic fields are placed within the parcel which they service. Of those properties that had location information in the database, 647 septic fields were on the property, and only 2 were located outside the property on an adjacent easement.

Washtenaw County contains a wide variety of parcel sizes, most of those with septic systems are ¼ to ½ acre in size. The maximum distance from the house for a gravity-fed system is 100 ft, but in most cases the closest limiting boundary is the parcel boundary, not the maximum distance.

For this first study, 1,027 parcels were selected from the database within a three-township study area, which covered all the parcels where there was a TOS record within the study area. A Classification and Regression Tree (CART) software, See5 (Rulequest, 2006) was used to develop predictive models. Saturation Class (A-E) was regressed against categorical and continuous variables listed in Table 2. On the first model run, the results indicated that Biomat was the major predictor of Saturation Class. Many other variables were chosen for the model, but Biomat was always the first determinant. Figure 1 shows the results of the first model, in which Measured Saturation Class was compared with Predicted Saturation Class from the CART model.

Measured Sat. Class	Predicted Saturation Class A	B	C	D	E	Total	Accuracy
A	105	11	0	0	1	117	89.7%
B	47	65	1	2	4	119	54.6%
C	10	6	12	0	3	31	38.7%
D	4	4	3	4	0	15	26.7%
E	6	1	2	1	20	30	66.7%
Total	172	87	18	7	28		
Accuracy	61.0%	74.7%	66.7%	57.1%	71.4%		66.0% overall

Figure 1: Accuracy of predicted Saturation Class when compared to measured Saturation Class from the TOS database.

Using all variables listed above, the model had an overall accuracy of 66%. This result was mainly as a result of the high correlation between Biomat and Saturation Class. To gauge the importance of Biomat, a second model was run dropping that variable (Figure 2).

Measured Sat. Class	Predicted Saturation Class (no biomat in model) A	B	C	D	E	Total	Accuracy
A	76	33	2	1	5	117	65.0%
B	53	59	2	1	4	119	49.6%
C	14	13	2	1	1	31	6.5%
D	4	8	0	1	2	15	6.7%
E	15	10	0	0	5	30	16.7%
Total	162	123	6	4	17		
Accuracy	46.9%	48.0%	33.3%	25.0%	29.4%		45.8% overall

Figure 2: Accuracy of predicted Saturation Class when compared to measured Saturation Class from the TOS database after Biomat was dropped from the model.

Removing Biomat as an independent variable resulted in a drop from 66.0% to 45.8% (20.2%) in overall accuracy, the correlation drop was particularly important for the higher saturation ratings, which are the cases of greatest interest for the project.

Figure 3 shows the probability of obtaining a Saturation Class predicted purely from the Biomat Class. High correlations are when the numbers are closer to 1.

Saturation Class	Biomat class A	B	C	D	E
A	0.647	0.076	0.034	0.000	0.015
B	0.263	0.800	0.086	0.086	0.061
C	0.043	0.066	0.638	0.057	0.076
D	0.019	0.034	0.069	0.714	0.000
E	0.028	0.024	0.172	0.143	0.848

Figure 3: Degree of correlation between Biomat Class and Saturation Class from the TOS database.

If information regarding biomat extent was available uniformly for all the data, it would be a very good predictor of Saturation Class. However, these data are normally only collected during inspections, when problems are already suspected or the property is in preparation for sale.

Since the objective of this analysis was to find whether a simple GIS analysis of the available data such as age of house, location etc. would allow a prioritization of households that had a high risk of septic failure, these results showed that no pattern was discernible using the data available. Therefore the identification of failure would need to be detected either by using remote sensing methods or by ground survey.

4.3 Imagery

4.3.1 Thermal

At the inception of this project, one of the main questions was whether or not aerial thermal imagery would be useful for locating problematic and failing systems. Several investigations have been conducted prior to this project to locate failing septics using imagery, mostly Color Infrared (CIR) imagery. CIR and True-color imagery were also used in this study, but the hypothesis was that thermal imagery flown at a period when the water table was high would be sensitive to differing degrees of biological activity. Ideally the timing of acquisition would be when conditions were fairly dry, so that differences between affected and unaffected areas would be evident. Another possible set of conditions would be at snowmelt in the spring, so long as the snowpack was not too heavy. Biological activity would theoretically cause the snow to melt more quickly. Timing for such a flight would need to be precise.

The Spring of 2011 in Southeastern Michigan was particularly wet. A local firm, ArgonST, was contracted to acquire the imagery and had to time the flight carefully. The criteria set forth for the acquisition were that there could not have been significant rainfall during the 48 hours prior to the flight, the imagery should be flown during the late evening/ nighttime hours, prior to leaf-on, and in conditions when ground fog is not likely to occur. The month of April was the target timeframe, but the near-constant rain during that month meant that there were no satisfactory dry windows. The plane and pilot were on standby during late April and early May, and the flight took place in the evening of May 4th. The prior dry period was much shorter than ideal, less than 24 hours, with spotty showers occurring even within that period and with a prolonged period of wetness before that.

Thermal imagery was collected over the three target townships beginning around 11 pm on May 4. The majority of the imagery was collected prior to 4:30 am the next morning, but due to an error in altitude calculations, the northern half of Scio and Freedom townships had to be reflown. The reflight took place around 10 pm on the evening of May 5. A nominal flight altitude of 490 m above ground level (AGL) provided a ground resolution of 0.6 m. The raw scanner data was georeferenced to a resolution of 0.6 m using Digital Elevation Models (DEM) from the USGS Seamless server, differential GPS data (to 0.5 m) and aircraft attitude measurements. Ground temperature was 37.4 °F (3 °C), with a dew point of 28.4 °F (-2 °C) the first night and 59.0 °F (15 °C) and 32.0 °F (0 °C) the second night. Due to the ground temperature differences between the first and second nights, and changing temperatures within the timeframe of a single flight, temperature differences are evident in the flightlines of the imagery. Since the review of the imagery was looking for relative differences in temperatures and the interpretation was manual, the variation in ground temperatures across the project areas did not negatively impact the results of the analysis. Examples of the imagery used are shown in the following figures.

Figure 4: A single tile of thermal imagery collected over Scio Twp., MI. The lighter colors indicate higher surface temperatures.

