6.0 STREAM SENSITIVITY ANALYSIS MODEL

In 1998, the Center for Watershed Protection (CWP) published the Rapid Watershed Planning Handbook. This document introduced rapid assessment methodologies for watershed planning. Recently, the CWP released the *Watershed Vulnerability Analysis* as a refinement of the techniques used in the *Rapid Watershed Planning Handbook* (Zielinski 2002). The vulnerability analysis focuses on existing and projected impervious cover as the driving forces impacting stream quality within a watershed. Based on studies pointing to the relationship between impervious thresholds and stream quality (Schueler 1994; Brabec *et al*, 2002), the CWP developed an impervious cover model, based upon unmitigated urbanization. The model is used to classify subwatersheds and associated streams into one of three categories: Sensitive, Impacted, or Non-Supporting.

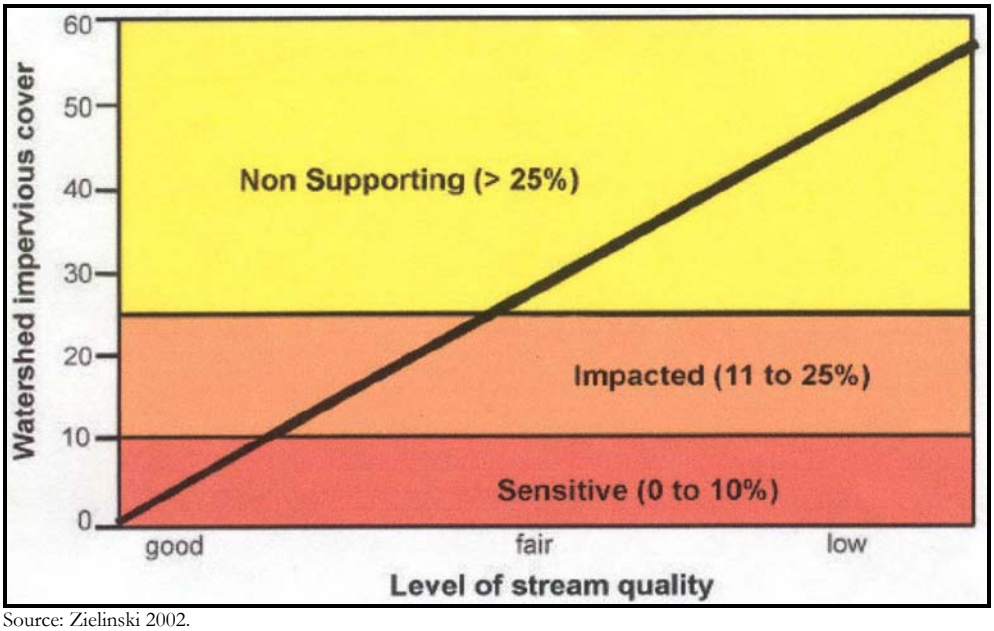
In general, Sensitive subwatersheds have less than 10% impervious cover, stable channels, excellent habitat, good water quality, and diverse biological communities. They are called "sensitive" to indicate that while they are in a fairly stable, natural state, these subwatersheds are extremely sensitive to increases in impervious cover resulting from development. Streams in Non-Supporting subwatersheds generally have greater than 25% impervious cover, highly degraded channels, degraded habitat, poor water quality, and poor-quality biological communities. Impacted subwatersheds fall somewhere in-between these two extremes. Table 6.0-i describes the impervious categories in more detail.

Table 6.0-i. Impervious categories and descriptions based on the Impervious Cover Model.

Category	% Impervious Cover	Description
Sensitive	Less than 10%	Subwatershed generally exhibits very little impervious cover (≤10%), stable stream channels, excellent habitat, good water quality, and diverse biological communities.
Impacted	Greater than 10% less than 25%	Subwatershed generally possesses moderate impervious cover (10-25%), and somewhat degraded stream channels, altered habitat, decreasing water quality, and fair-quality biological communities.
Non-Supporting	Greater than 25%	Subwatershed generally has high impervious cover (>25%), and highly degraded stream channels, degraded habitat, poor water quality, and poor-quality biological communities.

