A comprehensive review of microbiology in a western arid urban watershed and insight on the reasonableness of proposed stream limits for E. coli

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ABSTRACT

The Urban South Platte River (USP) runs through the center of metropolitan Denver, Colorado. Since 1998, the watershed has been extensively monitored for E. coli. Comprehensive data from the watershed study will be presented to demonstrate that regulatory limits of 126 cfu/100 ml of sample will be difficult, if not impossible, to attain in a TMDL plan. Previously unpublished E. coli data from a USGS urbanization impact study in the same geographic area demonstrates similar findings and show that there is also no relationship between the degree of urbanization and E. coli concentrations.

KEYWORDS E. coli, microbiology, watershed, stream standards, sediments.

INTRODUCTION

The South Platte River originates high in the Rocky Mountains and exits from the mountainous regions just before the urban Denver metropolitan region. The South Platte River then runs north through the center of metropolitan Denver, Colorado. Near Greely, Colorado, it turns east and eventually becomes part of the Missouri River. Since 1998, the urban Denver watershed has been extensively monitored by the South Platte Coalition for Urban River Evaluation (SPCURE) watershed study group. The stretch of the river researched for this article includes a run of ~50 miles from Chatfield dam south of Denver, north to near rural Platteville, Colorado. The area of the study is presented in Figures 1a and 1b. In Figure 1a, the South Platte River in Colorado is shown in blue and the general area of the urban watershed study is shown in the orange ellipse. A more detailed look at the area is presented in Figure 1b; the watershed starts at Chatfield dam and runs north to near Platteville located on the western edge of the Great Plains.

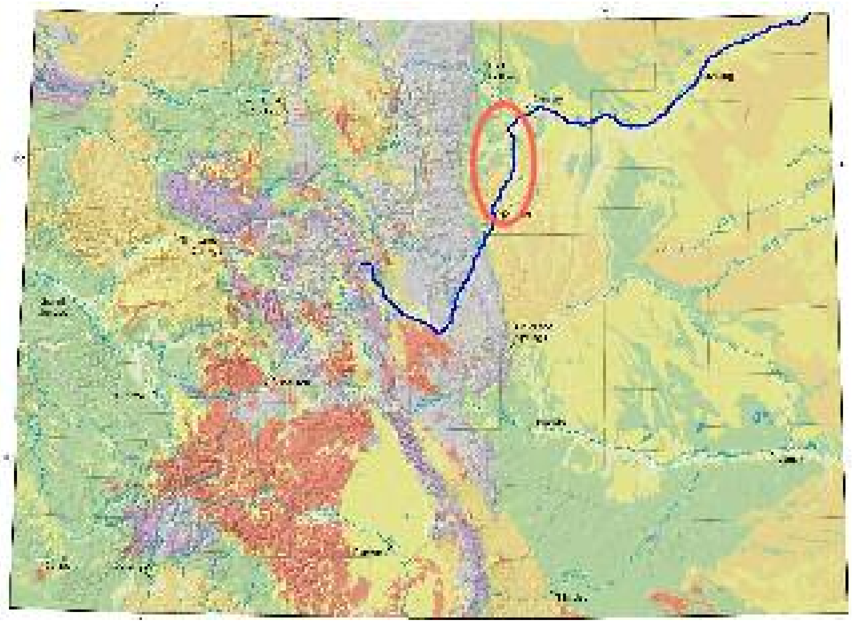

Figure 1a. The general area of interest for the watershed study in Colorado.

Figure 1b. A more detailed map of the area of interest.

One of the variables measured during the period since the SPCURE watershed project started has been E. coli. The State of Colorado has also been requiring increased monitoring for E. coli by various utilities in anticipation of a TMDL plan that will use the protective stream limits for E. coli of 126 cfu/100ml of sample (USEPA 1986). The use of an E. coli standard is based on the premise that E. coli is an accurate indicator of human fecal contamination. A review by SPCURE indicates that there are considerably more sources E. coli than humans, including pets, wildlife (mammalian and non-mammalian), and even fish. Further contributing to the problem is the observation that recent advances in E. coli methods may have produced higher than expected values because of increased sensitivity compared to previous methods.

RESULTS

General Watershed Observations:

E. coli samples and analyses have been conducted by SPCURE members since 1998. The results of all the SPCURE participants are presented in figure 2a. Since the South Platte River runs consistently northward and sample sites are referenced by geographical coordinates, river distance, south to north, is presented in degrees latitude. E. coli measurements are presented as Log_{10} values (1.0 = 10, 2.0 = 100, 3.0 = 1000, etc.); the black dotted line indicates the E. coli stream limit of 126 cfu/100ml. The location of various cities and towns along the river is presented in the upper part of the graph. The two red arrows indicate the location of two wastewater treatment facilities that discharge into the river at rates of 30 and 200 mgd, respectively. The red line running through the data points is a least square model fit to the data. Figure 2b shows the seasonal trend and variability of the same data set with observed higher average numbers in the summer than the winter. Figure 2c compares two different years worth of data in a similar manner to Figure 2a. Initially the difference in the two different year trends seemed to be attributed to differing flow regimes, 2006 was a relatively high flow year while 2002 was a significant drought year, with record low flows and almost no Spring runoff. However, a more detailed analysis of flow to E. coli concentration relationship does not support this hypothesis. While there appear to be significant differences in the watershed from year to year, the cause(s) has not yet been identified.

