A Watershed Approach to Managing Onsite Wastewater Systems
Project 1300 FY01 CWA Section 319(h)

Final Report

By

Rodney D. Williams. P.E., Ph.D.
And
Mark A. Gross, P.E., Ph.D.
Department of Civil Engineering
University of Arkansas

For

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Executive Summary

One of the factors in characterizing the effect of non-point source pollution on the waters of the state in Northwest Arkansas is the impact of decentralized wastewater systems. Another related issue is the overall effect of the urbanization of rural areas on water quality at the watershed level. A unique data set recently became available for analysis. Development of an initially rural, primarily forested area in Northwest Arkansas was documented along with water quality data collected on a quarterly basis for approximately 30 years. The Property Owners' Association of Bella Vista Village agreed to allow examination of all 38 sampled sites including 9 stream locations, 10 springs, and 18 sites on reservoirs. In addition, the discharge from a community wastewater treatment plant (serving the multiple-family dwellings such as townhouses, apartments, and the retirement center) was sampled.. Bella Vista Village is unique in that it is a 25,000 acre planned community utilizing individual onsite wastewater treatment systems for single-family dwellings. The implication of this data set is that by proper application of statistical analyses and trend analyses, water quality impacts of the onsite wastewater systems along with the development of a mountainous region over Karst topography may be evaluated. Analysis of this data set and assessment of the effects of this urbanization process have much promise for use in the development of water quality modeling parameters, trend analyses and quantification of non-point source impacts at the watershed level. These trends and factors could potentially be applied to other watersheds in similar regions of the state. In addition, assessment of the watershed can lead to a better understanding of the level of management necessary to minimize the environmental impact of onsite wastewater systems at the watershed level.

The contribution of this project to the state of the knowledge and to other work includes a first attempt at quantifying the effects of a development using onsite wastewater systems upon stream quality. This work could be directly related to the issue of Total Maximum Daily Loads (TMDLs) and stream quality assessment. The data has been available for several years to the Arkansas Department of Health and to the Arkansas Department of Environmental Quality, however the resources have not been available to perform an analysis of the long-term trends.

With the assistance of the Bella Vista Property Owners Association, Cooper Communities, The Arkansas Department of Health and with funding and other support from the United States Environmental Protection Agency, the Arkansas Department of Health, Arkansas Onsite Sewage Disposal System Advisory Committee (ISDSAC), The Arkansas Soil and Water Conservation Commission, the Arkansas Department of Environmental Quality, the Arkansas Water Resources Research Center and the University of Arkansas, this study was completed within the two year time frame originally established. (See the original work plan in Appendix A) An overview of the project chronology and scope follows.

A Quality Assurance Project Plan (QAPP) was developed and subsequently approved by the Arkansas Soil and Water Conservation Commission (ASWCC) and the United States Environmental Protection Agency (USEPA). Tasks outlined in the work plan and QAPP included obtaining and organizing available data, entry of data into spreadsheet format, analysis for any trends in water quality due to the development, mapping of sampling sites and watershed

boundaries along with other information deemed pertinent by the researchers and an attempt to develop relationships between urbanization utilizing on site wastewater systems and water quality at the watershed level. (See Appendix B for full QAPP)

In the analyses of the data researchers found significant trends in several constituents of interest. Generally it was discovered that where there were significant trends, pH increased (water became more basic); fecal coliform, chloride, nitrate-nitrogen and total phosphorus concentrations increased while total dissolved solids (TDS), sulfate, total nitrogen and turbidity decreased. Some of the reservoir sites show significant increasing trends in the fecal coliform concentrations. Of the lakes in the Bella Vista Village watershed, the one having the highest median fecal coliform concentration has a median concentration of 3 CFU/10 mL. Only one reservoir site had a median fecal coliform concentration greater than 100 CFU/100 mL, and that reservoir is Lake Bella Vista. Lake Bella Vista is outside of the Bella Vista Village watershed, and is not impacted by activities within the village. Although some of the trends are increasing, in order to determine if the trend has meaning in terms of impact to the environment or the public health, the concentration of the measured parameter should be considered. Of the spring and creek sites, the highest median fecal coliform concentration at the sites having increasing significant trends was 105 CFU/100 mL at site #2 (Sugar Creek, South of Bella Vista). These values are well below the concentrations allowable for primary contact water.

The nitrate-nitrogen concentrations at the sites having increasing significant trends are above 3 mg/L, with the highest being 3.7 mg/L at site number 1 (McKissic Creek South of Bella Vista). Of the remaining sites with increasing significant trends, only two others had median nitrate-nitrogen concentrations greater than 3.0. The site with the highest nitrate-nitrogen concentration was site number 41 (Spring Behind Linen Room), having a median NO_3-N concentration of 3.85 mg/L. Interestingly, this site did not have a significant trend, and its trend was decreasing. All of the NO_3-N median concentrations were well below the primary drinking water standard of 10 mg/L NO_3-N.

