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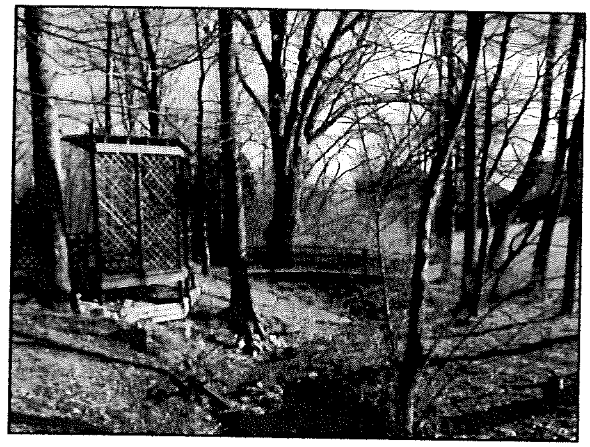

BOONE VALLEY WATERSHED STUDY

May 2008

CITY OF FLORENCE KENTUCKY

Boone Valley Watershed Analysis
Executive Summary

May 2008

City of Florence
Kentucky

VIOX & VIOX
Civil Engineers, Surveyors, and Landscape Architects

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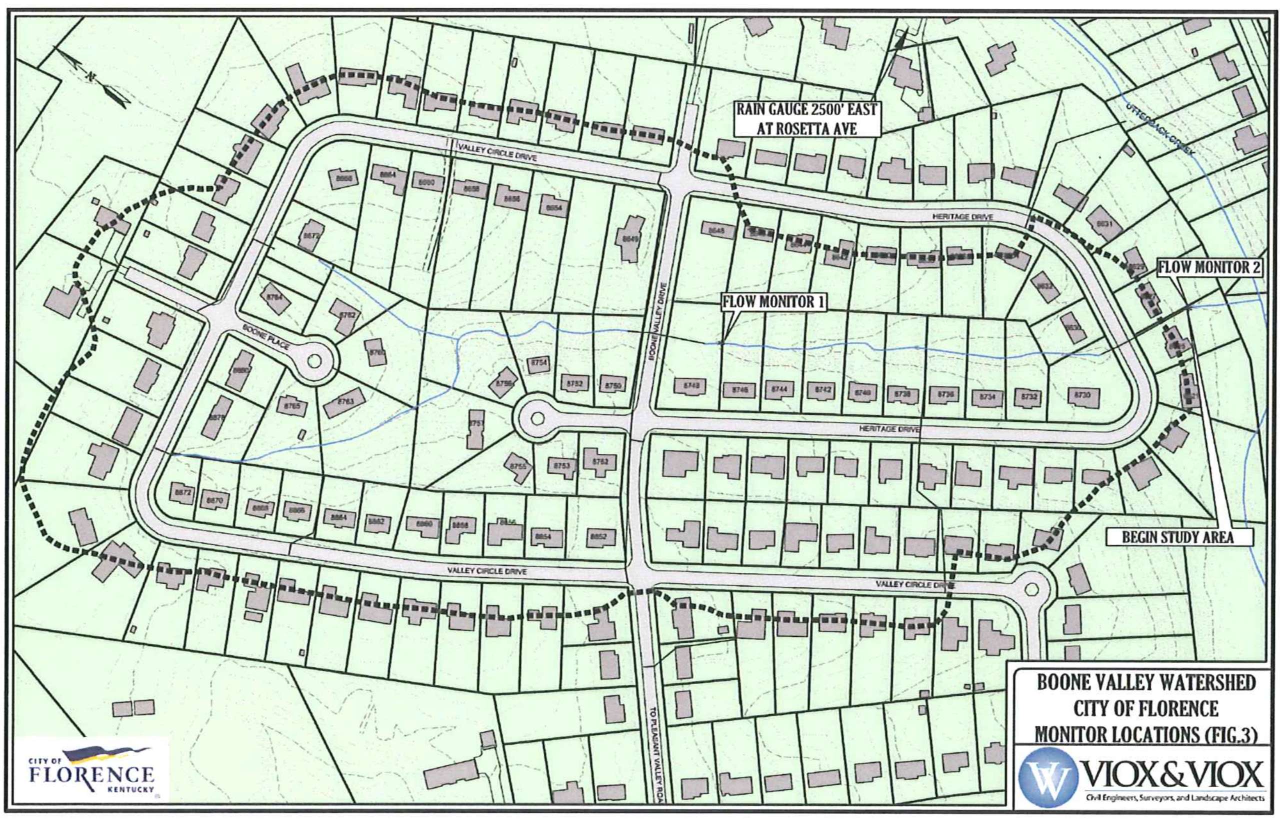
EXECUTIVE SUMMARY

Introduction

In 2007, the City of Florence directed Viox & Viox to conduct a study of the flooding and drainage issues in the Boone Valley Watershed. The study was conducted over a nine-month period and included four main phases: data collection, data analysis, preparation of findings, and recommendations. Viox & Viox prepared a detailed final report as well as this Executive Summary.

The Boone Valley Watershed consists of approximately 39.0 acres in the City of Florence, Boone County, Kentucky. The watershed is bound to the east by Valley Circle Drive and Heritage Drive, to the north by Valley Circle Drive, and to the south by the Utterback Creek. Residential development in this watershed began in approximately 1975 and continued until about 1987. The watershed is completely within the fully developed Boone Valley Estates Subdivision.



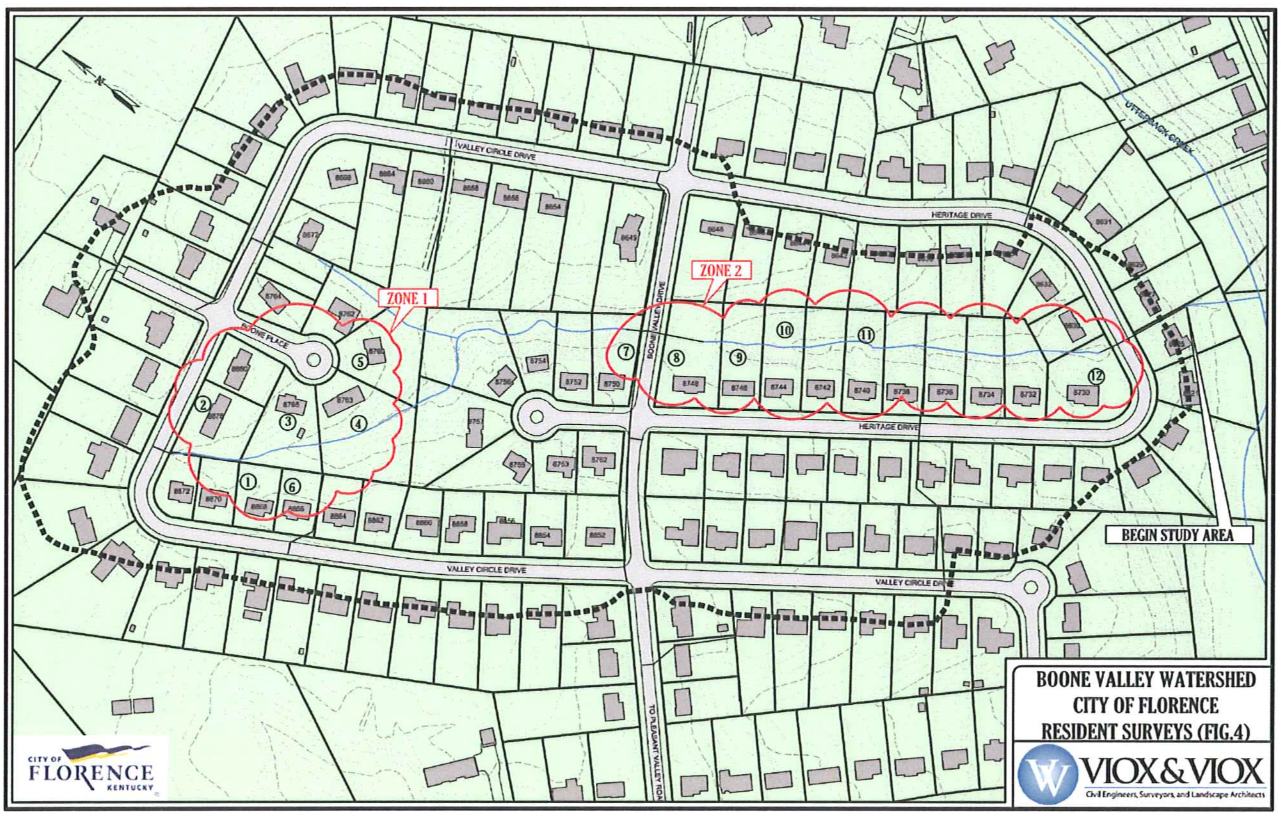
For further information, see Appendix A, Figure 3 of full "Boone Valley Watershed Report"

EXECUTIVE SUMMARY

Data Collection

In order to provide the most accurate analysis possible, data was obtained through various sources. Viox & Viox, through its sub-consultant XCG Consultants, Inc., located and monitored two flow measuring devices and one rain gauge for approximately 3 months.

The analysis was also aided by residents' comments. In August 2007, Viox & Viox sent a survey to 23 residents in the Boone Valley area; 12 were returned with comments. Also, several personal and telephone interviews were conducted to obtain additional information. Furthermore, this study had the benefit of previous residents' comments expressed to the City, Viox & Viox, as well as the Florence Water and Sewer Commission. The majority of the resident comments can be grouped into two areas. The first group is residents located in the northwest corner of the watershed near Boone Place Drive (Zone 1) and second is residents located on Heritage Drive (Zone 2).



For further information, see Appendix A, Figure 4 of full "Boone Valley Watershed Report"

Comments received from the Zone 1 residents were reasonably consistent. Several times each year, the creek experiences high velocity flows that erode the banks, and the water exceeds the banks of the creek. In one case, the water inundated a bridge and gazebo in a resident's yard. These instances usually occur in conjunction with short intense storms as well as longer slower storms.

Standing water was the most common complaint among Zone 2 residents. Some residents did report property damage, such as basement flooding and a collapsed retaining wall. These instances usually occur in conjunction with short intense storms as well as longer slower storms. Additionally one Zone 2 resident, 8744 Heritage Drive, reported an off-channel drainage issue in their front yard along the street.

The residents were questioned as to what type of solutions they preferred. One Zone 1 resident did not want to lose trees although the others were open to such a solution. Zone 2 residents did not comment on possible solutions.

Data Analysis

For the purpose of design and analysis, storms are typically classified by their likelihood of occurrence (one every X number of years). During the monitoring period, there were several storms of varying intensity. The most significant storm occurred on July 4, 2007. After careful analysis, it was determined that this storm roughly approximated a 6-month storm (likely to happen once every 6 months). Storm water piping is generally designed to convey a 10-year storm, and storm water detention facilities are usually designed to accommodate storms ranging from 2 to 100-years.

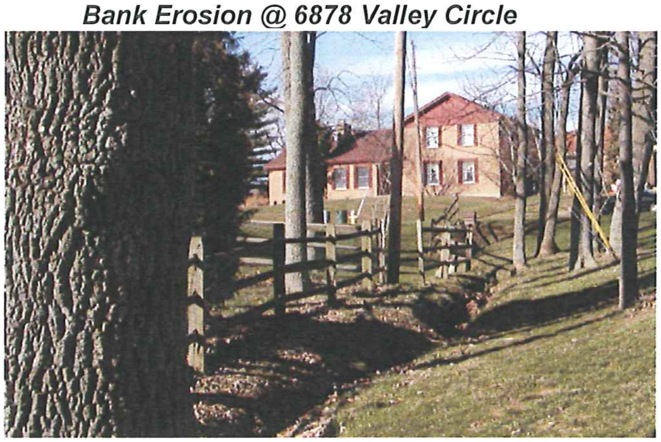
Bridge and Gazebo @ 8763 Boone Place

The analysis was performed using the EPA's Storm Water Management Model software (SWMM). This computer model allowed the hydrologic data from the July 4th storm to be projected forward to simulate the larger design storms. A full narrative of the analysis is available in the "Data Analysis" section of the full report.

In general, the residents' comments agreed with the analysis. The analysis did show that short intense storms have a greater effect than long slow storms, however, residents reported problems with long slow storms as well. While some slow storms may have isolated impacts, it should be noted that most long storms contain several short cloudbursts.

Although several residents reported basement flooding, this analysis did not find any causes for such flooding within the public infrastructure system. The off-channel situation uncovered at 8744 Heritage Drive was not included in this analysis and will require further investigation.

Bank Erosion @ 6878 Valley Circle



Many of the residents' comments were concerned with erosion of the channel and surrounding areas. While erosion is a difficult phenomenon to quantify, development in the drainage basin has certainly increased flow rates and velocities in the channel and thus contributed to additional erosion. Another contributing factor in erosion is the quality and amount of vegetation on stream banks. Through the questionnaires and visual inspections, it is apparent that many residents have mowed or cleared their yards up to and including the stream banks. This lack of vegetation will result in significant erosion even under natural (undeveloped) flows. It should also be noted that the one resident in Zone 1 who did not feel the situation was critical has left significant vegetation along their creek bank, which has helped to protect it.

Recommendations and Conclusions

Upon the conclusion of the analysis, Viox & Viox prepared six recommendations designed to improve the conditions of the Boone Valley Watershed. Furthermore, the numbering of the recommendations is insignificant; they may be implemented in any order. The recommendations are as follows:

EXECUTIVE SUMMARY

Recommendation 1

- Investigate off-channel drainage issues that were identified through resident questionnaire.

The resident at 8744 Heritage Drive reported a front yard flooding issue that they believed resulted from a previous City project. This issue should be investigated to see if the City has any responsibility. Depending on this determination, the City should either repair the issue or provide direction to the resident as to how it may be corrected.

Recommendation 2

- Repair or maintain the existing sanitary sewer aerial crossing.

The existing aerial sewer crossing just north of Boone Valley Drive has been subject to several poorly conceived maintenance procedures over the years, most notably, the addition of concrete encasement. Combined with steam erosion, this encasement began to put unnecessary stress on the pipe. As of the date of this writing, most of the encasement has been removed. This situation should continue to be monitored. Additionally, it may be feasible to further fortify this crossing as part of the repairs suggested in Recommendation 3.

Recommendation 3

- Extend the existing storm sewer at 6878 Valley Circle Drive.

Looking Downstream @ 6878 Valley Circle

This recommendation is dependent upon easement dedication from residents as well as Federal stream permitting. After much consideration, it was determined that the most effective solution to the erosion issues in the northwest portion of the watershed was to extend the storm sewer piping. "Green" solutions were considered but the low environmental quality and potential of the stream make a piping solution possible. A preliminary layout for this system has been included at the back of this summary. Based on resident comments, the layout preserves existing vegetation where possible.

Recommendations 4

- Remove existing private culverts and restore creek vegetation south of Boone Valley Drive.

North of Boone Valley Drive

The area of creek just north of Boone Valley Drive has been left largely untouched and the stream bank vegetation has been maintained. As a result, the creek is in good environmental condition, The section of creek south of Boone Valley Drive is characterized by a widening flood plain with softer slopes. Based on this condition, most bank side vegetation has been removed and several residents have enclosed the creek in private culverts to expand their yards. These private culverts are the cause of the standing water noted in the residents' comments. With resident cooperation, we recommend that these culverts be removed and the stream banks be restored and stabilized.

Recommendation 5

- Extend channel protection at terminus of study area.

The residents at the terminus of the study area have installed semi-effective velocity dissipation at the headwall between 8625 & 8627 Heritage Drive. The existing protection consists of rock reinforced with wire mesh. Upon resident approval, we recommend this protection be extended to eliminate the large scour pit that currently exists.

Recommendation 6

- Monitor the bank erosion between 8756 & 8757 Heritage Drive.

Bend in Creek

This recommendation requires no immediate action. There is a significant bend in the creek channel behind 8756 & 8757 Heritage Drive. Due to this change of direction, the bank behind these homes has eroded. This problem would be largely a private issue except for the fact that the erosion could eventually threaten public sanitary sewers. As of now, the existing creek bank vegetation is effectively stabilizing this area. The residents should be encouraged not to remove this bank vegetation. The City and the residents should continue to monitor this situation to avoid any future issues.

All proposed solutions will require detailed engineering design and construction. Before any stream improvements are implemented, individual property owners must grant easements. Any costs associated with easement acquisition will become part of the overall expense of the improvement.

The implementation of these recommendations will improve the functionality of the watershed, particularly during the most common smaller storm events. However, it is unrealistic to expect to eliminate all problems in a watershed that is densely populated and was largely developed before the advent of storm water control regulations.

Detailed explanations of all aspects of this study are available in the full "Boone Valley Watershed Study."

SECTION 1: INTRODUCTION

1.0 City of Florence Storm Water Management

The City of Florence has been active in storm water maintenance and improvements since 1990. In that year, the City completed a comprehensive Storm Water Drainage Master Plan. The Plan provided much needed information on the general locations of flooding issues.

Since 1990, the City, first through the Florence Water & Sewer Commission, and now, the Department of Public Services, started to study and resolve areas of flooding outlined in the Master Plan.

In 2005, the City updated the Storm Water Master Plan. The updated plan outlined the agencies that have jurisdiction within a drainage way. The updated plan also outlined the specific regulations related to design within the drainage way. The plan defined waters of the United States, waters of the Commonwealth of Kentucky, and waters of the City of Florence. The New Uri watershed includes areas within all three jurisdictions. Activities proposed within the waters of the United States will require a Corps of Engineers permit. Activities proposed within the waters of the Commonwealth of Kentucky will require permitting by the Kentucky Division of Water. Some improvements may require mitigation of lost stream. Mitigation can be accomplished by replacement of lost stream or payment to the State Mitigation Fund.

In 2007, the City of Florence completed the *New Uri Watershed Study.* It was the first watershed specific study completed by the City. That Study resulted in 6 recommendations, several of which are in the process of implementation. The remaining recommendations are scheduled for future budget cycles.

