

**CANINE INVESTIGATIONS FOR SOURCE TRACKING OF  
HUMAN SEWAGE CONTAMINATION IN THE NAVESINK RIVER  
MONMOUTH COUNTY, NJ**



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## Introduction: Canine Source Tracking

Environmental Canine Services LLC (ECS) uses scent trained canines to identify and source track human contamination in stormwater systems and surface waters that is caused by leaking sewer lines, illicit sewer pipe connections and discharges, and faulty septic systems. ECS canines have been nationally recognized as a useful rapid screening and source tracking tool for human sewage contamination and utilized in over 60 illicit discharge field investigation projects in 13 different states since the company began in 2009.

Canines have a powerful and sophisticated sense of smell that allows them to be utilized in a variety of situations to detect specific odors that are difficult or impossible for humans to detect. ECS canines are highly trained to specifically detect the presence of human fecal components of sewage contamination in waterbodies. This type of contamination can be a source of pathogens that are harmful to the health of humans, animals, aquatic life, and the entire ecosystem of the waterbodies. Additionally, the canines are able to detect greywater components of human sewage, such as detergents and fats/oils/grease, etc. which can also be harmful to human health and impact water quality. The canines respond to the presence of any one or more of human sewage components by demonstrating a trained behavior, called an “alert”, such as sitting, lying down, or barking when smelling containers of collected water samples, or in different field locations such as at outfalls, stormwater manholes, catch basins, drains, creeks, rivers, or shorelines. The canines are specially trained to discriminate between human and animal sources of fecal contamination and will only alert to the presence of human sources of fecal contamination. This rapid, human-specific contamination detection can lead to immediate source tracking in the field and provide valuable information for future monitoring and investigations. Results from the canine investigations can be used in conjunction with other lab-or field-based analytical testing for pathogens and other contaminants such as detergents at these “problem” sites in order to help draw meaningful conclusions and to plan for better management strategies.

ECS has developed standard protocols and quality assurance methods for its canine screening and source tracking investigations based on knowledge of the complexities of canine scent tracking in general, and particularly in the context of stormwater conveyance systems and water body environments. Although ECS canines are able to detect human sewage that contains bacteria levels below federal or state water quality standards, each canine may have a different sewage scent detection level for giving their alert. Also, some canines will alert to the presence of greywater components such as detergents and fats/oils/grease when no fecal material in the sewage is present and other canines will not. Using two canines in tandem to scent test locations and water samples is therefore a recommended protocol as it can provide information about the strength and components of the sewage scent at each location, which helps guide decisions for systematic source tracking. Typically, when one canine alerts at a location and the other does not, it means the sewage source is further upstream and/or is

highly diluted. When both canines alert at a location, it means the sewage source is closer and/or is highly concentrated.

Standard protocol for canine investigations recommends starting the scent-testing at the stormwater outfalls or waterbody discharge areas of concern, during low tide if in a tidal system, and working upstream through the conveyance systems by scent testing stormwater manholes, catch basins, and the tributaries feeding into the waterbodies. Stormwater and sewer maps of the areas should be reviewed simultaneously to strategically guide the canine scent testing locations in order to help isolate potential contamination sources and define other areas with no contamination.

A research study on the use of ECS canines for human wastewater source tracking was funded by the Water Environment Research Foundation (WERF) and conducted by the City of Santa Barbara Creeks Division and the University of California, Santa Barbara in (WERF, 2011).<sup>1</sup> Side-by-side lab testing for bacterial, chemical, and human DNA markers was conducted for each of the locations investigated by two ECS canines. This study found that both canines were 100% accurate on their negative responses to non-sewage occurrences in the samples. One canine was 100% accurate and the other was 86% accurate (when factoring for a scent volume phenomena at one site) on their positive responses to the presence of sewage when the lab results found at least one human sewage indicator. This WERF study concluded that using canines for source tracking had major advantages including: (i) real time results in a shorter time frame; (ii) the ability to test a high number of sites per day; and, (iii) the low cost to test a sample.

## Project Background

In 2006, the New Jersey Department of Environmental Protection (NJDEP) downgraded 152 acres of waters in the upper portion of the Navesink River from a “*Special Restricted*” shellfishing classification to a “*Prohibited*” shellfishing classification. As a result of NJDEP and local stakeholder concern over the water quality of the Navesink, a microbial source tracking study was conducted by NJDEP to identify pollution sources impacting the upper Navesink River. Extensive water sampling was conducted and analyzed in order to identify potential causes of nonpoint source (nps) pollution. In their report published in 2008, the NJDEP suggested that stormwater discharges and failing infrastructure were the most likely sources and that several sampled areas contained human source bacteria. A TMDL for total coliform bacteria for shellfishing was approved by the EPA in September 2006 and adopted into the Monmouth County Water Quality Management Plan in October 2011.

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<sup>1</sup> Water Environment Research Foundation (WERF), Canine Scent and Microbial Source Tracking in Santa Barbara, California, 2011, available at <https://www.santabarbaraca.gov/civicax/filebank/blobdload.aspx?BlobID=16725>

In February 2016, the NJDEP finalized a downgrade of 565.7 acres of the Navesink River to a “Prohibited” shellfishing classification. The river is also impaired for swimming and other direct contact activities, especially after rainfall. These clearly indicate that the water quality in the river is significantly deteriorating day by day. This adversely impacts the health of the river ecosystem, its aquatic biota as well as the economy and health of humans who utilize the river for fishing and recreation.

In early spring 2016, Clean Ocean Action (COA) began spearheading a collaborative effort called “Rally for the Navesink” to help improve the water quality of the Navesink River by collaborating with the municipalities along the river, the NJDEP, and public participation. In June 2016 COA released a report (documenting the deterioration of water quality in the river, and identified potential sources of pathogen pollution.<sup>2</sup> This report was released at the first of several ongoing public meetings designed to engage and educate the community. COA invited ECS to join the collaboration in order to help with its rapid and cost-effective human-source pathogen pollution tracking method using canines.

A preliminary assessment of the current presence of human sewage sources of pathogens in the river was conducted by COA and ECS in early June 2016. COA collected water samples during dry weather conditions during the month of June 2016 from different locations of the river that were previously identified by the NJDEP as areas of concern. Eight of these collected samples were shipped to ECS for off-site canine scent testing for the presence of human sewage (“Ship and Sniff” test). These samples were individually scent tested by two ECS canines, Sable and Logan. Both canines alerted to the presence of human sewage in five of the eight samples. Water samples were also collected simultaneously by Rutgers University School of Engineering for q-PCR studies to investigate human-specific fecal biomolecular markers. Samples were collected first during dry weather, then later in the day during a rain event (rain amount measured at 0.51” at a monitoring station nearby). Both dry weather and wet weather samples were analyzed in the Rutgers lab study.



*Figure 1: Sable scent testing a COA Ship and Sniff sample*

The NJDEP conducted a new assessment of select locations of concern in the Navesink by collecting and analyzing water samples on June 5, July 7, and July 18, 2016 respectively. The sampling included dry weather conditions during varying tide cycles and two rain conditions during varying flush timings.

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<sup>2</sup> Clean Ocean Action, *Pathogen Pollution in the Navesink River*, June 2016, available at [https://www.cleanoceanaction.org/fileadmin/editor\\_group2/Beach\\_Sweeps/COA\\_Navesink\\_Report\\_FINAL\\_1.pdf](https://www.cleanoceanaction.org/fileadmin/editor_group2/Beach_Sweeps/COA_Navesink_Report_FINAL_1.pdf)

Water sample testing results from ECS, Rutgers, and NJDEP were shared with each other upon completion, then shared with the Navesink River communities at a Rally for the Navesink meeting on August 11, 2016.

Based on an analysis of the combined results, COA and ECS determined priority areas for additional canine investigation for source tracking of human sewage contamination of the Navesink River during the week of September 19, 2016. COA and ECS decided to implement the standard protocols of using two canines to investigate each area in tandem, starting at stormwater outfall and water body discharge areas during low tide and working upstream through those systems, and consulting stormwater and sewer maps to guide the investigations. The Navesink communities of Red Bank, Fair Haven, and Middletown, where the priority areas of concern were located, agreed to assist with the investigation efforts by providing personnel, stormwater and sewer maps, and other resources. The NJDEP agreed to assist by collecting water samples at key sites and conferring with the COA, ECS, and community personnel during the canine source tracking investigation.