Other parameters of current regulatory/water quality interest include chloride, Total Dissolved Solids (TDS), sulfate and forms of phosphorus. Median chloride concentrations for the most part are well below the eco-region standard of 13 mg/L. Sites 35 and 37 are samples from wastewater treatment facilities and their discharges are diluted in the stream system. Sulfate concentrations are all well below the eco-region standard of 17 mg/L. With the exception of the wastewater treatment facilities concentrations of TDS are also below the current eco-region standard of 240 mg/L. At five sites, median total phosphorus concentrations are higher than the narrative standard of 0.1 mg/L, but there is some question as to the source of phosphorus. Fertilization of lakes, lawns and nearby golf course facilities is assumed to be at least a partial contributor to nutrient levels in the system.

There are increasing trends in many of the constituents of concern, but the rate(s) of increase for any given parameter range from 10^{-3} to 10^{-8} mg/L per year. Using a worst-case scenario for total phosphorus (excluding the wastewater treatment facility at site 35) with a rate of increase of 3.76×10^{-4} mg/L per year, the total increase in 50 years would be only 0.019 mg/L. Data has been tabulated in a similar form for all sampled parameters and analyses of these data show similar minimal effects.

Generally, though there are increasing trends in some of the measured parameters, the water quality in the reservoirs, streams, and springs in Bella Vista Village watershed appears to be good in terms of the measured parameters and meets or exceeds regulatory criteria/standards. The effects of development upon the water quality do not seem to be harmful in terms of the parameters having increasing significant trends. Certainly the parameters typically attributed to onsite wastewater system degradation of the water quality – fecal coliform and nitrate-nitrogen – do not appear to have been increased greatly by the onsite wastewater systems in the Village. This 30-year data set suggests that onsite wastewater systems can provide a viable solution for single-family residences when used community-wide, while providing protection of the water resources.

The next phase of this analysis should involve using pertinent water quality data, trend data, soils, landcover/landuse data, watershed boundaries and other features previously entered into a Geographical Information System (GIS). This database should allow spatial analysis to further delineate potential effects of urban practices including the utilization of on-site wastewater treatment systems on water quality. These efforts may yield factors that can be used to estimate the contribution of on-site systems to nutrient enrichment in watersheds as well as suggest potential watershed management strategies to minimize the effects of urban development.

Table of Contents

Table of Figures and Tables

Introduction

Bella Vista, a planned community serving approximately 16,500 residents, is located near the Arkansas-Missouri border in Benton County, Arkansas. A majority of the residential units and businesses are serviced by decentralized wastewater systems (septic tanks). In an attempt to characterize the effects of point source and non-point source pollution in the area's local waters, the decentralized wastewater treatment systems were investigated. In the early 1970's, Cooper Communities, Inc. implemented a water quality-monitoring program at the request of the Bella Vista Property Owners Association (POA). A minor study was first performed in 1972 as a control for comparison of future studies to determine any change in water quality.

Background

The original ecological monitoring program, which was presented in 1972, consisted of two main objectives: 1) the use of infrared satellite photographs provided by "EROS" (the U.S. Coast and Geological Survey Satellite) and 2) monthly water quality monitoring. The satellite pictures were to be obtained on a regular 18-day schedule from the EROS Data Center in Sioux Falls, South Dakota. These infrared photographs were to provide a "birds-eye-view" of the area and be useful in comparing present pictures to past pictures through the infrared mosaic; in the long term, helping to identify changes in ecological conditions. However, when the original monitoring plan was implemented, the EROS satellite was not yet functioning and photographs were never taken of the Bella Vista area.

The second objective of the monitoring program was the initiation and continuation of periodic water quality testing at 38 control sites. Cooper Communities, Inc. suggested testing several different parameters; and if any of these parameters indicated a worsening condition, the test should be verified and causative factors determined. These original parameters included 1) Total coliform, fecal coliform, and fecal streptococci, submitted to a laboratory four times a year, 2) biochemical oxygen demand (BOD), 3) total solids, 4) suspended solids (obtaining dissolved solids from the subtraction of total solids and suspended solids, 5) total nitrogen, 6) ammonia nitrogen, and 7) total phosphates. A few monthly and yearly trend reports were written, but these reports simply stated whether a parameter had increased or decreased over a given period of time. Conclusions on the factors influencing the increases were never addressed. The recommendations put forth in the original ecological monitoring program where based extensively on the recommendations described in the Water Quality Criteria Report of the National Technical Advisory Committee to the Secretary of the Interior in April of 1968. This report defined limits and proposed standards for primary and secondary recreational uses in water bodies.