The Boone Valley Watershed Study is a continuation of the efforts begun with the New Uri Study. The City is taking a proactive approach to known storm water issues within the city limits. Like New Uri, this report includes several recommendations designed to address property owner concerns and improve the overall function of the watershed.

1.1 Boone Valley Watershed Study Defined

The Boone Valley Watershed, for the purpose of this analysis, consists of an approximate 39.0-acre area. The main channel of this watershed is an unnamed tributary of the Utterback Creek. The downstream starting point for this analysis is the intersection of this unnamed channel with the main channel of the Utterback Creek.

SECTION 1: INTRODUCTION

The watershed continues upstream approximately 2,300 feet to the north with an average width of about 1,000 feet. The highest reaches of the watershed are located near the northern terminus of Boone Place. The watershed extends to the east and west to the extents of Valley Circle Drive and Heritage Drive. The watershed is completely contained within the Boone Valley Estates Subdivision. The land use in the watershed consists entirely of single-family detached housing.

Figure 1 has been included in Appendix A and shows a photographic view of the watershed.

Figure 2 has been included in Appendix A and shows the watershed sub-basins and associated drainage areas.

1.2 Boone Valley Study Area Residential Developments

As previously mentioned, the Boone Valley watershed study area is entirely within the limits of the Boone Valley Estates Subdivision. The development of the subdivision occurred in multiple phases over the course of many years. The approximate dates of construction are as follows:

Subdivision Section	Date of Construction
• Section 2 *(Valley Circle south of Boone Valley)*	1975
• Section 3 *(Valley Circle west of Heritage Dr. north of Boone Valley Dr.)*	1975
• Section 4 *(Valley Circle west of Boone Pl.)*	1976
• Section 5 *(Heritage Dr. south of Boone Valley & east of Valley Circle.)*	1978
• Section 6 *(Boone Place & Heritage Dr. cul-de-sac)*	1979
• Section 7 *(Southern most curve of Heritage Dr.)*	1981
• Section 8 *(Boone Valley Dr. / Valley Circle / Heritage Dr. Intersection)*	1983
• Section 9 *(Heritage Dr. southeast area)*	1986

- Section 10 — 1986
  (Valley Circle Dr. north of Boone Valley Dr. east of Heritage Dr. cul-de-sac)
- Section 11 — 1987
  (Valley Circle Dr. northeast area)

1.3 History of Boone Valley Watershed

The Boone Valley residential neighborhood was developed from about 1975 through the 1990's. The Boone Valley Estates Subdivision was once selected as the Northern Kentucky Home Builders annual home show site. The development theme included leaving natural streams and woodlands as part of the privately owned lots. Many areas included stands of mature mostly deciduous trees.

In the early 1980's, property owners began experiencing stream erosion and backyard flooding. An owners group approached the Florence Water and Sewer Commission about this issue in the late 1990's. The Florence Water and Sewer Commission has since been absorbed by the City of Florence Public Services Department. Members of the Boone Valley neighborhood have continued discussing storm water issues with the City of Florence Public Services Department.

1.4 Boone Valley Watershed Study Scope of Services

In 2007, the City of Florence asked Viox & Viox to conduct a study of the flooding and drainage issues in the Boone Valley Watershed. The study was conducted over a nine-month period. The study's scope included four main phases: data collection, data analysis, preparation of findings, and recommendations.

The data collection phase included the compilation of eyewitness accounts of the flooding problems through resident questionnaires, interviews, photographs, and videos. In addition, courthouse research of the years of development within the New Uri basin was conducted.

Data collection also included flow monitoring and rain gauge data. Viox & Viox, through its sub-consultant XCG Associates (specialists in Flow monitoring), placed and monitored two flow meters and one rain gauge. The flow monitors were located at the downstream end of the Heritage Drive culvert (between 8625 & 8627 Heritage Drive) and the downstream end of the Boone Valley Drive culvert behind 8750 Heritage Drive.

The rain gauge was located at the Rosetta Avenue Sanitary Sewer Pump Station, which is approximately 2,500 feet east of the study area. The stream and rain monitoring was performed between May 8, 2007 and August 6, 2007. During that time, several storms occurred of varying durations and intensities. The monitoring equipment recorded the rainfall in 5-minute increments, as well as the flow rate, depth, and velocity of the storm water at the aforementioned locations.

After the thorough collection of data, Viox & Viox performed a careful analysis of the information. The data was primarily analyzed using the EPA Storm Water Management Model (SWMM) V5.0.008. The collected data allowed Viox & Viox to test and calibrate the computer modeling programs to ensure precision and accuracy. With this model a wide range of storm events can be simulated.

Viox & Viox prepared the study findings and developed recommendations based on the computer simulations, onsite observations, public comments, and other historical data. These recommendations were carefully considered based on sound engineering principles, cost, and, most importantly, public safety.

SECTION 2: DATA COLLECTION

2.0 Field Data Collection and Observation

In order to provide reliable conclusions and recommendations, this analysis is based on actual field collected data and observation rather than relying on standard hydrologic assumption. The data collected for the purpose of this analysis can be divided into three categories: Physical Structures, Field Observations, and Hydrologic Data.

2.1 Physical Structures

Viox & Viox, Inc. precisely located all major storm sewer structures in the watershed area using standard surveying methods as well as survey quality Global Positioning System (GPS) methods. The structures located include the road crossings at Heritage Drive and Boone Valley Drive.

2.2 Field Observation

On October 15, 2007, Viox & Viox engineering staff participated in a site walk with City staff. This inspection was a valuable tool during the analysis. The inspection included detailed assessment of known problem areas, such as a heavily eroded sanitary sewer crossing, north of Boone Valley Drive. Evidence, such as the location and level of debris, was noted for comparison to the eventual hydrologic model. This data assisted in the calibration and refinement of the computerized model.

2.3 Hydrologic Data

Viox & Viox, through its sub-consultant XCG Engineering, placed two flow monitoring stations and one rain gauge throughout the analysis area. The flow monitors and rain gauge were in place and recording data from May 8, 2007 to August 6, 2007. During that time period there were several storms of varying size and durations.

The first flow monitor (BV-01) was located near the midpoint of the study area at the outlet headwall of the Boone Valley Drive road crossing. This crossing consists of a 36" diameter corrugated metal pipe.

The second flow monitor (BV-02) was located near the downstream end of the study area at the outlet headwall of the Heritage Drive road crossing. This crossing consists of a 36" diameter reinforced concrete pipe.

Both flow monitors were model Sigma 920. These monitors have the ability to measure flow depth, flow velocity, and flow rate. These measurements were taken at 5 minute intervals, 24-hours a day.

The rain gauge was located at the Rosetta Drive Sanitary Sewer Pump Station. The rain gauge was a Nova Lynx Tipping Bucket, and recorded readings at 5 minute intervals, 24-hours a day.

Figure 3 has been included in Appendix A and shows the locations of these flow monitors.

2.4 Property Owner Surveys, Interviews and Documentation

Since the early 1990's, the residents within the Boone Valley watershed study area have been given opportunities to discuss, with the City of Florence and/or Viox & Viox, their personal experiences with the creek.

Also, in the early 1990's, Florence Water & Sewer Commission held a neighborhood meeting at the Florence Government Center to discuss the existing flooding problems with the residents living within the study area. The meeting was well attended and several residents submitted written comments to the City.

In August 2007, Viox & Viox sent a survey to 23 property owners within the Boone Valley Drainage Basin study area. The residents were asked to return the survey with their comments. The residents were also given the opportunity to schedule a personal interview with William R. Viox, P.E., P.L.S., Vice President and Megan V. deSola, A.I.C.P., Director of Planning Services of Viox & Viox, to discuss their experience with drainage issues. Viox & Viox received 12 survey responses (52% response rate). Of the 12 responding property owners, four (4) requested a personal interview. The interviews were conducted at the Florence City Building on August 29, 2007.

The residents' responses have been compiled and documented and are summarized in Appendix E. The original written comments submitted by the residents have been photocopied and are also located in Appendix E of this document.

For the purposes of this study, each resident was given a number, which corresponds, to their location on Figure 4: Boone Valley Watershed Appendix A.

Out of the twelve property owners who responded, three (3) reported that they had not experienced any drainage/flooding problems. Nine (9) respondents indicated that they had experienced drainage/flooding issues of varying degrees. The problems reported included creek bank erosion, yard flooding, stagnant and/or standing water in yards, rushing water, and basement/garage flooding.

SECTION 2: DATA COLLECTION

According to the surveys, the flooding issues center around two areas: the common area to the rear of 8868 and 8878 Valley Circle Drive and 8763 and 8765 Boone Place (Zone 1); and the east side of Heritage Drive from Boone Valley Drive to the southernmost point of the Heritage Drive circle (Zone 2).

2.5 Summary of Zone 1 Residents' Comments

The residents on and around the Boone Place cul-de-sac have generally experienced flooding and standing water in the yard, creek bed erosion, and fast rushing water after heavy rains. One property owner indicated that the water level of the creek frequently rises above an existing gazebo and bridge on his property. The residents also reported a bad mosquito problem in the area. Generally, the problems will arise after both heavy rains and short cloudbursts during the spring, summer, and fall months.

The four residents that attended the interview sessions at the Florence City Building all reside on either Valley Circle Drive or Boone Place. The four residents, who attended the interview session together as a group, all indicated that they had experienced flooding and creek bed erosion problems to varying degrees. While three of the property owners reported that the problems were significant and required a prompt solution, one resident stated that the problem was not significant enough to require any type of solution that would place his trees and other property in danger. Likewise, of the surveys received, many indicated that they would like to see a solution, while at least one property owner reported that the problem was not a significant issue.

Viox & Viox found that the residents' comments were generally consistent with the data presented in this study. Further explanations of the data and the residents' comments are located in Section 3: Data Analysis of this document.

2.6 Summary of Zone 2 Residents' Comments

The residents on Heritage Drive reported creek bed erosion, flooding and standing water in the yard, and basement/garage flooding. One property owner reported that their retaining wall near the creek collapsed due to erosion over the years. Three residents reported that the problems only occur after a long, hard rain, while two residents reported the problems occur after both long rains and short cloudbursts. The two residents that reported basement/garage flooding indicated that the problem occurs after long rain events, several times a year. Also, during the interview / questionnaire process one homeowner (8744) indicated a front yard (off channel) issue which should be investigated.

SECTION 2: DATA COLLECTION

Viox & Viox found that the residents' comments were generally consistent with the data presented in this study. Further explanations of the data and the residents' comments are located in Section 3: Data Analysis of this document.

SECTION 3: DATA ANALYSIS

3.0 Summary of Field Observations and Hydrologic Data

During the planning portion of this project, it was determined that the storms of highest interest would likely be short duration high intensity events. This was determined due to the fact that the watershed is reasonably small and most accounts of flooding were of the flash flood variety. Several rain events matching this description occurred during the monitoring period. These storms are summarized in the following table:

Table 1

Date	Total Rainfall (in)	Duration (min)	Intensity (in/hr)
5/28/2007	0.21	35	0.36
7/4/2007	0.51	20	1.53
7/8/2007	0.15	40	0.23
7/19/2007	0.47	35	0.81

- XCG Rain Gauge Data

Detention and flood control design use a storm's frequency of occurrence as a basis for design. For example, local regulations require detention facilities to be designed to detain the 2, 10, 25, and 50-year storm events and provide flood control in the 100-year storm event. Therefore, it is useful to estimate the frequency rating of the monitored storms in order to gain a better understanding of the measured data. It is also relevant to note that the short duration high intensity storms described above roughly follow a Type II 24-hr rainfall distribution. The "rainfall distribution" is an approximation of how the rainfall comes down throughout the day. In this case, a "Type II 24-hr" is a distribution that assumes a high peak (most of the rainfall at one time). For example, while the 6-month storm consists of 2.07 inches of rain over 24 hours, the Type II distribution assumes that nearly half of that rainfall will come in 30 minutes midday. The Type II 24-hr distribution is the distribution most common in local detention facility design. The following table summarizes the rainfall quantities and their associated frequency of occurrence:

SECTION 3: DATA ANALYSIS

Table 2

	SCS 24-hr Rainfall (in)*	IDF Intensity (in/hr) (Tc=15min)**
6-month	2.07	Not available
1-year	2.56	Not available
2-year	3.05	3.0
10-year	4.36	3.9
25-year	5.15	4.5
50-year	5.78	5.2
100-year	6.44	6.3

* Soil Conservation Service, Technical Release 55
** KDOT Intensity Duration Curve, Cincinnati Ohio, 1904-1965

The most significant storm during the monitoring period occurred on July 4, 2007. The distribution of this storm was even more peak intensive than a standard Type II distribution, so comparison to Table 2 is somewhat difficult. However, based on the totality of the information, it was estimated that the peak of the July 4 storm was roughly equivalent to that of the 6-month storm.

3.1 Site Specific Data and Analysis

From the physical data collected, an accurate computer model of the watershed was created and calibrated. The main program used in the analysis was the United States Environmental Protection Agency Storm Water Management Model (EPA SWMM) Version 5.0. This program is designed for small urban watersheds and is therefore well suited for this application.

When looking at the field data, it is useful to compare it to the standard hydrologic assumption typically used in storm sewer design. In the *New Uri Watershed Study* our analysis revealed that the standard assumption used to design storm sewers and detention facilities were very conservative, when compared to the actual field data. In this analysis the results were compared to standard rational method calculations. This comparison revealed that while the standard assumptions are still conservative they do not very to the same degree as in the *New Uri Watershed Study.* For example, a rational method calculation for the 2-year storm at the down stream end of this watershed would predict a flow rate of about 65 cfs. However the calibrated SWMM model shows the predicted flow rate to be 45 cfs. There are two factors that likely account for this change. First, the Boone Valley watershed is significantly smaller than the New Uri watershed. It is well known that hydrology calculations, particularly the rational method, become more inaccurate as the size of the watershed increases. Also, this watershed does not include any detention facilities, as opposed to the New Uri watershed, which included two. Those detention facilities added several more layers of assumption, which do not affect this analysis.

As stated before, the standard hydrologic assumptions common across the region have been shown to be conservative. Therefore it is important to note that this study has the advantage of real hydrologic data; this data was compared to the output of the original SWMM model. Upon this comparison, we were able to adjust our assumptions to better model the specifics of this watershed. After these adjustments were made and the 7/4/07 storm had been accurately modeled, the rainfall data was modified to simulate the 6-month, 1, 2, 10, 25, 50, and 100-year storm events.

When viewing this analysis, it should be noted that the largest storm recorded during the monitoring period was estimated at 6-month intensity. Therefore, the projection of the 2, 10, 25, 50, and 100-year storm events represent an extrapolation of the measured results. While the methods used in this analysis represent the most accurate projections of watershed behavior available, any statistical result is limited in accuracy by the size of the sample data. For this reason, only the data up to the 25-year storm will be presented in this section. The data printouts for the 50 and 100-year storms are available in Appendix B. In the *New Uri Watershed Study* the data was reported up the 100-year storm because the measured storms were of sufficient size to support such an extrapolation. Due to an unusually dry year this study was completed with less extensive data. Therefore, the study team felt it necessary to limit the results.

Now that the model has been properly calibrated, the analysis can begin in the upper reaches of the basin and proceed downstream. The first area of concern is at the culvert outlet near the northwest quadrant of Valley Circle Drive. This culvert outlets into a small open channel and has been the subject of multiple complaints over past years. When this outlet was analyzed using the calibrated SWMM model the following data was obtained.

Table 3

Storm	Peak Flow (cfs)	Peak Velocity (fps)	Peak Depth (ft)
6-month	1.10	6.02	0.28
1-year	1.37	6.51	0.32
2-year	1.64	6.93	0.35
10-year	2.36	7.71	0.42
25-year	2.85	8.01	0.47

- SWMM Model Analysis

SECTION 3: DATA ANALYSIS

Typically, the 10-year storm is used for the design of storm sewers and velocity dissipation. The 10-year velocity of the natural channel, at the above location was calculated to be approximately 2.8 fps. This is significantly less than the approximate 7.7 fps predicted in the preceding chart. A velocity as low as 2-4 fps can be expected to produce erosion, while typically a velocity of 15 fps is considered to be highly erosive. It should also be noted that the velocity at this point is largely due to the culvert itself. Velocity downstream quickly reverts to natural channel conditions. It should be noted that some erosion is a natural stream phenomenon. However, possible remediation techniques will be discussed in the recommendations section.

The velocities and flows noted above are characteristic of the channel flow for the next stretch of the creek leading to the confluence of the two main upper reaches of the creek. The analysis at this point is insignificant due to the isolated nature of the confluence. However, it should be noted that slightly downstream of this point the study team noted a severely eroded sanitary sewer crossing that is in need of repair. This will be further discussed in the recommendations section.

The next area of significance occurs at the culvert crossing under Boone Valley Drive. The upper end of this culvert consists of a 36" diameter reinforced concrete pipe that was likely installed as part of the road construction. However, the downstream end of this culvert is a 36" corrugated metal culvert. Flow monitor BV-01 was located on the downstream side of this culvert. When this area was analyzed using the calibrated model, the following data was obtained:

Table 4

Storm	Peak Flow (cfs)	Peak Velocity (fps)	Peak Depth (ft)
6-month	7.23	6.51	0.64
1-year	11.68	7.47	0.82
2-year	16.27	8.21	0.97
10-year	31.79	9.85	1.40
25-year	42.55	10.58	1.66

- SWMM Model Analysis

Over the next several hundred feet the creek continues downstream and passes though several private culverts. The culverts generally consist of approximately 36" corrugated metal pipe. These culverts were not specifically included in the analysis due to the fact that they are privately owned and outside the City's control. Excluding these culverts from the analysis results in a more conservative model for the downstream areas. However, it should be noted that these culverts inevitably cause ponding of water, which is consistent with resident comments. This would become significant should a private homeowner remove one of the culverts, without the City's knowledge, and release additional flows downstream.