Source: (Zielinski 2002)

Figure 6.0-A. The Impervious Cover Model predicts Sensitive streams will begin to degrade when impervious surfaces exceed 10% of a catchment's area and will become Non Supporting at 25% imperviousness.



Source: Zielinski 2002.

Photo 6.0-1. A Sensitive subwatershed generally exhibits very little impervious cover, resulting in stable stream channels, excellent stream habitat, good water quality, and diverse biological communities.

Photo 6.0-2. Impacted subwatersheds generally possess moderate impervious cover. As impervious cover exceeds 10%, stream channels begin to degrade, habitat is altered, water quality decreases, and the diversity of biological communities decreases.

Photo 6.0-3. Non-Supporting subwatersheds generally have high impervious cover. Impervious cover that exceeds 25% leads to highly degraded stream channels, degraded habitat, poor water quality, and poor-quality biological communities.

AES used a modified Stream Sensitivity Analysis Model to compare subwatershed quality across the Bonne Femme watershed. Four steps are followed and used to generate four primary outcomes that can be used by watershed planners and resource managers. The four steps/outcomes are listed below and described in detail in the following paragraphs:

1. Initial classification of subwatershed based on current impervious cover.
2. Final classification/restorable potential of borderline subwatershed using a field criteria analysis.
3. Ranking of most vulnerable subwatersheds based on projected impervious cover.
4. Ranking of priority subwatersheds for immediate planning and BMP implementation.

Step 1: Initial Classification

The first step in the vulnerability analysis involves an initial classification of each subwatershed based on existing measured impervious cover. Existing impervious cover for each subwatershed is calculated based on the methodology outlined at the end of this chapter (Chapter 6). Each subwatershed then receives an initial classification (Sensitive, Impacted, or Non-Supporting) based solely on percent of existing impervious cover (Table 6.0-ii, Figure 6.0-A).

Originally nineteen (19) watersheds were delineated for the study area. This delineation was strictly based upon topographic breaks and ridges within the watershed. Subwatershed boundaries were later modified in order to account for the complexities of the karst geology, specifically the Devils Ice Box and Hunters Cave recharge areas. As a final cut twenty-three (23) subwatersheds were identified and utilized for the Bonne Femme Watershed Analysis.

Two subwatersheds are initially classified as Impacted, North Branch Little Bonne Femme (23% IC) and Clear Creek (14.5% IC), while the remaining 21 are classified as Sensitive. The two Impacted subwatersheds are located in the northern portion of the watershed along the southern developed portions of Columbia. All remaining subwatersheds exhibit little development that contributes to impervious surfaces. Table 6.0-iii, located at the end of this chapter, lists existing impervious cover percentage and existing impervious classifications for all 23 subwatersheds.

Step 2: Final Classification

Analysis using existing impervious cover may not exactly reflect actual stream or subwatershed conditions. Therefore, field criteria are analyzed in Step 2 of the vulnerability assessment process so that *borderline* initial subwatershed classifications are more accurately categorized into final classifications and restorability potential. Three borderline subwatersheds were identified following the initial classification (Step 1). Sensitive subwatersheds with an impervious range between 7 -10% are borderline Impacted. Impacted subwatersheds with impervious ranges between 10-13% are borderline Sensitive, and those with 22-25% are borderline Non-Supporting. Non-Supporting subwatersheds between 25-28% impervious area are borderline Impacted.

