San Pedro River Targeted Watershed

E. coli Reduction Improvement Plan

Coronado Resource Conservation & Development
450 S. Haskell Ave.
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Coronado Resource Conservation & Development (RC&D)

Plan development oversight was provided by Coronado RC&D in conjunction with the San Pedro Targeted Watershed Improvement Council (WIC). Coronado RC&D is a 501(c)(3) nonprofit organization with the mission to empower rural communities to conserve natural resources and increase opportunities for economic stability.

San Pedro Targeted Watershed Improvement Council (WIC)

The WIC is a voluntary group of watershed stakeholders including local and state government and land management agencies, as well as local residents and community groups. Organizations represented on the WIC include:

Apache Nitrogen Products, Inc.
Hereford NRCD
San Pedro NRCD
St. David Water District
Cochise County
Bureau of Land Management (BLM)

Technical Support

Technical support was provided by:

ADEQ
Non-point Education for Municipal Officials (NEMO)
Bureau of Land Management (BLM)
Apache Nitrogen Products, Inc.
Soil, Water, and Environmental Science Department The University of Arizona

FORWARD

The Coronado Resource Conservation & Development Council (RC&D), in collaboration with multiple partners in the San Pedro watershed, was awarded a grant by Arizona Department of Environmental Quality (ADEQ) to identify possible causes of biological changes in surface water quality in the reach of the San Pedro River located between the confluence of the Babocomari River – near Fairbanks, to the mouth of the Dragoon Wash - near St. David in Cochise County Arizona. The grant goals included establishing a Watershed Improvement Council (WIC), provide a water sampling monitoring plan, and develop a list of best management practices (BMP's).

The fact that sampling over time indicated the presence of *E. coli,* justified further study to determine type and source. Due to the large geographic area involved and a pathogen, it was imperative that residents of the watershed be involved in the project from the onset and assumes responsibility for watershed health at the close of the project.

A six month extension was granted for this study due to the variable conditions for monitoring the existing reach of the river. During the extension additional water samples were collected and analyzed. In addition a rancher's conference was held to provide material and information to help educate landowners and interested parties in BMP's that could be applied for long term solutions for the reduction of *E. coli* loads in the river.

Results of the analysis indicate a complex system with many variables leading to the impairment of this reach of the river. Research to date has identified varied potential *E. coli* sources within the watershed and still deserves much investigation. The final goal is the delisting of the San Pedro River from the EPA impairment list.

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ABBREVIATIONS

ADEQ	Arizona Department of Environmental Quality
ATV	All Terrain Vehicle
BLM	Bureau of Land Management
BMP	Best Management Practice
Bo	Bovine
C	Celcius
CFS	Cubic Feet per Second
CFU	Colony Forming Unit
CMP	Conservation Management Plan
CWA	Clean Water Act
DWF	Dry Weather Flow
EECS	Estimated Environmental Concentrations
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
FBC	Full Body Contact
EQIP	Environmental Quality Incentive Program
Hu	Human
MST	Microbial Source Tracking
NOAA	National Oceanic and Atmospheric Administration
NEMO	Non-point Education for Municipal Officials
NPS	Non-point Source
NRCD	National Resource Conservation District
NRCS	National Resources Conservation Service
SPRNCA	San Pedro Riparian National Conservation Area
TMDL	Total Maximum Daily Load
TNC	The Nature Conservatory
UDA	Undocumented Alien (U.S. Border Patrol)
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USPR	Upper San Pedro River
U of A	University of Arizona
WIC	Watershed Improvement Council
WIP	Watershed Improvement Plan
WQIG	Water Quality Improvement Grant

CHAPTER 1: BACKGROUND

The objective of this study is to identify the sources of *Escherichia coli (E. coli)* and to identify projects within the watershed to restore water quality in the San Pedro River.

Water quality concern and watershed description

Pollutant of Concern

E. coli is the name of a bacterium that lives in the digestive tracts of humans and other warm blooded animals. There are many types of *E. coli* and most of them are harmless, however they can be an indicator for the possible presence of pathogenic (disease causing) bacteria that also live in human and animal digestive systems. *E. coli* infection is caused by coming into contact with the feces of humans or animals. This happens when you ingest water or eat food that has been directly or indirectly contaminated by feces.