ECS co-owners Karen and Scott Reynolds conducted the September investigations as canine handlers with their ECS canines Sable and Logan, who have been investigating human sewage pollution across the country since 2009, and Remi, who completed her canine certification with ECS in Spring 2016. Scott handled Sable and Karen alternated handling Logan and Remi, therefore only two of the three canines conducted investigations in tandem at any point in time. Sable alerts to the presence of human sewage by barking. Logan and Remi alert by sitting. Typically, Logan is able to detect and alert to the presence of human sewage at very low levels, such as would occur long distances from the source, at high dilution rates, or in areas of previous contamination that are currently dry. Sable typically alerts to the presence of human sewage when the source is closer or more concentrated. Rem's detection levels are still being studied, but appear to be somewhere between those of Logan and Sable.

## Red Bank - Field Investigation Results

### September 19

ECS worked with COA, NJDEP, Red Bank Borough officials, and Red Bank Public Utilities personnel to conduct field investigations in key areas of Red Bank. Stormwater and sewer system maps were provided by the Borough of Red Bank. Rain of .20" had occurred the day before, and there was an additional 1.16" of rain during the September 19 investigations.

The following areas of Red Bank were investigated:

1. **Marine Park Area** – In the June Ship and Sniff testing, ECS canines alerted to the presence of human sewage in a water sample (sample COA 4) collected from the river at the stormwater outfall (outfall 14 on stormwater map provided by Red Bank) at the end of Wharf Avenue. On September 19, investigations began at low tide in the parking lot at the end of Wharf Avenue. The canines investigated the stormwater system upstream

of outfall 14. They determined that some branches of the stormwater system were not a source of human sewage pollution by not alerting at catch basins or manholes in those branches. The locations where the canines alerted to the presence of human sewage contamination are listed below (Red Bank stormwater map numbers are used):

- a. Catch basin 4 near the corner of Wharf Avenue and Union Street.
- b. Manhole 36 at the corner of Mechanic Street and Globe Court.
- c. Manhole 44 on Wallace Street between Mount Street and Broad Street.



*Figure 2: Scott & Sable checking catch basin in Red Bank with Remi looking on Sept 19*

2. **Maple Cove Area** – In the June Ship and Sniff testing, ECS canines alerted to the presence of human sewage in a water sample collected from the river at the end of Maple Avenue (sample COA 3). qPCR analysis of a water sample from this area on June 8, which was simultaneously collected by Rutgers University (sample COA 10) also indicated the presence of human source bacteria markers. Additionally, antibiotic resistance analysis (ARA) of dry and wet-weather samples collected by NJDEP in June and July also indicated human source bacteria markers.

On September 19, canine investigations began at low tide at the end of Maple Avenue. The canines investigated the stormwater system that outfalls to the river at Maple Cove. They determined that some branches of the stormwater system were not a source of human sewage pollution by not alerting at catch basins or manholes in those branches. The canines alerted on other branches of the stormwater system, indicating the presence of human sewage. The locations where the canines alerted to the presence of human fecal contamination are listed below (Red Bank stormwater map numbers are used):

- a. The first catch basin (not marked on Red Bank stormwater map) upstream of the stormwater outfall to the river, at the end of Maple Avenue.
- b. A catch basin (not marked on Red Bank stormwater map) on the west side of Maple Avenue in front of the corporate building.
- c. Catch basin 141 on the corner of Maple Avenue and Front Street, next to Chipotle restaurant.

3. **Oyster Point and Hubbards Bridge Area** – Analysis of water samples collected at Oyster Point by the NJDEP in June and July indicated human source bacteria markers. On September 19, investigations began at low tide in the area north of the intersection of Riverside Avenue and Bridge Avenue. The canines checked catch basins and manholes in the area and did not alert at any of these locations. Investigations continued at the shoreline of the river west of Cooper's Bridge. The locations where the canines alerted

to the presence of human fecal contamination are listed below (Red Bank stormwater map numbers are used):

- a. Outfall 1, which was broken and deteriorated.
- b. One canine alerted along the banks of the river south of outfall 1. Outfall 2 is located nearby but was not accessible.
- c. Outfall 3 at Hubbards Bridge and Front Street. qPCR analysis of a sample collected by Rutgers University during a rain event on June 8 (COA 11) indicated human source bacteria markers at this location. Human indicators were also detected by NJDEP in June and July using multiple antibiotic resistance analysis.

### September 22

During wet weather investigations, such as the September 19 canine scent testing in Red Bank, a higher level of human sewage contamination in many areas of stormwater systems is common. This happens as runoff from both urban and rural areas flushes sewage discharges from leaking sewer pipes, faulty septic systems, and other sources through the stormwater system. During wet weather investigations, ECS canines may alert to the presence of human sewage in more areas of stormwater systems than in dry weather investigations due to this runoff effect.

COA, ECS, NJDEP, and Red Bank personnel reviewed the results of the September 19 wet weather investigation and determined that a follow up investigation during dry weather would be beneficial to confirm the previous results and continue with source tracking in additional areas. The follow up investigation was conducted on September 22, which was approximately 36 hours after the September 19 rain event. Stormwater and sewer system maps were provided by the Borough of Red Bank. For consistency in comparing scent testing results, canines Sable and Logan worked in the morning and Sable and Remi worked in the afternoon on September 22, as they had during the September 19 investigations.



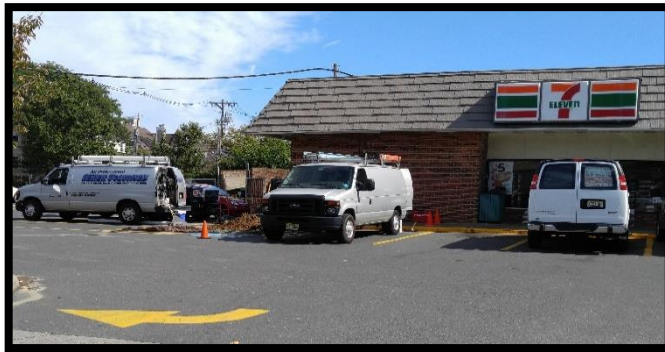
*Figure 3: NJDEP and Red Bank personnel collect a sample from a manhole in Red Bank Sept 22*

The following areas of Red Bank were again investigated:

1. **Marine Park Area** – Sable and Logan began scent-testing at the intersection of Mechanic Street and Globe Court and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
  - a. Both canines alerted at manhole 36 at Mechanic Street and Globe Court, which was also an alert location on September 19.

- b. Logan alerted at the manhole (not marked on the Red Bank stormwater map) on Wallace Street in front of 23 Wallace Street parking lot entrance on the West side of the building. Sable did not alert at this location.
  - c. Logan alerted at manhole 53 in front of 19 Hudson Avenue near the intersection of Canal Street. Sable did not alert at this location.
  - d. Both canines alerted at manhole 91 on the corner of Elm Place and Hudson Avenue.
  - e. Logan alerted catch basins 97 and 98 at the intersection of Branch Avenue and Harding Road, and catch basin 111 at Harding Road and Hudson Avenue. Sable did not alert at these locations.
  - f. Logan alerted at catch basin 122 on the corner of Elm Place and Horace Place, on the corner next to the green mailbox. Sable did not alert at this location. Both canines did not alert at catch basin 119 on the opposite corner.
  - g. Both canines alerted at manhole 93 at Elm Place and Hudson Avenue. NJDEP collected a water sample at this location. ECS recommended they use optical brightener tests on this sample and as many samples as possible to help determine if the canines were alerting on greywater components instead of fecal components of a sanitary discharge.
  - h. Neither canine alerted on a water sample collected by the NJDEP at outfall 14 at the end of Wharf Avenue.
2. **Maple Cove Area** – Sable and Logan began scent-testing at the North end of Maple Avenue at the river at low tide and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
- a. Neither canine alerted on a water sample collected at outfall 11 at the end of Maple Avenue.
  - b. Neither canine alerted at the catch basin on the West side of Maple Avenue in front of the corporate building where they had both alerted on September 19. Based on existing stormwater maps for the area, it appeared that this catch basin may not be connected to the rest of the system, and may get some miscellaneous runoff from upstream (catch basin 141) during wet weather events. Due to the absence of continuous contamination at this location, the canines may not detect and alert to any scent during dry weather as observed on September 22.
  - c. Both canines alerted at catch basin 141 at the corner of Maple Avenue and Front Street, where they also alerted earlier on September 19. This catch basin only collects street runoff from the area. To investigate whether it was possible that sewage leakage from a nearby structure was being carried into the street runoff during the September 19 rain event, the canines were walked west from catch basin 141 along Front Street to check for any sewage scent. At the end of the Rite Aid store near the corner of Front Street and Pearl Street, Logan alerted on a grass area along the wall of the building facing East, then again on a grass area on the opposite side of that end of the building, facing West. It was noted that the two lateral lines (47 and 47A on the Red Bank sanitary sewer map) are in this

area and an unknown sewer line structure south from the intersection of Front Street and Pearl Street.