For this report, AES examined nine field criteria for analyzing the borderline classifications (Listed below). In the following list of criteria, wetlands were mapped according the National Wetland Inventory data created by the Fish and Wildlife Service (FWS). Natural Heritage Points were provided by the Missouri Department of Conservation (MODOC) and refer to recorded locations of threatened and endangered species or ecosystems of conservation concern. State Natural Heritage Programs gather objective scientific information about these species and ecosystems to improve natural resource management decisions. Also in the criteria, floodplain refers to the 100-year regulated floodplain as delineated by the Federal Emergency Management Agency (FEMA). A buffer analysis was generated using the National Land Cover Data (NLCD) from the United States Geologic Survey (USGS). Cover types pertaining to humanized features such as urbanization and agriculture were eliminated and the remaining cover types were quantified and normalized as the percent of vegetated 100 foot and 200 ft buffers. Dams data were provided by MISDIS and the conservation lands, groundwater recharge and karst areas were provided by Boone County.

Table 6.0-ii outlines the final classification guidelines for adjusting borderline initial subwatershed classifications using field criteria. If, for example, a borderline Sensitive subwatershed (10-13% imperviousness) meets the majority of field criteria (at least 5 of 9), the subwatershed is re-classified as Sensitive. Likewise, if the same borderline Sensitive subwatershed meets 0-4 field criteria, the subwatershed is re-classified as Restorable Sensitive.

The described criteria were used because of their availability and their documented overall contribution to maintaining a healthy and functioning ecosystem. Each data layers serves as a surrogate for an important or a series of important ecological roles that a particular feature services in the overall health of a subwatershed.

The field criteria used in the analysis are as follows:

1. Subwatershed contains more than 10% wetland area.
2. Subwatershed contains greater than 20 Natural Heritage Points.
3. Subwatershed contains greater than 10% floodplain.
4. Subwatershed has greater than 80% 100-foot vegetated buffer.
5. Subwatershed has greater than 80% 200-foot vegetated buffer.
6. No barriers (Dams) impede movement of fish and other aquatic organisms between the subwatersheds.
7. Subwatershed has greater than 10% state or conservation land.
8. Subwatershed contains groundwater recharge zones.
9. Subwatershed contains karst topography.

Table 6.0-ii. Final classification guidelines for borderline subwatersheds.

Category	Field Criteria Analysis
Sensitive	(7-13% impervious & ≥5 field criteria met)
Restorable Sensitive	(7-10% impervious & <5 criteria met) or (10-13% impervious & ≥5field criteria met)
Impacted	(10-13% impervious & 0 field criteria met) or (22-25% impervious & ≥5 field criteria met) or (25-28% impervious & ≥5 field criteria met)
Restorable Impacted	(22-25% impervious & 1-4 criteria met) or (25-28% impervious & ≥5 field criteria met)
Non-Supporting	(25-28% impervious & 0 field criteria met)
Restorable Non-Supporting	(>28% impervious & ≥5 field criteria met)

During the analysis, the subwatershed in question either meets or does not meet each of the 9 field criteria. Three borderline subwatersheds (North Branch Little Bonne Femme, Middle Little Bonne Femme and Bass Creek) were subjected to the field criteria analysis. Based on this analysis, all three of the borderline subwatersheds were given adjusted final classifications (Table 6.0-iii, Figure 6.0-B Final Subwatershed Classification). One Impacted subwatershed (North Branch Little Bonne Femme) was re-classified to Restorable Impacted. The Middle Little Bonne Femme subwatershed was re-classified from Sensitive to Restorable Sensitive. And the Bass Creek subwatershed was reclassified from Sensitive to Restorable Sensitive.

Step 3: Projected Impervious Cover and Vulnerability Ranking

Projected impervious cover was evaluated during Step 3 of the vulnerability analysis process. For this study, projected imperviousness was based on a 25-year build-out analysis, assuming current practices with few required post-construction BMPs. The build-out was created to provide a best estimate of what is planned for the future and therefore errors are inherent and the analysis is meant to provide a ballpark estimate of what could happen. The build-out analysis used information from a variety of sources, including CATSO 2030, Vision 2020, infrastructure plans, population projections, and the professional judgment of planners and engineers about where development is likely to occur. As with the initial classification, a projected classification of Sensitive, Impacted, or Non-Supporting is assigned to each subwatershed. This analysis is important to watershed planners when trying to identify Sensitive, Restorable Sensitive, and Impacted subwatersheds that are most vulnerable to future development pressure.