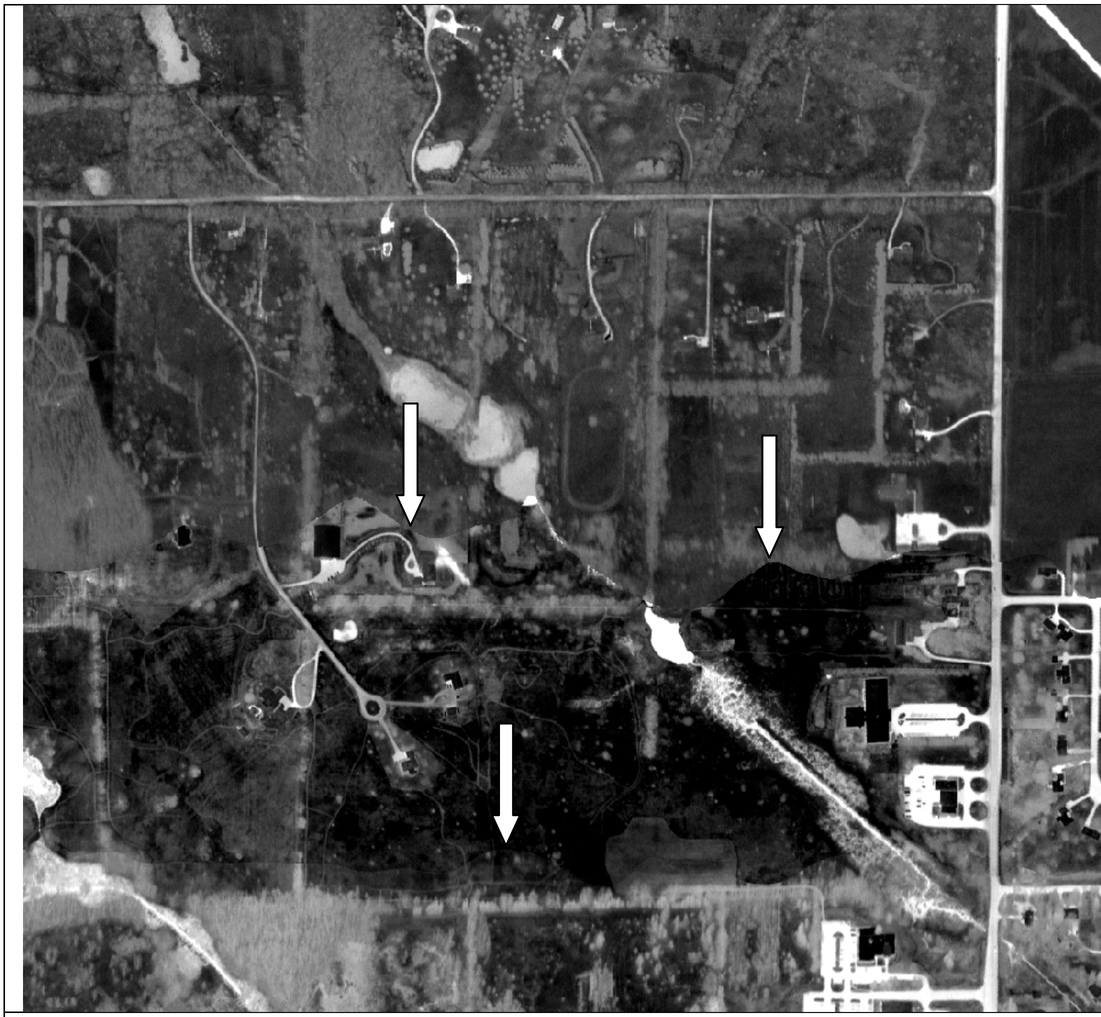


Figure 5: Differences in surface temperatures (white arrows) between flight lines resulting from different ambient surface temperatures.

Figure 6: Possible septic signatures for a property in Scio Twp. These areas seem to indicate a lower temperature than the surrounding ground; this is probably an indication of a wetter area, which could indicate failure.

4.3.2 CIR and True Color Imagery

In conjunction with the thermal imagery collected specifically for this project, use was made of several sources of CIR and True-Color aerial imagery. These are listed below:

1. 2010 SEMCOG (Southeast Michigan Council of Governments): 4-band, 1 ft resolution. Acquired during leaf-off conditions (April).
2. 2010 NAIP (National Agricultural Imagery Program): True color, 1 m resolution. Acquired during leaf-on conditions.
3. 2009 NAIP: True color, 1 m resolution. Acquired during leaf-on conditions.
4. 2006 NAIP: True color, 2 m resolution. Acquired during leaf-on conditions. This year's NAIP was scanned from a film collect.
5. 2005 NAIP: 4-band, 1 m resolution. Acquired during leaf-on conditions.
6. 2005 SEMCOG: 3-band true color, 6-inch resolution. Acquired during leaf-off conditions (late leaf-off in the project area; trees were in the process of leafing out).

The primary imagery dataset used was the 2010 SEMCOG collect. This imagery was high-resolution (6 inch), and included the color infrared band that allowed for more subtle discrimination of vegetation health and moisture patterns when compared to true color and the leaf on NAIP collects. Examples of the imagery are shown below.

Figure 7: 2010 SEMCOG imagery displayed in a CIR band combination. This high-quality imagery was critical to discriminating moisture and vegetation patterns.

4.4 GIS analysis to identify field location

Prior to locating failing septic signatures through manual or automated means, the search area was refined to those areas where septic fields are likely placed. Early in the project, team members met at the offices of the WCEHD to discuss criteria for siting septic fields. In Washtenaw County, there are many criteria to consider when planning a septic system. These include:

1. Soil type – more sand and less clay is better
2. Water table depth – drier is better, the health department seeks locations where the depth to water table is >= 5 ft
3. Not within 100 ft. of a well
4. Not within 50 ft. of surface water (lake, pond, wetland, or stream)
5. 10 – 15 ft. from buildings
6. No woody vegetation or agriculture on field
7. Slope of the land will dictate the type of field. If the field is to be placed above the house, then a pump system will be used. For a system below the house, a gravity system will be used.
    a. A gravity field has a maximum distance from the house of 100 ft.

b. A pump system can be up to ¼ mile from the house, but is usually within 500 ft.

Using these criteria, a GIS layer of potential septic locations was constructed using the following input layers:

1. Building footprints
2. Well locations (State of Michigan, not up-to-date)
3. SSURGO soils, crosswalked for septic suitability
4. Slope percentage, as derived from 10 m resolution NED
5. Washtenaw County parcels

The figure below shows the identification of the potential septic field locations based on GIS modeling.