*Figure 4: Sewer or drain line repair on Sept 23 at 7 Eleven across the street from CB 141*

Note: While driving through Red Bank and passing the corner of Maple Avenue and Front Street on September 23, Karen and Scott Reynolds noticed that the 7 Eleven store across the street from catch basin 141 appeared to be in the process of having either a

sewer or drain pipe being serviced during that time. The service provider's vehicles were parked nearby in the lot. It was observed that the parking lot was dug up, and the water from the trench was flowing down the parking lot to the street. It was noted that a lateral line (#68 on the Red Bank sanitary sewer map) runs through the parking lot in that location to a sewer manhole next to catch basin 141. It is possible that the leakage from the lateral line seeps into catch basin 141 and is flushed through during rain events.

3. **Oyster Point and Hubbards Bridge Area** – Sable and Logan began scent-testing at the Birravino restaurant parking lot on Riverside Avenue near Bridge Avenue and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
  - a. Logan alerted at a catch basin in the restaurant parking lot. Sable did not alert at this location.
  - b. Neither canine alerted at a catch basin numbered 1059 at Brower Place and Bridge Avenue.
  - c. Logan alerted at a catch basin numbered 1058 on Brower Place next to the dry cleaners. There was an approximately 3" cast iron pipe coming into the back of the catch basin. The catch basin was dry. Sable did not alert at this location.
  - d. Logan alerted at catch basin 6 next to the restaurant at Front Street and Bridge Avenue. Sable did not alert at this location.
  - e. Logan alerted at a catch basin at Front Street and Rector Place. Sable did not alert at this location.
  - f. Neither canine alerted at low tide at outfall 3 to the river where Hubbards Bridge crosses over the Navesink River. Both canines had alerted at this same location during wet weather investigations on September 19. As in the Maple cove site, dry weather and wet weather conditions appear to influence the scent testing result in this outfall also.

4. **Swimming River Outfalls** – Investigations of some of the stormwater outfalls to the Swimming River upstream of Hubbards Bridge were conducted. Results of the investigations were as follows:

- a. Neither canine alerted at outfall 4 at the West end of Locust Avenue or two catch basins (2 and 3) in the street above the outfall.
- b. Neither canine alerted at the outfall at the West end of Bank Street.
- c. Sable, the only canine able to traverse with his handler to outfall 6 in the difficult terrain (steep hill, heavy vegetation) at the West end of Drs James Parker Boulevard, did not alert at the outfall.

- d. In the June Ship and Sniff testing, ECS canines alerted to the presence of human sewage in a water sample collected from the Swimming River just upstream of the outfall at the end Chapin Avenue, near where Newman Springs Road crosses over the river (sample COA 8). On September 22, Logan alerted on the water at the banks of the river across from the nursing home at the end of Chapin Avenue and at a catch basin on the bank above it. There was extensive stormwater erosion at the site, and outfall pipe 25A may have existed at some point in time, but it was no longer visible. Sable did not alert at this location. Logan investigated and alerted at an area of dumpsters, trash trolleys, and other containers in the parking lot behind the nursing home, across the street from the outfall area. There was no visible sign of a human sewage contamination source in this area. Standing water was seen around the various containers, which may indicate that those containers have been rinsed or washed onto the ground there. Logan's alert could be from the detergents from washing, but it is also possible that the dumpsters and other containers may contain human waste that is also being washed out. The direction of flow of the water may carry it through the parking lot and into the catch basin discharging to the river across the street.




*Figure 5: Sable swims in the Swimming River at the end of Locust Ave Sept 22 after not alerting at this site*

5. **Stormwater System Upstream of Schwenker's Pond** – Investigations were conducted on the stormwater system that connects an eastern section of Red Bank to an outfall in Schwenker's Pond in Fair Haven. This was due to canine investigations of the Schwenker's Pond and Shippees Pond areas on September 20, that resulted in alerts on the stormwater system on the East side of Schwenker's Pond. The follow up investigations began on Harrison Avenue between Mechanic Street and Marion Street and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:

- a. Both canines alerted strongly at manhole 7 on Harrison Avenue between Mechanic Street and Marion Street. There was flowing water and a strong sanitary odor.

- b. Sable did not alert at the manhole (not marked on Red Bank map) on Harrison Avenue at Marion Street, and Remi did not initially alert, but gave a hesitant alert after a few moments. No odor was noticed by personnel at this manhole but may have been able to be detected by Remi through air flowing through the stormwater system from manhole 7.
- c. Both canines alerted at a catch basin numbered 264 (catch basin 13 on Red Bank map) next to the tennis courts and across the street from 44 Marion Courts. There was flowing water and a strong sanitary odor.
- d. Neither canine alerted at the next catch basin numbered 261 (catch basin 14 on Red Bank map) upstream in the stormwater system on Marion Street. There was less water flow. The catch basin depth, which is actually a drop inlet to the main stormwater line, is 6-8' deep. The adjacent sanitary line depth was 3-4' deep, and there was flow in the sanitary line and debris in the channel, with potential blockage.



*Figure 6: Shallow sanitary manhole on Marion Street Sept 22*

The sanitary infrastructure in this area appeared to be very old, with sinking manholes, and settling, erosion, and cracking noticeable along the pavement above the infrastructure. There may be sanitary line leakage between catch basin 264 and 261 which is seeping into the stormwater line below it.
- e. Neither canine alerted on catch basin 17 at the end of Marlin Place off of Mechanic Street. There did not seem to be any underground infrastructure at this location, and the catch basin was dry.
- f. Neither canine alerted at catch basin 18 at the intersection of Marion Street and Worthley Street. A resident at a house at that intersection stated that the stormwater system consistently backs up into that catch basin and floods the street during heavy rain.

## Red Bank – Summary and Recommendations

Canine responses to each area investigated were mapped on Google Earth and analyzed along with the stormwater and sewer infrastructure maps provided by The Borough of Red Bank to determine where source tracking had either isolated or eliminated potential sources. The summary of these findings and recommendations and canine result maps are provided below:

### **Marine Park Area**

Canine source tracking of the human sewage contamination in the river at the stormwater outfall 14 at Marine Park led south through the stormwater systems to the “5 corners” area where Hudson Avenue, Branch Avenue, and Harding Road intersect. Investigations were not able to continue past this area due to the multi-jurisdictional issues, the lack of the presence of

a Monmouth County representative during the investigation, and the absence of infrastructure maps beyond the area. Recommendations are as follows:

- It is recommended that Red Bank and Monmouth County officials collaborate to share sewer and stormwater infrastructure maps and resources and further investigate the stormwater systems to the South of the “5 corners” area along Branch Avenue and Hudson Avenue, and East and West along Harding Road, to continue source tracking upstream in the stormwater system that flows from this area down Hudson to Mechanic/Globe intersection and to outfall 14 at the Navesink River.

#### **Maple Cove Area**

The canine investigations helped to narrow potential sources of human sewage contamination at the stormwater outfall 11 at the river at the end of Maple Avenue to a small area. The contamination may be due to leaking lateral lines from the Chipotle restaurant and/or the 7 Eleven store at the corner of Front Street and Maple Avenue, and/or the Rite Aid building near Front Street and Pearl Street. These discharges could be carried in runoff during rain events into catch basin 141 next to Chipotle restaurant on Maple Avenue, which ultimately flows down the stormwater system to outfall 11. Recommendations are as follows:

- Investigate a possible faulty sewer line along Front Street between Maple Avenue and Pearl Street, and/or faulty lateral lines from the buildings, particularly at the locations along the wall of the Rite Aid building alerted at by Logan.
- Investigate whether lateral line 68 from the 7 Eleven store across the street from catch basin 141 may have been leaking and was subsequently repaired on September 23.