The final analysis point studied was at the most downstream point of the study area. This is the outlet from the Heritage Drive culvert crossing. This location consists of a 36" reinforced concrete pipe and was the location of flow monitor BV-02. The data from this location is a follows.

Table 5

Storm	Peak Flow (cfs)	Peak Velocity (fps)	Peak Depth (ft)	
6-month	25.36	11.33	1.06	
1-year	34.96	12.36	1.26	
2-year	44.39	13.17	1.44	
10-year	83.15	15.11	2.20	
25-year	97.60	15.92	5.00	Surcharged

- SWMM Model Analysis

Beyond this data, visual inspection of the location reveals a history of erosion problems. Specifically, it is evident that the local homeowners have gone to significant trouble to install rock channel liner fortified with steel fencing at the culvert outlet. Despite this fact there is evidence of continued erosion. There is a significant scour pit at the end of the existing channel protection.

SECTION 4: RECOMMENDATIONS & CONCLUSIONS

4.0 Recommendations

Viox & Viox has prepared the study findings and developed recommendations based on the computer simulations, onsite observations, public comments, and other historical data. These recommendations were carefully considered based on sound engineering principles, cost, and, most importantly, public safety.

The following recommendations are based on the study findings. All recommendations will require further detailed design at a later date prior to implementation.

Recommendation #1

There was an off channel, front yard, issue noted by the resident at 8744 Heritage Drive. A previous owner of the property indicated that the problem was the result of City storm water repairs from a number of years ago. We recommend this issue be further investigated to identify any City responsibility.

Recommendation #2

As was discussed in the data analysis section, there is a sanitary sewer creek crossing north of Boone Valley Drive that is heavily eroded. This creek crossing should be repaired or replaced at the earliest possible date to avoid any possible environmental concerns. Furthermore, the crossing should be repaired such that there is no new flow restriction along the creek.

Recommendation #3

There have been consistent resident complaints regarding the section of creek in the most northwest portion of the watershed. This portion of creek is just down stream of a public storm sewer under Valley Circle Drive. In general, this portion of creek experiences relatively small flows due to the fact it is located in the highest portion of the watershed. The creek has cut a small channel just down stream of the afore mentioned headwall and continues downstream, where it has undermines several property fences and a gazebo. This is not an uncommon issue in the upper reaches of watersheds. Creeks in these areas are relatively small and often overtaken by resident's yards. Given today's regulatory environment, situations like this should first be approached from a "green solution" perspective. Alternatively, this situation could be alleviated by extending the storm sewer and piping the water past the affected properties. Although this is typically a last option it does have merit for the current situation. The stream in question is of low environmental quality and already bisected by several fences which collect debris and act as flow restrictions. Therefore we recommend that the storm sewer be extended. This project would depend on resident cooperation and easement acquisition. Also, the route of this pipe will have to be carefully selected, as several residents expressed reservations about losing existing vegetation along the creek.

Recommendation #4

The portion of the creek just north of Boone Valley Drive is generally in good condition. The local residents have left the creek essentially in a natural state. However, the portion of the creek south of Boone Valley Drive is characterized by a widening flood plain and softer slopes around the creek banks. Because of this fact, several residents have enclosed the creek in private culverts, causing ponding. Additionally, this section of creek has been essentially cleared of bank vegetation. We recommend that the City consult with residents as to the removal of these private culverts and the re-vegetation of the creek banks. Obviously, this would require resident cooperation since the areas in question are located on private property. However, undertaking this effort would provide a long-term environmental benefit to the stream and the community.

Recommendation #5

The analysis noted the high velocities and apparent erosion at the Heritage Drive outlet headwall, at the downstream terminus of the study area. As mentioned in the analysis, the homeowners have installed some effective channel protection in the form of rock reinforced with wire mesh. We recommend that the City extend this channel protection to alleviate the existing erosion problem just past the resident installed channel protection. The channel liner needs to be extended downstream in order to properly dissipate the flow velocity. This recommendation will require resident cooperation.

Recommendation #6

While do not believe any action is necessary at this time, we recommend that the City continue to monitor the creek erosion between 8756 & 8757 Heritage drive. Vegetation is currently stabilizing the creek bank. However, if the vegetation is removed or dies the bank could begin to erode into the resident's yards.

SECTION 4: RECOMMENDATIONS & CONCLUSIONS

4.1 Conclusions

The implementation of these recommendations need not be completed in any specific order. Although we highly recommend that recommendation #1 be completed as soon as possible in order to determine City responsibility. We also advise that recommendation #2 be completed promptly to avoid any possible stream contamination.

Any future design based on this study should also consider that the simulated flow data does not include a factor of safety that is always present in standard engineering assumptions. A factor of safety is essentially a ratio by which the project is over-designed. This allows the designer to offset some of the uncertainty introduced by the extrapolation of data and limited sample sizes.

The implementation of these recommendations will improve the functionality of the watershed, particularly during the most common smaller storm events. However, it is unrealistic to expect to eliminate all problems in a watershed that is somewhat densely populated and was developed before the advent of storm water control regulations.

All solutions proposed will require detailed engineering design and construction. Before any stream improvements are proposed, individual property owners must grant easements. Many of these storm sewer improvements could necessitate sanitary sewer improvements, which will add to project cost.

Acknowledgements

City of Florence

Robert Townsend
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Project Coordinator

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Cincinnati Office Manager

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Michelle Bollman, PE

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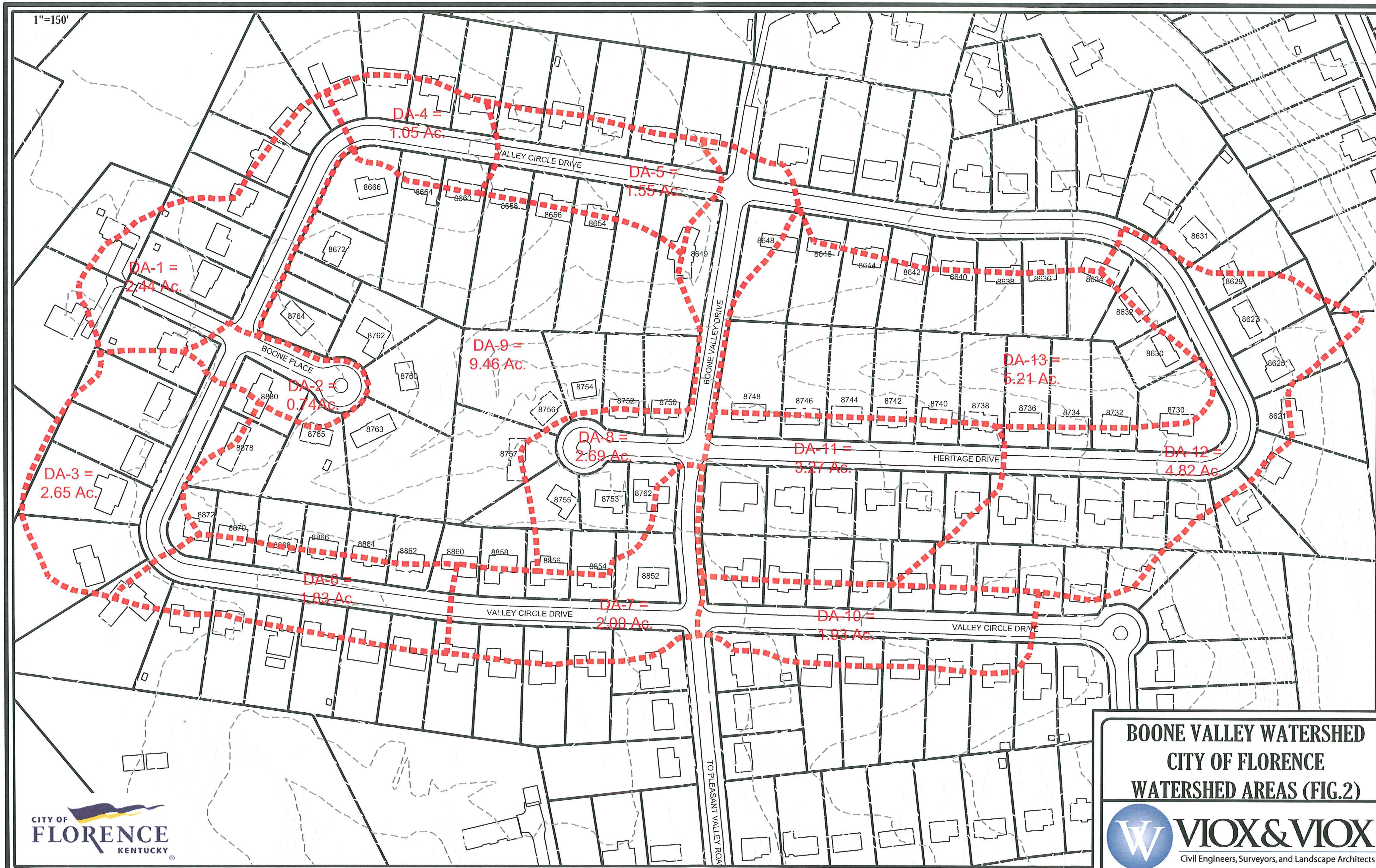
Carter Dickerson, ASLA

Megan deSola, AICP

APPENDIX

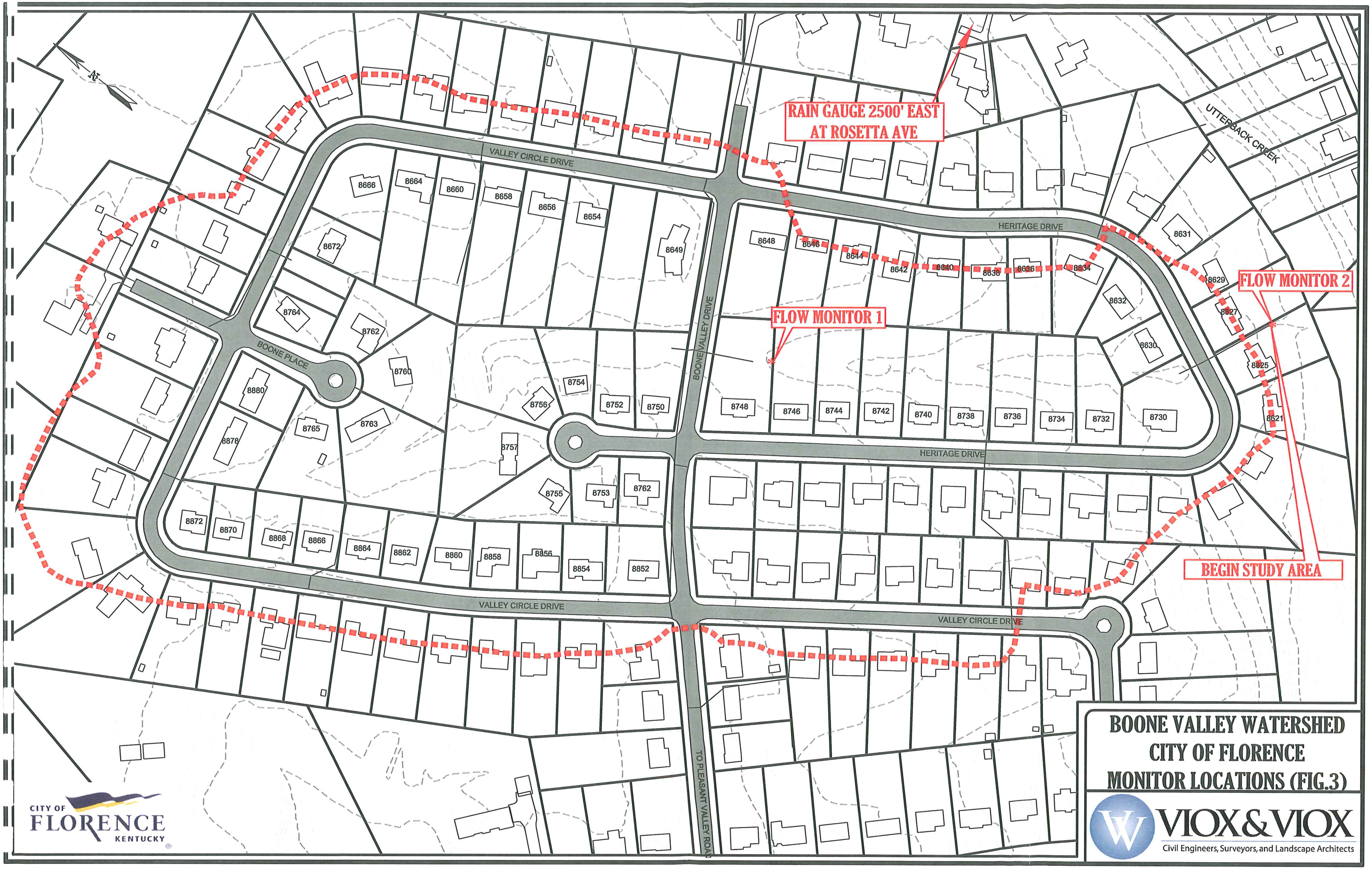
A


WATERSHED BOUNDARY
N
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
UTTERBACK CREEK
BEGIN STUDY AREA
TO PLEASANT VALLEY ROAD
CITY OF FLORENCE KENTUCKY
BOONE VALLEY WATERSHED
CITY OF FLORENCE
AERIAL MAP (FIG.1)
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



BOONE VALLEY WATERSHED
CITY OF FLORENCE
WATERSHED AREAS (FIG.2)

VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



RAIN GAUGE 2500' EAST AT ROSETTA AVE
UTTERBACK CREEK
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
FLOW MONITOR 1
FLOW MONITOR 2
BEGIN STUDY AREA
TO PLEASANT VALLEY ROAD
N
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8660
8658
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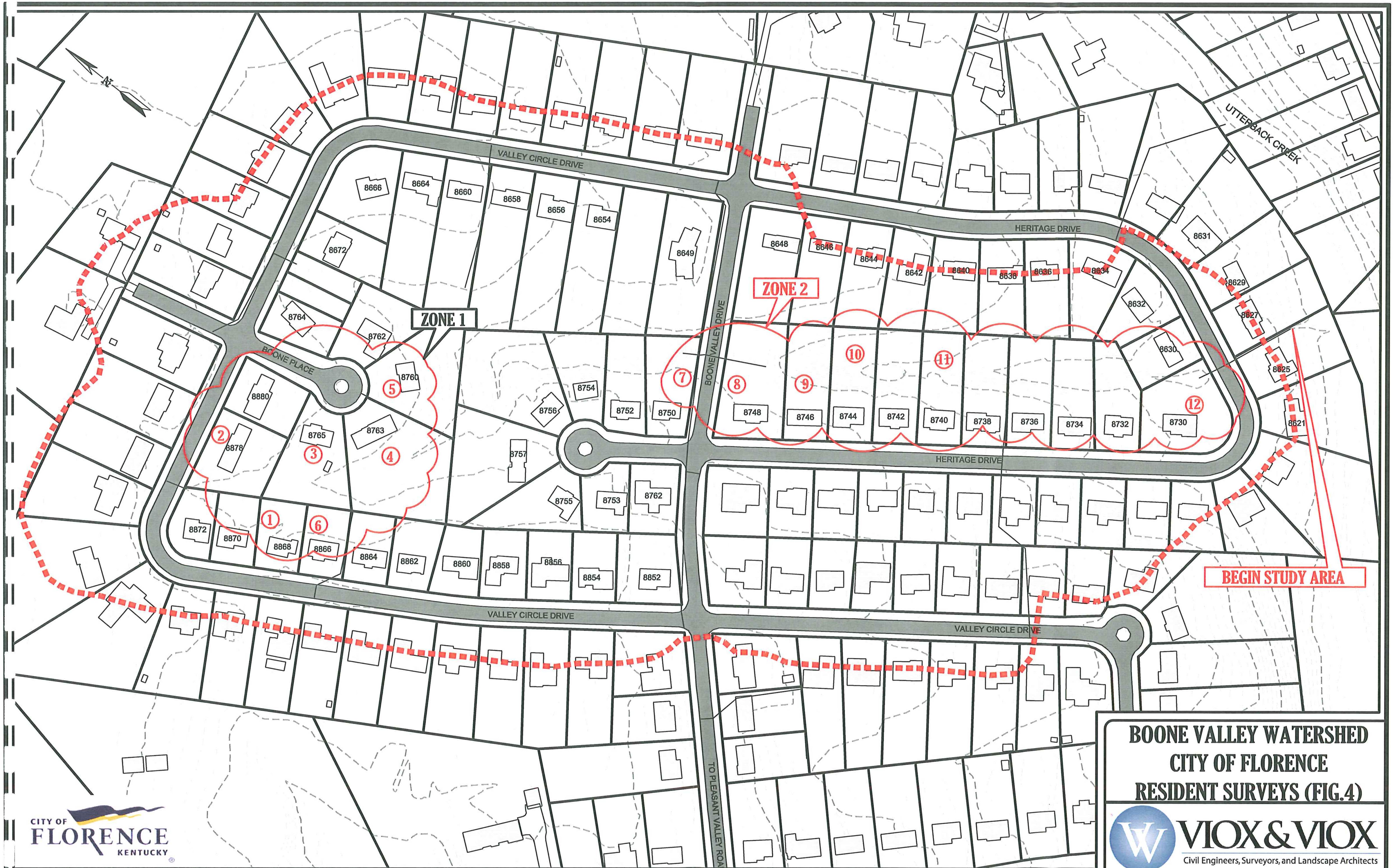
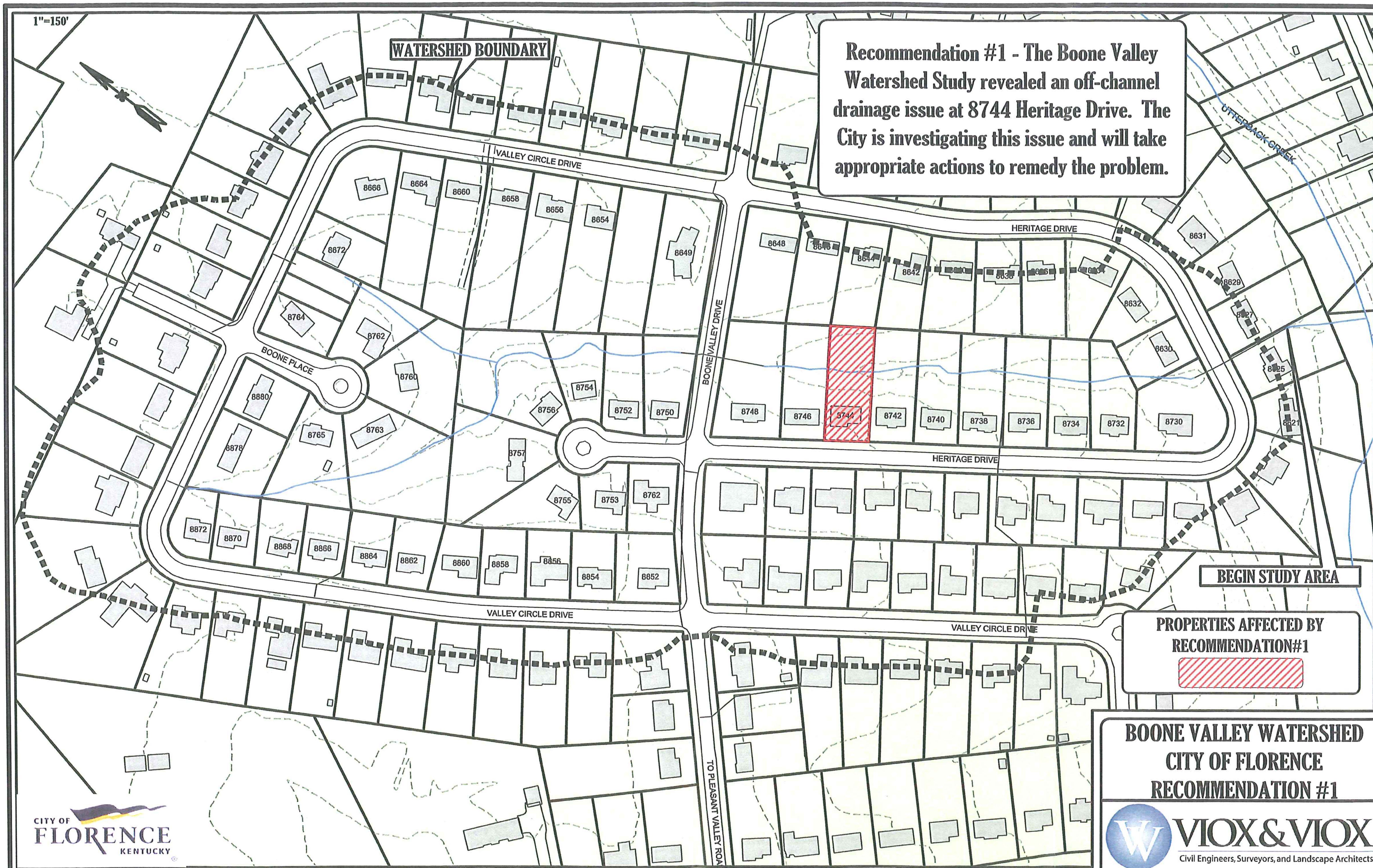
8852
BOONE VALLEY WATERSHED
CITY OF FLORENCE
MONITOR LOCATIONS (FIG.3)
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