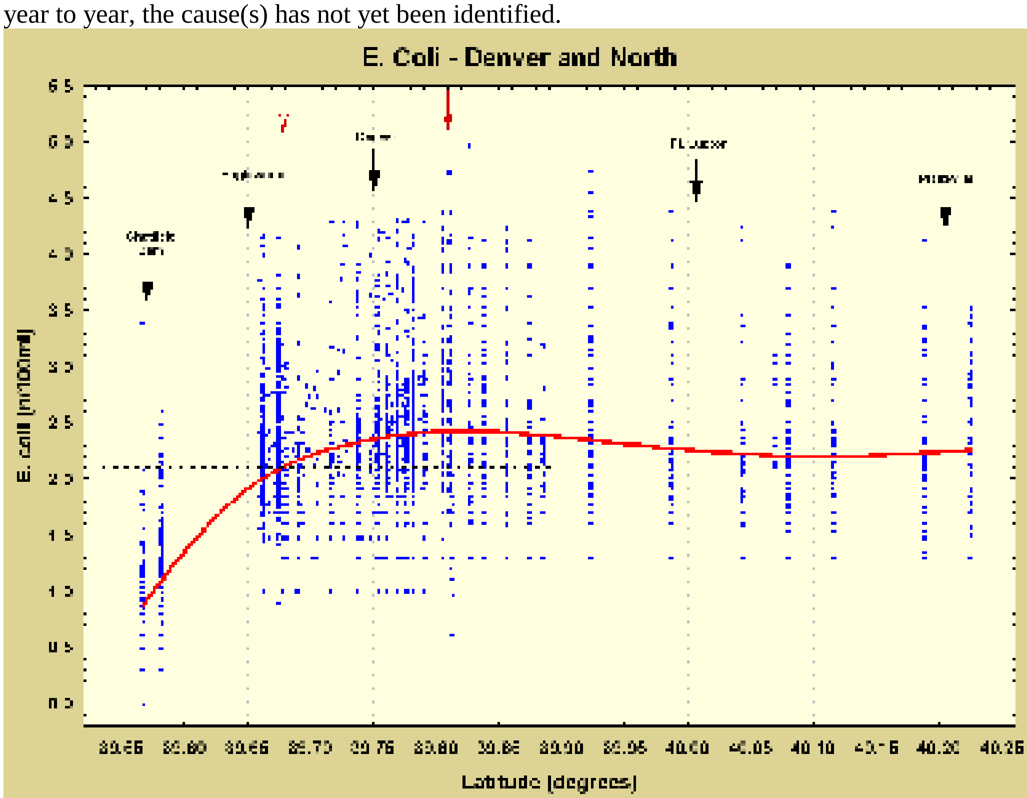

Figure 2a. Summary *E. coli* data for Urban South Platte.

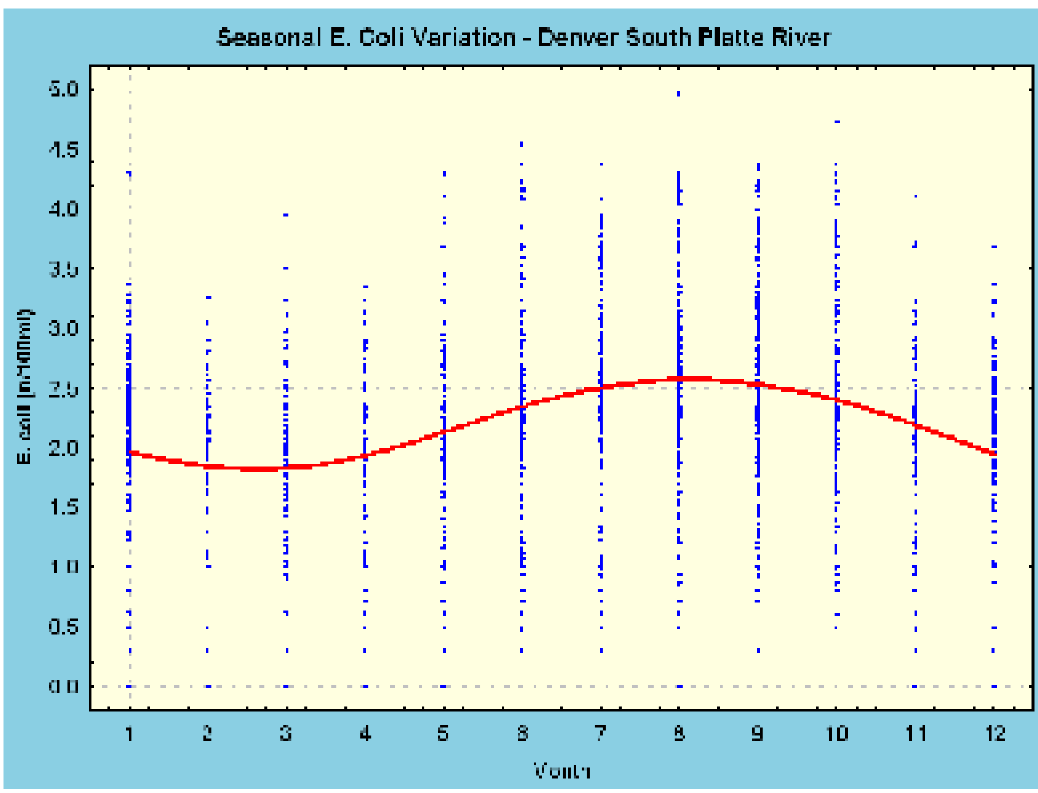

Figure 2b. Summary of seasonal variation *E. coli* data, Urban South Platte river.