#### **Oyster Point and Hubbards Bridge Area**

The canines alerted to the presence of human sewage contamination at outfalls 1 and 3 during wet weather, but when outfall 3 was investigated again during dry weather, there were no alerts. Potential sewage inputs to the stormwater system in this area would originate either from Bridge Avenue or places east of Bridge Avenue. Canine investigations narrowed down the most probable source as originating from the Bridge Avenue and Front Street area. The isolated stormwater system from there flows directly to outfall 3, and rain runoff may carry sewage discharges down Bridge Street to catch basins that flow to outfall 1. Recommendations are as follows:

- Investigate a possible faulty sewer line and/or lateral lines at the Bridge Avenue and Front Street area.
- Investigate a possible faulty sewer line and/or lateral lines on Bridge Avenue between Riverside Avenue and Front Street.

#### **Swimming River Outfalls Area**

The stormwater systems that outfall to the Swimming River at Locust Avenue (outfall 4 on Red Bank map), Bank Street (outfall 5), and Drs James Parker Boulevard (outfalls 6 and 6A) were eliminated as potential sources of human sewage contamination based on no alerts from the canines when investigating these areas. The catch basin/outfall at the end of Chapin Avenue was a source of concern for greywater and/or human sewage discharges from the dumpster area of the nursing home across the street. Recommendations are as follows:

- Follow up with the nursing home administrators to ensure that the facility follows appropriate waste management practices for both contaminated human waste as well as general trash. This will eliminate the possibility of these wastes being washed into the Swimming River at the outfall on Chapin Avenue.

#### **Stormwater System Upstream of Schwenker's Pond**

Investigations of human sewage contamination in Shippees Pond and Schwenker's Pond in Fair Haven on September 20 led to follow up investigations of the stormwater and sewer systems southwest of there in Red Bank. The canines isolated a probable broken sewer line on Marion Street between Harrison Avenue and Worthley Street. The sewer infrastructure was very old, shallow, and appeared to be sinking under the road. It is likely that it has collapsed and is leaking sewage into the stormwater infrastructure below it, which carries the sewage down the stormwater system to Harrison Avenue, then to the east on River Road to Schwenker's Pond, which drains to Shippees Pond, which discharges to the Navesink River. This is potentially a large and potent source of human sewage contamination to Schwenker's Pond, Shippees Pond, and the Navesink River. Therefore it is recommended that further investigations be given high priority. Recommendations are as follows:

- Investigate the sewer infrastructure on Marion Street between Harrison Avenue and Worthley Street for a possible broken/leaking sewer line.
- Investigate the stormwater infrastructure on Marion Street between Harrison Avenue and Worthley Street for infiltration of sewer discharges and for possible broken lines causing malfunction of stormwater runoff from upstream.

## Fair Haven - Field Investigations Results

### September 20

ECS worked with COA, NJDEP, and Fair Haven personnel to conduct field investigations in key areas of Fair Haven. A representative from Monmouth County joined the efforts for part of the day. Stormwater and sewer system maps were provided by Fair Haven. A rain event of 1.16" had occurred the day before, but most of the water appeared to have flushed through the stormwater system in Fair Haven. The following areas of Fair Haven were investigated:

1. **Fourth Creek and McCarter Pond Area** - In the June Ship and Sniff testing, ECS canines alerted to the presence of human sewage in a water sample collected from the Navesink River at the end of Battin Road, where Fourth Creek drains to the river (sample COA 6). On September 20, investigations began at low tide at the end of Battin Road where Fourth Creek drains to the Navesink River and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
  - a. Both canines investigated accessible parts of Fourth Creek at low tide. Logan alerted at two locations in Fourth Creek. The first location was at the bank of the creek directly below where boats are stored on the hill in the River Rats sailing club area. The second location was at the tip of land south of the sailing club where Fourth Creek appears to divide into two branches, with separate drainages to the river. Sable did not alert at these locations. There was a portable toilet near the boat storage area but it appeared to have been well maintained.
  - b. Both canines alerted at the driveway of 715 River Road where Fourth Creek crosses under the driveway. Sable investigated the creek to the North of this location and alerted on a broken old clay pipe on the West side of the creek.
  - c. Both canines alerted at a PVC pipe in Fourth Creek next to the parking lot of The Commons at 740 River Road. The pipe was connected to a catch basin in the parking lot at the bank of the creek, and both canines alerted at the catch basin. There was greyish looking water in the catch basin but not enough to sample. Logan investigated and alerted at a nearby trash dumpster with greyish water and grease stains around it that appeared to have flowed downhill into the catch basin. The canine alerts at the pipe and catch basin may be due to the presence



*Figure 7: Scott/Sable and Karen/Logan investigating Fourth Creek at low tide Sept 20*

of greywater components leaking from the dumpster. Sable investigated the creek immediately upstream of The Commons and did not alert.

- d. Logan alerted at the creek where the driveway to a sanitary pump station crosses it upstream of The Commons. Sable did not alert at this location. The next stormwater system outfall to the creek upstream of this location was inaccessible for investigation.
- e. Both canines alerted at manhole FHFC8-1 on 3<sup>rd</sup> Street near the Knights of Columbus building at the corner of Fair Haven Road. There was water flow coming in the manhole from two directions. One was flowing from McCarter Pond, and the other was flowing from Fourth Creek. Neither canine alerted along the banks of McCarter Pond near the overflow outlet on the northwest end, so investigations continued upstream along Fourth Creek.
- f. Both canines alerted in an open channel of Fourth Creek behind a residence upstream of the Knights of Columbus building.
- g. Both canines alerted at catch basins FH-2 and FH-3 on both sides of the creek crossing on Hendrickson Place.
- h. Both canines alerted at catch basins FH-4 and FH-5 at the creek crossing on McCarter Avenue.
- i. The canines investigated the creek bed in the Fair Haven Fields Natural Area from where it originates at Dury Pond. Logan alerted on the east side of the creek bed downstream of the pond. He investigated the ground above the east side of creek bed, both north and south of the alert site and alerted along the ground in a straight line in a defined area from near where a small bridge crosses the creek south to near where a marked sanitary manhole is located. A review of the sewer line map in that area showed that Logan had alerted on the ground directly over the sewer line (between 290 and 291 on Fair Haven sewer line map), which indicates a potential sewer line leak at that location. Sable investigated the creek downstream of this location and alerted in several locations.



*Figure 8: Logan alerts on the ground above the sewer line in Fair Haven Field Natural Area Sept 20*

- 2. **Hance Road Area** – Investigations began at outfall FHNR3 to the Navesink River at the end of Hance Road and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
  - a. Neither canine alerted at the outfall to the river.

- b. Logan alerted at two catch basins (FHNR3-2 and FHNR3-3) on Hance Road and Cooney Terrace. Sable did not alert at this location.
  - c. Logan alerted at two catch basins on Hance Road in front of residences at 23 and 26 and two catch basins on Hance Road in front of 36 and 39. There appeared to be some sort of bubbles or foam in the catch basin at 36. Sable did not alert at these locations.
  - d. Logan alerted at a catch basin on Hance Road in front of a residence at 40. It appeared that a sanitary lateral line had been repaired in the road there. Sable did not alert at this location.
  - e. Logan alerted at manhole FHNR3-12 on Hance in front of a residence at 55. Sable did not alert at this location.
  - f. Logan alerted at a catch basin at the intersection of Hance Road and Briarwood Road. Sable did not alert at this location. The stormwater system on Briarwood Road and between Briarwood Road and River Road could not be investigated due to an interruption in efforts by a television crew.
  - g. Neither canine alerted on manholes or catch basins south of River Road to Forman Street.
  - h. Neither canine gave an alert along Cooney Terrace between Hance Road and Grange Avenue, where a strong sanitary scent was detected earlier by COA and ECS personnel during a Ship and Sniff follow up site visit on June 29, 2016.
3. ***Shippees Pond and Schwenker's Pond*** - In the June Ship and Sniff testing, ECS canines alerted strongly to the presence of human sewage in a water sample collected from Shippees Pond (sample COA 5). On September 20, investigations began at the Schwenker's Pond spillway on the South side of River Road and moved along the stormwater system and its branches in that area. Results of the investigations were as follows:
- a. Both canines alerted on a water sample collected by the NJDEP at the spillway and alerted at the spillway itself.
  - b. The Schwenker's Pond spillway flows to Shippees Pond, which flows to the Navesink River. The canines investigated a portion of the Shippees Pond shoreline from the back yard of a residence near the end of Laury Drive, near the Laury Drive outfall and alerted at that location. It was not possible to access Shippees Pond from any other locations.
  - c. Both canines alerted at the culvert on the north side of River Road that drains to Schwenker's Pond to Shippees Pond. The water in the culvert appeared to have an almost gelatinous film on the surface.