BOONE VALLEY WATERSHED
CITY OF FLORENCE
RESIDENT SURVEYS (FIG.4)

VIOX & VIOX
Civil Engineers, Surveyors, and Landscape Architects


1"=150'
WATERSHED BOUNDARY
Recommendation #1 - The Boone Valley Watershed Study revealed an off-channel drainage issue at 8744 Heritage Drive. The City is investigating this issue and will take appropriate actions to remedy the problem.
UTTERBACK CREEK
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
HERITAGE DRIVE
VALLEY CIRCLE DRIVE
VALLEY CIRCLE DRIVE
TO PLEASANT VALLEY ROAD
8666
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8660
8658
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8672
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8642
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8625
8621
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8757
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8753
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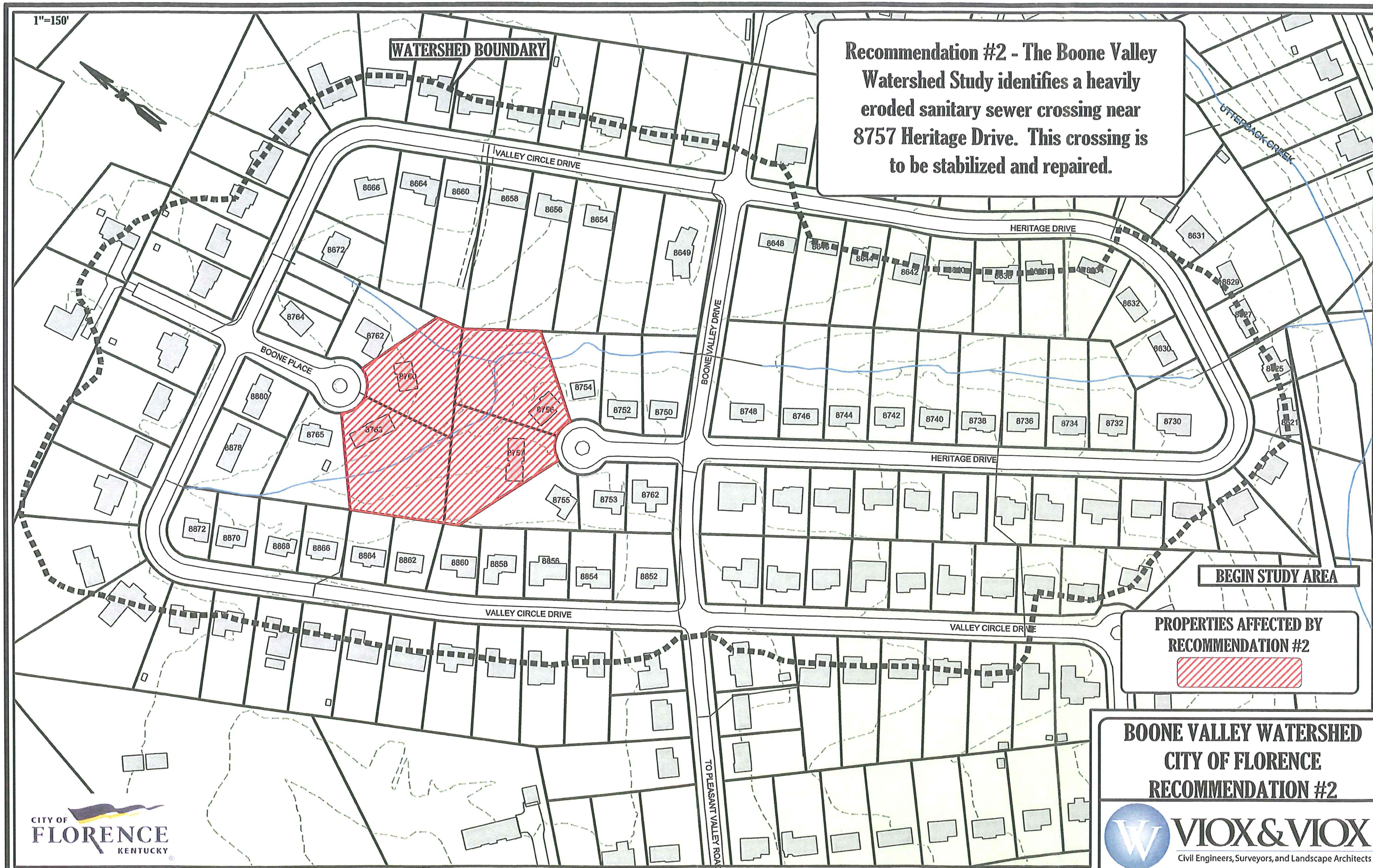
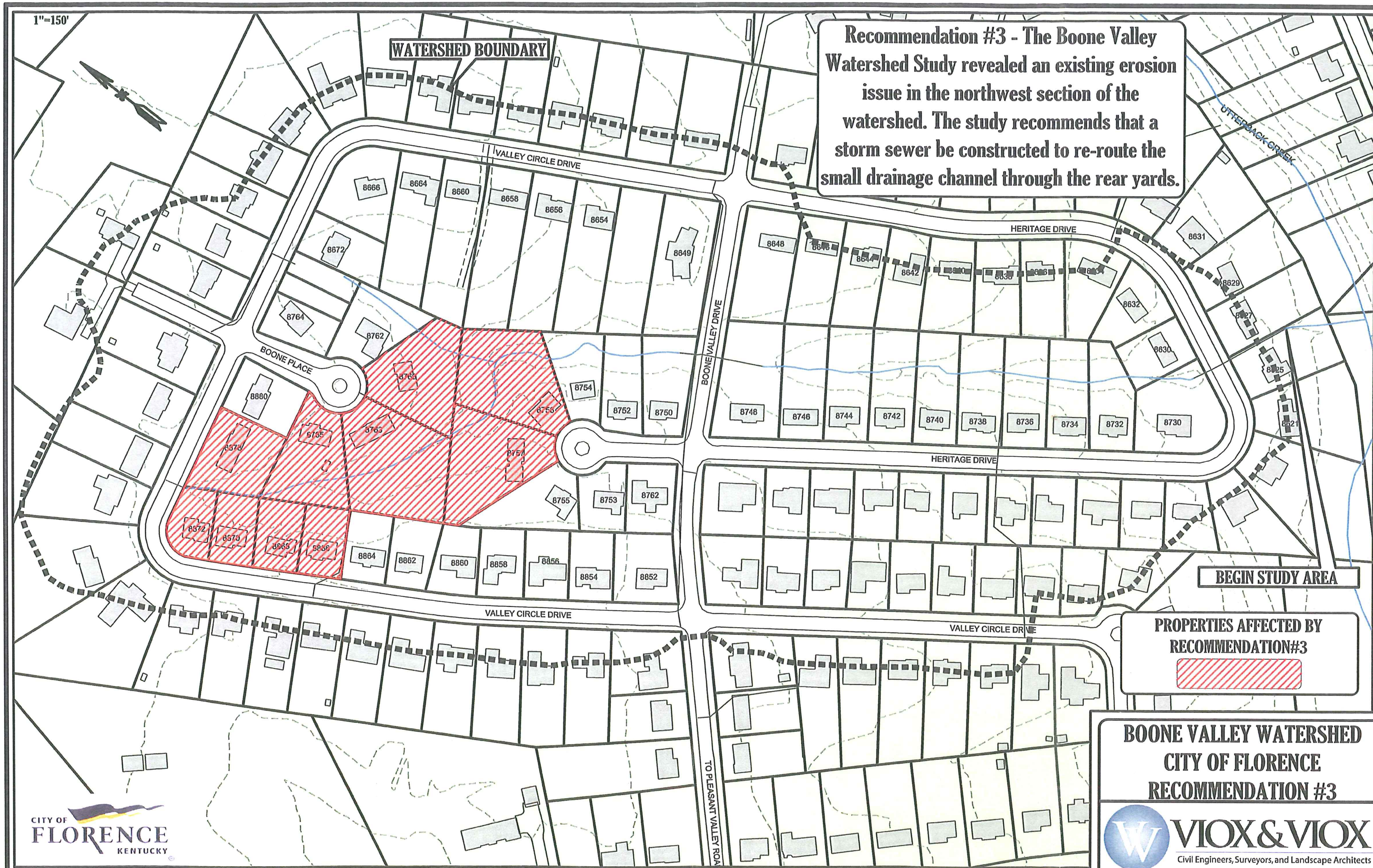
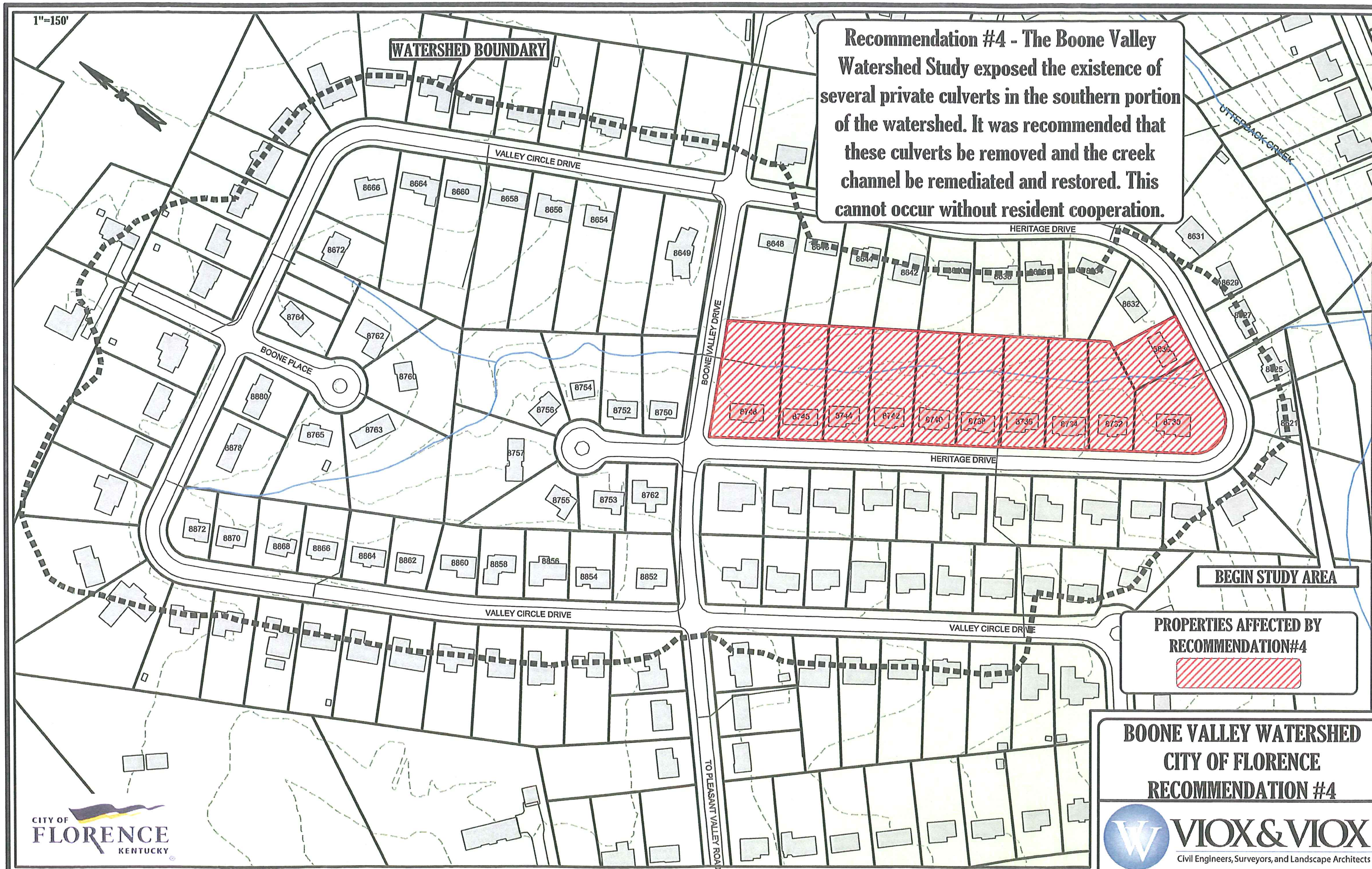
8852
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION#1
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #1
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects

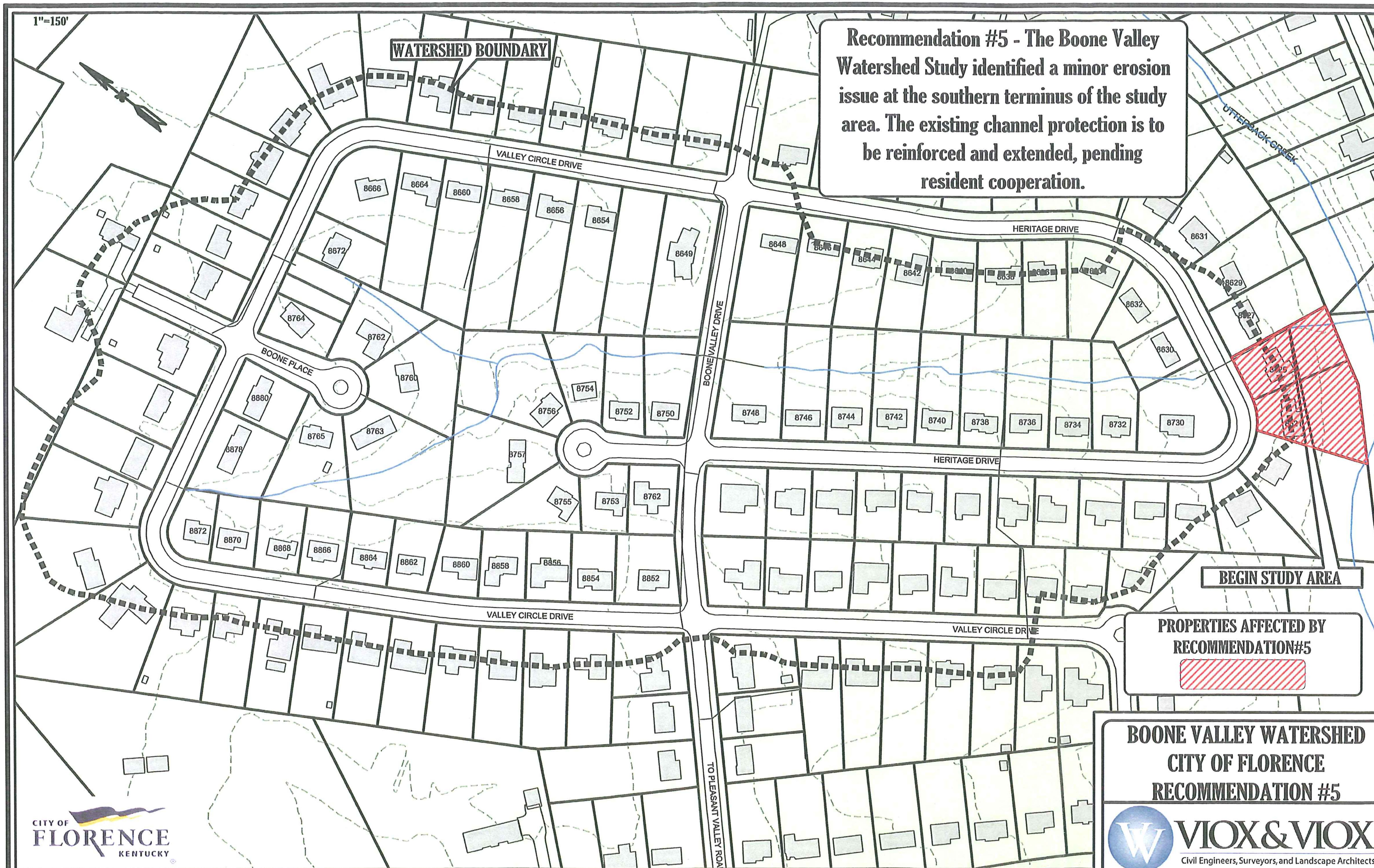


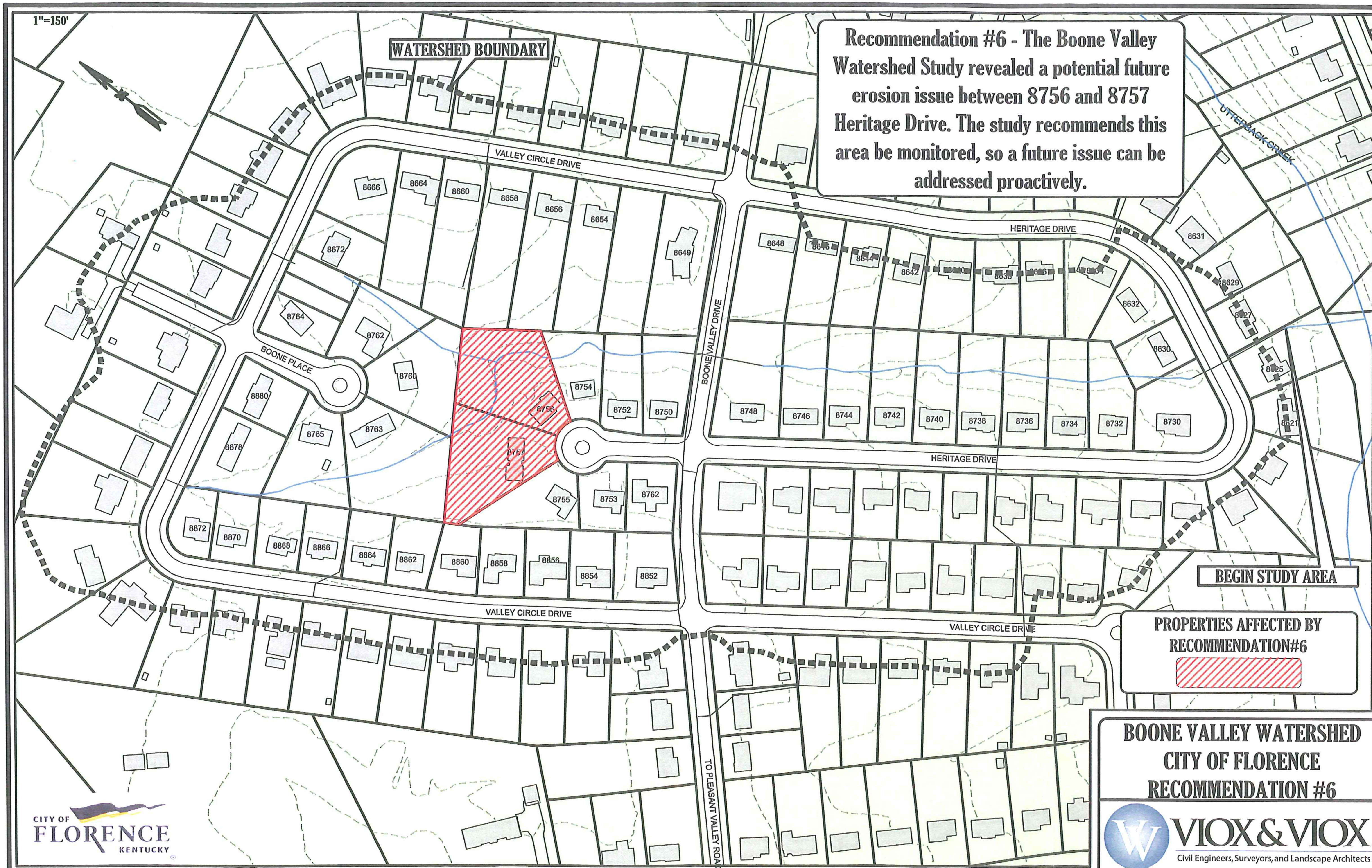
1"=150'
WATERSHED BOUNDARY
Recommendation #2 - The Boone Valley Watershed Study identifies a heavily eroded sanitary sewer crossing near 8757 Heritage Drive. This crossing is to be stabilized and repaired.
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
UTTERBACK CREEK
BOONE PLACE
BOONE VALLEY DRIVE
TO PLEASANT VALLEY ROAD
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION #2
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #2
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



1"=150'
WATERSHED BOUNDARY
Recommendation #3 - The Boone Valley Watershed Study revealed an existing erosion issue in the northwest section of the watershed. The study recommends that a storm sewer be constructed to re-route the small drainage channel through the rear yards.
UTTERBACK CREEK
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
TO PLEASANT VALLEY ROAD
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION#3
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #3
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects


1"=150'
WATERSHED BOUNDARY
Recommendation #4 - The Boone Valley Watershed Study exposed the existence of several private culverts in the southern portion of the watershed. It was recommended that these culverts be removed and the creek channel be remediated and restored. This cannot occur without resident cooperation.
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
UTTERBACK CREEK
TO PLEASANT VALLEY ROAD
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION#4
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #4
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects


1"=150'
WATERSHED BOUNDARY
Recommendation #5 - The Boone Valley Watershed Study identified a minor erosion issue at the southern terminus of the study area. The existing channel protection is to be reinforced and extended, pending resident cooperation.
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
UTTERBACK CREEK
TO PLEASANT VALLEY ROAD
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION#5
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #5
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects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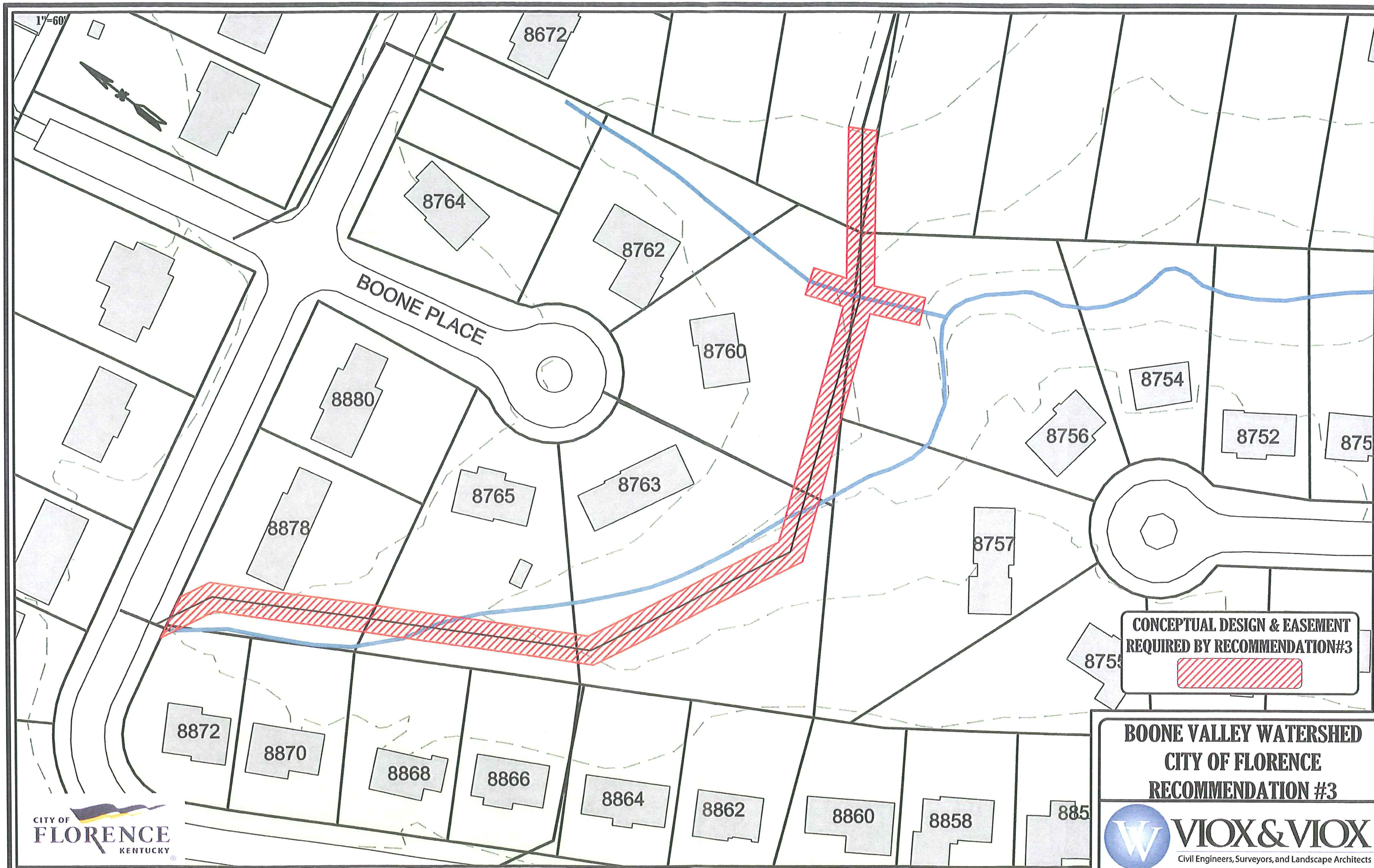
WATERSHED BOUNDARY
Recommendation #6 - The Boone Valley Watershed Study revealed a potential future erosion issue between 8756 and 8757 Heritage Drive. The study recommends this area be monitored, so a future issue can be addressed proactively.
VALLEY CIRCLE DRIVE
HERITAGE DRIVE
BOONE VALLEY DRIVE
BOONE PLACE
UTTERBACK CREEK
TO PLEASANT VALLEY ROAD
BEGIN STUDY AREA
PROPERTIES AFFECTED BY RECOMMENDATION#6
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #6
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



1"=60'
8672
8764
8762
BOONE PLACE
8760
8880
8765
8763
8878
8754
8756
8752
875
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8755
8872
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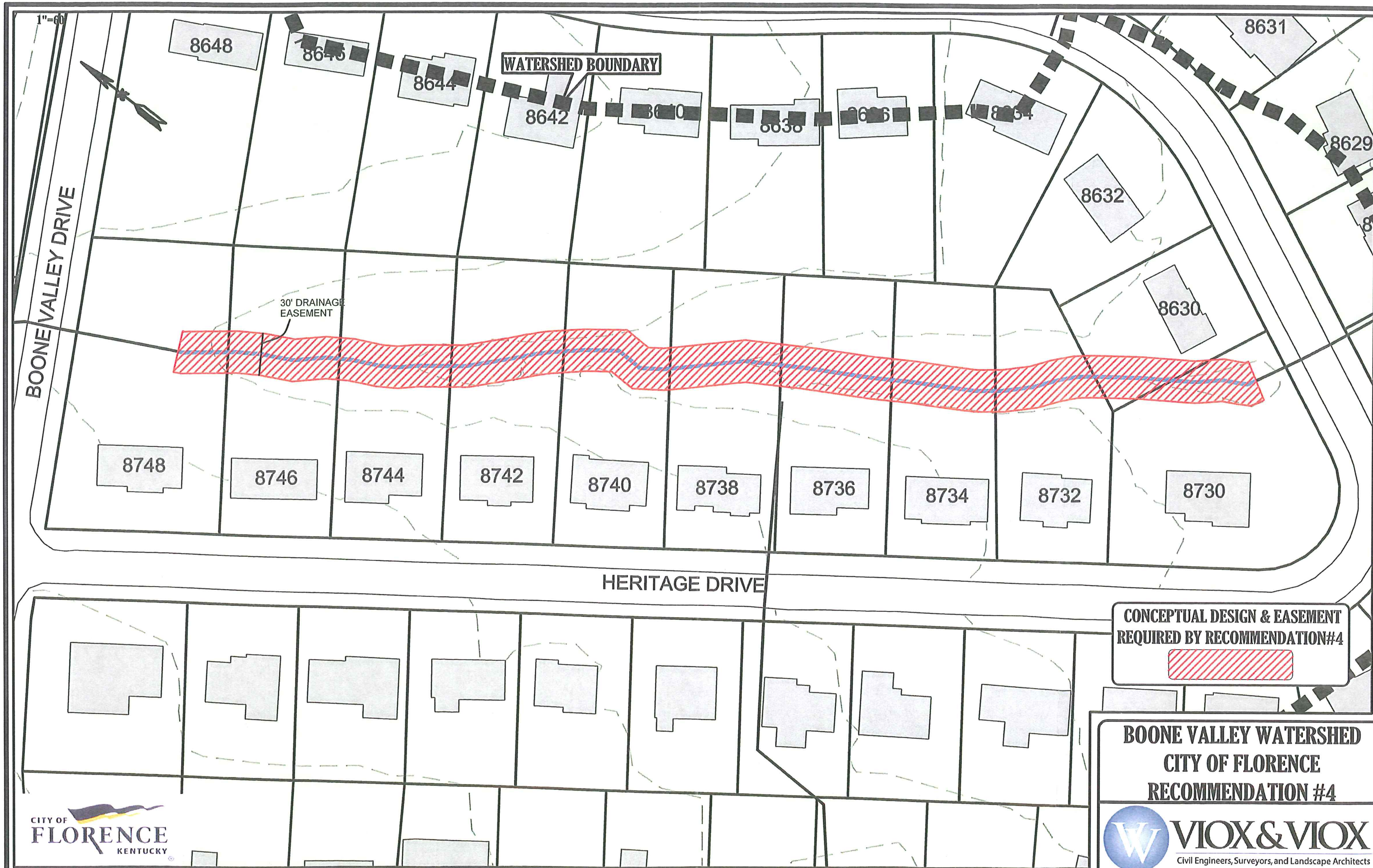
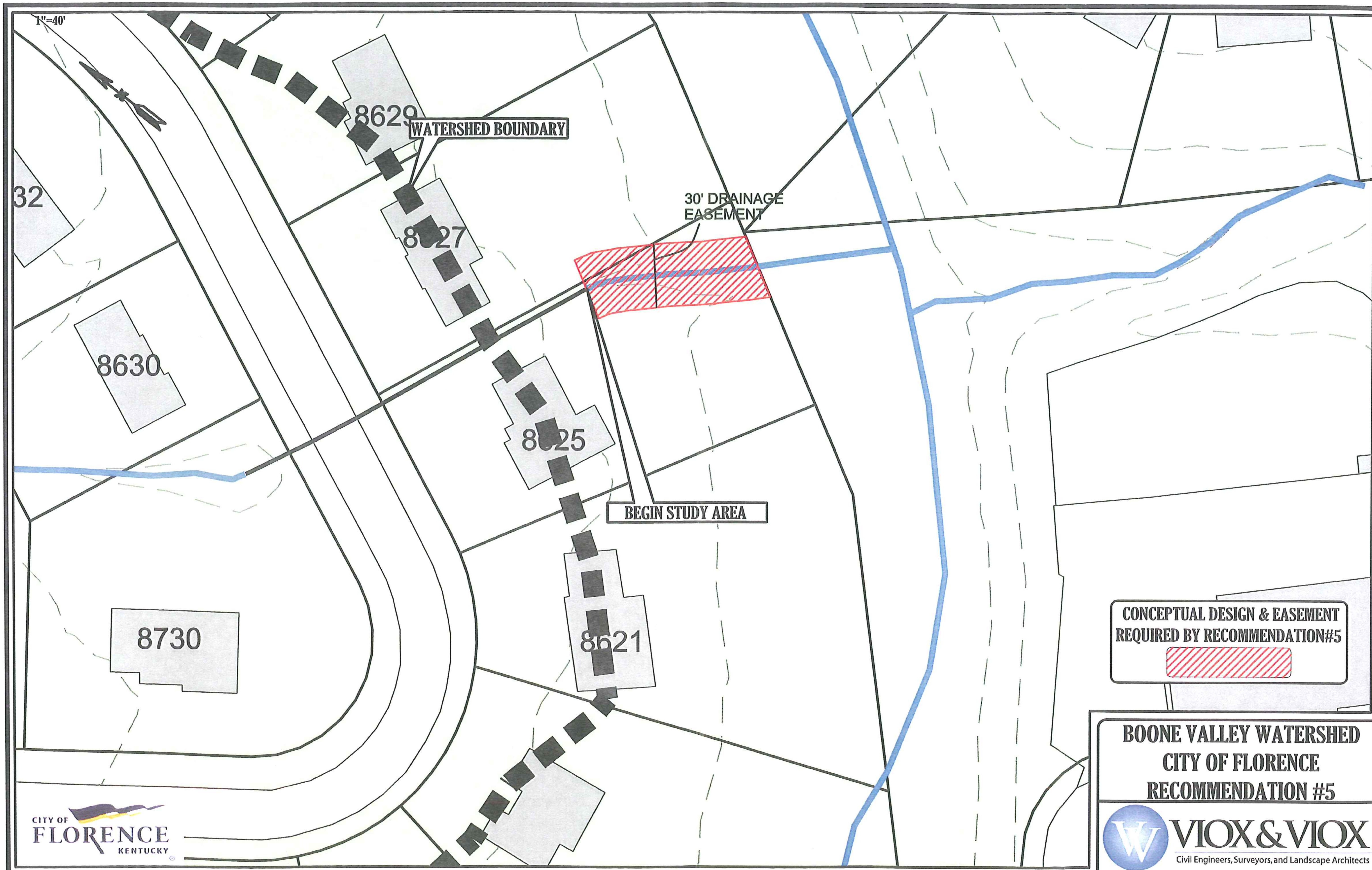
8868
8866
8864
8862
8860
8858
885
CONCEPTUAL DESIGN & EASEMENT REQUIRED BY RECOMMENDATION#3
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #3
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects



1"=60'
WATERSHED BOUNDARY
BOONE VALLEY DRIVE
30' DRAINAGE EASEMENT
8648
8644
8642
8631
8629
8632
8630
8748
8746
8744
8742
8740
8738
8736
8734
8732
8730
HERITAGE DRIVE
CONCEPTUAL DESIGN & EASEMENT REQUIRED BY RECOMMENDATION#4
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #4
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects


1"=40'
8629
WATERSHED BOUNDARY
32
30' DRAINAGE EASEMENT
8630
BEGIN STUDY AREA
8730
CONCEPTUAL DESIGN & EASEMENT REQUIRED BY RECOMMENDATION#5
BOONE VALLEY WATERSHED
CITY OF FLORENCE
RECOMMENDATION #5
CITY OF FLORENCE KENTUCKY
VIOX&VIOX
Civil Engineers, Surveyors, and Landscape Architects

APPENDIX

B

Base

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)

Analysis Options

```
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ JUL-04-2007 14:05:00
Ending Date .............. JUL-04-2007 19:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec
```

Runoff Quantity Continuity	Volume acre-feet	Depth inches
Total Precipitation	1.756	0.540
Evaporation Loss	0.000	0.000
Infiltration Loss	1.201	0.369
Surface Runoff	0.410	0.126
Final Surface Storage	0.160	0.049
Continuity Error (%)	-0.863	

Flow Routing Continuity	Volume acre-feet	Volume Mgallons
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.411	0.134
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	0.410	0.134
Surface Flooding	0.000	0.000
Evaporation Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.003	0.001
Continuity Error (%)	-0.466	

Subcatchment Runoff Summary

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB2	0.540	0.000	0.000	0.419	0.070	1.03	0.129
SUB3	0.540	0.000	0.000	0.414	0.056	0.10	0.104
SUB4	0.540	0.000	0.000	0.426	0.037	0.13	0.068
SUB5	0.540	0.000	0.000	0.444	0.038	0.08	0.070
SUB6	0.540	0.000	0.000	0.354	0.148	4.81	0.273
SUB7	0.540	0.000	0.000	0.295	0.231	10.56	0.429
SUB8	0.540	0.000	0.000	0.436	0.067	0.35	0.124
SUB9	0.540	0.000	0.000	0.281	0.260	3.13	0.482
Totals	0.540	0.000	0.000	0.369	0.126	10.56	0.234

Node Depth Summary

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.12	0.93	793.93	0	01:50	0	0
J2	JUNCTION	0.11	0.81	794.81	0	01:50	0	0
J3	JUNCTION	0.06	0.57	808.57	0	01:50	0	0
J4	JUNCTION	0.10	0.59	818.59	0	01:50	0	0
J5	JUNCTION	0.10	0.60	826.10	0	01:50	0	0
J6	JUNCTION	0.08	0.27	828.27	0	01:53	0	0
J7	JUNCTION	0.03	0.15	838.15	0	01:52	0	0
J8	JUNCTION	0.02	0.14	856.14	0	01:50	0	0
J9	JUNCTION	0.02	0.27	870.27	0	01:50	0	0
J10	JUNCTION	0.02	0.27	871.27	0	01:50	0	0
OUT1	OUTFALL	2.18	3.00	793.00	0	01:36	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	1.03	0	01:50	6.06	1.00	0.16	0
C2	CONDUIT	1.01	0	01:50	5.38	1.00	0.00	0
C3	CONDUIT	1.03	0	01:52	2.37	1.00	0.00	0
C4	CONDUIT	1.09	0	01:53	2.16	1.00	0.00	0
C5	CONDUIT	1.16	0	01:53	3.76	1.00	0.02	0
C6	CONDUIT	5.47	0	01:50	5.61	1.00	0.09	0
C7	CONDUIT	5.26	0	01:51	3.61	1.00	0.00	0
C8	CONDUIT	14.73	0	01:50	5.67	1.00	0.00	0
C10	CONDUIT	19.66	0	01:50	19.54	1.00	0.21	0
C9	CONDUIT	14.93	0	01:50	9.75	1.00	0.16	0

****
Routing Time Step Summary
****

```
Minimum Time Step           :     30.00 sec
Average Time Step           :     30.00 sec
Maximum Time Step           :     30.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.05
```

Analysis begun on: Tue Sep 02 11:41:35 2008
Total elapsed time: 00:00:01

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)

```
****************
Analysis Options
****************
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-10-2002 00:05:00
Ending Date .............. APR-10-2002 23:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec

**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         6.629         2.038
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         3.824         1.176
Surface Runoff ...........         2.469         0.759
Final Surface Storage ....         0.211         0.065
Continuity Error (%) .....         1.883

**************************        Volume        Volume
Flow Routing Continuity        acre-feet      Mgallons
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         2.466         0.803
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         2.457         0.801
Surface Flooding .........         0.000         0.000
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.007         0.002
Continuity Error (%) .....         0.030

***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB2	2.038	0.000	0.000	1.730	0.250	1.16	0.123
SUB3	2.038	0.000	0.000	0.943	0.934	1.79	0.458
SUB4	2.038	0.000	0.000	1.008	0.870	3.05	0.427
SUB5	2.038	0.000	0.000	1.031	0.866	1.85	0.425
SUB6	2.038	0.000	0.000	1.430	0.552	5.29	0.271
SUB7	2.038	0.000	0.000	1.193	0.765	11.60	0.376
SUB8	2.038	0.000	0.000	0.948	0.914	2.34	0.448
SUB9	2.038	0.000	0.000	1.189	0.832	5.49	0.409
Totals	2.038	0.000	0.000	1.176	0.759	11.60	0.372

```
******************
Node Depth Summary
******************
```

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.20	1.06	794.06	0 11:48	0	0
J2	JUNCTION	0.18	0.96	794.96	0 11:49	0	0
J3	JUNCTION	0.10	0.65	808.65	0 11:48	0	0
J4	JUNCTION	0.18	0.83	818.83	0 11:54	0	0
J5	JUNCTION	0.18	0.84	826.34	0 11:54	0	0
J6	JUNCTION	0.14	0.64	829.64	0 11:56	0	0
J7	JUNCTION	0.07	0.38	838.38	0 11:55	0	0
J8	JUNCTION	0.04	0.23	856.23	0 11:54	0	0
J9	JUNCTION	0.04	0.28	870.28	0 11:48	0	0
J10	JUNCTION	0.04	0.29	871.29	0 11:48	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0 00:04	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	1.14	0 11:48	6.23	1.00	0.17	0
C2	CONDUIT	1.10	0 11:49	6.02	1.00	0.00	0
C3	CONDUIT	2.55	0 11:55	3.10	1.00	0.00	0
C4	CONDUIT	5.53	0 11:56	3.58	1.00	0.00	0
C5	CONDUIT	7.23	0 11:56	6.51	1.00	0.10	0
C6	CONDUIT	10.81	0 11:54	6.80	1.00	0.17	0
C7	CONDUIT	10.74	0 11:55	4.40	1.00	0.00	0
C8	CONDUIT	18.82	0 11:48	6.31	1.00	0.00	0
C10	CONDUIT	25.36	0 11:48	11.33	1.00	0.27	0
C9	CONDUIT	20.80	0 11:48	10.69	1.00	0.22	0

****
Routing Time Step Summary
****

Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.02

Analysis begun on: Tue Sep 02 11:40:04 2008
Total elapsed time: 00:00:01

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)
--------------------------------------------------------------

*****************
Analysis Options
*****************
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-10-2002 00:05:00
Ending Date .............. APR-10-2002 23:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         8.421         2.589
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         4.607         1.417
Surface Runoff ...........         3.380         1.039
Final Surface Storage ....         0.262         0.081
Continuity Error (%) .....         2.033


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      Mgallons
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         3.376         1.100
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         3.366         1.097
Surface Flooding .........         0.000         0.000
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.010         0.003
Continuity Error (%) .....        -0.004


***************************
Subcatchment Runoff Summary
***************************

------------------------------------------------------------------------------------------
                        Total      Total      Total      Total      Total       Peak    Runoff
                       Precip      Runon       Evap      Infil     Runoff     Runoff     Coeff
Subcatchment               in         in         in         in         in        CFS
------------------------------------------------------------------------------------------
SUB2                    2.589      0.000      0.000      2.173      0.321       1.44     0.124
SUB3                    2.589      0.000      0.000      1.049      1.342       2.96     0.518
SUB4                    2.589      0.000      0.000      1.129      1.266       5.26     0.489
SUB5                    2.589      0.000      0.000      1.160      1.260       2.93     0.487
SUB6                    2.589      0.000      0.000      1.799      0.705       6.67     0.272
SUB7                    2.589      0.000      0.000      1.499      0.984      15.14     0.380
SUB8                    2.589      0.000      0.000      1.058      1.308       3.29     0.505
SUB9                    2.589      0.000      0.000      1.498      1.064       7.05     0.411
------------------------------------------------------------------------------------------
Totals                  2.589      0.000      0.000      1.417      1.039      15.14     0.401


******************
Node Depth Summary
******************
```

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.23	1.26	794.26	0 11:48	0	0
J2	JUNCTION	0.22	1.15	795.15	0 11:48	0	0
J3	JUNCTION	0.13	0.77	808.77	0 11:48	0	0
J4	JUNCTION	0.21	1.02	819.02	0 11:54	0	0
J5	JUNCTION	0.21	1.03	826.53	0 11:54	0	0
J6	JUNCTION	0.17	0.80	828.80	0 11:56	0	0
J7	JUNCTION	0.09	0.49	834.49	0 11:55	0	0
J8	JUNCTION	0.05	0.29	856.29	0 11:54	0	0
J9	JUNCTION	0.04	0.32	870.32	0 11:48	0	0
J10	JUNCTION	0.04	0.32	971.32	0 11:46	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0 00:03	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	1.40	0 11:48	6.63	1.00	0.22	0
C2	CONDUIT	1.37	0 11:48	6.51	1.00	0.00	0
C3	CONDUIT	3.93	0 11:55	3.64	1.00	0.00	0
C4	CONDUIT	9.02	0 11:56	4.13	1.00	0.00	0
C5	CONDUIT	11.68	0 11:56	7.47	1.00	0.16	0
C6	CONDUIT	16.14	0 11:54	7.62	1.00	0.25	0
C7	CONDUIT	16.04	0 11:55	4.91	1.00	0.00	0
C8	CONDUIT	26.13	0 11:48	6.89	1.00	0.00	0
C10	CONDUIT	34.06	0 11:48	12.36	1.00	0.37	0
C9	CONDUIT	29.12	0 11:48	11.74	1.00	0.31	0

****
Routing Time Step Summary
****

```
Minimum Time Step           :     30.00 sec
Average Time Step           :     30.00 sec
Maximum Time Step           :     30.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.00
```

Analysis begun on: Tue Sep 02 11:44:02 2008
Total elapsed time: < 1 sec

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)
--------------------------------------------------------------

****************
Analysis Options
****************
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-10-2002 00:05:00
Ending Date .............. APR-10-2002 23:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         9.836         3.024
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         4.787         1.472
Surface Runoff ...........         4.517         1.389
Final Surface Storage ....         0.312         0.096
Continuity Error (%) .....         2.233


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      Mgallons
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         4.513         1.471
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         4.501         1.467
Surface Flooding .........         0.000         0.000
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.012         0.004
Continuity Error (%) .....        -0.007


***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB2	3.024	0.000	0.000	2.223	0.646	1.72	0.214
SUB3	3.024	0.000	0.000	1.115	1.686	4.16	0.558
SUB4	3.024	0.000	0.000	1.206	1.604	7.56	0.531
SUB5	3.024	0.000	0.000	1.242	1.593	4.04	0.527
SUB6	3.024	0.000	0.000	1.840	1.043	8.07	0.345
SUB7	3.024	0.000	0.000	1.534	1.364	18.41	0.451
SUB8	3.024	0.000	0.000	1.127	1.634	4.37	0.540
SUB9	3.024	0.000	0.000	1.537	1.439	9.52	0.476
Totals	3.024	0.000	0.000	1.472	1.389	18.41	0.459

```
******************
Node Depth Summary
******************
```

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	Time of Max Occurrence hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.27	1.44	794.44	0	11:48	0	0
J2	JUNCTION	0.25	1.31	795.31	0	11:48	0	0
J3	JUNCTION	0.15	0.87	808.87	0	11:48	0	0
J4	JUNCTION	0.24	1.20	819.20	0	11:54	0	0
J5	JUNCTION	0.24	1.21	826.71	0	11:54	0	0
J6	JUNCTION	0.19	0.97	828.97	0	11:55	0	0
J7	JUNCTION	0.10	0.59	838.59	0	11:55	0	0
J8	JUNCTION	0.06	0.34	856.34	0	11:54	0	0
J9	JUNCTION	0.06	0.35	870.35	0	11:48	0	0
J10	JUNCTION	0.06	0.35	871.35	0	11:48	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0	00:03	0	0

Link Flow Summary

Link	Type	Maximum Flow CFS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	1.70	0	11:48	6.98	1.00	0.26	0
C2	CONDUIT	1.64	0	11:48	6.93	1.00	0.00	0
C3	CONDUIT	5.24	0	11:59	3.88	1.00	0.00	0
C4	CONDUIT	12.61	0	11:56	4.55	1.00	0.00	0
C5	CONDUIT	16.27	0	11:55	8.21	1.00	0.23	0
C6	CONDUIT	21.66	0	11:54	8.26	1.00	0.34	0
C7	CONDUIT	21.53	0	11:55	5.33	1.00	0.00	0
C8	CONDUIT	33.41	0	11:54	7.33	1.00	0.00	0
C10	CONDUIT	44.39	0	11:48	13.17	1.00	0.47	0
C9	CONDUIT	37.33	0	11:48	12.56	1.00	0.40	0

Routing Time Step Summary

Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.03

Analysis begun on: Tue Sep 02 11:44:22 2008
Total elapsed time: < 1 sec

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)

Analysis Options

```
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-10-2002 00:05:00
Ending Date .............. APR-10-2002 23:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec
```

Runoff Quantity Continuity	Volume acre-feet	Depth inches
Total Precipitation	14.129	4.344
Evaporation Loss	0.000	0.000
Infiltration Loss	5.144	1.582
Surface Runoff	8.252	2.537
Final Surface Storage	0.363	0.112
Continuity Error (%)	2.620	

Flow Routing Continuity	Volume acre-feet	Volume Mgallons
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	8.245	2.687
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	8.230	2.682
Surface Flooding	0.000	0.000
Evaporation Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.015	0.005
Continuity Error (%)	-0.007	

Subcatchment Runoff Summary

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB2	4.344	0.000	0.000	2.310	1.826	2.48	0.420
SUB3	4.344	0.000	0.000	1.260	2.779	8.10	0.640
SUB4	4.344	0.000	0.000	1.376	2.686	15.47	0.618
SUB5	4.344	0.000	0.000	1.425	2.666	7.49	0.614
SUB6	4.344	0.000	0.000	1.912	2.248	11.85	0.517
SUB7	4.344	0.000	0.000	1.593	2.561	34.13	0.589
SUB8	4.344	0.000	0.000	1.290	2.672	7.68	0.615
SUB9	4.344	0.000	0.000	1.591	2.679	13.96	0.617
Totals	4.344	0.000	0.000	1.582	2.537	34.13	0.584

Node Depth Summary

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	Time of Max Occurrence hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.35	2.20	795.20	0	11:54	0	0
J2	JUNCTION	0.33	1.97	795.97	0	11:54	0	0
J3	JUNCTION	0.20	1.21	809.21	0	11:54	0	0
J4	JUNCTION	0.30	1.72	819.72	0	11:54	0	0
J5	JUNCTION	0.32	1.72	827.22	0	11:54	0	0
J6	JUNCTION	0.25	1.40	829.40	0	11:54	0	0
J7	JUNCTION	0.14	0.83	838.83	0	11:54	0	0
J8	JUNCTION	0.08	0.49	856.49	0	11:54	0	0
J9	JUNCTION	0.10	0.42	870.42	0	11:48	0	0
J10	JUNCTION	0.10	0.43	871.43	0	11:48	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0	00:03	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	2.45	0	11:48	7.70	1.00	0.37	0
C2	CONDUIT	2.36	0	11:48	7.71	1.00	0.01	0
C3	CONDUIT	9.85	0	11:55	4.67	1.00	0.00	0
C4	CONDUIT	24.86	0	11:55	5.49	1.00	0.00	0
C5	CONDUIT	31.79	0	11:54	9.85	1.00	0.44	0
C6	CONDUIT	40.05	0	11:54	9.64	1.00	0.62	0
C7	CONDUIT	39.83	0	11:55	6.28	1.00	0.01	0
C8	CONDUIT	66.12	0	11:54	8.69	1.00	0.01	0
C10	CONDUIT	83.15	0	11:54	15.11	1.00	0.89	0
C9	CONDUIT	72.38	0	11:54	14.72	1.00	0.77	0

****
Routing Time Step Summary
****

```
Minimum Time Step           :     30.00 sec
Average Time Step           :     30.00 sec
Maximum Time Step           :     30.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.04
```