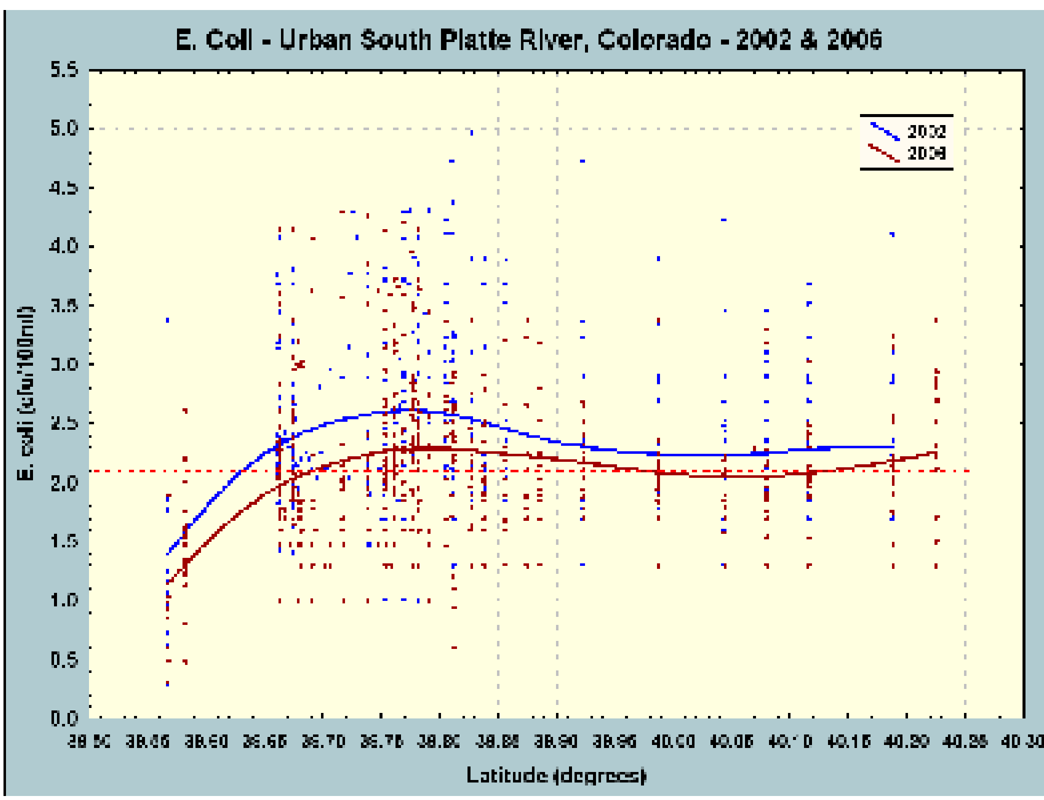

Figure 2c. Possible impact of flow on variation *E. coli*, Urban South Platte River.

Wastewater Impact:

Data from a wastewater facility located near Englewood, Co, (see Fig. 1b) is presented in Figure 3a. On average, treated wastewater *E. coli* levels are considerably less than those observed in the river. Because there is considerable scatter, even using a logarithmic model, individual sample measurements frequently exceed proposed limits; data smoothing can reduce this variability to a limited extent.