The Clean Water Act, 1980, created standards to measure *E. coli* bacteria in its fresh water lakes, rivers, and streams to protect people from infection and disease while using public waters for fishing, swimming and boating activities. The Arizona standard for full body contact (FBC) as in swimming is 235 colony forming units (cfu) per 100 ml. The standard for partial body contact as in boating and fishing, is 576 cfu/100 ml. (*Bacteria Water Quality Standards for Recreational Waters Freshwater Marine Water Status Report,* document 133 of 6970)

The presence of *E. coli* in the San Pedro River suggests that pathogenic organisms may also be present and that full body contact or partial body contact might be a health risk. The fact that sampling over time has indicated the presence of *E. coli* in the San Pedro River during high monsoonal flow justifies further study to determine its type and source.

Watershed Description

The San Pedro River begins from the mountains near Cananea, Sonora, Mexico, for approximately 10 miles, enters the United States and flows north winding its way through southeastern Arizona before entering the Gila River near Winkelman, Arizona, for approximately another 140 miles. (ADEQ, FS 06-14)(Wikipedia) To the west are the Huachuca Mountains rising 9,596 feet above sea level and to the east the Mule Mountains with a peak elevation of 7,382 feet above sea level (Simpson 2006). Figure 1 is a map of the Upper San Pedro River watershed north of the United States/Mexico border.

Precipitation ranges 14-30 inches a year with summer monsoon season starting in July and lasting through September. Stream flow is lowest April through June generally declining as soon as cottonwood trees, mesquites, and other shrubbery along the river leaf out.

The San Pedro River flows through the San Pedro Riparian National Conservation Area (SPRNCA) covering 57,000 acres of public land between the Mexican border and St. David, Arizona. The targeted reach sampled in this project begins at the confluence of the Babocamari River, a major tributary to the San Pedro River, which is approximately 30 miles north of the international border (Figure 1). 35,603 acres of the SPRNCA lies within the targeted reach of this project (BLM GIS Specialist Leslie A. Uhr). The riparian area was designated by Congress as a Riparian National Conservation Area on November 18, 1988, its primary purpose:

...to protect the riparian area and the aquatic, wildlife, archeological, paleontological, scientific, cultural, educational, and recreational resources of the public lands surrounding the San Pedro River in Cochise County. (Public Law 100–696)

The river's stretch is home to a variety of mammals, fish, reptiles and birds. Livestock grazing has been excluded except for a few small allotments in the SPRNCA. Because of its unique nature, the SPRNCA draws people from around the country to observe 250 species of migrant and wintering birds.

The Nature Conservancy has been conducting wet dry mapping of the San Pedro River annually since 1999 before monsoon season begins. The event takes place the third Saturday of June when temperatures can get over 100 degrees daily with no rain. Measuring this time of the year provides the best information of ground water conditions that support surface flow. The community event includes members of the Bureau of Land Management (BLM), Nature Conservancy, local residents, and landowners who cover 220 miles of the river. From 1999 to 2011 an average of 32% of the river through the SPRNCA exhibited perennial flow before the summer monsoon season. (Turner & Richter, 2011)