Since the implementation of the program in 1972, the original recommendations have undergone dramatic changes. Over the years, equipment upgrades and executive decisions have caused major variability in the collecting and reporting of water samples and data. In February 1977, Bella Vista POA decided to monitor 10 parameters, some differing from the recommendations suggested in the original Cooper Communities, Inc. program. These monitoring parameters included 1) pH, 2) fecal Coliform, 3) Chlorides, 4) temperature, 5) sulfates (SO_4), 6) dissolved oxygen (D.O.), 7) total dissolved solids (TDS), 8) turbidity, 9) total nitrogen/nitrates (N and NO_3^--N), and 10) total phosphorus/phosphates/acid-hydrolysable phosphorus (PO_4^{3-}). The current program has data starting in February of 1977 and has dwindled from 38 sites at various lakes, streams, and springs to 16 sites consisting mainly of lakes and no springs. However, the Little Sugar is monitored both north and south of Bella Vista Village. Table 1 shows a list of all the sampling sites and the longevity of sampling. Table 2 consists of latitude and longitude points for spring and stream sites included in this study. Table 3 lists the units of measurement for each constituent. Figure 1 is a generalized map of the location of Bella Vista in Arkansas. Detailed maps in both paper format and GIS format are included as deliverables for this project and will be made available upon request.

Table 1: **Sample Site List**

Site #	Description	Length of Sampling
1	McKissic Creek	Feb. 1977 to Present
2	Sugar Creek South of Bella Vista	Feb. 1977 to Present
3	Lake Bella Vista East Side of Dam	Feb. 1977 to May 1991
3A	Spillway West End of Lake Bella Vista	April 1977 to Nov. 1998
3B	Spillway East End of Lake Bella Vista	April 1977 to Dec. 1989
4	Spring Behind Trout Farm	Feb. 1977 to March 1996
5	Spring at Riordan Road	Feb. 1977 to Jan. 1999
6	Spring at Kingsdale Barn	Feb. 1977 to May 1991
7	Blowing Springs at Spring	Feb. 1977 to Jan. 1999
8	Sugar Creek South by Kingsdale #18 Green	Feb. 1977 to March 1999
9	Spring Southeast of Kingsdale Proshop	Feb. 1977 to Nov. 1998
10	Lake Ann East End	Feb. 1977 to Present
11	Lake Ann Spillway	Feb. 1977 to Present
12	Spring at Nottingham Subdivision	Feb. 1977 to May 1991
13	Sugar Creek, North of Hwy. 340 Bridge	Feb. 1977 to Nov. 1998
14	Lake Windsor Spillway	Feb. 1977 to Present
15	Lake Windsor South End	Feb. 1977 to Present
16	Lake Avalon Spillway	Feb. 1977 to Present
17	Lake Avalon West End	Feb. 1977 to Present
18	Spring at John Cooper Jr.'s House	Feb. 1977 to April 1990
19	Sugar Creek at Stateline Bridge	Feb. 1977 to Present
26	Lake Brittany Dam	May 1996 to Present
27	Lake Rayburn Dam	Feb. 1977 to Present
28	Lake Rayburn East End	Feb. 1977 to Present
29	Lake Norwood Dam	Feb. 1977 to Present
30	Lake Norwood East End	Feb. 1977 to Present
31	Spring by #3 Tee	May 1977 to Nov. 1998
33	Spring South End Lake Brittany	Feb. 1977 to July 1984
34	Lake Brittany Spillway	Feb. 1977 to July 1984
35	Sewage Lagoon at Swan Lake	Feb. 1977 to Jan. 1999
37	Package plant at Hilldale Bridge	Feb. 1977 to May 1991
40	Sugar Creek, West of Linen Room	Feb. 1977 to June 1998
41	Spring Behind Linen Room	Feb. 1977 to Jan. 1999
42	Sugar Creek North of Trailer Park	Feb. 1977 to Nov. 1998
43	Sugar Creek South of Ford Springs	June 1980 to March 1997
44	Spring Below Hog Farm	Feb. 1977 to May 1991
45	Loch Lomond Dam	June 1980 to Present
46	Stonykirk Boat Launch	Oct. 1980 to Present