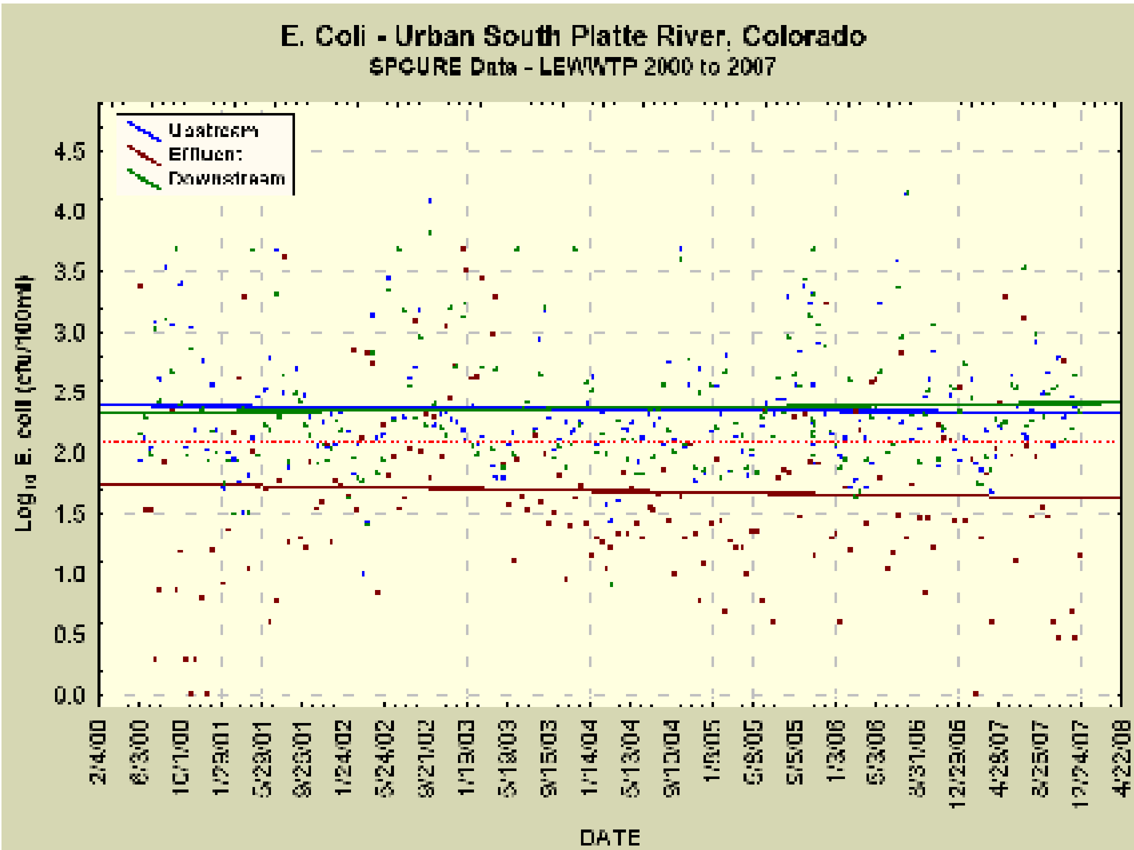

Figure 3a. Wastewater treatment plant impact on river E. coli levels, 2000 - 2007.

During 2005 a small study was performed on river samples collected below a wastewater treatment plant effluent to assess the potential for E. coli re-growth in the river. Sample periods were selected when low river flow enhanced the potential contribution from E. coli introduced by wastewater effluent. Samples were aerated for 24 hours and sub-sampled to observe E. coli concentrations. Figure 3b is an example of observations of 10 samples collected on different days in the Spring of 2005. During each run, no sample showed any indication of re-growth (or inactivation). A similar study conducted in the Fall of 2005 produced similar results.

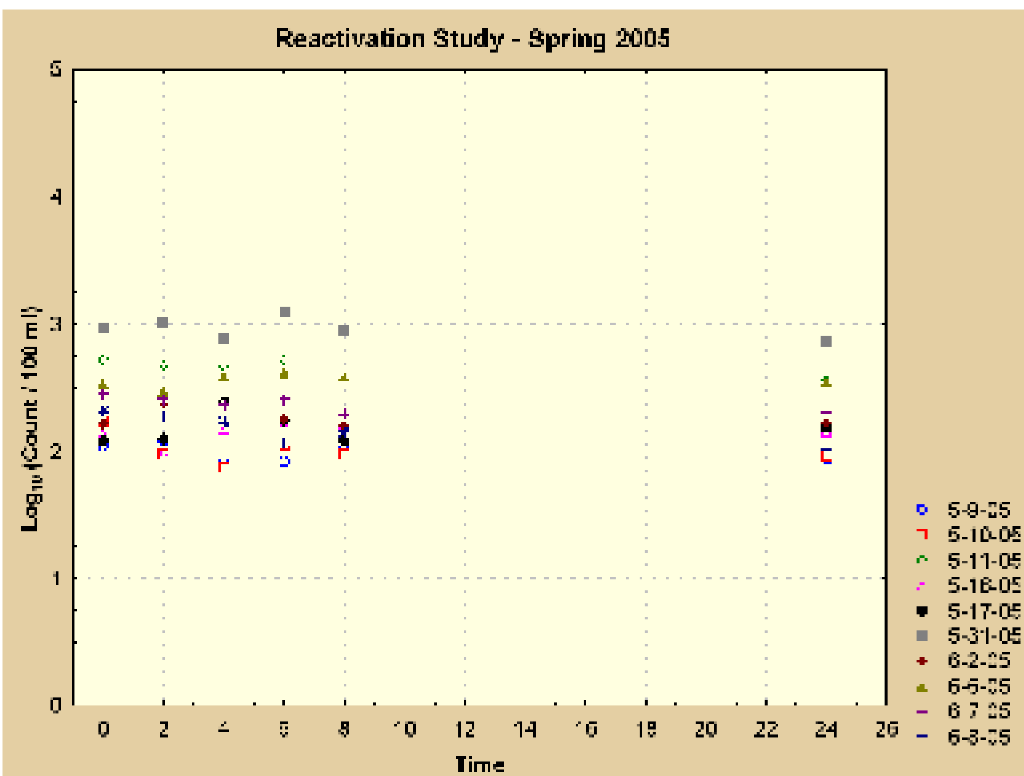

Figure 3b. E. coli reactivation study, 2005.