The future classification, based on projected impervious cover, resulted in 19 Sensitive, 2 Impacted, and 2 Non-Supporting subwatersheds (Table 6.0-ii Adjusted Final Classifications of Subwatersheds; Figure 6.0-C Future Conditions - Impervious Cover Model). The Clear Creek and North Branch Little Bonne Femme subwatersheds are expected to change from Impacted to Non-Supporting subwatersheds as a result of expanded development in the southern portion of Columbia. Gans and Bass Creek subwatershed are both expected to change from Sensitive to Impacted. Bass Creek is a result of projected development in the southern portion of the watershed near Ashland and Gans is associated with Columbia's expansion.

The vulnerability to land use change of each subwatershed was determined by considering the following questions:

1. Will the subwatershed classification change? (e.g. shift from sensitive to impacted);
2. Does the subwatershed classification come close to changing (within 2%)? (e.g. future impervious cover is projected at 24%);
3. What is the absolute change in impervious cover? (e.g. if two subwatershed increase impervious cover by 9% a shift from 3% to 12% may be more vulnerable than a subwatershed that shifts from 6% to 13%, even though its total impervious cover is lower).

A vulnerability of low, medium, or high was assigned to each subwatershed (Table 6.0-iii, Figure 6.0-D) based on the following:

Low = no change in classification, <5% change in impervious cover
Medium = classification close to changing or changes from borderline to more impacted and/or 5-10% change in impervious cover
High = change in classification and/or >10% change in impervious cover

The vulnerability to land use change analysis resulted in the classification of 13 subwatersheds as low, 6 subwatershed as medium, and 4 subwatersheds as high. Nearly all low vulnerable subwatersheds are located in the southwest, south central and northeast portions of the watershed where very little if any development is expected in the next 25 years. The six medium ranked vulnerable subwatershed were classified as Sensitive in Step 1 of the process but are expected to change by >7% impervious cover in the future. The 4 highly vulnerable subwatersheds are directly associated with the development expected in the southern portion of Columbia and the northern portion of Ashland.

Step 4: Priority Ranking

The last step in the analysis includes an evaluation of restoration capability and a ranking of priority subwaterseds based on results obtained from Steps 1, 2, and 3. This is accomplished by creating a priority ranking that identifies the most sensitive subwatersheds in need of immediate BMP implementation, open space acquisition, or restoration. The following criteria are used to rank each subwatershed as Lesser, Moderate, or Elevated relative to the other subwatersheds in the Bonne Femme watershed:

1. Vulnerability, as determined under Step 3.
2. The presence of karst topography.
3. The presence of cave recharge zones.
4. Development pressure within the subwatershed, as determined by the fraction of land that is projected to change to a more impervious land use in the next 25 years.
5. Fraction of subwatershed that is conservation area.
6. Fraction of subwatershed that is publicly owned.

Points are given to each criteria listed above and are shown on Table 6.0-iii. In general, values for each criteria are classified as Lesser, Moderate, or Elevated priority and were assigned 1, 2, or 3 points, respectively. However, Criteria 1 and 2 (subwatershed vulnerability and Karst Topography) are weighted heavier than other criteria due to the importance of land use change and unique karst features. All points are summed to determine the final priority ranking. Out of a possible range of 5

to 18 points, subwatersheds with a total of 5 points are considered Lesser Priority. Subwatersheds with a total of 6-10 points are Moderate Priority, and those with 11-18 points are considered Elevated Priority (Figure 6.0-E).

The priority ranking analysis resulted in 10 Lesser, 5 Moderate, and 8 Elevated ranking subwatersheds. The results of the priority ranking are shown in Table 6.0-iii and depicted in Figure 6.0-E. Most of the Lesser ranked subwatersheds are located in areas where little future development is expected and where no karst topography or recharge zones exist. Most Moderate ranked subwatersheds are not expected to see much future development but do contain karst topography, recharge zones, or extensive conservation and publicly owned lands. Most Elevated ranked subwatersheds are located in areas where expected future development is high, karst topography and recharge zones are present, and conservation and/or publicly owned land is fairly abundant.