Table 2. Sampling Site Location

Site #	Site Description	Latitude	Longitude	Altitude (feet)[b]
1	McKissic Creek	N 36° 25.432'	W 94° 13.280'	1076
2	Sugar Creek South of Bella Vista	N 36° 25.504'	W 94° 12.957'	1044
3A	Spillway West End of Lake Bella Vista	N 36° 25.985'	W 94° 13.808'	1055
3B	Spillway East End of Lake Bella Vista	N 36° 25.957'	W 94° 13.903'	1032
4	Spring Behind Trout Farm	N 36° 26.058'	W 94° 13.457'	1121
5	Spring at Riordan Road	N 36° 26.833'	W 94° 14.610'	1074
6	Spring at Kingsdale Barn	N 36° 26.800'	W 94° 14.241'	1066
7	Blowing Springs at spring	N 36° 26.763'	W 94° 13.401'	1182
8	Sugar Creek South of Kingsdale #18 Green	N 36° 27.336'	W 94° 14.657'	1018
9	Spring South-East of Kingsdale Proshop	N 36° 27.330'	W 94° 14.744'	1059
12[a]	Spring at Nottingham Subdivision	N 36° 28.087'	W 94° 14.886'	
13	Sugar Creek North of Hwy. 340 Bridge	N 36° 28.657'	W 94° 15.150'	1015
18	Spring at John Cooper Jr.'s House	N 36° 29.594'	W 94° 15.772'	1034
19	Sugar Creek at Stateline Bridge	N 36° 29.860'	W 94° 16.366'	967
31	Spring by #3 Tee	N 36° 29.215'	W 94° 15.638'	1061
33	Spring South End of Lake Brittany	N 36° 27.665'	W 94° 12.026'	1302
34	Lake Brittany Spillway	N 36° 28.214'	W 94° 12.187'	1189
35	Sewage Lagoon by Swan Lake	N 36° 29.589'	W 94° 16.083'	1018
37	Package Plant at Hilldale Bridge	N 36° 26.047'	W 94° 13.800'	1031
40	Sugar Creek West of Linen Room	N 36° 25.534'	W 94° 13.366'	1113
41	Spring Behind Linen Room	N 36° 25.688'	W 94° 13.374'	1175
42	Sugar Creek North of Trailer Park	N 36° 26.192'	W 94° 14.090'	1040
43	Sugar Creek South of Ford Springs	N 36° 25.268'	W 94° 12.790'	1050
44	Spring Below Hog Farm	N 36° 24.897'	W 94° 12.171'	1113
46	Stonykirk Boat Launch	N 36° 28.400'	W 94° 20.226'	1193

[a] The spring has been built over and rerouted, exact location not known.

[b] Altitude for general idea only, hand-held GIS system could be off in altitude.

Table 3. Constituent Measurement Units

CONSTITUENT	UNITS
Fecal coliform[a]	c.f.u./100 ml
pH	(typical)
Sulfate	mg/l SO_4
Total Dissolved Solids (TDS)	mg/l
Dissolved Oxygen (D.O.)	mg/l
Temperature	^oC
Chloride	mg/l
Total Nitrogen	mg/l
Nitrate as Nitrogen (NO_3-N)	mg/l
Turbidity[b]	JTU, FTU, NTU
Total Phosphorus	mg/l
Acid-Hydrolysable Phosphorus	mg/l
Phosphate as Phosphorus	mg/l

[a] c.f.u. = colony forming units.

[b] Units changed from JTU to FTU to NTU over data sampling period.

Scope-Methods

Available data from Bella Vista Village collected over the last 32 years is statistically analyzed in this project. One of the original goals of the monitoring program was to identify areas of worsening water quality and determine the causative factors to correct them. In this study, the observer is interested in whether a statistically significant change exists at these sites. From the statistical findings, a conclusion can be reached on whether or not a certain data set or collection of data sets has a statistically significant trend, be it a positive or negative one. The data is first determined to be normal or non-normal (non-parametric) through conventional normality statistics by using Microsoft Excel™ spreadsheets. The non-parametric data is then analyzed by a seasonal Kendall test, while the normal data is analyzed by both Microsoft Excel™ linear regression analysis and the seasonal Kendall test. (A detailed description of the statistical analyses performed can be found in a technical supplement included in project deliverables.) These procedures not only establish whether or not a trend exists, but puts the information in terms of a predictive mathematical model. Once the data was analyzed, various maps (constituent maps and watershed map) were constructed to help determine what the cause of a trend might be (i.e. runoff or septic systems). In the future, these maps can be coupled with a land use map, septic tank density map and septic system construction dates to reach conclusions concerning Bella Vista's water bodies. Hopefully, the conclusions reached in this report will help to provide the framework for further analyses of this community.