Analysis begun on: Tue Sep 02 11:45:19 2008
Total elapsed time: < 1 sec

25-4

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)
--------------------------------------------------------------

****************
Analysis Options
****************
Flow Units ............... CFS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-10-2002 00:05:00
Ending Date .............. APR-10-2002 23:55:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......        16.604         5.105
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         5.279         1.623
Surface Runoff ...........        10.456         3.215
Final Surface Storage ....         0.397         0.122
Continuity Error (%) .....         2.846


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      Mgallons
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......        10.445         3.404
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........        10.212         3.328
Surface Flooding .........         0.044         0.014
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.018         0.006
Continuity Error (%) .....         1.648


***************************
Subcatchment Runoff Summary
***************************

----------------------------------------------------------------------------------------------------
                           Total      Total      Total      Total      Total       Peak     Runoff
                          Precip      Runon       Evap      Infil     Runoff     Runoff      Coeff
Subcatchment                  in         in         in         in         in        CFS
----------------------------------------------------------------------------------------------------
SUB2                       5.105      0.000      0.000      2.336      2.526       2.99      0.495
SUB3                       5.105      0.000      0.000      1.319      3.427      10.70      0.671
SUB4                       5.105      0.000      0.000      1.445      3.333      20.85      0.653
SUB5                       5.105      0.000      0.000      1.500      3.311       9.71      0.649
SUB6                       5.105      0.000      0.000      1.933      2.958      14.25      0.579
SUB7                       5.105      0.000      0.000      1.611      3.256      48.62      0.638
SUB8                       5.105      0.000      0.000      1.342      3.288       3.77      0.644
SUB9                       5.105      0.000      0.000      1.614      3.400      19.97      0.666
----------------------------------------------------------------------------------------------------
Totals                     5.105      0.000      0.000      1.623      3.215      48.62      0.630


******************
Node Depth Summary
******************
```

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.40	5.00	798.00	0 11:48	0.52	5
J2	JUNCTION	0.36	3.00	797.00	0 11:55	0	0
J3	JUNCTION	0.22	1.41	809.41	0 11:54	0	0
J4	JUNCTION	0.36	2.08	820.08	0 11:54	0	0
J5	JUNCTION	0.36	2.09	827.59	0 11:54	0	0
J6	JUNCTION	0.28	1.66	829.66	0 11:54	0	0
J7	JUNCTION	0.16	0.96	832.96	0 11:54	0	0
J8	JUNCTION	0.09	0.57	856.57	0 11:54	0	0
J9	JUNCTION	0.11	0.47	870.47	0 11:48	0	0
J10	JUNCTION	0.11	0.47	871.47	0 11:48	0	0
OUT1	OUTFALL	2.99	5.00	793.00	0 00:03	0	0

****

Link Flow Summary

****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	2.96	0 11:48	8.09	1.00	0.45	0
C2	CONDUIT	2.85	0 11:48	8.01	1.00	0.01	0
C3	CONDUIT	13.25	0 11:55	5.05	1.00	0.00	0
C4	CONDUIT	33.51	0 11:55	5.95	1.00	0.00	0
C5	CONDUIT	42.55	0 11:54	10.58	1.00	0.59	0
C6	CONDUIT	53.26	0 11:54	10.22	1.00	0.83	0
C7	CONDUIT	52.95	0 11:55	6.76	1.00	0.01	0
C8	CONDUIT	91.53	0 11:54	9.43	1.00	0.01	0
C10	CONDUIT	97.60	0 11:52	15.92	1.00	1.03	6
C9	CONDUIT	99.45	0 11:54	15.39	1.00	1.05	1

****

Routing Time Step Summary

****

```
Minimum Time Step            :     30.00 sec
Average Time Step            :     30.00 sec
Maximum Time Step            :     30.00 sec
Percent in Steady State      :      0.00
Average Iterations per Step  :      1.04
```

Analysis begun on: Tue Sep 02 11:46:13 2008

Total elapsed time: < 1 sec

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)

Analysis Options

Flow Units	CFS
Infiltration Method	CURVE_NUMBER
Flow Routing Method	KINWAVE
Starting Date	APR-10-2002 00:05:00
Ending Date	APR-10-2002 23:55:00
Antecedent Dry Days	0.0
Report Time Step	00:05:00
Wet Time Step	00:05:00
Dry Time Step	00:05:00
Routing Time Step	30.00 sec

Runoff Quantity Continuity	Volume acre-feet	Depth inches
Total Precipitation	18.920	5.817
Evaporation Loss	0.000	0.000
Infiltration Loss	5.389	1.657
Surface Runoff	12.538	3.855
Final Surface Storage	0.427	0.131
Continuity Error (%)	2.988	

Flow Routing Continuity	Volume acre-feet	Volume Mgallons
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	12.526	4.082
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	11.849	3.861
Surface Flooding	0.253	0.083
Evaporation Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.020	0.007
Continuity Error (%)	3.228	

Subcatchment Runoff Summary

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB2	5.817	0.000	0.000	2.362	3.182	4.09	0.547
SUB3	5.817	0.000	0.000	1.364	4.044	12.95	0.695
SUB4	5.817	0.000	0.000	1.498	3.951	25.62	0.679
SUB5	5.817	0.000	0.000	1.559	3.927	11.59	0.675
SUB6	5.817	0.000	0.000	1.955	3.622	16.31	0.623
SUB7	5.817	0.000	0.000	1.629	3.902	64.05	0.671
SUB8	5.817	0.000	0.000	1.390	3.878	11.53	0.667
SUB9	5.817	0.000	0.000	1.629	4.080	24.27	0.701
Totals	5.817	0.000	0.000	1.657	3.855	64.05	0.663

Node Depth Summary

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.44	5.00	798.00	0 11:46	1.90	11
J2	JUNCTION	0.44	10.00	804.00	0 11:47	1.14	9
J3	JUNCTION	0.25	1.54	809.54	0 11:54	0	0
J4	JUNCTION	0.39	2.56	820.56	0 11:55	0	0
J5	JUNCTION	0.40	3.00	828.50	0 11:53	0	0
J6	JUNCTION	0.31	1.90	929.90	0 11:54	0	0
J7	JUNCTION	0.18	1.07	839.07	0 11:54	0	0
J8	JUNCTION	0.10	0.64	856.64	0 11:54	0	0
J9	JUNCTION	0.12	0.57	870.57	0 12:00	0	0
J10	JUNCTION	0.13	0.57	871.57	0 12:00	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0 00:03	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	4.09	0 12:00	8.79	1.00	0.62	0
C2	CONDUIT	4.07	0 12:00	8.51	1.00	0.01	0
C3	CONDUIT	16.64	0 11:55	5.36	1.00	0.00	0
C4	CONDUIT	41.53	0 11:55	6.30	1.00	0.01	0
C5	CONDUIT	52.38	0 11:54	11.09	1.00	0.73	5
C6	CONDUIT	66.46	0 11:55	10.61	1.00	1.03	[illegible]
C7	CONDUIT	65.96	0 11:55	7.24	1.00	0.01	[illegible]
C8	CONDUIT	112.73	0 11:54	9.94	1.00	0.01	0
C10	CONDUIT	101.65	0 11:58	15.43	1.00	1.08	12
C9	CONDUIT	100.77	0 11:56	15.25	1.00	1.07	9

****
Routing Time Step Summary
****

```
Minimum Time Step           :     30.00 sec
Average Time Step           :     30.00 sec
Maximum Time Step           :     30.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.03
```

Analysis begun on: Tue Sep 02 11:46:39 2008
Total elapsed time: 00:00:01

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.007)

Analysis Options

Flow Units	CFS
Infiltration Method	CURVE_NUMBER
Flow Routing Method	KINWAVE
Starting Date	APR-10-2002 00:05:00
Ending Date	APR-10-2002 23:55:00
Antecedent Dry Days	0.0
Report Time Step	00:05:00
Wet Time Step	00:05:00
Dry Time Step	00:05:00
Routing Time Step	30.00 sec

Runoff Quantity Continuity	Volume acre-feet	Depth inches
Total Precipitation	20.823	6.402
Evaporation Loss	0.000	0.000
Infiltration Loss	5.463	1.680
Surface Runoff	14.266	4.386
Final Surface Storage	0.432	0.133
Continuity Error (%)	3.174	

Flow Routing Continuity	Volume acre-feet	Volume Mgallons
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	14.254	4.645
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	13.120	4.275
Surface Flooding	0.538	0.175
Evaporation Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.021	0.007
Continuity Error (%)	3.969	

Subcatchment Runoff Summary

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Peak Runoff CFS	Runoff Coeff
SUB1	6.402	0.000	0.000	2.378	3.734	5.66	0.583
SUB3	6.402	0.000	0.000	1.394	4.560	15.24	0.712
SUB4	6.402	0.000	0.000	1.535	4.471	30.50	0.698
SUB5	6.402	0.000	0.000	1.598	4.443	13.48	0.694
SUB6	6.402	0.000	0.000	1.958	4.178	19.70	0.653
SUB7	6.402	0.000	0.000	1.640	4.437	78.23	0.693
SUB8	6.402	0.000	0.000	1.423	4.361	13.29	0.681
SUB9	6.402	0.000	0.000	1.640	4.640	30.15	0.725
Totals	6.402	0.000	0.000	1.680	4.386	79.28	0.685

Node Depth Summary

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	Time of Max Occurrence hr:min	Total Flooding acre-in	Total Minutes Flooded
J1	JUNCTION	0.47	5.00	798.00	0	11:45	2.96	15
J2	JUNCTION	0.47	10.00	804.00	0	11:46	3.06	11
J3	JUNCTION	0.26	1.67	809.67	0	11:48	0	0
J4	JUNCTION	0.42	3.00	821.00	0	11:52	0	0
J5	JUNCTION	0.44	6.00	831.50	0	11:51	0.54	7
J6	JUNCTION	0.33	2.17	830.17	0	11:54	0	0
J7	JUNCTION	0.19	1.17	839.17	0	11:54	0	0
J8	JUNCTION	0.11	0.71	856.71	0	11:54	0	0
J9	JUNCTION	0.13	0.72	870.72	0	12:00	0	0
J10	JUNCTION	0.13	0.72	871.72	0	12:00	0	0
OUT1	OUTFALL	2.99	3.00	793.00	0	00:03	0	0

****
Link Flow Summary
****

Link	Type	Maximum Flow CFS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Maximum Velocity ft/sec	Length Factor	Max/ Full Flow	Total Minutes Surcharged
C1	CONDUIT	5.66	0	12:00	9.38	1.00	0.96	0
C2	CONDUIT	5.65	0	12:00	9.46	1.00	0.02	0
C3	CONDUIT	20.32	0	11:55	5.66	1.00	0.00	0
C4	CONDUIT	49.92	0	11:55	6.62	1.00	0.01	0
C5	CONDUIT	62.61	0	11:54	11.44	1.00	0.87	0
C6	CONDUIT	67.84	0	11:59	10.65	1.00	1.05	11
C7	CONDUIT	70.92	0	11:51	20.39	1.00	0.01	0
C8	CONDUIT	131.21	0	11:48	11.19	1.00	0.01	0
C10	CONDUIT	100.01	0	12:00	15.50	1.00	1.06	15
C9	CONDUIT	100.24	0	11:57	15.34	1.00	1.06	11

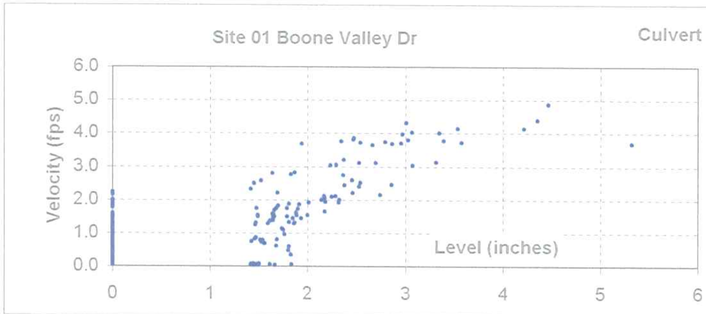
****
Routing Time Step Summary
****