E. coli in sediments:

During 2007 a pilot study was conducted to evaluate a sampling scheme for collecting E. coli sediment samples and examine the possibility that re-entrainment could change stream concentrations. The results are presented in Figures 4 a, b and c. In Figure 4a E. coli concentrations in sediment are presented in terms of sample date and show potential seasonal variability. In Figure 4b E. coli data is presented in relationship to the distance from mainstem South Platte River; there appears to be a significant decrease in concentration as the tributary approaches the river. A previous study (Russell 2007) of another tributary stream suggested that E. coli levels may increase as samples are collected when they run through an urban environment. Current observations may be related more to the micro-environment conditions. Figure 4c illustrates the relationship between E. coli concentrations in the water collected from the sediment samples and the water overlaying the sediment. There appears to be an order of magnitude higher concentration of E. coli in the sediment water than in the water covering the sediments. Based on the results of this investigation, any significant disturbance of the sediment would logically increase E. coli levels in the stream.

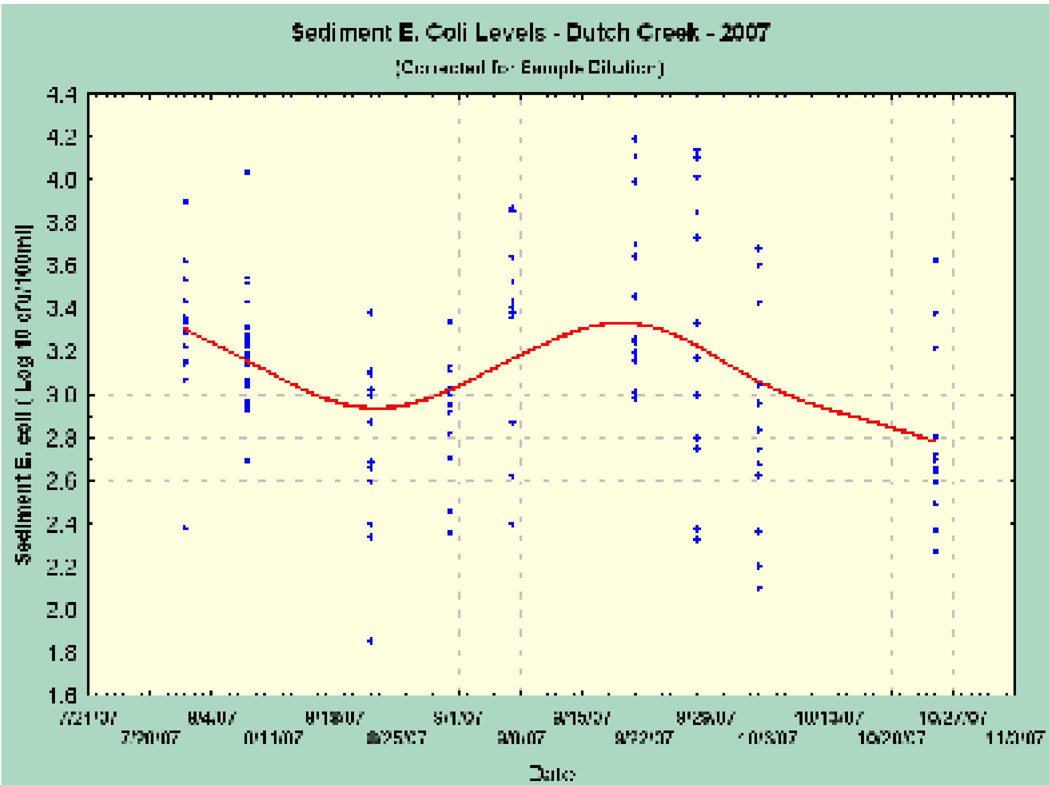

Figure 4a. Summary of tributary, sediment *E. coli* data for Dutch Creek by date.