Figure 1. Map of San Pedro Targeted Watershed

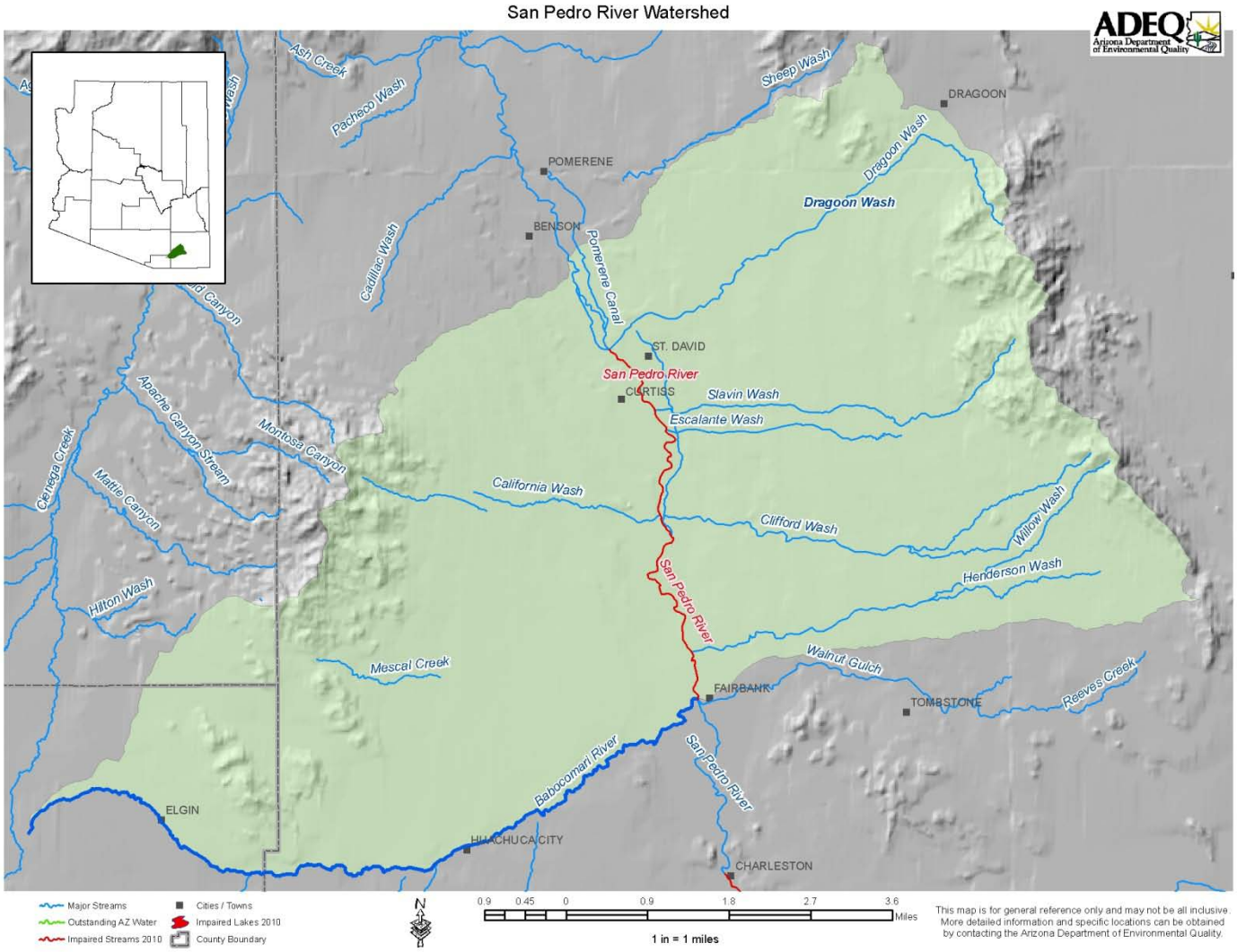
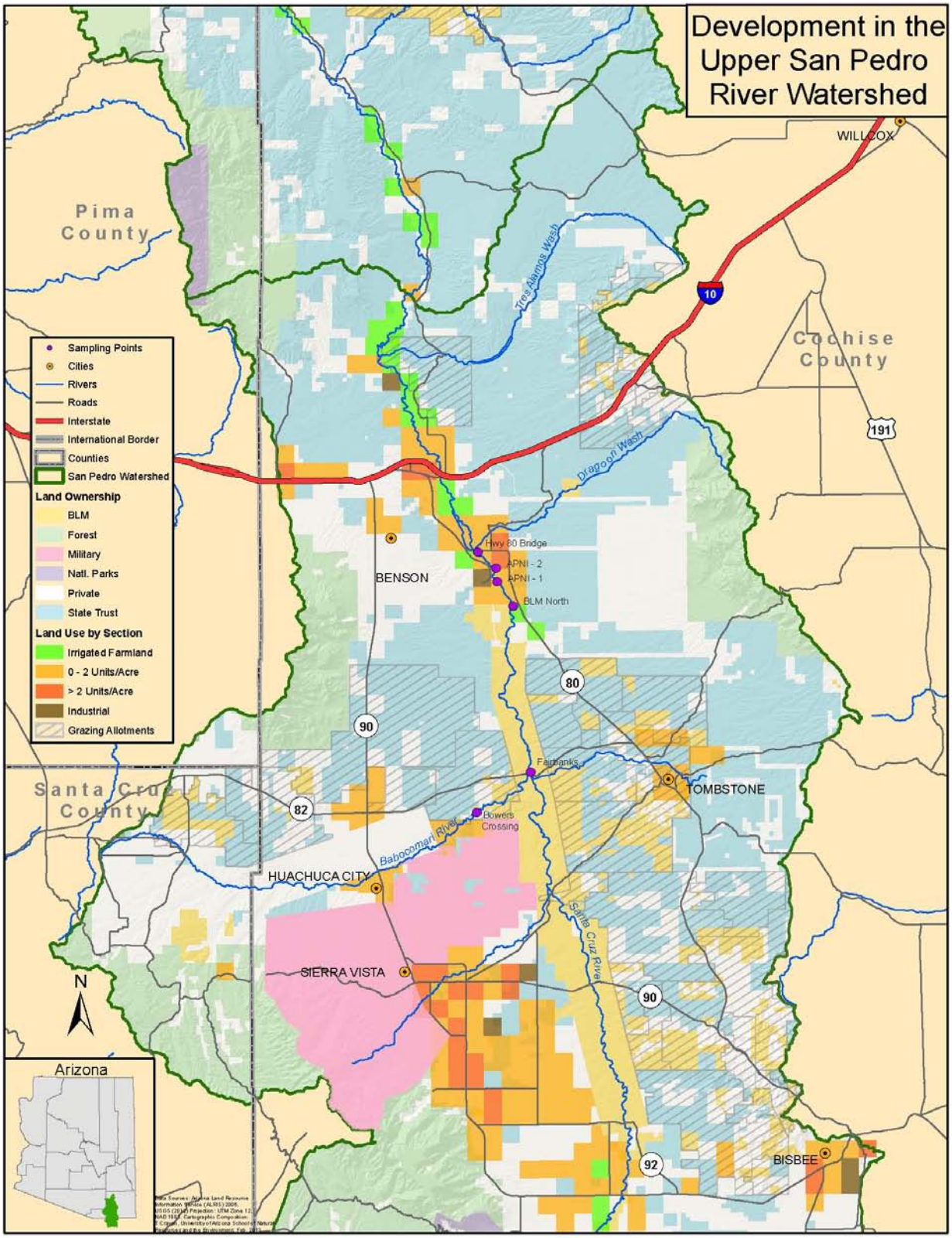