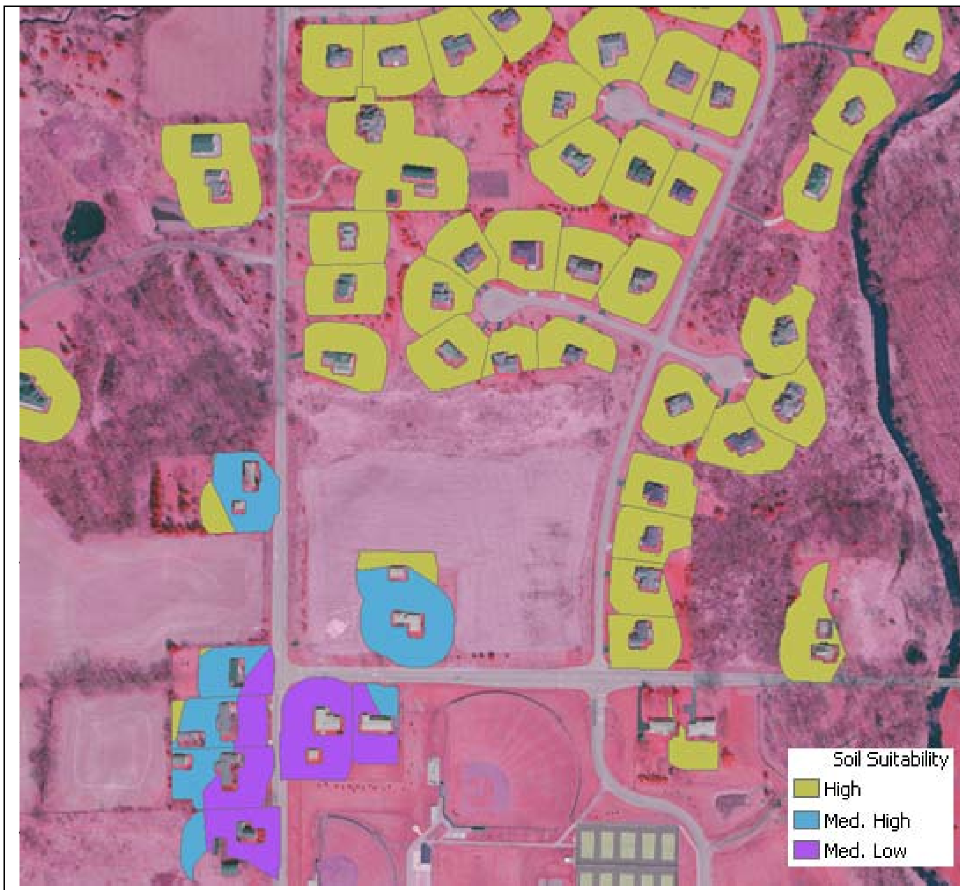


Figure 8: Potential septic system buffers displayed according to soil suitability for the selected parcels in Scio Twp.
b

Prior to analyzing WCEHD record data to determine whether or not failing or problematic systems could be detected, it was necessary to understand if the GIS analysis using the minimum and maximum distance parameters described above could accurately locate the field. Put more simply: were the analysts looking in the right place? Using the potential septic system buffers, 52 fields were located using data from the TOS database. The fields were digitized into a shapefile which could be overlaid on the buffers. Out of the 52, 50 fields were within the buffers. Of the two that were not within the buffers, one was far enough from the house that it was likely a pump system that was mistakenly coded as a gravity-fed system in the TOS database. These results translate to a 96% accuracy rate for predicting potential septic locations.

4.5 Signature Analysis of Parcels Identified by TOS Database to Identify Failure

Areas identified as unsewered within Washtenaw County were merged with the county's parcel layer and the TOS database. This overlay resulted in a dataset with 4,096 parcels for which there was a data source available from which to verify the septic field location. From these, 96 were chosen at random. An analyst examined each location with the available imagery (thermal, 2010, 2009 NAIP, 2006 NAIP, and 2005 NAIP) to attempt to locate the field. Since visual clues will most likely depend on the condition of the field, the saturation and degree of Biomat were reviewed from the TOS database. A significant portion of the parcels examined had neither a high saturation nor high Biomat indicators in the TOS database suggesting that there was no problem with the septic field, so no indicators in the imagery would be expected. Those parcels were not used for the final analysis in this phase. Figure 9 below compares the ability to detect a septic field from the imagery with its saturation rating as indicated in the TOS database. The properties were divided into three Failure Classes:

- Class 3: Not found – No visible signs of a field on the property suggesting that the field is functioning as it should
- Class 2: Possibly found – Possible signs of a field suggesting from thermal and/or CIR that there may be some malfunction of the field
- Class 1: Found – Distinct signs from thermal and/or CIR of a field suggesting malfunction of the field

	Saturation class					
Failure Class	A	B	C	D	E	Total
Class 1	3	3	0	5	6	17
Class 2	3	3	3	2	4	15
Class 3	8	9	11	5	3	36
Total	14	15	14	12	13	
						68

Figure 9: Comparison of the ability to detect a septic field from the imagery with its Saturation Class from the TOS database. Saturation Class definitions are found in Table 1.

The Saturation Class, which for the purposes of this study is a surrogate for failure probability, ranges from A (no saturation of the drain field), to E (50 - 100% saturated above the tile holes). The results of this phase of the investigation show a correlation of the visible detectability of the Failure Class with the Saturation Class measured in the field.

The conclusions from this analysis were:

- 10 out of 13 high Saturation Class (E) were identified
- 7 out of 12 moderate Saturation Class (D) were identified
- 6 out of 17 low Saturation Classes (A – C) were mistaken for higher Saturation Classes
- Some of the errors may have resulted from the issues being fixed before the imagery was taken
- Some septic field detection results from shallow cover depth
- Overall a decent correlation between photo-interpreted signatures and septic field saturation

4.6 Photo interpretation of sites for field verification (First Round)

The next step in the analysis was to determine whether failing septic systems could be detected, as opposed to a "healthy" system. The inputs for this phase were the imagery sources used previously: True-Color, CIR, and Thermal, and probable septic location polygon shapefiles as created for the GIS field location phase. The protocol was to examine the delineated polygons for each of the randomly-chosen parcels, and to place a point if a suspect site was spotted. When all of the chosen sites were examined, a random sample was given to the WCEHD for field checks. The samples given to WCEHD were stratified based on Failure Class as identified by the photointerpreter.

During the first round, 1,149 parcels were reviewed using CIR imagery and Thermal imagery. The parcels were stratified randomly throughout the selected areas of Scio, Freedom and Lima Townships (i.e. those without sewers). The probable septic locations were placed on the imagery, and each site was then reviewed to look for anomalies in either the CIR, Thermal or both. In the case of the thermal imagery the anomalies generally appeared cooler in temperature than the surrounding areas. Although there are many factors that impact field temperature, the one that appeared to dominate in this context was water flow, any heating impact by bacteria activity did not appear to make a difference to the field temperature. Under different environmental conditions the results could be different.

During the review, a point feature class was created within a geodatabase with two fields, one for CIR identification and another for thermal. They both had a domain that allows for Yes, No and Maybe. It is important to note that anomalies found could relate not only to problems with the septic field but to the tank as well. If *a priori* information was not available regarding the location of either the field or the tank, either could be flagged if an anomaly was spotted. It is also important to emphasize that not all vegetation anomalies are caused by septic failure, dead vegetation may result from a number of other causes and so the pattern of vegetation death and its association with wet areas and location of the septic field need to be considered in the interpretation of the imagery.

- Yes - an anomaly was seen
- No - no anomaly was seen
- Maybe - a possible match to a failing septic, but the interpreter was less certain.

Once that was complete a stratified sample was taken from across the County and the points were sorted in to a Failure Class.

- Class 1 - Yes in both the thermal and the CIR
- Class 2 - Anything that had values for the IR and thermal that were Yes or Maybe with the other having a Yes or Maybe
- Class 3 - Anything that had a value of No in at least one of the image types

The matrix is shown below in Table 3.

IR	Thermal	Failure Class
Yes	Yes	1
Maybe	Maybe	2
Maybe	Yes	2
Yes	Maybe	2
No	Maybe	3
No	Maybe	3
Yes	No	3
No	Yes	3

Table 3: Matrix of analyst interpretations that made up the Failure Class for the field survey

Points were selected using a stratified random sample for field visits. Each point that was selected was reviewed using the documents from the TOS database if they existed. If a record was found indicating the field's location, it was compared to the photo-interpreted point. If the septic field was somewhere other than where the point was dropped, then the point was moved to that area if an anomaly was seen. Once completed, a total of 60 points were given to WCEHD to perform site visits to verify the results.