*Figure 9: COA, NJDEP, and Fair Haven personnel inspect the spillway at Schwenker's Pond Sept 20*

- d. Neither canine alerted at catch basins or manholes on the east side of Schwenker's Pond on Chestnut Street, at 1<sup>st</sup> Street, 2<sup>nd</sup> Street, Poplar Avenue, and at the intersection of Poplar Avenue and Cypress Court.
- e. Sable walked along the bed of the tributary to Schwenker's Pond to the south and investigated three outfalls to the tributary at Park Road and Cambridge Avenue. The outfall in the center had water flow. Sable did not alert on any of the outfalls.
- f. Sable investigated the bed of the tributary that crosses on Forrest Avenue south of Beekman Place and did not alert. Neither canine alerted at the manhole on the Forrest Avenue at this location.
- g. Remi alerted at two catch basins (FHSC4-1 and FHSC4-2) at the northeast corner of Schwenker Place, above the headwall. Sable alerted strongly several times pointing his nose towards the headwall. Black staining was noticeable in the water in the catch basin and in the invert of the pipe.
- h. Both canines alerted on catch basin FHSC1-2 with the outlet on the outside of the curve at Forrest Avenue and Glen Place. Remi alerted at catch basin FHSC1-3 on the inside of the curve, and neither canine alerted at an additional catch basin at the curve.
- i. Remi investigated and alerted at catch basin FHSC11-4 on the south side of River Road near Schwenker's Pond, across the street from Tyson Drive. There was water flowing very fast and high in the catch basin. Sable was not available to investigate at this site.

## **Fair Haven – Summary and Recommendations**

Canine responses to each area investigated were mapped on Google Earth and analyzed along with the stormwater and sewer infrastructure maps provided by Fair Haven to determine where source tracking had either isolated or eliminated potential sources. The summary of these findings and recommendations and canine result maps are provided below:

### **Fourth Creek and McCarter Pond Area**

The canine investigations led to a potential sewer line leak in the Fair Haven Fields Natural Area as the probable source of human sewage contamination the canines were alerting to all along the Fourth Creek tributary downstream to the discharge area to the Navesink River. They did not alert at the northwest end of McCarter Pond where it drains to the stormwater system that flows to Fourth Creek, therefore eliminating McCarter Pond as a contamination source.

Recommendations are as follows:

- Investigate a possible sewer line leak in Fair Haven Fields Natural Area between 290 and 291 on Fair Haven sewer line map. The consistent and strong canine alerts from this area all the way downstream to the Navesink River indicate that the leakage is likely significant and therefore should be given high priority for follow up investigation.
- Follow up with owners of The Commons at 740 River Road to ensure that detergents and/or fats/oils/grease are being properly disposed of and not leaking from the trash dumpster site in the parking lot downhill into Fourth Creek.

### **Hance Road Area**

The lack of canine alerts at the outfall to the Navesink River, followed by alerts only by Logan at some catch basins and manholes upstream in the stormwater system between Cooney Terrace and River Road may indicate that there was a previous faulty sewer line or lateral line in this area that has been repaired or still has a slight leak. A portion of Hance Road at house number 40 appeared to have been patched, indicating that a lateral line may have been repaired there. This does not seem to be a high priority area for further investigation. Recommendations are as follows:

- If high bacteria levels and human source markers are found in future water sampling at the stormwater discharge at the end of Hance Road, the stormwater and sewer systems on Lewis Point Road, Briarwood Road, and from Briarwood Road to River Road must be investigated for possible leakage and discharge into the river.

### **Shippees Pond and Schwenker's Pond**

The canines indicated the presence of human sewage contamination in both Shippees Pond and Schwenker's Pond, suggesting contamination sources upstream of Schwenker's Pond. They did not alert at the stormwater system on the east side of the pond. The two branches to the upstream tributary to the pond were investigated and eliminated as sources. The canines alerted to two catch basin locations (FHSC4-1 and FHSC4-2) on the west side of the pond. One location was on the northeast corner of Schwenker Place, which drains directly to Schwenker's Pond. The other location was the corner of Glen Place and Forrest Avenue (catch basin FHSC1-2), which drains directly to the upstream tributary to the pond before it splits to the two branches.

Remi investigated and alerted at catch basin FHSC11-4 on the south side of River Road, across the street from Tyson Drive, which flows to Schwenker's Pond. The catch basin is at the end of another stormwater system that originates in Red Bank. The investigation team was not able to source track the stormwater system upstream of this catch basin across Lake Avenue to Harrison Avenue because of a municipal boundary with Red Bank in that area. However, during canine investigations of Red Bank on September 23, a possible leaking sewer line on Marion Street between Harrison Avenue and Worthley Street was found. This is a probable source of contamination of the stormwater system flowing from there to the catch basin on River Road next to Schwenker's Pond, which drains to Shippees Pond and out to the Navesink River.

Recommendations are as follows:

- Investigate the sewer line and lateral lines from Schwenker Place to Forrest Avenue and on Forrest Avenue from the corner of Beekman Place to Lake Avenue. It is possible that there is a leak on these lines discharging to the stormwater system where the canines alerted on Schwenker Place and the corner of Glen Place and Forrest Avenue.
- It has been recommended to The Borough of Red Bank that they conduct further investigations of the possible leaking sewer line on Marion Street. The results of the investigation and any remediation efforts should be shared with Fair Haven, since the downstream end of that stormwater system flows through Fair Haven to the river.

## Middletown - Field Investigation Results

### September 23

ECS worked with COA, NJDEP, and Middletown personnel to conduct field investigations in key areas of Middletown. The representative from Monmouth County that assisted with investigations for part of the day in Fair Haven on September 22 was present for the Middletown investigations. A representative from U.S. EPA Region 2 was also present to observe investigations in Middletown. Maps showing areas with sewer and septic systems and stormwater outfalls were provided by Middletown, but no stormwater or sewer system maps were provided. This was a dry weather investigation. The following areas of Middletown were investigated:

1. **McClees Creek Area** - In the June Ship and Sniff testing, one of the two ECS canines alerted to the presence of human sewage in a water sample collected at the outlet of McClees Creek into the Navesink River (sample COA 1). On September 23, Sable and Remi began scent-testing investigations at low tide at McClees Creek at the Navesink River Road crossing and moved upstream along the creek. Results of the investigations were as follows:
  - a. Both canines alerted on a water sample collected from the main branch of the creek by the NJDEP at the Navesink River Road crossing and taken to a lower traffic area on Cooper Road for scent testing. Analysis of water samples collected from the creek at the Navesink River Road crossing by Rutgers University (sample COA 12) during the Ship and Sniff sampling and by the NJDEP in June and July indicated human source bacteria markers. Additional sampling by the NJDEP during the rain event on September 19 also showed very high fecal bacteria counts.
  - b. Both canines alerted on a water sample collected by the NJDEP from the main branch of the creek at Cooper Road. Sable also alerted on the creek from the bridge above it at this location. Analysis of a water sample collected by the NJDEP in June and July indicated human source bacteria markers at this location.
  - c. Sable alerted at the box culvert at the main branch of the creek crossing at Whipporwill Valley Road. Remi alerted at the headwall on the upstream side but did not alert on the downstream side.
  - d. Both canines displayed excited, agitated behavior and alerted very strongly at an old concrete trench structure at the southwest end of Haskell Pond (GPS 49.385745, -74.069199) on Whipporwill Valley Road along the main branch of the creek. There was a lot of very dark organic material in the trench, and some of the investigation personnel identified a sanitary-like smell. Information provided by a resident of the property was that an



Figure 10: Haskell Pond

old ice house had been at that location, and the concrete structures were part of its foundation. Neither canine alerted at the southeast side of Haskell Pond along the bank. Due to property access issues, the north side of the pond and the creek that drains to it on the west side could not be investigated.