6.1 Results and Discussion

Many of the results, trends and findings have been presented thus far in the narrative of the model. However, there are some important points that should be noted and that become evident upon a more detailed analysis of the model. The overall results are presented on Table 6.0-iii and a summary of the top four subwatersheds for each piece of the model are presented on Table 6.0-iv-6.0-vi.

Table 6.0-iii. Adjusted final classifications of subwatersheds.

				ield Criteria & Final Classifiation												Step 3: Vulnerablity Assessment						Step 4: Priority Ranking							
Watershed ID #	Subwatershed	Existing Impervious C	Existing Impervious C	Borderline ?	>10% Floodplain	>10% Wetland	>80% Vegetated 100	>80% Vegetated 200	No Dam Present	>20 Natural Heritage	>10% Conservation L	Cave Recharge	Karst	Total Field Score	Final Classification	Projected Impervious	Future Impervious Co	% Change between F	Classification Change	Classification close to	Vulnerablity	Vulnerability	Recharge	Karst	Development Pressur	% Conservation Land	% Publically Owned	Priority Score	Priority Rank
3	Turkey/Bass Confluence	0	S	N	1	1	1	1	1	0	1	0	1	7	S	0	S	0	N	N	L	2	0	2	1	3	3	11	E
6	Bonne Femme Middle	3	S	N	0	0	0	0	1	1	0	0	0	2	S	3	S	0	N	N	L	2	0	0	1	2	1	6	L
7	Bonne Femme Lower I	3	S	N	1	0	0	0	1	0	0	0	0	2	S	3	S	0	N	N	L	2	0	0	1	1	1	5	L
21	Smith Creek	3	S	N	0	0	1	1	1	0	0	0	0	3	S	3	S	0	N	N	L	2	0	0	1	1	1	5	L
8	Gans Creek North	4	S	N	0	0	0	0	0	1	0	0	0	1	S	4	S	0	N	N	L	2	0	0	1	1	1	5	L
9	Gans Creek South	3	S	N	0	0	0	0	0	1	0	0	0	1	S	3	S	0	N	N	L	2	0	0	1	1	1	5	L
10	Clear Creek	15	IM	N	0	0	0	0	0	1	0	0	0	1	IM	26	NS	11	Y	N	H	6	0	0	3	1	2	12	E
11	Upper Little Bonne Femme	3	S	N	1	0	1	1	1	1	1	0	1	7	S	7	S	4	N	Y	M	4	0	0	1	3	3	11	E
12	North Branch Little Bonne Femme	23	IM	Y	0	0	0	0	0	1	0	0	0	1	RI	27	NS	4	Y	N	H	6	0	0	1	1	2	10	M
13	Middle Little Bonne Femme	8	S	Y	1	0	0	0	1	0	0	0	0	2	RS	8	S	0	N	Y	M	4	0	0	1	1	1	7	L
20	Lower Little Bonne Femme	5	S	N	0	0	0	0	0	1	0	0	0	1	S	8	S	3	N	Y	M	4	0	0	1	1	1	7	L
16	Missouri River Tributary	5	S	N	1	0	0	0	1	0	0	0	0	2	S	5	S	0	N	N	L	2	0	0	1	1	1	5	L
18	Fox Hollow Branch	3	S	N	0	0	0	0	1	0	0	0	0	1	S	3	S	0	N	N	L	2	0	0	1	1	1	5	L
19	Bonne Femme Lower II	4	S	N	1	0	0	0	1	0	0	0	0	2	S	4	S	0	N	N	L	2	0	0	1	1	1	5	L
17	South Branch Little Bonne Femme	6	S	N	0	0	0	0	1	1	0	0	0	2	S	7	S	1	N	Y	M	4	0	0	1	2	1	8	M
14	Gans Creek	6	S	N	0	0	0	0	0	1	1	0	0	2	S	14	IM	8	Y	N	H	6	0	0	2	3	2	13	E
2	Upper Bonne Femme	5	S	N	0	0	0	0	1	1	0	1	1	4	S	9	S	4	N	Y	M	4	1	2	1	1	1	10	M
15	Pierpont	6	S	N	0	0	0	0	1	1	1	1	1	5	S	7	S	1	N	Y	M	4	1	2	1	3	3	14	E
1	Upper Bonne Femme Lower	4	S	N	0	0	1	1	1	1	1	0	1	6	S	4	S	0	N	N	L	2	0	2	1	3	3	11	E
5	Turkey Creek	4	S	N	0	0	1	0	1	1	0	0	1	4	S	4	S	0	N	N	L	2	0	2	1	2	2	9	M
4	Hunters Cave	3	S	N	0	0	1	1	1	0	0	1	1	5	S	3	S	0	N	N	L	2	1	2	1	2	1	9	M
23	Bass Creek	8	S	Y	0	0	0	0	1	1	0	1	1	4	RS	12	IM	4	Y	N	H	6	1	2	1	2	2	14	E
22	Bass/Hunters Confluence	1	S	N	1	0	1	1	1	1	1	0	1	7	S	1	S	0	N	N	L	2	0	2	1	3	3	11	E