4.7 Field Protocols

Prior to conducting field surveys, the field survey team initiated the downloading of Washtenaw County onsite sewage system permit information (permit and plot plans) for site access approved addresses. The probable investigation locations were plotted on aerial photos using GIS methodologies, in preparation of field survey site visits to aid in locating drain field boundaries.

Site survey field data was collected using a handheld, mobile GPS/GIS data collection unit (Trimble GeoXH GeoExplorer 2008 series). The unit was prepared for the Field Sampling Subtask by adding selected data layers and data storage layers. Data layers added to the unit included the County-wide aerial photo, Township jurisdictional boundary, and field survey data collection layer. The field survey data collection layer was embedded with the data variables consistent with the Washtenaw County Time of Sale Program database to ensure consistent data quality between sites.

ESRI ArcPAD development tools were used to create digital forms for electronic data collection. Screen shots presented below reflect some of the information collected.

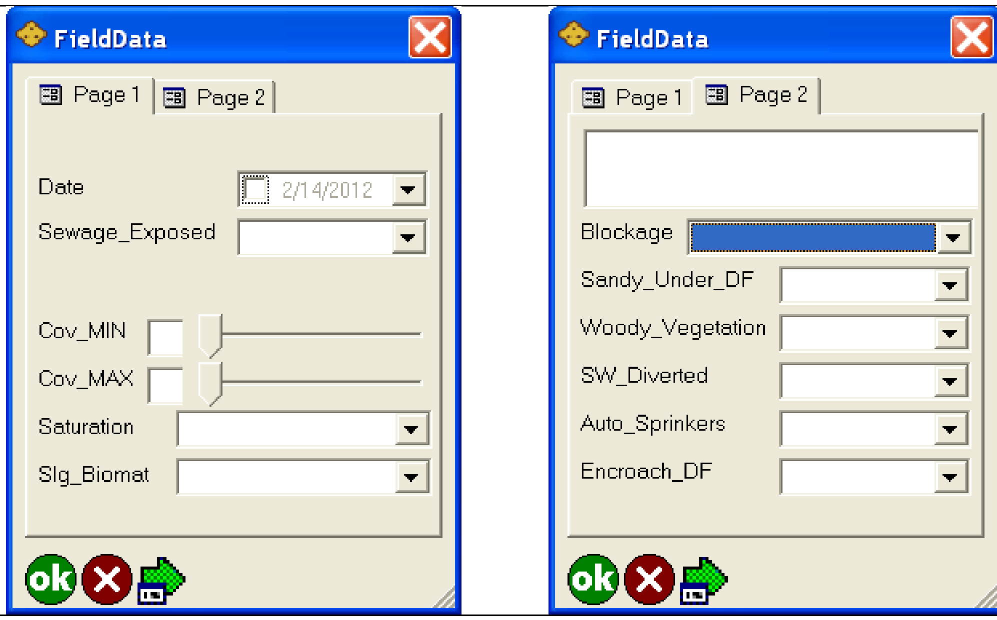


Figure 10; ArcPAD digital data collection forms

Data collected was also maintained on paper field forms as backup.

The field survey team initiated site visits at those properties that had granted site access approval. Drain field bed locations were confirmed by inserting a handheld probe rod through cover soils with the intent of determining the presence or absence of the drain field stone. Drain field stone is a consistently identifiable feature of an onsite sewage system. Drain fields within Washtenaw County are commonly configured in a bed type configuration. Upon determining the boundaries of the drain field bed, typically one to three locations were selected to evaluate the drain field status using parameters consistent with the existing Washtenaw County Time of Sale program. Status of the drain fields were evaluated by hand augering through the cover material to the base of the stone layer and documenting the conditions. The latitude and longitude of hand augered locations were collected by the Trimble GPS/GIS hand-held units. During the acquisition of the positional information, the observed field conditions from the hand augered location were entered into the digital forms. The observed drain field conditions were also documented on hand written field forms.

4.8 First round of field verification of results

The first round of field verification involved extensive outreach to the selected property owners in order to gain access to their properties. No properties were visited where permission was not given, in accordance with WCEHD requirements. This requirement may have biased the ability to visit all selected properties.

In this first round, 29 separate properties were visited and 45 observations were taken. Some properties were sampled multiple times but not more than three times. At two properties, no samples were taken at the request of the homeowner. Of the 29 properties, 8 were in Failure Class 1, 17 in Failure Class 2 (note 2 of these properties were not sampled as mentioned above) and 4 in Failure Class 3. The sampling was biased towards sites that were of potential failures since failure is a rare case.

No sites visited had any exposed sewage. Saturation Classes were recorded on all sites. The results are summarized in Figure 11.

	Saturation Class					
Failure Class	**A**	**B**	**C**	**D**	**E**	**Total**
1	6	1	0	0	1	**8**
2	10	4	1	0	0	**15**
3	1	3	0	0	0	**4**
Total	**17**	**8**	**1**	**0**	**1**	**27**

Figure 11: Predicted Failure Class against measured Saturation Class.

Although this table does not have enough points to make a convincing case for the accuracy of the method, it does show that the two locations with indications of possible failures, i.e. Saturation Classes C and E, were picked up by Failure Classes 1 and 2. The number of false positives was high indicating that signals were being identified that did not correspond to septic system failure.

4.9 Refinement of methodology (Second Round)

During the second round of photo-interpretation, methods were refined based on findings from the first round. During the first round it was found that the CIR imagery was of more use in locating septic problems than the thermal imagery.

Again, this may be due to the fact that the thermal imagery was flown during one of the wettest springs on record in Michigan. During the second round, distinct spatial patterns and indicators of field edges or rectangular shapes were identified. These characteristics were often present in the positive hits from the first round (See Appendix A for examples). In the CIR imagery, a stressed or failing field would often have a darker red color than the surrounding area or darker red patches around the edges of the field. The field may also be brighter in color, indicating dead or dying grass, with a well-defined shape.

During the review, 1,007 parcels were reviewed to see if either failing fields or tanks could be identified. The imagery was stretched to try to help in identifying potential sites. The contrast range of the CIR imagery and the thermal imagery was altered from the default display method using a 1.5 standard deviation stretch from the current display extent. This meant that the contrast range was higher than normal, giving more separation of the image colors and tones in the display, and thus enabling the interpreter to more easily discern subtle changes. During the process of photo-interpretation, a point was dropped in the parcel to identify where the tank or the field were observed. Points were attributed again with Yes, Maybe and No for the CIR imagery and Thermal imagery. Yes denoted something that was considered to indicate the tank or field location was observed. Maybe indicated a possible match to a failing septic, but the interpreter was less certain. No indicated that no anomalies were visible; on these, points were placed as close to the field as possible.