```
Minimum Time Step           :     30.00 sec
Average Time Step           :     30.00 sec
Maximum Time Step           :     30.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.04
```

Analysis begun on: Tue Sep 02 11:47:27 2008
Total elapsed time: < 1 sec

APPENDIX

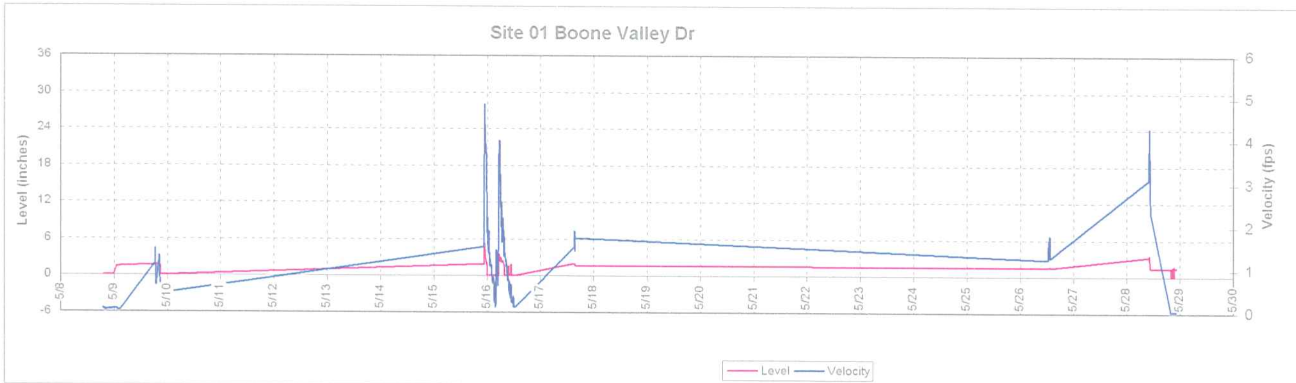
C

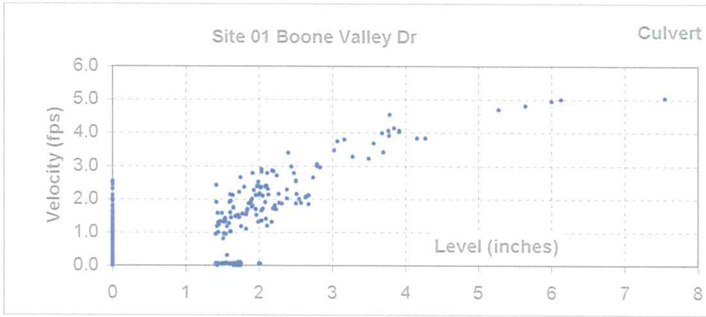


Valley View Watershed Study 2007 Site 01 Boone Valley Dr

	LEV (inch)	VEL fps)	FLOW (mgd)	RAIN (inch)
Min	0.00	-0.70	0.00	
Max	5.32	4.87	1.59	0.11
Average	0.04	0.11	0.01	
Total				0.22

Notes:

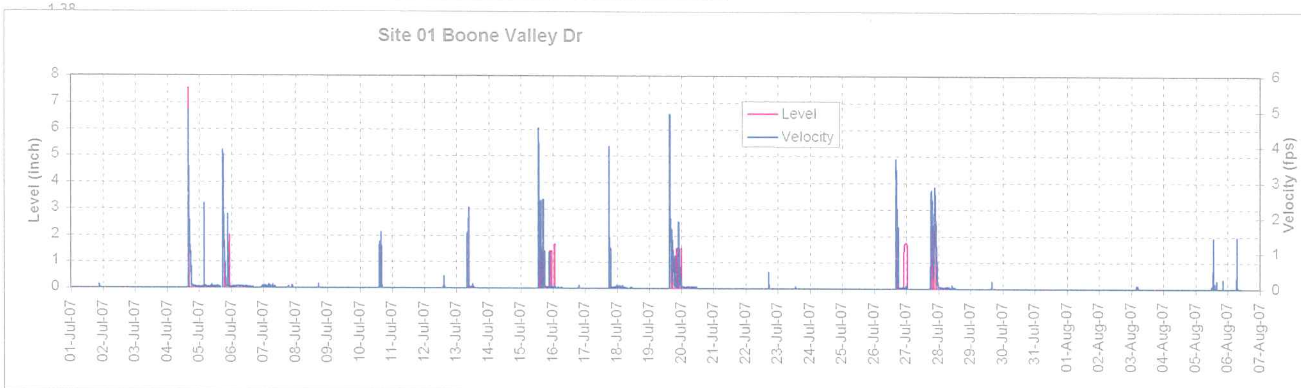


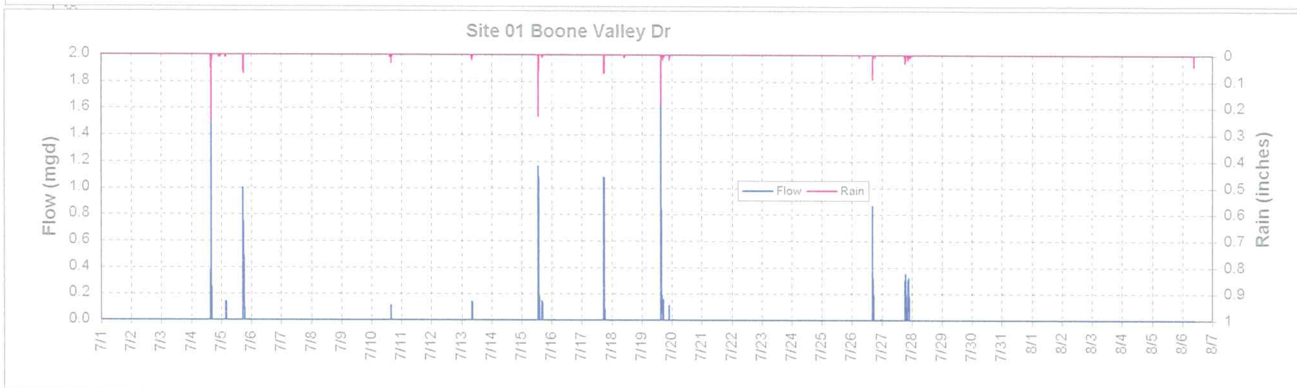


Valley View Watershed Study 2007 Site 01 Boone Valley Dr

	LEV (inch)	VEL fps)	FLOW (mgd)	RAIN (inch)
Min	0.00	-3.39	-0.20	
Max	7.55	5.05	3.51	0.25
Average	0.04	0.04	0.00	
Total				1.95

Notes:



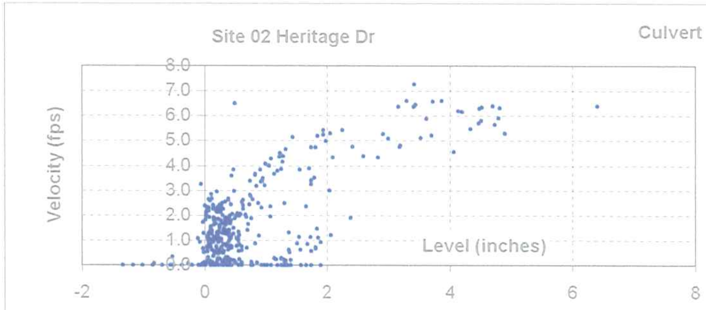


Site Name:	Site 01 Boone Valley Dr	MH:		Depth:		Valley View watershed study				
Location:	Boone Valley Dr	Pipe Size:	36in	El. MH:		Site Conditions:				
Site Features:	Culvert	Pipe Shape	Circular	Other:		Night installation	Supplied air	Drive up	ETC	
Meter Type:	Sigma 910					No	No	Yes		

Actual Job Site			DEPTH			VELOCITY			Computer Current Read						COMMENTS:
Date	Time	Crew	Flow at Probe	Flow at Center (in)	Invert Debris	At Probe	At Center (ft/sec)	Average	Depth - inches	Velocity- fps	Signal Strength	DATA	Batt. Volts	Data Interval Min	Record current Meter ID (Code or SN) and Sensor ID in comments
5/8/07	18 50	DS, ML													Equipment Installed at site and turned on to begin collecting data
5/16/07	14.53	DS, KS			0			0.16	0	0.06	92		4.6v	5	Checked Status, Changed Battery, Downloaded Readings
5/30/07	9.39	DS, KS			0			0.11	0	0.05	98		4.3v	5	Changed Battery, downloaded readings

APPENDIX

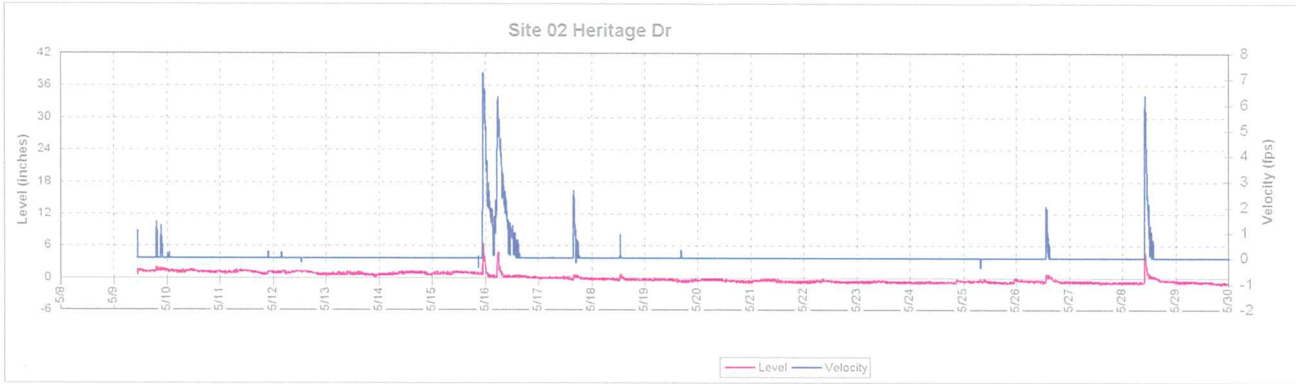
D

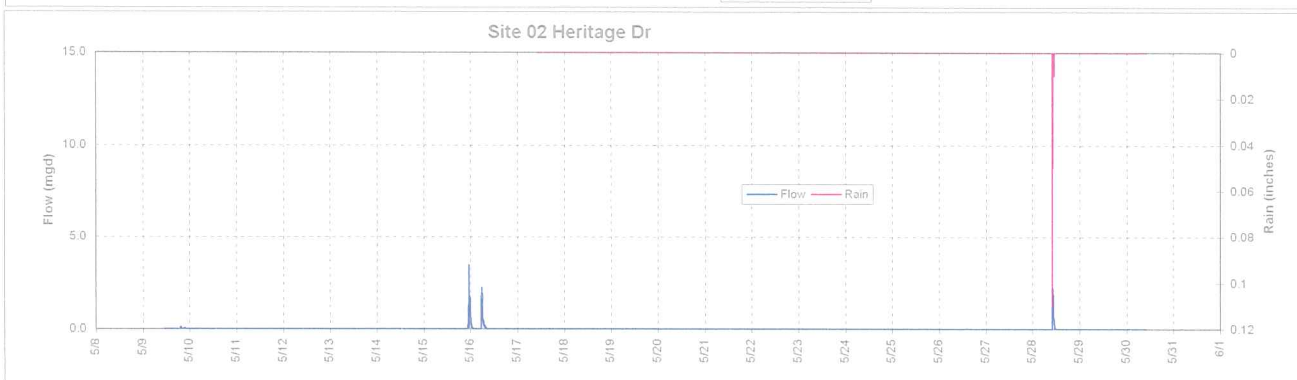


Valley View Watershed Study 2007 Site 02 Heritage Dr

	LEV (inch)	VEL fps)	FLOW (mgd)	RAIN (inch)
Min	-1.33	-0.37	-0.01	
Max	6.40	7.26	3.51	0.11
Average	-0.03	0.11	0.01	
Total				0.22

Notes:

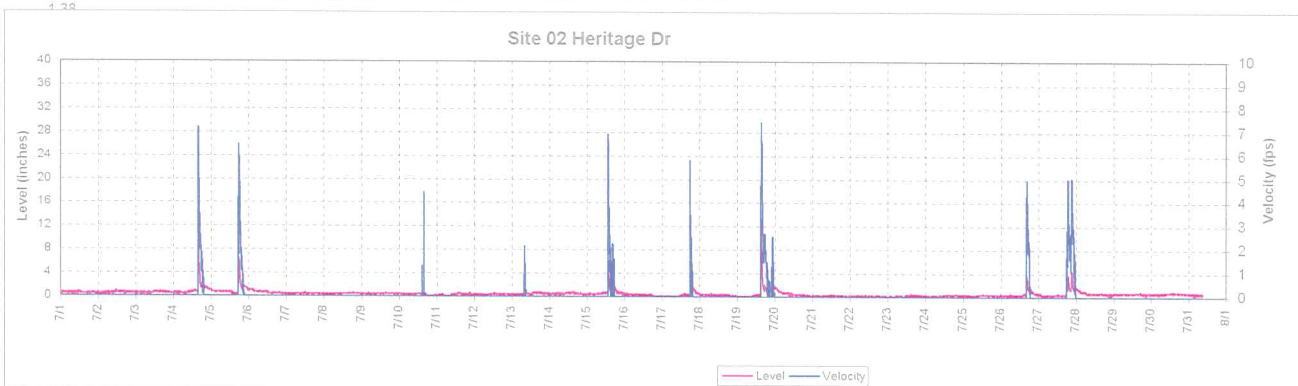


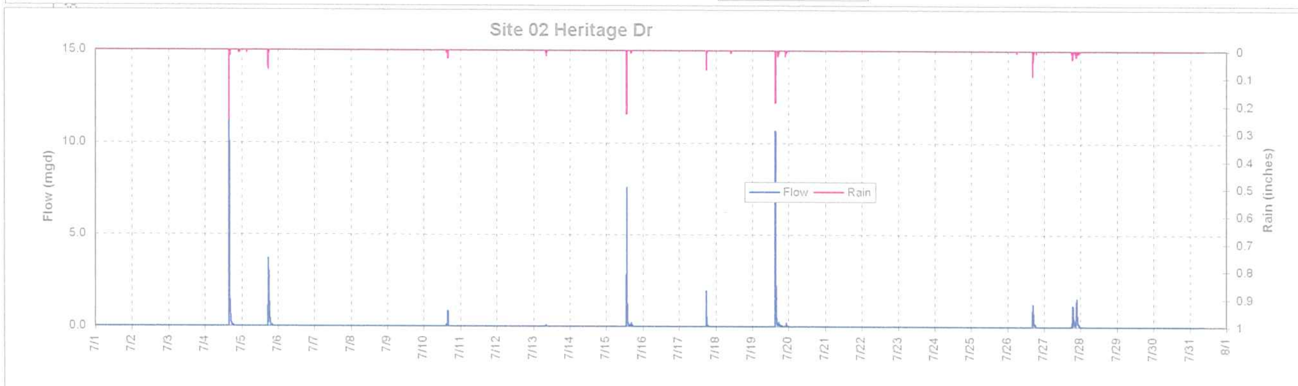


Valley View Watershed Study 2007 Site 02 Heritage Dr

	LEV (inch)	VEL fps)	FLOW (mgd)	RAIN (inch)
Min	-0.69	-4.09	-0.09	
Max	24.16	7.45	21.13	0.25
Average	0.55	0.09	0.03	
Total				2.50

Notes:





Site Name:	Site 02 Heritage Dr	MH:		Depth:		Valley View watershed study			
Location:	Heritage Dr	Pipe Size:	36 in.	El. MH:		Site Conditions:			
Site Features:	Culvert	Pipe Shape	Circular	Other:		Night installation	Supplied air	Drive up	ETC
Meter Type:	Sigma 920					No	No	Yes	

Actual Job Site			DEPTH			VELOCITY			Computer Current Read						COMMENTS:
Date	Time	Crew	Flow at Probe	Flow at Center (in)	Invert Debris	At Probe	At Center (ft/sec)	Average	Depth - inches	Velocity-fps	Signal Strength	DATA	Batt. Volts	Data interval Min	Record current Meter ID (Code or S#) and Sensor ID in comments
6/9/07	16:25	DS, ML							n/a	n/a	n/a		12v	n/a	Installed equipmenr and turned on
6/16/07	11:40	DS, KS			0			0.23	.541 in.	0.56	53		11.5	5	Changed Batteries and downloaded readings
6/30/07	9:55	DS, KS			0			0.11	.237 in.	0	0		11.2v	5	Downloaded readings, did not need to change batteries

APPENDIX

E

E.1 Compilation of Zone 1 Residents' Comments

Ms. Beth Jones (1)
8868 Valley Circle Drive
In August 2007, Ms. Jones submitted a written survey to Viox & Viox. She stated that she has lived at the property for 30 years and the creek channel runs just behind her property. She has experienced yard flooding near the creek and creek bed erosion. She stated that the rate at which the water would recede from her yard depended on how much rain had been received.

Mr. Keen Johnson (2)
8878 Valley Circle Drive
On August 29, 2007, Mr. Johnson met with Mr. Bill Viox at the City of Florence. Mr. Johnson did not return a survey; however, he did state that he has lived in his home for 27 years and the creek channel runs through his property. Mr. Johnson said that when he moved into his home, the creek was not very wide, but the continued erosion has ruined his yard. It was discussed that water drains from a pipe behind 8866 Valley Circle Drive and then stops, at which point the water comes out with force. The water that comes into Mr. Johnson's yard is originating from the street. His trees are rotting because of the water. The mosquitoes are very bad because of the standing water. He would like to have the problem corrected and does not mind losing more of his trees if the problem is resolved.

Mr. and Mrs. Robert and Arleen Lakeman (3)
8765 Boone Place
In August 2007, Mr. and Mrs. Lakeman submitted a completed written survey to Viox & Viox. In addition, they both met with Mr. Bill Viox at the City of Florence on August 29, 2007. They stated that they have lived in their home for 7 years and the creek channel is running through their property. They have experienced standing water in their yard which has attracted bugs, mosquitoes, and snakes. Their yard has also flooded several times. They have seen erosion of the creek bed, as well as garbage, cans and other debris floating in the creek. They stated that the creek has become very dangerous for young children and pets. They said the problems occur in the spring, summer, and fall after both long rain events and short cloudbursts. They also said that the water does not recede quickly and sometimes remains for several days or weeks.

Mr. and Mrs. Lakeman stated that they would prefer the channel to be enclosed in a pipe. It was discussed at the interview that the force of the channel water begins at a catch basin behind the Lakeman house. They remembered that similar problems were addressed by the City years ago, while the erosion on their part of the creek has not been addressed.

Mr. Charlie Knox (4)
8763 Boone Place
In August 2007, Mr. Knox submitted a completed written survey to Viox & Viox. In addition, he met with Mr. Bill Viox at the City of Florence on August 29, 2007. He stated that he has lived in his home for 28 years and the creek channel runs through his property. He has experienced water standing in his yard for a period of time after heavy rains. He has also experienced yard flooding after heavy rains and the water tends to rush at a high rate of speed during the rain. The creek bed has been eroding on both sides and, because of this, he is close to losing the gazebo and bridge on his property. The problems tend to occur from March to December and can happen after a long rain event or after a short cloudburst. He said the water will tend to recede shortly after the rain subsides. Mr. Knox added that the problems have attracted a lot of mosquitoes.

Mr. Knox stated that water behind his home is coming in from multiple directions. He said that he would just like to see the water contained in whatever means possible.

Mr. Donald Schneider (5)
8760 Boone Place
In August 2007, Mr. Schneider submitted a completed written survey to Viox & Viox. In addition, he participated in an interview with Mr. Bill Viox at the City of Florence on August 29, 2007. Mr. Schneider has lived in his home for 27 years and the creek channel runs through his property. He has not experienced any problems and stated that drainage is working properly in the original natural channel. Mr. Schneider stated that he was very concerned about the possibility of losing his trees. He does not want the channel to be closed. It was discussed that water runs down Mr. Schneider's driveway and into a storm drain.

Mr. and Mrs. Jim and Nancy Higgins (6)
8866 Valley Circle Dirve
In August 2007, Mr. and Mrs. Higgins returned a completed written survey to Viox & Viox. They stated that they have lived in their home for 30 years and the creek channel does not run through their property. They have not experienced any problems.

E.2 Compilation of Zone 2 Residents' Comments

Mr. Joe Freimuth (7)
8750 Heritage Drive
In August 2007, Mr. Freimuth returned a completed written survey to Viox & Viox. He stated that he has lived in his home for 3 years and the creek channel runs through his back yard. He has experienced standing water and flooding in his front yard (to the left side if looking at his home). In addition,

Mr. Freimuth has seen a small amount of water enter the front of his garage to the back wall of the garage (front of house). The problem tends to occur in the spring, summer, and fall after long rain events. The water does tend to recede shortly after the rain stops. Mr. Freimuth added that the flooding has not been a significant problem.

Mr. David Rice (8)
8748 Heritage Drive
In August 2007, Mr. Rice returned a completed written survey to Viox & Viox. He stated that he has lived in his home for 10 years and the creek channel runs through his property in a drain pipe. He has not experienced any problems.

Mr. Anthony Depenbrock (9)
8746 Heritage Drive
In August 2007, Mr. Depenbrock returned a completed written survey to Viox & Viox. He stated that he has lived in his home for 28 years and the creek channel runs through his property. Mr. Depenbrock has experienced flooding in his yard after a hard rain. He has also witnessed erosion of the creek bed. He stated the problem occurs most often in the spring, after a short cloudburst or a long day of hard rain. The water will recede after a few hours.

Mr. Todd McEntyre (10)
8744 Heritage Drive
In August 2007, Mr. McEntyre returned a completed written survey to Viox & Viox. Mr. McEntyre stated that he has lived in his home for 5 years and the creek channel runs through his property. He stated that he experiences yard flooding about 3 to 4 times a year. He said that flooding occurs in his front yard where, according to the previous owner, the City of Florence dug up a pipe years ago. In addition, Mr. McEntyre said, during heavy rain, some water seeps into his basement due to the previous stated problem. Mr. McEntyre's retaining wall by the creek has collapsed because of the continued erosion of the creek bed. He added that the problems occur after a steady, long rain event and the water will usually recede after a day or two. After one incident, however, he spread out extra mulch on his property to try and soak up the rain water.

Mr. McEntyre stated that he is unsure what transpired prior to his purchasing his home, but there is a small valley in his front yard. As stated previously, the previous owner said it was caused by the City of Florence. He believes that the erosion problem may be related to the original landscaping by the creek which became weathered by time.

Ms. Kathy Lawson (11)
8740 Heritage Drive
In August 2007, Ms. Lawson submitted a completed written survey to Viox & Viox. She stated that she has lived in her house for 10 years and the creek channel runs through her property. She has experienced standing water in her yard from the creek. In addition, she has noticed some erosion of the creek bank after heavy rain. The problem can occur after either long rains or short cloudbursts. Ms. Lawson added that she is concerned with the horrible condition of the creek and that other home owners on her street are not keeping up with their vegetation. She stated that she is concerned with her property value if she were ever to sell her home.

Mr. Stanley Bond (12)
8730 Heritage Drive
In August 2007, Mr. Bond submitted a completed written survey to Viox & Viox. He stated that he has lived in his home for 17 years and the creek channel is running through his property. He has experienced standing water and flooding in his yard. He stated that it occurs at least 7 to 8 times a year. The creek bank has eroded so badly that he can no longer get his riding tractor near the edge in some places, as the drop-off is nearly 12 inches. The problem occurs all year, and usually after short cloudbursts. The water will recede shortly after the rain ends, unless the drain is blocked with debris.

APPENDIX

F

CD