Table 6.0-iv. Highest four subwatersheds impacted by impervious cover.

LEGEND						
Vulnerability	**Karst Topography**	**Recharge**	**Development Pressure**	**% Conservation Areas**	**% Publicly Owned**	**Priority Ranking**
2 = Low	0 = Not Present	0 = Not Present	1 = <5% land projected to change to more impervious use	1 = <5%	1 = <10%	L = total score <6
4 = Medium	2 = Present	1 = Present	2 = 5-10%	2 = 5-15%	2 = 10-30%	M = total score 6-10
6 = High			3 = >10%	3 = >15%	3 = >30%	E = total score 11-19

Table 6.0-v shows the top four subwatersheds impacted by impervious cover. This is a measure of which subwatersheds are currently being impacted the most. The North Branch Little Bonne Femme (23% IC) is significantly more impacted than remaining watersheds with the second-most impacted subwatershed being Clear Creek, with 15 % impervious cover. With the field criteria added to the North Branch Little Bonne Femme, this subwatershed was bumped up (more degraded) from its original classification of impacted to restorable impacted. This means that through the use of BMPs and restoration practices, it could be returned back to a subwatershed classification of impacted.

When future or predicted development is used in the model the North Branch Little Bonne Femme has the highest impervious value and is classified into the highly vulnerable category (Table 6.0-vi). Based upon predicted development trends imperviousness within this subwatershed will increase from 23% to 27%. This would mean that BMP and restoration practices must be carefully incorporated into this subwatershed or watershed and stream quality will quickly become degraded. It should also be noted that Clear Creek impervious percentages are drastically increased from 15% to 26% changing its classification from Impacted to Non-supporting.

Table 6.0-vii identifies the 5 subwatersheds that offer the most restoration value for the dollar or areas where the most immediate difference could be made through the use of BMP implementation, open space acquisition, or restoration practices. Bass Creek has the highest priority ranking with 14 points. This is because of the large amount of conservation land already in place as well as its karst and recharge features. Because this subwatershed has all of these characteristics as well as a fairly high development pressure, immediate attention would be recommended. The next highest priority subwatershed is Pierpont with a score of 14. This subwatershed is similar to Bass in that it too has karst and recharge features with substantial land already in public ownership. Because of the large amount of open space already present this subwatershed may be restored back to a sensitive classification fairly efficiently. The Gans creek has a large amount of public land in place while also having a high vulnerability ranking making it a subwatershed that should be considered for restoration, enhancement and preservation. Clear Creek is ranked 2nd highest in both steps 1-2 and 3rd in step 3, meaning its imperviousness values are currently high and will continue to increase as development pressure works south from Columbia. This subwatershed is high priority mainly because of its vulnerability score and development pressure. There are some publicly owned parcels that would suggest BMPs may be implemented fairly inexpensively and efficiently.