Figure 2. Map of San Pedro River Upper Watershed Land Ownership and Uses



Impaired Waters

The presence of E. coli concentrations exceeding the Arizona Water Quality Standard for full body contact of 235 colony forming units (CFU) per 100 mL were observed in the San Pedro River by Arizona Department of Environmental Quality (ADEQ) during 2006. These samples were taken at various sites of the river between the mouth of the Babocomari River to Dragoon Wash. Monitoring by ADEQ and the subsequent exceedences have led to the listing of this reach as impaired in Arizona's Integrated Assessment (305(b) and ADEQ's 303(d) lists. (ADEQ Water Quality 2010)

These lists have been used as a justification for information compiled by the Arizona Non-point Education for Municipal Officials (NEMO) program in their Watershed Based Plan for the Upper San Pedro Watershed. The NEMO Watershed Based Plan for this area has provided an excellent resource for local area detailed assessment, sampling, planning and implementation of practices to address this impairment.

Sampling conducted for the purpose of developing the document did not necessarily duplicate those sites monitored in the past by ADEQ, but were determined by multi-layered gathering of information about recreations sites, wildlife and/or livestock watering spots, human foot traffic activity, active and abandoned septic systems, agricultural fields, and waste water treatment plants.

Potential Sources of Contamination

E. coli comes from human and animal wastes. During rainfalls, snow melts, or other types of precipitation, *E. coli* may be washed into creeks, rivers, streams, lakes, or ground water by the resulting runoff.

I. Livestock

The majority of the area adjacent to the river is contained within the Bureau of Land Management's (BLM) SPRNCA which mostly excludes grazing. However, trespass cattle frequently get into the SPRNCA. Livestock grazing is a practice on the Babocamari River below Huachuca City, and in the areas of the watershed outside of the SPRNCA the St. David community area has crop production and small livestock operations.

II. Failing septic systems

Huachuca City is a small to medium size community with sewer ponds adjacent to the Babocamari River and scattered private septic tanks in the outlying areas. The Town of Tombstone is located on Walnut Gulch which flows into the subject reach of the San Pedro River. The other community is St. David which lies right on the river at the northern most border of the targeted project area. Additionally there are numerous septic tanks serving home sites along the river.

III. Recreation

The San Pedro River is home to a variety of mammals, fish, reptiles, amphibians, and birds. The area provides opportunities for various recreational activities that include wildlife viewing, picnicking, hunting, hiking, camping, fishing, biking, horseback riding, and off road vehicles (off road vehicles are not permitted in the SPRNCA). It is an important stop-over point in the migratory corridor of many bird species attracting bird watchers from around the United States and there is no boating with minimal swimming.

IV. Other

The San Pedro River is unique in that the flow of the river is south to north, its source located in the mountains near Cananea, Sonora, Mexico. The region is a travel corridor for undocumented entrants traveling from Mexico. There are numerous areas littered with garbage and human waste left by humans as they travel north or by recreationist in the area. These sites are monitored by the US Border Patrol, the BLM, and help of local residents and ranchers in the area. In addition to the human activity and transient occupancy in the river bed, large storm events can cause the river flow to potentially move human waste north from Cananea in Mexico into this reach of the river. This poses a real concern as untreated human waste has the opportunity to reach large stretches of the river.

There is abundant wildlife in the San Pedro area. This study investigated traditional sources of fecal pollution, however understanding the role of free-ranging wildlife populations is needed in order to better describe additional sources of fecal contamination.

Monitoring Data

Sampling and monitoring goals were established to determine bacteroides and *E. coli* levels during both storm run-off events and dry weather flow (DWF) periods. The objective was to quantify exceedances and differentiate among human, cattle, and other animal sources of *E. coli.* Supporting documentation included, but was not limited to: flow, turbidity, air and water temperature, climate conditions (ex. flooding), pH and specific conductivity measurements, field observations, anecdotal information on land uses gathered from different communities accessing the watershed, research on records of past and present human habitations, and research on seasonal/meteorological factors affecting the above.

Sampling was done over time at sites the sampling team determined may have contributed to past exceedances. Sampling sites were limited to locations where property owner's permission to sample and measure had been acquired. Sampling schedules were weather-dependent to sample under conditions as close as possible to those in which past exceedances had occurred. Baseline sampling was utilized in primary locations to track *E. coli* levels under different conditions, (dry weather flow would be the primary factor in baseline sampling) on a weekly/monthly basis.

All samples were tested for *E. coli* and subject to genotype testing based upon regular occurring patterns observed during analysis. Due to the fact that the San Pedro water flow is inconsistent, monitoring teams were recruited as close to the monitoring sites as possible. This enabled volunteers to respond rapidly to storm flow sampling events even if areas of the watershed did not receive enough rainfall.

The primary objective of the sampling and measurements were to identify the sources of *E. coli* wherever it was found at exceedance levels. Bracketing practices, based on both known and newly observed sites of animal and human waste exposure, helped refine test results. The microbial genetic typing differentiated among three categories of *E. coli*: human, bovine, and all sources.

Critical Conditions

Critical conditions are the conditions under which exceedances have occurred and are identified as storm flow events resulting in overland runoff and high creek flows.

