Overview

A study to document the locations, magnitude and sources of fecal contamination was conducted on a twelve mile stretch of Fountain Creek, a high-gradient stream on the Front Range of the Rocky Mountains in Colorado. This study area focused on Upper Fountain Creek from Green Mountain Falls to the confluence of Fountain Creek with Monument Creek in Colorado Springs. In 2006, Upper Fountain Creek was placed on a list of water quality impaired stream segments referred to as the 303(d) list for E. Coli (see sidebar on page 2 for more information), a bacteria used to determine the presence of fecal contamination.

The designated uses of Upper Fountain Creek include water supply, agriculture, recreation, and support of aquatic life; the headwaters drain Pikes Peak, a major destination for tourism. The area is mostly undeveloped except for substantial populations around Manitou Springs and Colorado Springs. Possible sources of fecal contamination included humans, horses, grazing cattle, wildlife, and domestic pets.

This was a two year study and began in 2007. E. coli samples were taken at 16 sites (Figure 1) after which five samples sites were selected to track fecal contamination in more depth:

- Upstream from Manitou Springs (Site 4: Fountain Creek below Green Mountain Falls),
- Within Manitou Springs (Sites 7.9, 9 and 10: Fountain Creek above Ruxton Creek, Ruxton Creek, and below Ruxton Creek),
- Between Manitou Springs and Colorado Springs (Site 15: Fountain Creek below 8th Street).

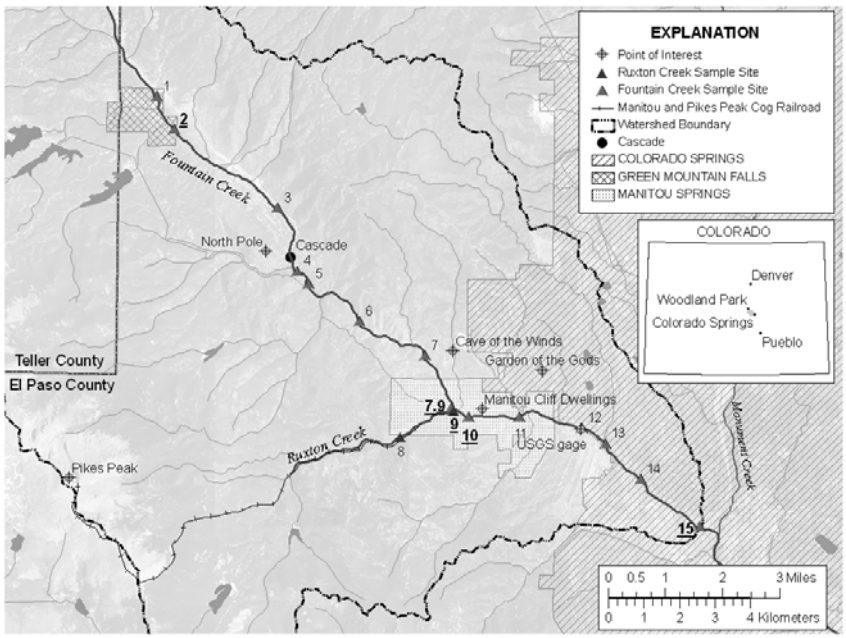

Figure 1: Study area map showing locations of sampling sites in the Fountain Creek and Ruxton Creek watersheds, Colorado, 2007 to 2008. Various municipalities are shown as shaded areas. Sample sites are indicated with numerals (1 to 15). Numerals that are bold underlined indicate sites intensive-monitoring sites at which a full suite of analytes was evaluated.

Study Objectives

The long-term objective of the Study was to meet the water quality standards for E. coli. To do this a new process was tested referred to as microbial source tracking (MST; see sidebar on page 3) DNA testing. This was used in conjunction with other information to evaluate potential contributions of fecal contamination from various sources.

Study results

The initial E. coli survey at 16 sites in 2007 identified the location where Ruxton Creek enters Fountain Creek as an important point in the watershed. Above this location E. coli concentrations in Fountain Creek were usually below water quality standards and below this location concentrations were above water quality standards. Ruxton Creek accounted for some, but not all, of the fecal contamination at this point. In addition to this location, Fountain Creek below Green Mountain Falls had occasional exceedances of the Colorado standard, and Fountain Creek below 8th Street (the most-downstream site) consistently exceeded the E. coli standard in summer months (June through September). In both years of sampling, E. coli concentrations were higher in summer than they were in the winter months (October through May; see Figure 2).

Tracking sources of fecal contamination: Why *E. coli*?

The Clean Water Act requires that all waters of the United States be classified according to designated uses. Each state has its own system of designated uses: examples of these designated uses include habitat for fish and wildlife, industrial uses such as cooling water, and recreation. The major limitation for recreational uses is public health risk caused by fecal contamination. Although the U.S. Environmental Protection Agency (USEPA) currently (2009) is re-evaluating the way that public health risk is measured, the current criteria require measurement of *Escherichia coli* (*E. coli*) or enterococci, another type of fecal-indicator bacteria.

USEPA puts forth guidance for the states so that each state may regulate its water to meet designated uses. The State of Colorado standard specifies that Class E (existing) recreational waters must maintain a geometric mean concentration of *E. coli* that is less than 126 per 100 mL. In Colorado and other States, the Federal Clean Water Act requires adding waterways that do not meet standards for their designated use to a list of "impaired" waterways which are contained in a 303(d) list. Under the Clean Water Act, if existing management of impaired waterways is insufficient to bring *E. coli* to within standards, a Total Maximum Daily Load plan must be created to manage *E. coli* contamination in that waterway.