When photo-interpretation was complete, a single value was given to each point. The classes were “Field or Tank Identified” (Failure Class 1), “Field or Tank Possibly Identified” (Failure Class 2), “Nothing Visible” (Failure Class 3), and “Covered by Trees” (Failure Class 4). “Field or Tank Identified” indicated points that matched the new criteria for identifying the tank or field. A class of “Field or Tank Possibly Identified” were usually sites in which an anomaly was apparent, but it did not meet the new criteria for shape or color separation in the CIR. “Nothing Visible” meant that analysts were unable to identify anything that represented the tank or the field and the point was placed in the most likely location for the field or tank. Lastly when a location was obscured by tree canopy and the photointerpreter was unable to examine the ground surface, the class “Covered by Tree” was used.

Of the 1,006 sites, identified the break out of Failure Classes were

- Class 1 – 52
- Class 2 – 178
- Class 3 – 689
- Class 4 (covered by trees) - 87

A subset of around 200 residents was contacted for a field verification visit. Again the sample was biased towards the failure end of the spectrum to maximize the possibility of identifying failures. These sites were visited during the spring and summer of 2012. The results are shown in Section 4.10.

4.10 Field-based accuracy assessment

There were 31 valid observations made during the second field assessment. In order to have a single variable against which to compare against the Failure Class, the Saturation Class became the lowest class among the saturation, Biomat and blockage classes for that site (i.e. if a site had Saturation C, Biomat A and Blockage A then the Saturation Class C was selected). It can be seen having a Saturation Class of C, D or E is a rare event. The second field analysis supports the conclusions of the first analysis that the severest manifestations of failure, i.e. Saturation Class E, are identified in Failure Class 1. Failure Class 2 may be able to identify some Saturation Class B and Cs and so may offer some value but will contain a large number of false positives.

	Saturation Class					
Failure Class	**A**	**B**	**C**	**D**	**E**	**Total**
1	2	2	0	0	2	**6**
2	15	3	1	0	0	**19**
3	4	1	1	0	0	**6**
Total	**21**	**6**	**2**	**0**	**2**	**31**

Figure 12: Relationship between Predicted Failure Class and Measured Saturation Class for the second iteration of the field work.

The combination of the field work of both field campaigns is shown in Figure 13.

	Saturation Class					
Failure Class	**A**	**B**	**C**	**D**	**E**	**Total**
1	8	3	0	0	3	**14**
2	25	7	2	0	0	**34**
3	5	4	1	0	0	**10**
Total	**38**	**14**	**3**	**0**	**3**	**58**

Figure 13: Relationship between Predicted Failure Class and Measured Saturation Class for both field campaigns.

In conclusion, the analysis suggests that the method should identify all sites where there are severe failures, i.e. Saturation Classes D and E (Note: no sites with Class D were observed in the field so this is an assumption). Although many signatures look like failures and are not, the majority of the Class C (2 out of 3 combining both field analyses) and the majority of the Class B (10 out of 14 combining both field analyses) fell in Failure Classes 1 and 2. Failure Class 3 contains 1 out of 10 (10%) Class C and no Class E. This suggests that significant failures (C, D and E) are not generally being missed by the analysis.

Of the 58 sites studied, only three properties were found to have a measured Saturation Class of E. The figures below show two of these signatures in the CIR and thermal imagery.

Figure 13a: Property 1 CIR imagery: Red point indicates location of anomaly found in imagery. Blue point and polygon indicate the true location of the field. Visual identification of the field in thermal imagery, possible identification in the CIR. Point was placed away from the field, most likely indicating a downslope area in which effluent was leaching from the field. No effluent was seen on the surface.

Figure 13c: Property 2 CIR imagery: Visual identification of the field in thermal imagery and the CIR. Inspection of the imagery revealed both the location of the tank and the septic field. WCEHD sampled 3 locations on the field, indicated by the 3 blue points. No effluent was seen on the surface, however.

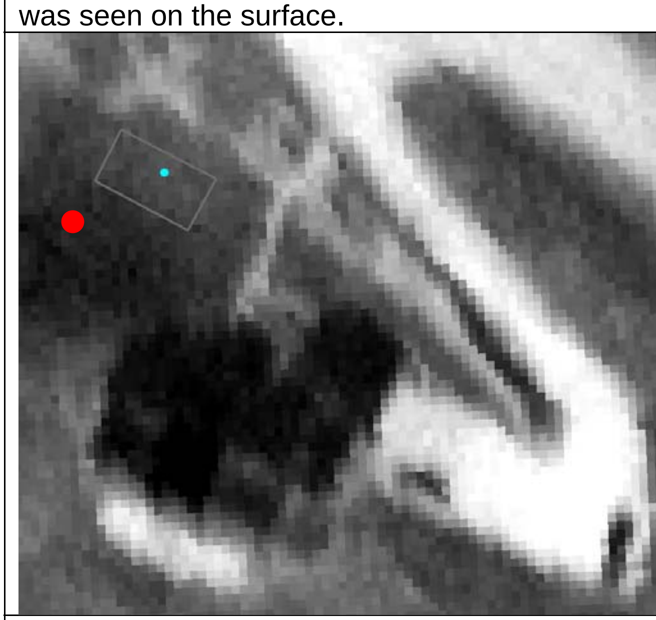


Figure 13b: Property 1 thermal imagery. Red point indicates location of anomaly found in imagery. Blue point and polygon indicate the true location of the field.

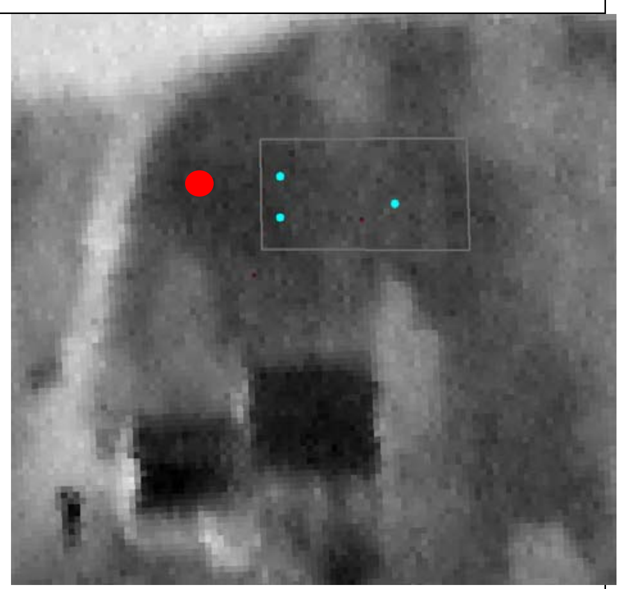


Figure 13d: Property 2 thermal imagery. Red points indicate location of anomalies found in imagery. Blue points and polygon indicate the true location of the field.

5 Final protocol

This method focuses on/highlights two levels of concern, one that the field is moving towards failure and second that the field has failed. The results suggest that identifying fields that have failed is highly probable with this approach. Identifying fields moving towards failure is possible but will have a high number of false positives. As experience with the identification of signatures increases, it is probable that one could reduce false positives.