- e. Both canines alerted on the downstream end of the main branch of the creek crossing at Chapel Hill Road and Whipporwill Valley Road. Neither canine alerted at an inlet coming in from catch basins at Whipporwill Valley Road. Water was flowing from the outlet pipe at the creek. Neither canine alerted at the upstream catch basin.
- f. Remi alerted at a catch basin at the main branch of the creek at the end of Tilton Place. The outfall to the creek was dry and neither canine alerted on the creek itself. Neither canine alerted at the three catch basins upstream in the stormwater system on Tilton Place.
- g. Neither canine alerted at the outfall to the main branch of the creek and three catch basins at the end of Farm Road.
- h. Neither canine alerted on the east branch of the creek where it crosses the driveway to Lancaster Farms.
- i. Neither canine alerted on an east branch of the creek where it crosses at Cooper Road nor at the north end of the east branch at a pond beside Presidential Path. It was noted that the stormwater detention area between the road and the pond was failing and in need of proper maintenance and repair.
- j. Sable alerted at the east branch of the creek where it crosses at Whipporwill Valley Road. Remi did not investigate this location.
- k. Neither canine alerted at a short tributary of the east branch of the main creek crossing at Cooper Road that connects to the main branch between Cooper Road and Navesink River Road.
- l. Both canines alerted at a tributary off the main branch of the creek where the tributary crosses at the corner of Mohican Drive and Seneca Drive. This location flows to Haskell Pond.

2. **Shadow Lake Area** - In the June Ship and Sniff testing, the ECS canines alerted to the presence of human sewage in a water sample collected from Shadow Lake at Hubbard Avenue (sample COA 9). On September 23, investigations began at the Shadow Lake spillway at Hubbard Avenue and moved along accessible outfalls to upstream tributaries to the lake. Results of the investigations were as follows:

- a. Both canines alerted at the Shadow Lake spillway.
- b. Both canines alerted at the outfall to a tributary on Michael Drive near Joyce Lane.



*Figure 11: Sable and Remi investigate the Shadow Lake spillway Sept 23*

- c. Neither canine alerted at catch basins on Joyce Lane.
  - d. Remi alerted at the tributary crossing on Ueland Road near Munch Road. Sable did not alert at this location.
  - e. Neither canine alerted at the catch basins on Munch Road.
  - f. Neither canine alerted at the tributary crossing on Buchanan Boulevard between Michael Drive and Ueland Road.
3. ***Unnamed Tributary East of Poricy Brook*** – Investigations were conducted at the area east of the brook where an unnamed tributary flows to the Navesink River. Results of the investigations were as follows:
- a. Neither canine alerted at catch basins on Roosevelt Circle.
  - b. Sable alerted at the unnamed tributary crossing at Navesink River Road near Lakeshore Drive. Remi did not alert at this location.
4. ***Green Pond Area*** – Investigations were conducted in the Green Pond area where a tributary flows to the Navesink River. The pond was covered with algae. Results of the investigations were as follows:
- a. Neither canine alerted at catch basins that drain to the pond on Green Lake Drive.
  - b. Neither canine alerted at the manhole on Arthur Drive.
  - c. Neither canine alerted at the catch basins on Grove Street.



**Figure 12: Green Pond Sept 23**

## **Middletown – Summary and Recommendations**

The Township of Middletown did not provide maps of stormwater and sewer infrastructure. While maps of outfalls and sewer and septic areas were provided, the lack of stormwater and sewer infrastructure mapping made source tracking difficult. It is recommended that if Middletown does not have its stormwater and sewer systems mapped, this should be done to facilitate system maintenance and contamination source tracking.

Canine responses to each area investigated were mapped on Google Earth and analyzed along with the maps of outfalls and sewer and septic areas provided by Middletown to determine where source tracking had either isolated or eliminated potential sources. The summary of these findings and recommendations and canine result maps are provided below:

### **McClees Creek Area**

The canines indicated that human sewage contamination is present in many portions of McClees Creek, including at Navesink River Road and Cooper Road and in several of the upstream tributaries, and is being discharged from the creek to the Navesink River.

The main branch of McClees Creek originates in a sewer residential area and flows southeast through a rural septic system area and into the Navesink River. The canines alerted at accessible points upstream of the Navesink River from Navesink River Road to Chapel Hill Road, including the southwest corner of Haskell Pond, then did not alert along the creek upstream of there. They also alerted at a tributary to the creek at the corner of Mohican Drive and Seneca Drive that flows to Haskell Pond. The pattern of these alerts indicates that there are sources of human sewage contamination flowing into Haskell Pond from the Chapel Hill Road and Whipporwill Valley Road intersection and from the tributary to the north of the Pond and flowing downstream to the Navesink River.

Another branch of McClees Creek originates east of the main branch at a pond along Presidential Path and flows South through a rural septic area past Whipporwill Valley Road and connects to the main branch of the creek at Cooper Road. The only location on this branch which was of some concern was at Whipporwill Valley Road, and Sable was the only canine able to investigate this area and did give an alert. The overall lack of alerts along the east branch of the creek indicates that this branch is not likely a source of human sewage contamination flowing from the creek into the Navesink River.

Recommendations are as follows:

- Investigate possible faulty septic systems, cross-connections, or septic discharges at the residences along the banks of McClees Creek between Navesink River Road and Cooper Road that may be contributing to the high bacteria counts in the creek between these two roads.
- Investigate possible faulty septic systems, cross-connections, or septic discharges at the residences along the banks of McClees Creek between Cooper Road and Whipporwill Valley Road that may be contributing to the high bacteria counts downstream.
- Investigate possible sources of human sewage contamination from the residences near the Chapel Hill Road and Whipporwill Valley Road intersection, especially faulty septic systems, cross-connections, or septic discharges. The canine alerts to human sewage in this area may indicate sources that are contributing to high bacteria counts downstream in McClees Creek.
- Investigate possible sources of human sewage contamination from the Mohican Drive and Seneca Drive area and upstream of there, including leaking sewer or lateral lines in the nearby Mohican Drive and Seneca Drive residential areas and failing septic systems, cross-connections, or septic discharges in the upstream area. The canine alerts to human sewage in this area may indicate sources that are contributing to high bacteria counts downstream in McClees Creek.
- Due to lack of accessibility, the canines were not able to investigate many of the smaller tributaries to the main branch of McClees Creek between Haskell Pond and the Cooper Road creek crossing. Any tributaries in this stretch of the creek that have residential or other structures that may have septic systems should be investigated to determine if

there are sewage discharges to McClees Creek from these tributaries in addition to the discharges upstream of Haskell Pond.

### **Shadow Lake Area**

Alerts from both canines at the Shadow Lake spillway indicate that Shadow Lake is contaminated with human sewage. The stormwater system upstream of Shadow Lake were difficult to investigate for source tracking due to the lack of access to a private neighborhood that spans the north side of the lake, the stormwater system complexity and accessibility along tributaries north of the lake, and the lack of stormwater system and sewer maps from Middletown. Both canines alerted at a tributary that crosses Michael Drive and one canine alerted at a tributary crossing on Ueland Road. Recommendations are as follows:

- Using stormwater and sewer system map information, investigate the stormwater and sewer systems in the private neighborhood that spans the north side of Shadow Lake for possible leaking sewer line or lateral line discharges.
- Using stormwater and sewer system map information, investigate the stormwater and sewer systems along the tributaries to the north side of the lake.
- Using stormwater and sewer system map information, investigate the stormwater and sewer systems in the residential areas and along the tributaries on the south side of the lake.

### **Unnamed Tributary East of Poricy Brook**

The canine investigations of Poricy Brook and the unnamed tributary east of Poricy Brook were brief due to the lack of stormwater and sewer system maps in the area to guide systematic source tracking upstream of these areas. An alert by Sable at the unnamed tributary crossing at Navesink River Road near Lakeshore Drive indicates that there may be human sewage contamination of the tributary that is flowing to the Navesink River. Recommendations are as follows:

- If Poricy Brook flowing from Poricy Pond is an area with high bacteria counts and possible human markers using lab analysis, the stormwater and sewer systems in the area, as well as the surrounding tributaries, should be investigated further using stormwater and sewer system map information.
- Using stormwater and sewer system map information, investigate the stormwater and sewer systems in the area of the unnamed tributary to the Navesink River near Lakeshore Drive.