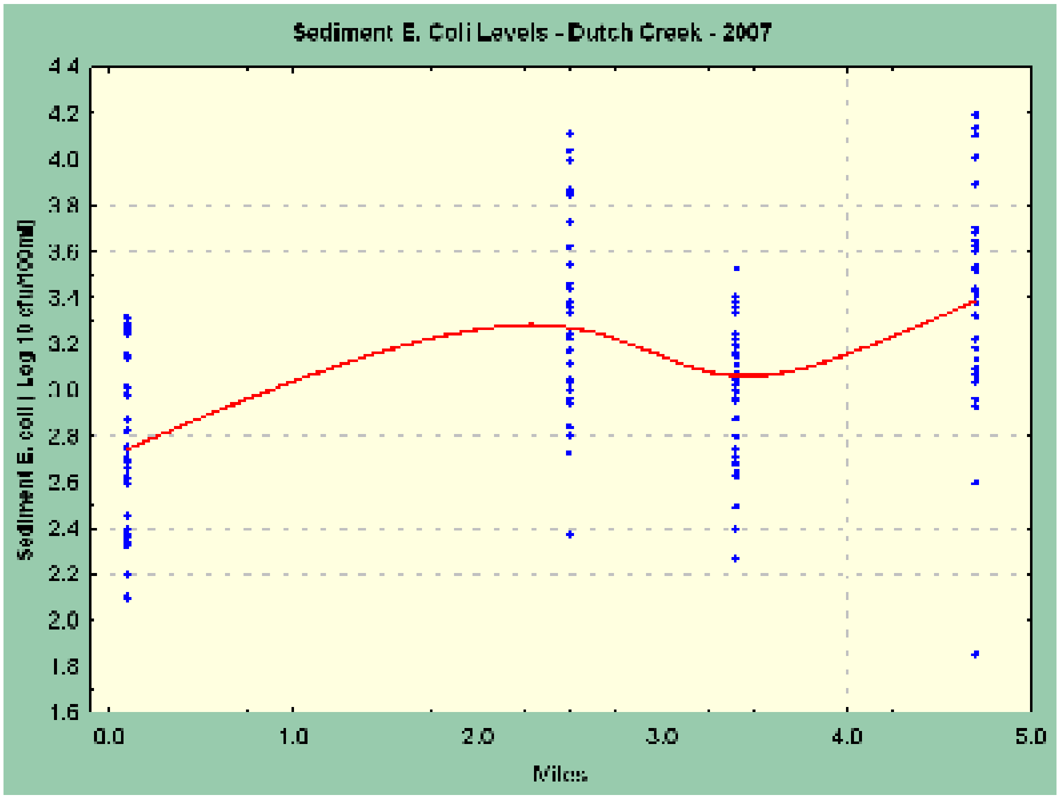

Figure 4b. Summary of tributary, sediment *E. coli* data for Dutch Creek by distance.

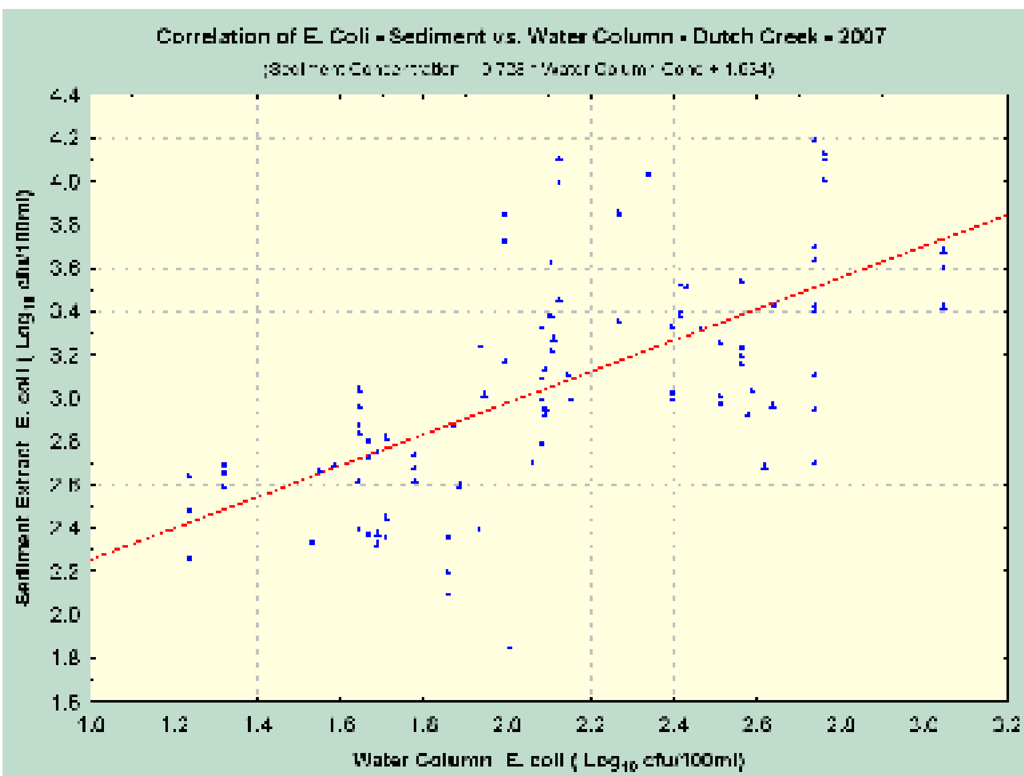

Figure 4c. Summary of tributary, sediment *E. coli* data, for Dutch Creek showing the relationship with observed levels to those in the overlaying stream water.

DISCUSSION

While it seems to be common knowledge that natural E. coli levels in streams and rivers can exceed stream limits of 126 cfu/100ml, a large study like that of the Denver urban watershed has not been previously presented. The portion of the river investigated included a reach below a reservoir, a reach surrounded by suburbs, a reach running through a metropolitan city, a reach running through an industrial area, and finally a long run through grass and farm lands. Based on the SPCURE watershed group data it is readily apparent that no matter where you examine E. coli in the urban South Platte (except in near proximity to the outfall of a large reservoir), (1) E. coli levels are extremely variable, (2) E. coli levels average about the same regardless of location and (3) on average, are often above the stream standard. There is also a seasonal variation in the data with lower values typically being observed in the winter and higher values in the summer. There are unexplained average differences from year to year.

Wastewater facilities are generally not a significant source of E. coli in the urban South Platte River. Neither does re-growth seem to be a factor in the observed spatial average stability or overall large variability observed. It is possible that some of the variability may be caused by sediment disturbance.