TMDL Findings or Status of Development

At this time a TMDL has not been completed for this area.

Plan Development

The goals of the ADEQ grant range from public education on watershed issues, formation of a watershed improvement council, and to develop and implement BMP's focused to improve water quality by reducing *E. coli* loads originating in the watershed. This report is meant to assist the accomplishment of the grants goals by providing watershed assessment data along with analysis and recommendation of best management practices.

Included in this report:

- Assessment of water sampling data collected
- Landowner concerns and needs gathered from outreach activities and survey
- Description and costs of BMP's focused on reduction of *E. coli* and supported by landowners

Watershed Improvement Council (WIC)

The San Pedro Targeted Watershed Improvement Council (WIC) was formed in December 2010, to direct the gathering of information, the planning process, and evaluate and prioritize the recommended projects.

The WIC represents the diverse interests and stakeholders within the watershed: Cochise County Board of Supervisor and Health Department, Hereford Natural Resource Conservation District, San Pedro Natural Resource Conservation District, Apache Nitrogen, St. David Water District, Bureau of Land Management, and property owners.

Table 1. Watershed Improvement Council

Linda Searle	Program Manager	Coronado RC&D
Robert Barnes	Rancher	San Pedro NRCD
Mike Hayhurst	Rancher	Brookline Ranch
Fred Kartchner	St. David	St. David Water District
Ben Lomeli	Hydrologist, CFM	Bureau of Land Management
Michael McGee	Health Department	Cochise County
Amy Charles	Lab/Environmental Coordinator 2011	Apache Nitrogen
Jeff Bauer	Lab/Environmental Coordinator 2012	Apache Nitrogen
George Monzingo	Rancher	San Pedro NRCD
Richard Searle	Cochise County Supervisor	Cochise County
Rachel Thomas	Property Owner	Hereford NRCD

Technical Resources

The WIC received technical guidance and support from ADEQ in addition to the University of Arizona's NEMO program, BLM, and Apache Nitrogen Products, Inc (APNI).

Community Involvement

The San Pedro Targeted Watershed was designed to be a community-driven process. Involving and educating citizens of the area was essential to the success of the Watershed Improvement Plan (WIP). The sampling and survey teams were comprised of employees of Apache Nitrogen and citizen volunteers who assisted the WIC through the collection of physical and chemical data that was the basis for the recommendations contained in this document.

WIC members spoke to various community groups, organizations, and students about the project, its goals, and findings. Several news articles have been published in local newspapers to share information about the project.

Volunteers received training and participated in water quality monitoring and boots-on-the-ground activities including the watershed field survey. These activities and the data collected are detailed in Chapter 2.

Picture of Field Day training with Dr. Guertin from University of Arizona

CHAPTER 2 – WATERSHED INVESTIGATION

Precipitation in the upper San Pedro River basin ranges from 35 to 76 cm/year (14–30 in/year) and is characterized by two seasons, a summer monsoon season from July through September, and a winter wet season December through March. (Turner and Richter, 2011)

Wet/dry mapping of the San Pedro River has been completed by The Nature Conservancy (TNC) annually since 1999. The event takes place the third Saturday of June where temperatures can get over 100 degrees daily with no rain. Measuring this time of year provides the best information of ground water conditions that support surface flow. The event includes members of the Bureau of Land Management (BLM), Nature Conservancy, local residents and landowners who cover 220 miles of the river. An average of 32% of the river through the San Pedro Riparian Natural Conservation Area (SPRNCA) has exhibited perennial flow before the summer monsoon season since 1999. (Figure 3; Turner & Richter, 2011)