### **Green Pond Area**

The canine investigations of the Green Pond area and its tributary that flows to the Navesink River were limited due to the lack of stormwater and sewer system maps in the area to guide systematic source tracking upstream of these areas, lack of access to several areas around Green Pond, including where the tributary enters the Navesink River, and time constraints. Recommendations are as follows:

- The canines did not alert at the locations the team was able to evaluate. However, if NJDEP indicates that Green pond at its tributary flowing to the Navesink River is an area with high bacteria counts and possible human markers using lab analysis, the

stormwater and sewer systems in the area, as well as the surrounding tributaries, should be investigated further using stormwater and sewer system map information.

## Appendix A

### Maps of Canine Investigation Results in Red Bank



## Appendix A

### Maps of Canine Investigation Results in Red Bank



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### Maps of Canine Investigation Results in Red Bank



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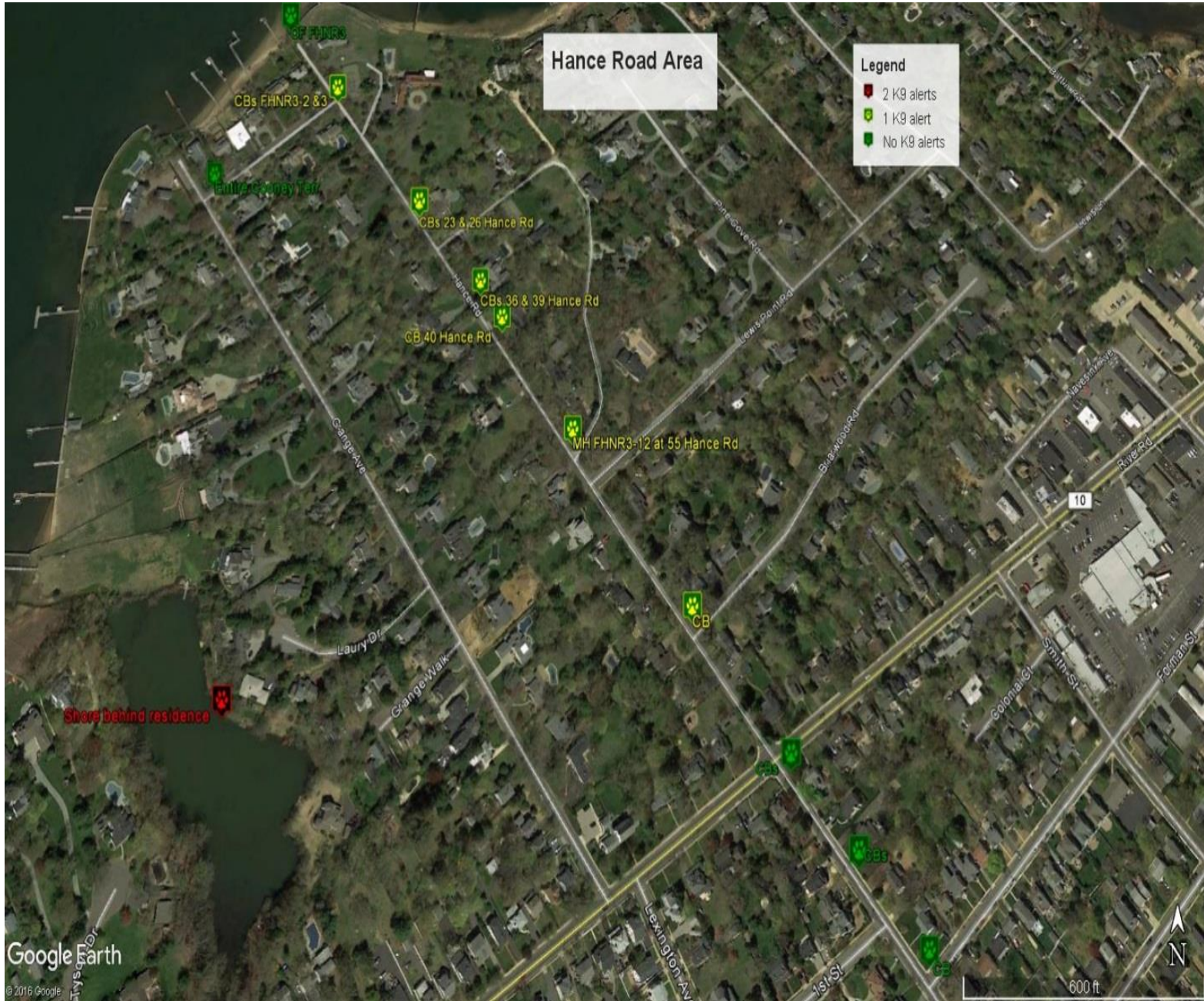
## Appendix B