Water was tested for total fecal contamination and contamination from human and ruminant sources by use of MST DNA tests. If humans or ruminants (cattle, deer, elk, and sheep) were the source of high summertime E. coli, the genetic markers for those animals would increase in the summer months. However, the various MST genetic markers did not increase in summer. Increased E. coli density was expected to coincide with elevated nutrient concentrations, since both nitrogen and phosphorus are high in fecal material. Although higher nitrogen concentrations were measured in the summer, when E. coli density was higher, nutrient concentration increases were not correlated with E. coli increases. Similarly, increased E. coli density was expected to coincide with detection of wastewater-associated chemicals at sites where the E. coli originated with human sewage. These chemicals were detected more often in Manitou Springs and Colorado Springs, and more often in the summer than the winter. Many of the chemicals were never detected, and many samples with high E. coli did not have wastewater chemicals in them.

In cool-weather months, in-stream E. coli may have been caused by either targeted source (humans and ruminants). However, since the levels of E. coli were generally below the standard in these months, this level of contamination was not considered to be a problem. In summer months, though, the high levels of E. coli generally could not be explained by human, or ruminant sources. Birds were the only tested source that could have contributed this much E. coli without an increase in MST genetic markers. In the area of Manitou Springs, pigeons were observed to roost in large numbers under bridges in the area between Manitou Springs and Colorado Springs, other birds may be a more likely explanation than pigeons.

Tracking sources of fecal contamination: Microbial source tracking

Microbial source tracking (MST) is as an emerging field of research, typically providing information to help make management decisions in recreational water, fisheries, or drinking source waters. The MST tests used in this study take advantage of bacteria that are associated with the guts of particular animals. These bacteria, the *Bacteroidales*, help the animal digest food. Different types are found in different animals, and the types are detected using genetic markers. In this study, one MST test for general fecal contamination was applied along with two tests for human-origin fecal contamination and one test for ruminant (cattle, sheep, deer and others) fecal contamination. The MST tests were used in conjunction with measured densities of *E. coli* to estimate which animals contributed more or less *E. coli* to each sample. Estimates based on MST genetic markers were coupled with other lines of evidence, such as land use patterns, nitrogen and phosphorus concentrations, and presence of chemicals (such as caffeine and aspirin) found in wastewater, to indicate when human sources of fecal contamination were important contributors to a sample.

The finding that human contamination was not the major cause of fecal contamination to Upper Fountain Creek in summer months was supported by other lines of evidence, in particular the lack of wastewater-associated chemicals. The data interpretation that indicated absence of substantial human-source contamination on most dates was supported by dates when human-source contamination was detected. In five samples (20% of the samples that were tested with high E. coli), high E. coli and human genetic marker coincided with high ammonia concentrations and unusually frequent detections of wastewater-associated chemicals.

Birds were identified as a probable source of E. coli contamination during warm-weather months. Just as in the water samples collected during this season, bird samples had high E. coli and low MST marker, including the general marker. Birds also are not expected to carry wastewater compounds. Birds droppings were the only source evaluated that had characteristics consistent with the water data collected.

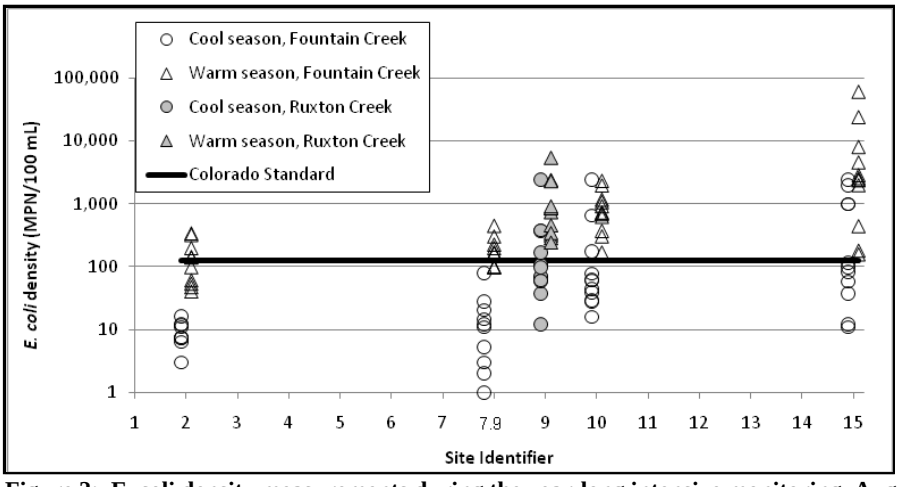

Figure 2: E. coli density measurements during the year-long intensive monitoring, August 2007 through September 2008. For the purposes of this plot, warm season extended from June 15 through September 15. Warm season and cool season values are associated with the same sites, but are offset from the true site ID to enhance visual clarity.

Conclusions

Birds were identified as a probable source of fecal contamination through the use of microbial source tracking methods and these conclusions were validated and supported through water quality testing of nitrogen, phosphorous and contaminants commonly found in wastewater. Based on these results stakeholders are working together to identify strategies that can be used to reduce the fecal contamination impacts from birds. As funding becomes available other stream segments within the Fountain Creek Watershed which are currently listed as water quality impaired for E. coli will also be investigated to determine possible sources.

Photo: Upper Fountain Creek flowing through downtown Manitou Springs, downstream of where Ruxton Creek enters.

Contact Information

The U.S. Geological Survey (USGS) conducted this study in cooperation with the Pikes Peak Area Council of Governments, Colorado Department of Public Health and the Environment, Colorado Springs Engineering, and Colorado Springs Utilities. For more information, including a copy of the USGS Report that was published, please contact David Mau, USGS Project Leader at dpmau@usgs.gov or Rich Muzzy with Pikes Peak Area Council of Governments at rmuzzy@ppacg.org