A study to determine urban impact on the Colorado and Wyoming Front Range was conducted by USGS in 2002-2003. While E. coli data was collected, it was not presented in the original report (Sprague 2006). The author graciously shared the data with this author and it is presented in Figure 5a. The area of the study included the Front Range from south of Denver into South-central Wyoming. The calculated degree of urbanization is presented on the x axis with a high number indicating a high degree of urbanization. This data mirrors and supports conclusions made from the SPCURE watershed study data and also indicates that there is no relationship between urbanization and measured E. coli concentrations (at least in the arid area east of the Rocky Mountain region). Seasonal variation, similar to SPCURE observations, is presented in Figure 5b. An a comparison of data distribution corrected for differences in low range capability is presented in Figure 5c for a comparable sample period between the USGS study and the SPCURE study; overall, variability and averages are near identical.

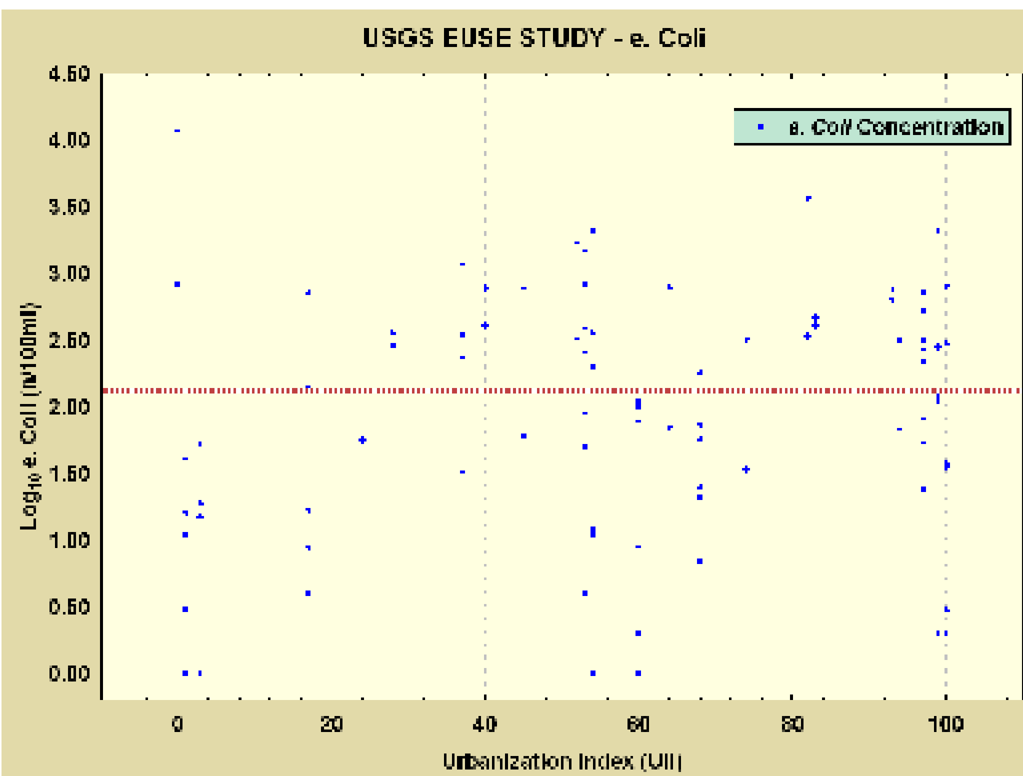

Figure 5a. *E. coli* relationship to urbanization from USGS EUSE Regional Study, Rocky Mountain Front Range.