The two levels of, probable failure and, moving to failure require different remedies from a health department perspective. Failure represents a requirement for the resident or health department to act in the best interest of public safety and compliance with regulations. The movement towards failure permits time for the resident to take actions to prevent failure and extend the life of their system, and offers an opportunity for education.

Based on the findings of this study a series of recommendation have been developed into a protocol that could be implemented for future projects for the detection of failing septic systems. Since it was found that the CIR gave as good results as the thermal imagery, the cost associated with a thermal is flight is not considered worthwhile for this type of project. This conclusion has the advantage of allowing many communities to use the leaf-off color infrared imagery often collected as part of a regular orthophoto update. Note that the IR band is highly important to signature identification and reduces the chances of error.

Once failing or failed systems have been identified, the information needs to be acted on for the process to have any long term value to the environment and the watershed residents. For this to be effective the Health Department will need to determine what action to take once the information has been collected.

5.1 Proposed Methods

Step 1: Obtain imagery and ancillary data. Imagery should be a 4-band spring leaf-off imagery collect; which is optimal for signature identification. The ancillary data needed for best results are the following:

- Parcel boundaries and associated attributes such as year built, number of bathrooms, etc.
- Building footprints
- Soil
- Vegetation (tree canopy)
- Sewered areas
- Slope/Elevation
- Any inspection data collected by the Health Department of the jurisdiction

Step 2: Run spatial models to identify the probable septic field locations. The rule sets developed for this project can be generalized to apply to most areas, but they may need to be modified to better represent different geographies of interest. Consultations should be made with engineers who install these systems to verify the rule set. The output would be a series of polygons where septic fields are likely to be located.

Step 3: Review identified properties for septic failure signatures. The imagery should be enhanced for identification of septic leakage by stretching or enhancing the bands in the wavelengths that emphasize the signatures. Examples of septic leakage signatures are shown in Appendix A. Areas for review are limited to the boundaries delineated by Step 2. Each site will be assessed into a Failure Class 1 to 3, where 1 is distinct pattern, 2 is possible pattern and 3 is no pattern. In order to make it clear which sites are highly probable for failure it is recommended that a Failure Class 1* is created to indicate where there is evidence of septic leakage to the surface and where site visits would be highly encouraged.

Step 3a: Verification of signature location. Since any field observations are expensive, if the health department wanted to make sure that the signature related to a septic field was a real failure, then any Failure Class 1 properties could have their information retrieved from a digital or paper database. An analyst would compare the location of the septic field, based on permits, to the location of the signature. If the location of the signature was in a different location to the location on the permit, it would indicate that the signature is not a septic failure, and that point would be attributed as an unlikely failure. Written records are not always accurate so this possibility for error should be considered when evaluating the location. If the documented field location and the signature coincide, then the likelihood of it being a failure signature increases. Step 3a would be undertaken if it was important to reduce the number of false positives. If the information is to be used primarily for an education plan, the costs associated with removing the false positives may not be worthwhile, since there is value to providing educational materials to a larger audience and the cost associated with sending extra literature out to those people who may not need it is small.

The next steps will depend on the approach the Health Department wants to take.

Step 4: Field review and enforcement: Based on the results of Step 3 those properties identified at Class 1* would be visited by a field crew to either verify the problem from the road or request permission to test the area with an auger. Surface septic leakage would be handled according to the health code.

Step 5: Education. Based on the results of Step 3 any properties that were classified as Failure Class 1 or 2 would be sent educational materials with a picture of their field and suggestions on how to address the potential problem. The personalized information likely will increase the property owner’s interest more than a generic mailing. In addition, mailing costs are reduced by mailing information only to those addresses that are most at risk will improve the cost-effectiveness of the program.

6 Conclusions

The objectives of this project were to develop a protocol to identify potential failures of septic systems preferably before they become ecological and human health risks. The project evaluated both thermal and color infrared imagery collected in the spring. Signatures were extracted from both thermal and color infrared imagery, and although thermal signatures did indicate areas of anomalies, those anomalies were most often also visible in the CIR imagery. Therefore the additional information provided by the thermal imagery did not appear to add sufficient information to justify its expense. The advantage to this conclusion is that many spring imagery collects are now available for analysis for septic failure at no addition cost to a health agency.

Prior to the image analysis, a GIS analysis was conducted to see if failure rates can be associated with environmental and property variables. Using the Washtenaw County Time of Sale database it was not possible to determine a significant relationship that would allow the modeling of potential failures.

The project was able to show how using the ancillary data yielded information on the potential location of the septic fields. This was important in the identification of signatures since it limited the area required to be reviewed by an analyst looking for failure signatures. The spatial models were developed with the support of the Health Department Staff.

As the project progressed analysts were able to identify characteristics of failure signatures and differentiate them from other anomalies. Not all signatures indicate failures, some indicated a thinner than usual soil depth covering the field or the tank. Imagery was manipulated to improve the analyst's ability to identify the signatures. By dividing the signatures into three main Failure Classes, it was possible to develop a classification of properties into those that require special attention and those that do not. Field verification showed that the worst situations were identified into the Failure Class 1. Many of the systems that were moving to failure were include in Failure Classes 1 and 2. Very few systems that were moving to failure were found in Failure Class 3. Although this indicates that the methods are reasonable at picking up failures, the false positives (i.e. where a positive signature is identified, but there is no problem) is high. The number of false positives can be reduced by better signature definition and checking the location of the signatures with written location information from permits.

The ultimate use of these data will depend on the specific health department but these data can be used to help focus enforcement actions and educational efforts. These methods and the characterization of failure signatures will allow automated pattern recognition programs to be developed so that Failure Classes can be created using semi-automated approaches. In addition, since many communities collect new imagery every 3 - 5 years the use of change detection methods to identify changes in signatures may lead to the identification of when fields are moving towards failure.

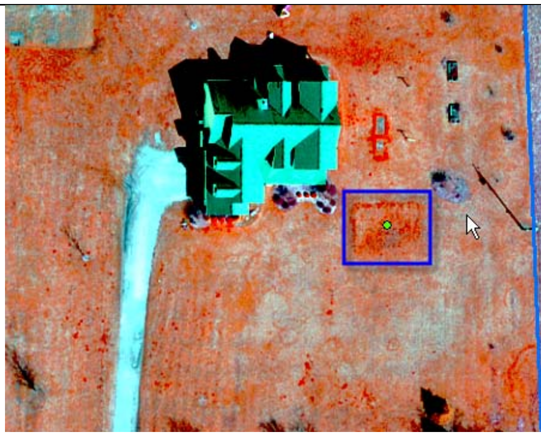
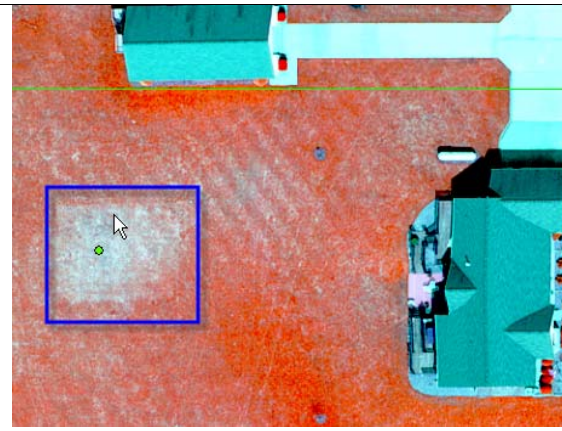
In summary, this project has developed and tested a protocol for focusing resources to address failing septic systems that can be applied across Michigan and the nation. Focusing these resources will lead to more efficient enforcement of existing rules and effective education of property owners. Increased awareness among property owners should lead to improved maintenance of systems and, ultimately, reduced environmental and human health risks.