Shaded Area: Ozark Plateau of Arkansas

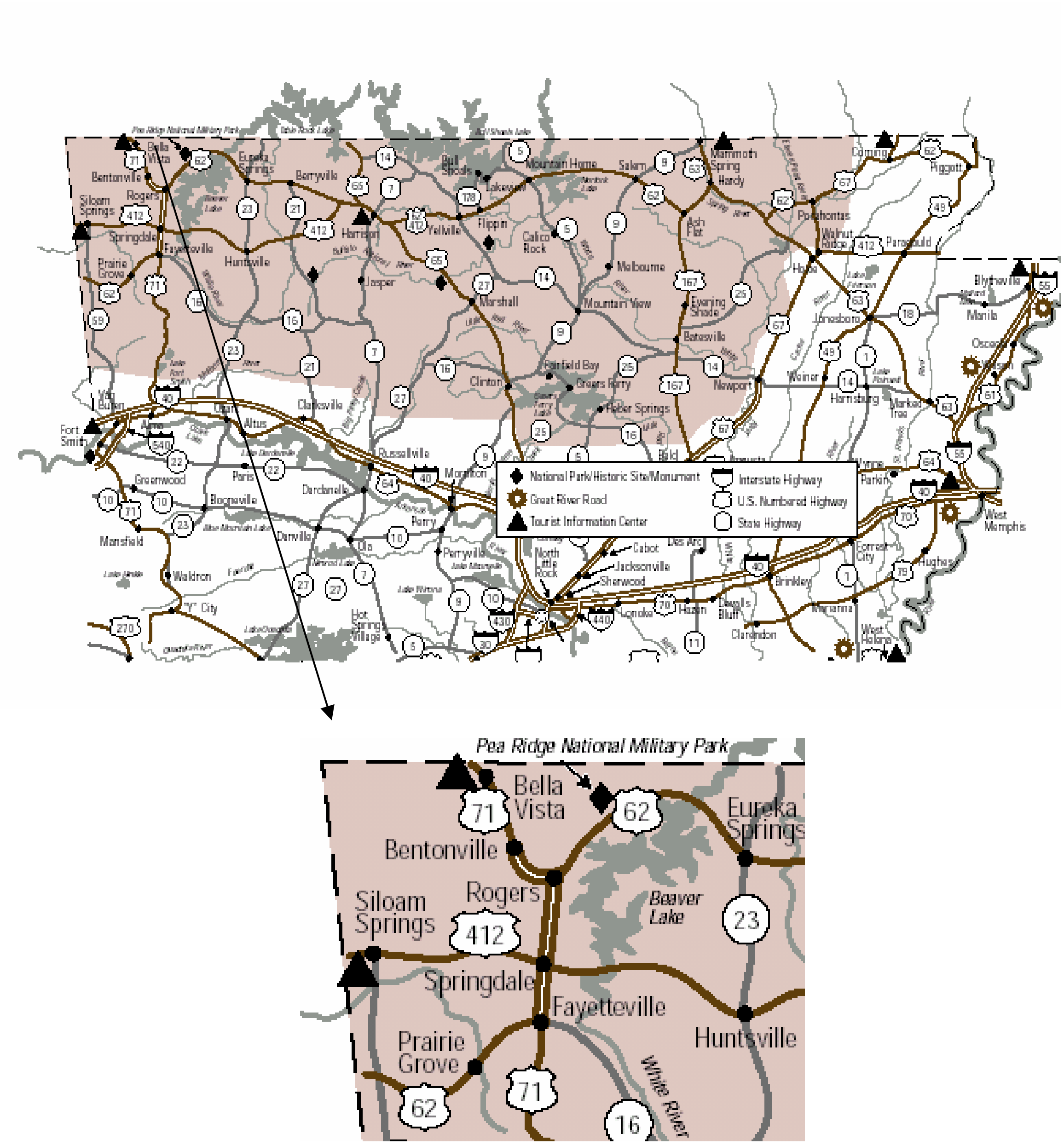

Figure 1. Generalized Location Map
Map provided by: www.arkansas.com/

Objectives

The objectives to be accomplished by this study are as follows:

- *Obtain and organize water quality data from data source*. This task is for determining test methodology and units of expression for each parameter and making necessary corrections to data to account for different methods of measurement and units if necessary. For example, phosphate data changed from µg/l to mg/l with the acquisition of a new measurement device in the mid- 1980's. This data needs to be in consistent units over the entire sampling period, and therefore would need to be adjusted into one set of data. Also, the type of measurement changed in the mid-1980's and will have to be adjusted for several parameters (ortho-phosphate vs. total phosphate). This data was compiled and organized for entry into spreadsheet format.
- *Enter water quality data from all sites into a spreadsheet format (Microsoft Excel™).* This data will include the information on springs and streams as recorded by the public works office of the Bella Vista POA. The data set consists of 38 sites measured over various time increments. Measurements were taken approximately once a month.
- *Assess/Analyze water quality data for potential trends and other relationships*. Statistical analysis will be performed in Microsoft Excel™. These statistical analyses followed the recommendations of EPA Manual #8441-R-93-003 "Statistical Methods for the Analysis of Lake Water Quality Trends" (Reckhow 1993). A non-parametric seasonal Kendall test was ran on each non-parametric parameter. Anthony Sarhan has written a seasonal Kendall equation with the help of Dr. Thomas Soerens, which was used for the analysis in Microsoft Excel™. Sarhan used the seasonal Kendall programs and other Excel applications to perform statistical analysis on all the lake data sites (refer to reference Sarhan et al. 2002). Statistical analyses were performed on all other sites by Shada Roberts (Roberts, 2003).
- *Map related watersheds and delineate sample locations.* Land use delineation and sample data was used to create a product capable of being implemented into a GIS application such as ARC View™. A "manual" statistical trend maps was created for the gathered data, followed by the creation of shape files for ARC View™.
- *Determine potential for spatial analysis.* GIS software can be used to help determine other potential relationships between urbanization practices and water quality through spatial analyses. The researchers will suggest options for further investigation.

Results

Tables 4 and 5 show results of trend analyses for all sites analyzed. Lake/reservoir sites were analyzed separately from stream sites and springs. Generally it was discovered that where there were significant trends, pH increased (water became more basic); fecal coliform, chloride, nitrate-nitrogen and total phosphorus concentrations increased while total dissolved solids (TDS), sulfate, total nitrogen and turbidity decreased. Table 6 shows median values for each of the parameters sampled at stream and spring sites. Regression and SEN slope indicators were also determined at stream and spring sites in order to estimate rates of change in any given parameter at sampling sites where trends were shown to be statistically significant. The range of slopes/rates of change varied from 10^{-3} to 10^{-7} units/year. A full listing of results of trend analyses can be found in the technical supplement included as part of the deliverables to ASWCC.