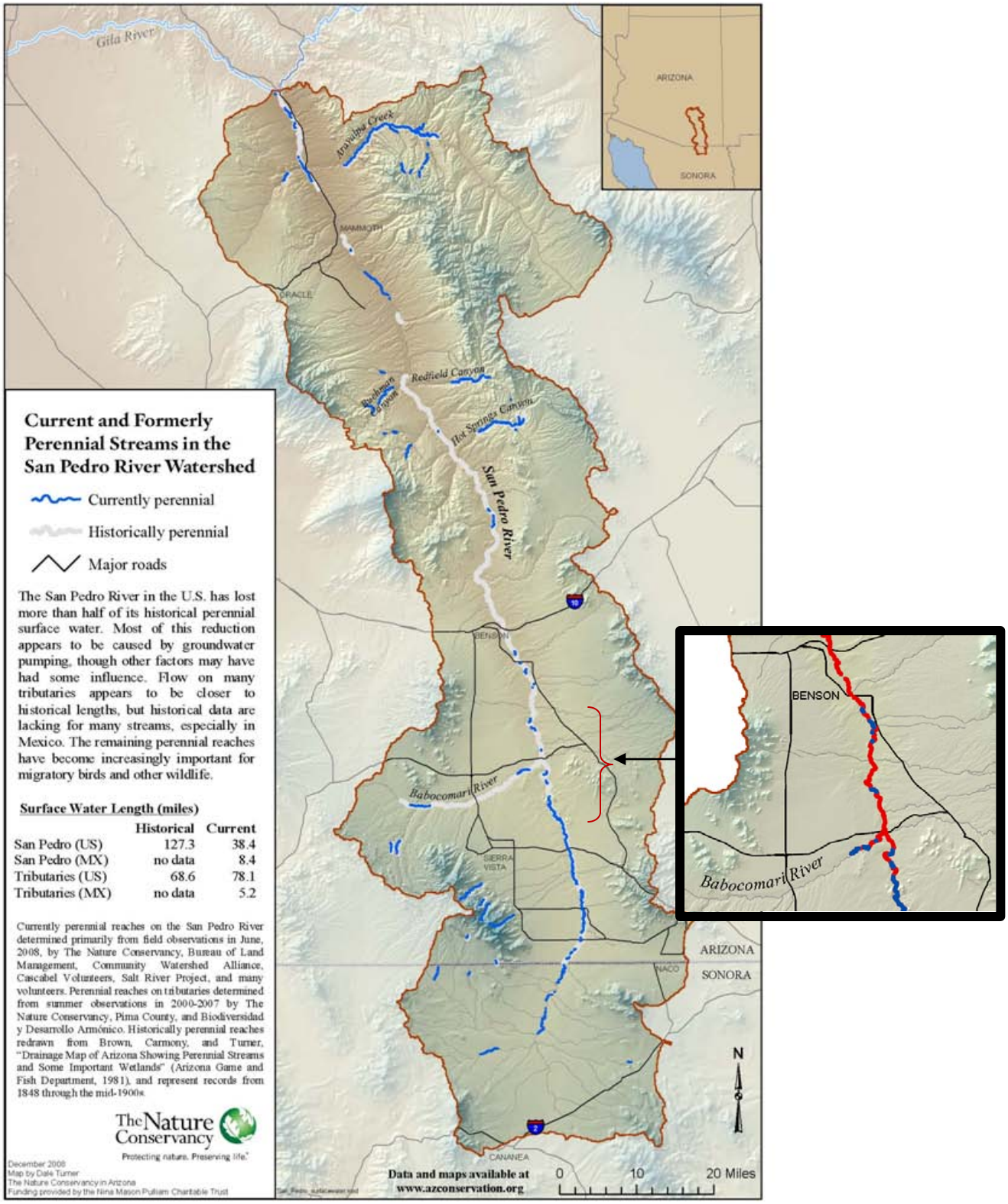
*Perennial stream sections display baseflow throughout the year, while intermittent stream sections only display baseflow on a seasonal basis when water tables in (*underlying) *aquifers are high enough to induce discharge to the stream channel. Channels of ephemeral stream sections are above the water table and, therefore, only flow during or shortly after storm events from runoff. (Upper San Pedro Water District, 2007)*

Dr. Phil Guertin, who has been an advisor to this project from the University of Arizona, states that the targeted reach of the San Pedro River is a complex system demonstrating intermittent and perennial, ephemeral flow conditions (Figures 4-9).