This study was carried out within Washtenaw County that has a history of septic regulations and excellent environmental stewardship. It is probable that these regulations have tended to limit the number of Class E failures. Survey results have shown that Washtenaw County when compared to other MI counties has fewer failures. So this may indicate that the value of these protocols may have even greater value in other parts of the State of Michigan.

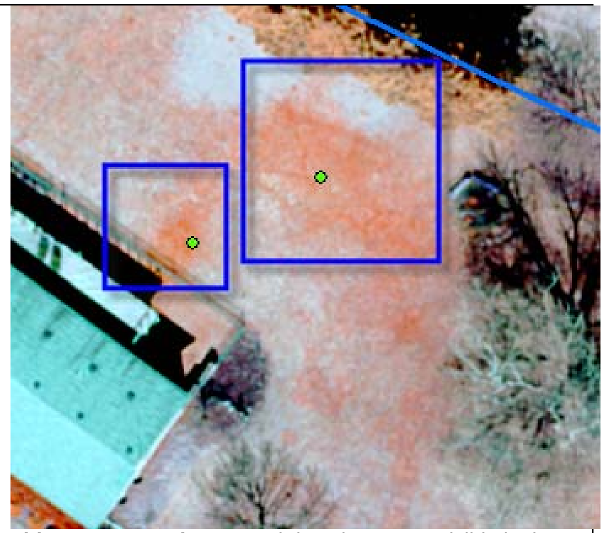
7 Appendix A: Example Signatures for Failures Classes 1 and 2

Locations identified as Class 1: "Field or Tank Identified"

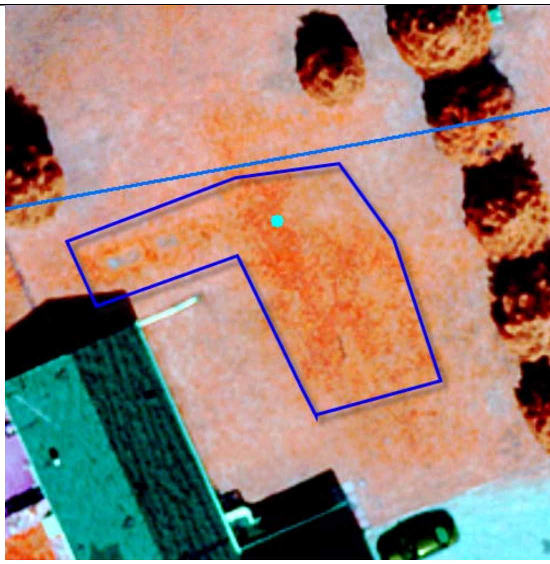
<table>
<tr>
<td>
Object ID 48: Visible in both the CIR and Thermal imagery. No field sampling performed.</td>
<td>
Object ID 60: Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.</td>
</tr>
<tr>
<td>
Object ID 74: Visible in both the CIR and Thermal imagery. No field sampling performed.</td>
<td>
Object ID 100: Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.</td>
</tr>
</table>

 **Object ID 101:** Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.	 **Object ID 152:** Visible in both the CIR and Thermal imagery. Location confirmed by field sample 24 May 2012, field was found to have no saturation or biomat.
 **Object ID 1016:** Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.	 **Object ID 947:** Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.

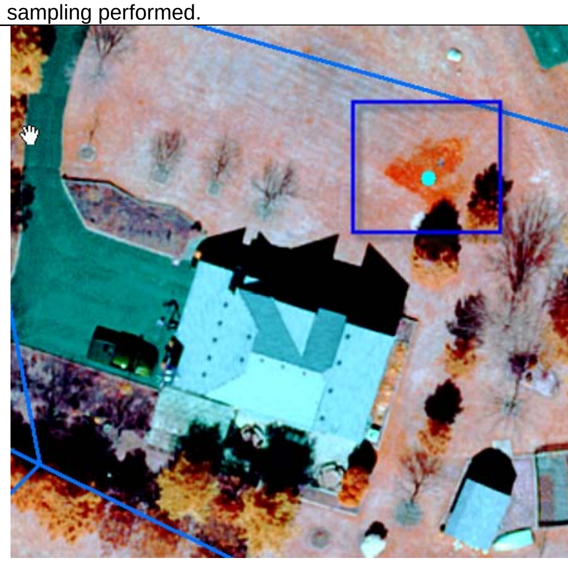
Object ID 925 and 926: Both locations were visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.



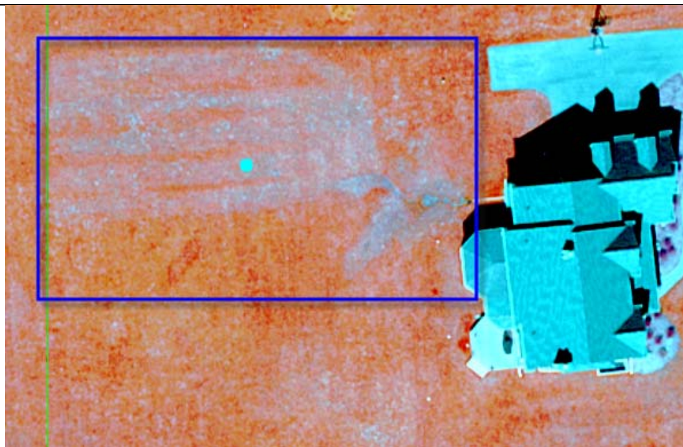
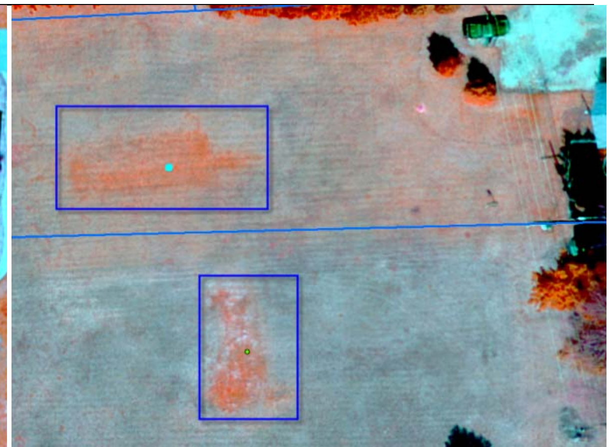
Object ID 741 and 742: Both locations were visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.