### Maps of Canine Investigation Results in Fair Haven



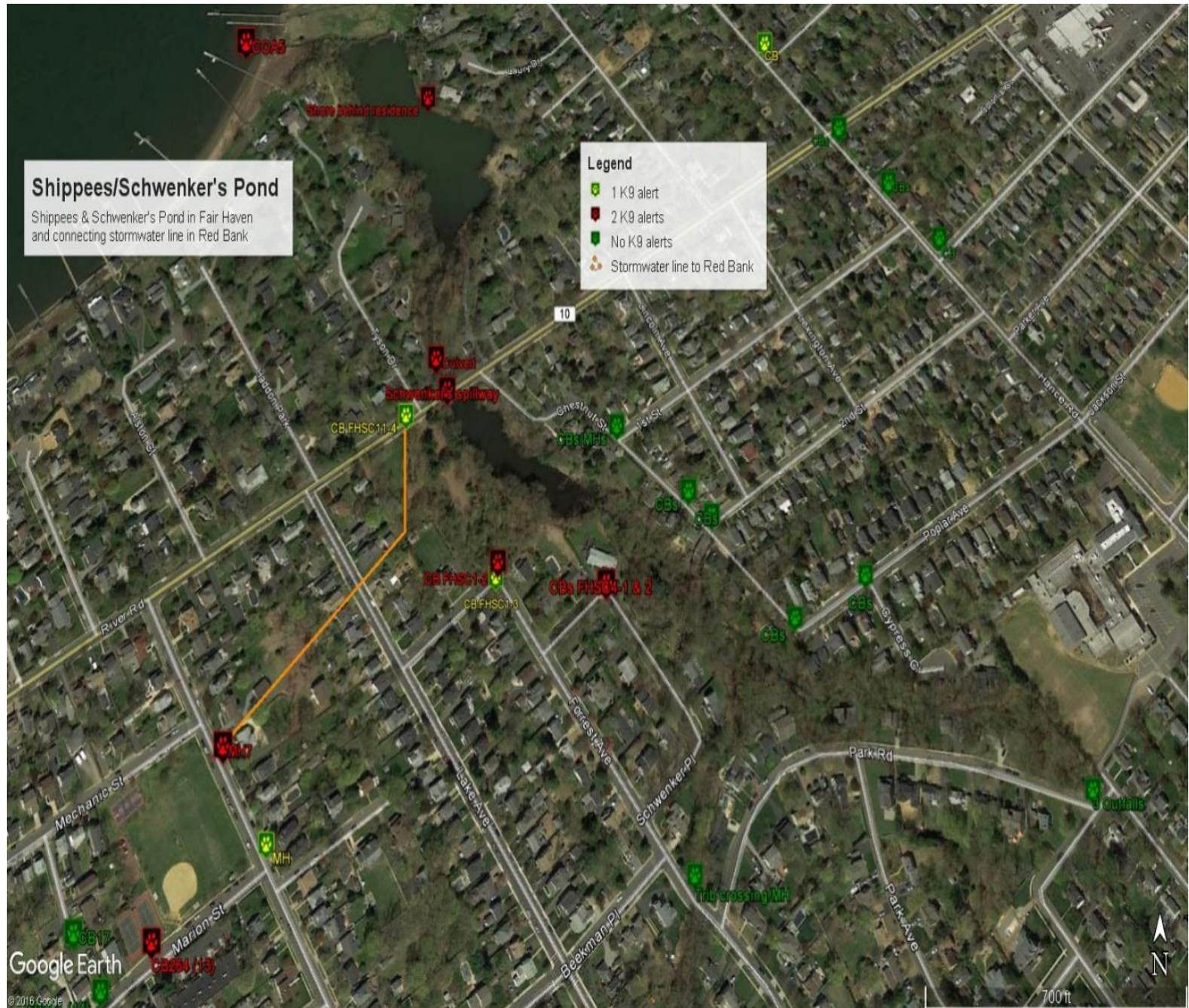
## Appendix B

### Maps of Canine Investigation Results in Fair Haven



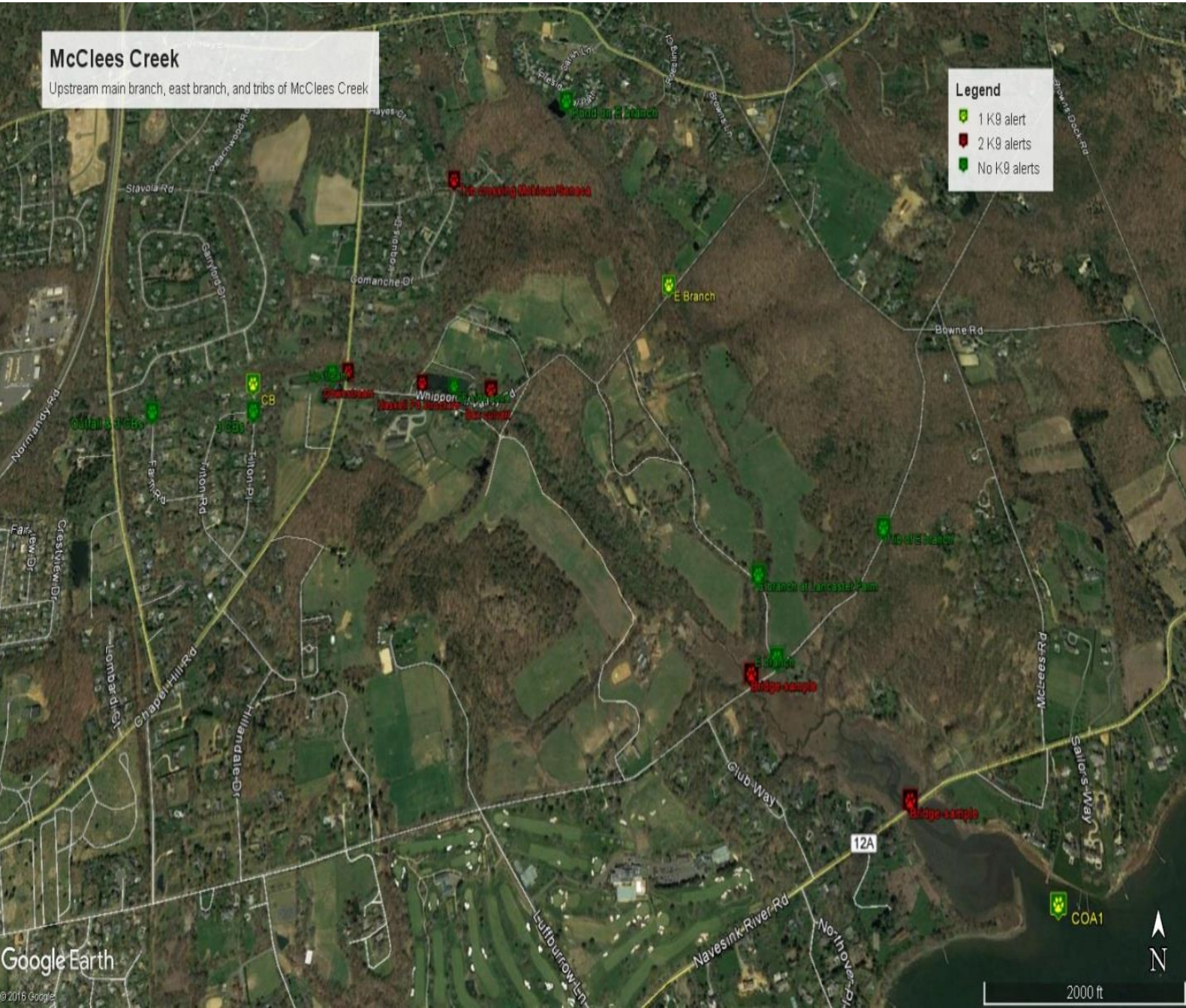
## Appendix B

### Maps of Canine Investigation Results in Fair Haven



Appendix C

Maps of Canine Investigation Results in Middletown

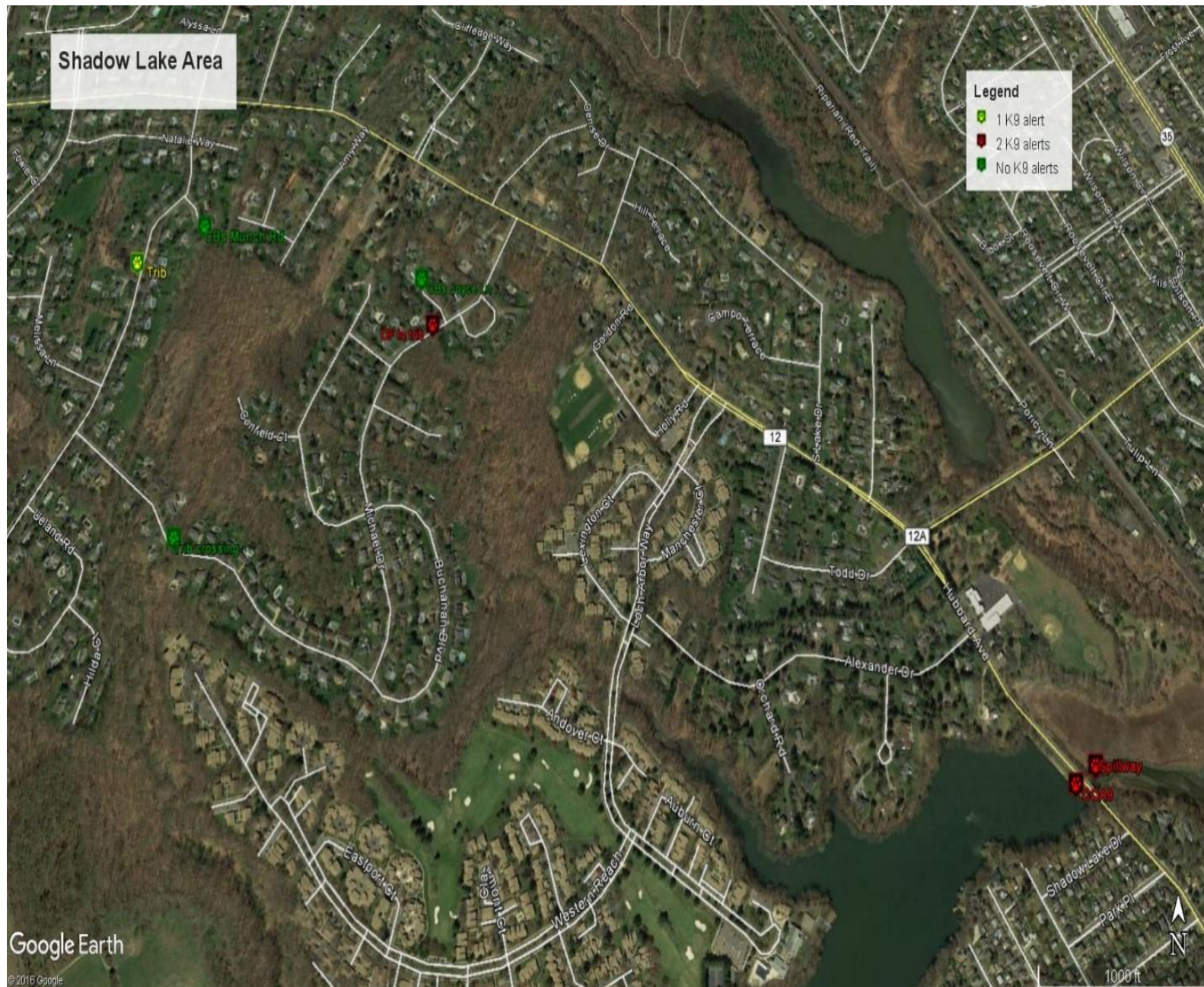


**Appendix C**  
**Maps of Canine Investigation Results in Middletown**



## Appendix C

### Maps of Canine Investigation Results in Middletown



Appendix C  
Maps of Canine Investigation Results in Middletown



**Appendix C**  
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