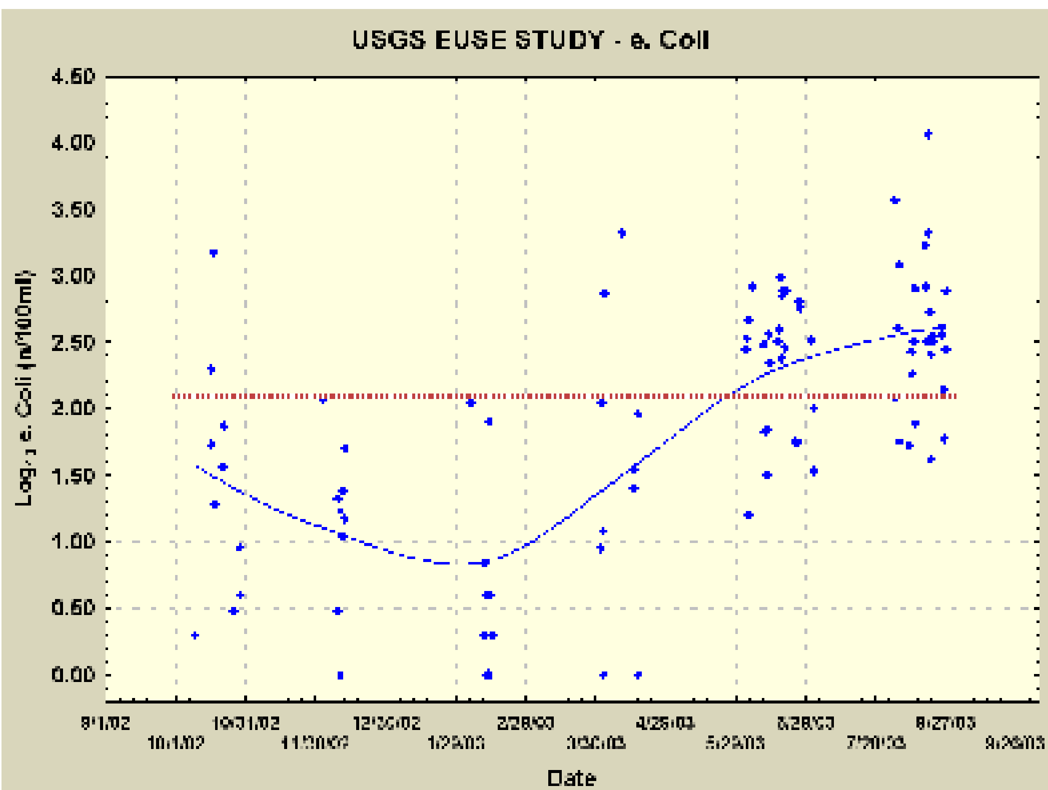

Figure 5b. *E. coli* relationship to season for USGS EUSE Regional Study, Rocky Mountain Front Range.

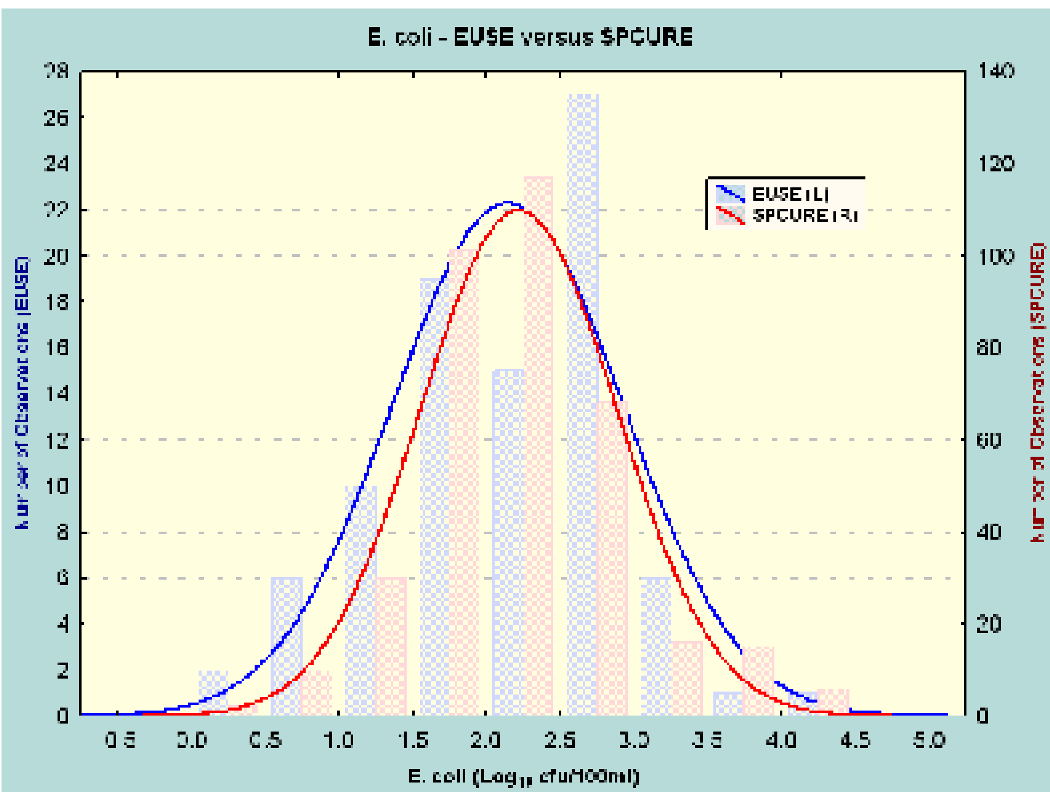

Figure 5c. Comparison of *E. coli* measurements form the USGS EUSE Regional Study, Rocky Mountain Front Range and SPCURE during same time period.

It would appear that normal E. coli concentrations observed in urban and more “natural” waters consistently and frequently exceed proposed stream standards. If that is the case:

A. Should a more reasonable stream standard for E. coli (or other indicator microorganisms) be developed?
B. When human sources have been ruled out, how far do implementation groups go to meet regulatory goals? Should BMPs be considered the best methods to assure protection from human transmitted infection?
C. Should natural streams be subject to intrusive remediation efforts to met proposed stream standards and TMDLs?
D. Should better methods be developed to identify and quantify specific human pathogens?

CONCLUSIONS

When it comes to measuring *E. coli* in streams in the arid west, natural levels of *E. coli* will frequently exceed the USEPA proposed stream standard of 126 cfu/100ml. It is also observed that the natural deviation observed between samples will exhibit considerable natural variation, whether collected in an urban area or not. The problems of naturally high concentrations and variability, and relating stream *E. coli* levels to health impact are also corroborated in a recent USEPA Workshop (USEPA 2007). Considering the "natural" levels of E. coli and the large variation that is observed in our watershed, the regional (and national) stream standards are not logically achievable without inordinate measures that could disturb, and possibly damage, the natural stream environments.

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