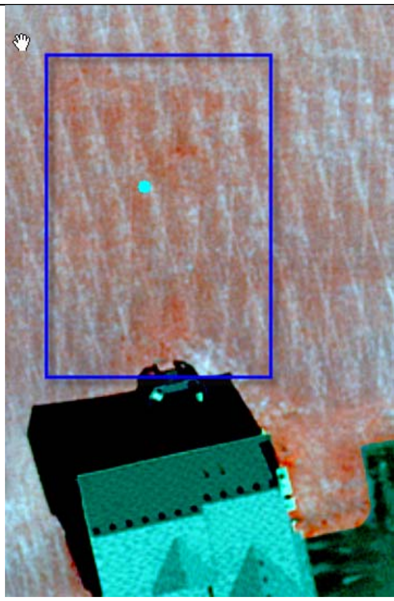
Object ID 676: Visible in both the CIR and Thermal imagery. No field sampling performed.



Object ID 621: Visible in both the CIR and Thermal imagery. No field sampling performed.

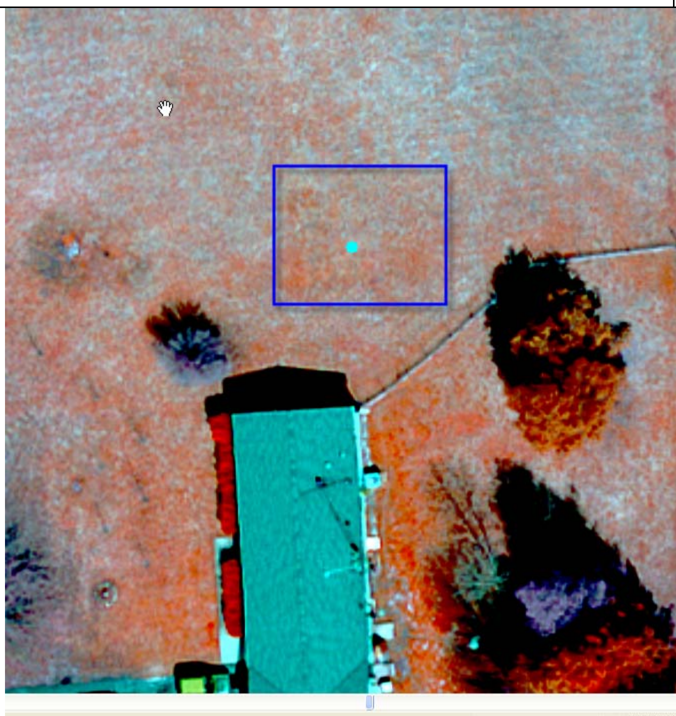
	
Object ID 588: Visible in the CIR, but no signature in the Thermal imagery. No field sampling performed.	**Object ID 353 and 354:** Both locations were visible in both the CIR and Thermal imagery. No field sampling performed.
	
Object ID 656: Visible in both the CIR and Thermal imagery. No field sampling performed.	

Locations identified as Class 2: "Field or Tank Possibly Identified"

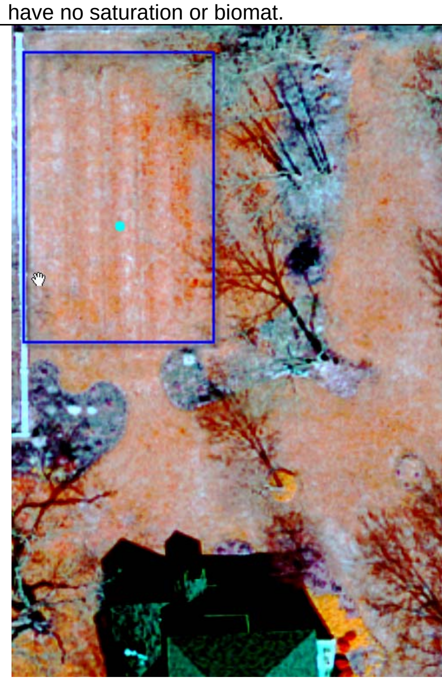


Object ID 2: Possible detections in both the CIR and Thermal imagery. No field sampling performed.

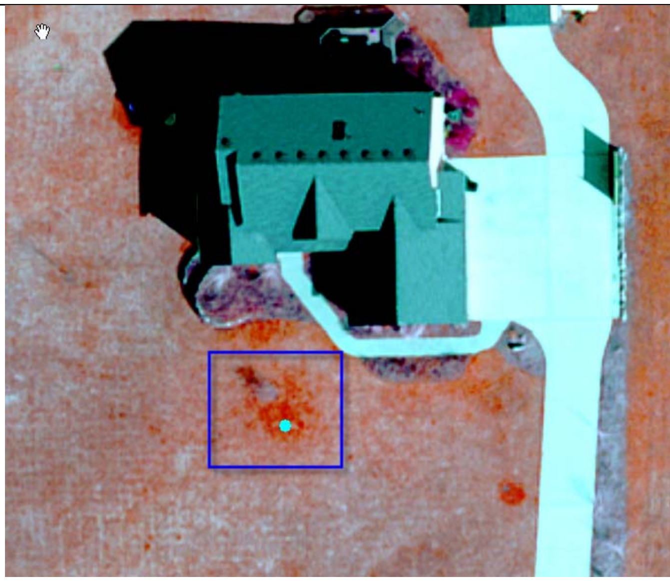
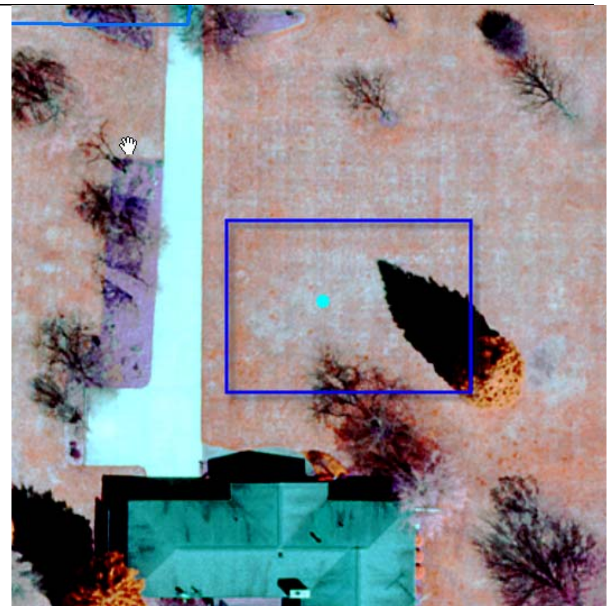
Object ID 14: Possible detection in the CIR imagery. Location confirmed by field sample 15 June 2012 as a septic tank. Field is 30 ft to the northwest, and was found to have no saturation or biomat.



Object ID 18: Possible detection in the CIR imagery. Location was found in a field sample on 5 April 2012 to NOT be the septic field. Field is 90 ft to the north, and was found to have no saturation or biomat.



Object ID 19: Possible detections in both the CIR and Thermal imagery. No field sampling performed.

 **Object ID 38:** Possible detection in the CIR imagery. No field sampling performed.	 **Object ID 73: :** Possible detection in the CIR imagery. Location confirmed by field sample 20 June 2012; field was found to have no saturation or biomat.

8 References

SSURGO Soils: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Survey Area, State]. Available online at http://soildatamart.nrcs.usda.gov. Accessed 12/13/2010.