Table 4. Trend Analysis Results for Springs and Stream Sites

Site #	pH	Fecal Coliform	TDS	Sulfate	D.O.	Temperature	Chloride	Total Nitrogen	Nitrate-Nitrogen	Turbidity	Total Phosphorus	Acid-Hydrolysable Phosphorus	Phosphate
1	+	-	-	NST	+	-	NST	-	+	-	+	NST	NST
2	+	+	-	-	NST	-	+	-	+	-	+	NST	+
3A	+	NST	-	NST	NST	-	+	-	+	-	+	NST	NST
3B	+	-	NST	-	+	NST	-	-		NST	+		
4	+	+	NST	-	NST	-	NST	-	NST	-	+	NST	
5	+	NST	-	NST	NST	-	+	-	+	-	+	NST	NST
6	+	+	+	-	NST	NST	NST	-	NST	NST	NST	NST	
7	+	NST	-	-	NST	-	+	-	+	NST	+	NST	NST
8	+	NST	-	NST	NST	-	+	-	+	NST	+	NST	NST
9	+	NST	-	+	NST	NST	-	-	+	-	+	NST	NST
12	NST	+	+	NST	+	+	+	-	NST	-	NST	NST	
13	+	-	-	NST	NST	-	+	-	NST	-	+	NST	-
18	NST	NST	-	NST	NST	NST	NST	-		NST	NST		
19	+	-	-	NST	NST	NST	+	-	+	-	+	NST	+
31	+	NST	-	-	NST	NST	+	-	+	-	+	NST	NST
33	NST	NST	+	NST	NST	+	+	-		NST	-		
34	NST	NST	+	NST	+	NST	NST	-		-	-		
35	NST	-	-	NST	NST	NST	-	-	+	-	+	-	NST
37	NST	+	-	-	+	NST	-	-		-	NST		
40	+	NST	-	NST	NST	-	+	-	NST	-	+	NST	-
41	+	NST	-	NST	NST	NST	+	-	NST	-	+	-	NST
42	+	-	-	NST	NST	NST	+	-	+	NST	+	NST	NST
43	+	-	-	-	NST	-	NST	-	NST	-	NST	NST	NST
44	+	NST	+	NST	NST	NST	NST	-	NST	NST	NST	NST	
46	NST	NST	-	-	NST	NST	+	-	NST	-	+	NST	+

Key: + = increasing trend, - = decreasing trend, NST = no significant trend

Table 5. Trend Analysis Results for Reservoir Sites

Site #	pH	Fecal Coliform	TDS	Sulfate	Temperature	Chloride	Nitrate-Nitrogen-N	Turbidity	Phosphate
10	+	No	-	-	-	+	No	-	+
11	+	+	-	-	-	+	+	-	NST
14	+	NST	-	-	NST	+	NST	-	NST
15	+	NST	-	NST	NST	NST	+	-	NST
16	+	NST	-	NST	NST	+	NST	-	NST
17	+	NST	-	-	NST	+	-	-	NST
26	NST	NST	+	N/A	+	NST	NST	-	+
27	+	+	-	-	NST	+	NST	-	NST
28	+	+	-	-	NST	NST	NST	NST	+
29	+	+	-	-	-	+	NST	-	NST
30	+	+	-	-	-	+	+	-	+
45	+	-	-	-	NST	NST	NST	-	NST
3	+	NST	+	NST	NST	NST	N/A	NST	N/A

Key: + = increasing trend, - = decreasing trend, NST = no significant trend, N/A = Not Applicable

Table 6. Median Values for Spring and Stream Sites

Site #	pH	TDS (mg/l)	Sulfate (mg/l)	D.O. (mg/l)	Temperature (°C)	Chloride (mg/l Cl^-)	Fecal Coliform Median[a] (c.f.u./100ml)[b]	Fecal Coliform Geometric[a, c] Mean (c.f.u./100ml)[b]
1	7.9	238	7	7.8	15	14.5	160	110
2	7.8	203	2	7.85	14	5.8	105	21
3A	8.1	210	3	8.9	16	9	90	28
3B	7.4	213.5	3	8.3	16	7.5	99	4
4	7.82	143.85	2	9.25	14	3.6	9	1
5	7.945	199.5	3	8.5	13.5	3.4	15	1
6	7.8	171.5	2	8.625	14	1.8	16	1
7	7.9	112.5	2	9.2	14	3.5	13	1
8	8	210	3	8.16	15.5	8.4	72	9
9	7.71	168	5	8.5	15	8	56	5
12	7.7	225.75	2	8.05	14.5	4.2	51	4
13	7.86	199.5	3	7.5	17	7.5	52	5
18	7.7	150.5	3.5	8	14.75	2.3	9	1
19	8.02	189	3	8.05	17	7.65	63	4
31	7.9	170.1	3	8.6	14	3.4	100	25
33	7.6	98	2	8.2	15	2	< 1	1
34	7.7	108.5	2	7.5	19.5	3.1	4	1
35	7.37	297.5	15	4.5	20	30.7	< 1	1
37	7.2	318.5	14	5.6	19.5	27	< 1	1
40	7.9	210	3	8	14.5	7	95	27
41	7.83	147	4.5	8.3	14.5	8.5	49	5
42	8.1	210	3	8.5	16	8.5	75	10
43	7.8	209.65	2	7.5	14.5	5.8	58	43
44	7.72	182	2	7.6	19	4.2	86	4
46	8.1	98	1	6.8	19	4	< 1	1