Table 6.0-v. Five subwatersheds that offer the highest restoration potential.

Step 1 & 2: Sensitivity Classification (Existing Conditions Rank)			
Rank	Most Sensitive Subwatersheds	% Impervious	Final Classification
1	North Branch Little Bonne Femme	23	Restorable Impacted
2	Clear Creek	15	Impacted
3	Bass Creek	8	Restorable Sensitive
4	Middle Little Bonne Femme	8	Restorable Sensitive

Table 6.0-vi. Summary Results by Subwatershed, Four Most Sensitive Based on Imperviousness and Field Criteria.

Step 3: Vulnerability Assessment			
Rank	Most Vulnerable Subwatersheds	Future % Impervious	Vulnerability Rank
1	North Branch Little Bonne Femme	27	High
2	Clear Creek	26	High
3	Gans Creek	14	High
4	Bass Creek	12	High

Table 6.0-vii. Summary Results by Subwatershed, Top Four Most Vulnerable Based upon Future Imperviousness.

Step 4: Priority Ranking			
Rank	High Priority Subwatersheds	Priority Score	Priority Rank
1	Bass Creek	14	Elevated
1	Pierpont	14	Elevated
2	Gans Creek	13	Elevated
3	Clear Creek	12	Elevated

Imperviousness

This section describes the technical approach used to create the impervious classification for the project. Space Imaging has developed a set of procedures related to the extraction of impervious surfaces from high resolution, remotely sensed imagery. Impervious surfaces are features that do not absorb water, i.e. buildings, roads, paved surfaces such as tennis courts and parking lots. By collecting representative samples within an image of the different types of impervious surfaces, their respective spectral signatures can be collected. Spectral signatures are based on the patterns of light reflected by an object and are recorded by a satellite or airborne camera. The signatures are used to discriminate similar features throughout the entire image using ERDAS Imagine image analysis software. While a signature composition approach does discriminate impervious surfaces from other features such as forestland or grassland, there is often confusion between surfaces or materials of similar composition. For example, sandy beaches and gravel are composed of the same material as that of a clay rooftop or paved roads. This similarity leads to confusion and must be accounted for. Space Imaging used modeling and machine learning algorithms to incorporate context and shape to discriminate between impervious surfaces and pervious surfaces with similar spectral signatures. The final step is to edit the map for areas of misclassification and to include areas of imperviousness that were obstructed from the sensor by vegetation or shadow. Throughout the process, an independent analyst assesses the quality and thoroughness of the modeling techniques and identifies possible misclassification errors for correction. In cases where an accuracy assessment has been performed, typical overall map accuracy percentages ranged around 90% when classifying IKONOS imagery with a nominal spatial resolution of one meter.

In order to further enhance the analysis for this study, AES used the extracted right-of-way (ROW) boundary from the Boone County cadastral information in addition to the IKONOS impervious data. This ROW boundary included the packed gravel and road footings that were not accounted for by the IKONOS classification. Once the IKONOS data was unioned with the cadastral ROW data the composited information was intersected with the subwatersheds and statistics were run to quantify impervious percentages.

Future Impervious Classification Strategies

Future Impervious data were generated in collaboration with the Boone County Planning and Building Inspection Department. The process began with base map creation and demographic analysis as well the culmination of CATSO 2030, Vision 2020, infrastructure plans, population projections, and the professional judgment of planners and engineers (Figure 5.5-B). These tools were used by a group of informed planning specialists who were aware of future planning trends, plans and project objectives. This group recorded its consensuses onto the base map for digitization. AES used parcel information to create areas of future development and/or preservation. The following classes were generated and given an impervious coefficients based upon the TR55 (USDA 1986): Low intensity residential, High intensity residential, Commercial, Parks and Industrial.