[a]Data represented as colony forming units per 100ml, converted from log base 10 values [b]c.f.u. = colony forming units
[c]Geometric mean of fecal coliform, appropriate summary indicator when log of data is taken.

Table 6. Median Values for Stream and Spring Sites (continued)

Site #	Total Nitrogen (mg/l)	Nitrate-Nitrogen (mg/l NO_3-N)	Turbidity (NTU)[a]	Total Phosphorus (mg/l)	Acid-Hydrolysable Phosphorus (mg/l)	Phosphate (mg/l)
1	3.4	3.7	4	2.0375	4.895	2.62
2	1.8	1.7	2	0.04	0.22	0.185
3A	1.95	2.2	9	0.6875	1.63	0.86
3B	2.7	--	8	0.4368	--	--
4	2.3	1.1	3	0.03	0.18	--
5	1.9	0.9	3	0.0326	0.215	0.12
6	1.9	0.37	4	0.0313	0.18	--
7	1.9	1.2	4	0.0326	0.18	0.1
8	2.375	1.9	7	0.4945	1.385	0.77
9	2.85	2.7	3	0.0652	0.28	0.185
12	2.7	3.1	3.5	0.04445	0.3	--
13	2.3	1.5	6	0.32925	0.965	0.31
18	2.3	--	7.5	0.0326	--	--
19	2.15	1.7	4	0.48	1.06	0.86
31	2.7	1.7	3	0.0489	0.225	0.12
33	5.6	--	5	0.0163	--	--
34	2.7	--	8	0.0179	--	--
35	1.55	0.9	17	6.39775	7.26	2.04
37	8.5	--	10	2.9	--	--
40	2.7	2	3	0.28198	0.93	2
41	4.05	3.85	3	0.5216	1.45	0.37
42	2.7	2.1	8.8	0.55	1.5	0.86
43	1.9	1.5	2	0.03	0.24	0.175
44	1.9	2.7	6	0.03	0.255	--
46	0.1	0.1	3	0.07	0.135	0.115

[a] units varied from JTU to FTU to NTU over thirty years of data gathering.

In addition to the above previewed results, GIS maps/databases for the development area were developed. These maps include digital elevation models for the area, watershed boundaries, land use/land cover, general soils, general geology, minimum, maximum and median values for all parameters at all sampling locations and other information deemed pertinent by the researchers. These GIS datasets are available as ARC View™ shape files and are included in deliverables to ASWCC. Arkansas Department of Health onsite wastewater permits for the development were also copied and are in the process of being compiled and entered into a database that will eventually be incorporated into the GIS database as applicable. Time and budget constraints for cooperating agencies and groups did not allow for completion of that database to date, but the researchers are continuing to gather this data and will incorporate it into a stand alone database and applicable GIS files as soon as possible. Completed ARC View shape files and other electronic versions of compiled data sets are included in deliverables to ASWCC. A line item workplan report and the final quality assurance report are in Appendices C and D respectively.

Conclusions

Onsite wastewater treatment systems, in particular, conventional septic systems have been suspected of contributing to the potential degradation of water quality in watersheds where they are present in significant numbers. The data set analyzed in this project consisted of approximately 30 years of monthly water quality sample data covering 10 parameters and sampled from reservoir, stream and spring sites. The primary method of wastewater disposal in the study area is septic systems on relatively small lots. Trend analyses performed indicated that there were statistically significant potential effects on water quality from the utilization of onsite septic systems but the long term effects are considered minimal. Applicable ecoregion water quality standards have been continuously met and/or exceeded in most cases. In the case of phosphorus, there a small number of sites with median values above the narrative standard, but without further investigation it is not possible to differentiate between the effects of lake fertilization practices, runoff from lawns and golf courses and septic system effluent. Data indicates that treated effluent from septic systems is moving through the groundwater system as evidenced by significant increasing trends in concentrations of chloride (a conservative constituent of wastewater) in almost all waters sampled. Other parameters of interest including bacteria and nutrients appear to be attenuated by the soil treatment system. What follows is an overview of trends as stated in the executive summary.

Where there were significant trends, pH tended to increase; fecal coliform, chloride, nitrate-nitrogen and total phosphorus concentrations also increased while total dissolved solids (TDS), sulfate, total nitrogen and turbidity decreased. Some of the reservoir sites show significant increasing trends in the fecal coliform concentrations. Of the lakes in the Bella Vista Village watershed, the one having the highest median fecal coliform concentration has a median concentration of 3 CFU/10 mL. Only one sampled reservoir site had a median fecal coliform concentration greater than 100 CFU/100 mL, and that reservoir is Lake Bella Vista. Lake Bella Vista is outside of the Bella Vista Village watershed, and is not impacted by activities within the village. Although some of the trends are increasing, in order to determine if the trend has meaning in terms of impact to the environment or the public health, the concentration of the measured parameter should be considered. Of the spring and creek sites, the highest median fecal coliform concentration at the sites having increasing significant trends was 105 CFU/100 mL at site #2 (Sugar Creek, South of Bella Vista). These values are well below the concentrations allowable for primary contact water and as a rule, cannot be directly attributed exclusively to the impact of onsite systems.

The nitrate-nitrogen concentrations at the sites having increasing significant trends are above 3 mg/L, with the highest being 3.7 mg/L at site number 1 (McKissic Creek South of Bella Vista). Of the remaining sites with increasing significant trends, only two others had median nitrate-nitrogen concentrations greater than 3.0. The site with the highest nitrate-nitrogen concentration was site number 41 (Spring Behind Linen Room), having a median NO_3-N concentration of 3.85 mg/L. Interestingly, this site did not have a significant trend, and its trend was decreasing. All of the NO_3-N median concentrations were well below the primary drinking water standard of 10 mg/L NO_3-N.

Other parameters of current regulatory/water quality interest include chloride, Total Dissolved Solids (TDS), sulfate and forms of phosphorus. Median chloride concentrations for the most part are well below the eco-region standard of 13 mg/L. Sites 35 and 37 are samples from wastewater treatment facilities and their discharges are subsequently diluted in the stream system. Sulfate concentrations are all well below the eco-region standard of 17 mg/L. With the exception of the wastewater treatment facilities concentrations of TDS are also below the current eco-region standard of 240 mg/L. At five sites, median total phosphorus concentrations are higher than the narrative standard of 0.1 mg/L, but there is some question as to the source of phosphorus. Fertilization of lakes, lawns and nearby golf course facilities is assumed to be at least a partial contributor to nutrient levels in the system.

There are increasing trends in many of the constituents of concern, but the rate(s) of increase for any given parameter range from 10^{-3} to 10^{-8} mg/L per year. Using a worst-case scenario for total phosphorus (excluding the wastewater treatment facility at site 35) with a rate of increase of 3.76×10^{-4} mg/L per year, the total increase in 50 years would be only 0.019 mg/L. Data has been tabulated in a similar form for all sampled parameters and analyses of these data show similar minimal effects.

There are statistically significant increasing trends in some of the measured parameters. The water quality in the reservoirs, streams, and springs in Bella Vista Village watershed appears to be relatively good in terms of the measured parameters and in the majority of cases meets or exceeds regulatory water quality criteria/standards. The effects of this type of development upon the water quality do not seem to be harmful in terms of the parameters having increasing significant trends. Certainly the parameters typically attributed to onsite wastewater system degradation of the water quality – fecal coliform and nitrate-nitrogen – do not appear to have been increased greatly by the onsite wastewater systems in the Village. This 30-year data set suggests that onsite wastewater systems can provide a viable solution for single-family residences when used community-wide, while providing protection of the water resources.

Recommendations for further analysis

The next phase of these analyses will involve using the pertinent water quality data, trend data, soils, landcover/landuse data, watershed boundaries and other features currently entered in the Geographical Information System (GIS). Spatial analyses can aid in differentiation between effects from onsite treatment systems and other urban factors. Rainfall-runoff simulations may be used to help develop/determine loading factors for water quality parameters of interest. These loading factors could then be used in simulations designed to set Total Maximum Daily Load (TMDL) allocations for similar watersheds. Further analysis of rates of change in sampled parameters can be useful in developing predictive models and management strategies for application to similar types of urban developments and the long term effects of such development on water quality. These rates of change and urbanization rates can potentially be examined for correlations. This set of data and initial analyses, encompassing almost 30 years of variations in water quality and attributed to urbanization and urban practices has much potential for aiding researchers in determining the overall effects of similar developments on water quality.

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Appendix A

Workplan

for

A Watershed Approach to Managing Onsite Wastewater Systems
Project 1300 FY01 CWA Section 319(h)

Appendix B

Quality Assurance Project Plan

for

A Watershed Approach to Managing Onsite Wastewater Systems
Project 1300 FY01 CWA Section 319(h)

Appendix C

Workplan Report

for

A Watershed Approach to Managing Onsite Wastewater Systems
Project 1300 FY01 CWA Section 319(h)

Appendix D

Final Quality Assurance Report

for

A Watershed Approach to Managing Onsite Wastewater Systems
Project 1300 FY01 CWA Section 319(h)