All tributaries that feed into the San Pedro within the targeted reach of the river are ephemeral with the exception of the Babocomari. Hedman and Osterkamp (1982) define perennial streams as those having measurable discharge 80% of the time, intermittent 10% - 80% of the time, and ephemeral <10% of the time. There is a substantial difference between seasonal precipitation and run-off resulting from monsoonal rains. The winter season accounts for 40% of the annual precipitation with 10% annual run-off while the monsoon season accounts for 60% of the annual precipitation with 90% annual run-off. The summer run-off accounts for the transport of large amounts of sediment into the system.

Nonpoint source pollution is dependent on stream flow duration. The findings of this study show large transport of sediment into the system during monsoon season demonstrating the complex properties of how organic and inorganic sediment enters the system. Dr. Phil Guertin, has stated that the high turbidity results gathered in this study are related to the overland flow pulsing sediment into the system. Analysis showed that *E. coli* density in samples was strongly related to turbidity, storm-flow characteristics as a result of overland flow. The presence and duration of flow of the targeted San Pedro River area has been used to analyze data in this study. (Figure 8)

Figure 3. Map of Wet/Dry Mapping Data used with permission from The Nature Conservancy



More detail of the Wet/Dry mapping can be found at The Nature Conservancy web site:
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arizona/howwework/mapping-the-san-pedro.xml

San Pedro River at HWY 80 Bridge 04.22.12

San Pedro River at HWY 80 Bridge 09.08.12

San Pedro River at BLM North 04.22.13

San Pedro River at BLM North 07.18.12

San Pedro River at Fairbanks 04.23.12

San Pedro River at Fairbanks 07.16.12

Watershed Resident Survey

A social survey of residents within the San Pedro River Targeted Watershed was conducted between June 1 and July 31, 2012. The survey was designed to gather information about watershed residents' knowledge of watershed and water quality issues. A copy of the survey can be found in **Appendix A.**

Delivery Modes

The survey was a self-administered questionnaire distributed by mail as an insert in the St David Water bill. The mail survey reached 493 households on St David's water service. Out of 493 that were mailed 12% were returned.

Data Analysis Methods

Participants were asked to rank their concern out of four categories, *Very Concerned, Concerned, Somewhat Concerned, and Not Concerned.* For the purpose of analysis, participant responses were grouped into two categories of 'Very Concerned/Concerned' and 'Somewhat Concerned/ Not Concerned' for questions in the survey. Scales, almost always one through five, or questions eliciting a specific response were either combined as a whole or grouped into one of these two groups.

Findings

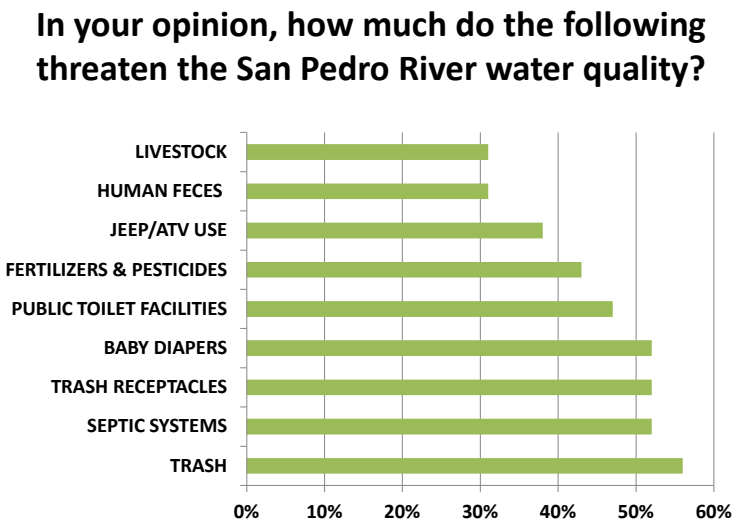
Protection of the river and the values reflected in reasons for protection were aligned with the knowledge and active involvement of residents living in the watershed area. Respondents' knowledge regarding water quality aligned with the category of concern they noted in taking the survey. These areas were closely examined for designing outreach efforts to broaden support for watershed improvement through education and awareness.

Those 11% of respondents who responded to the survey (numbering 59) were mostly strong in favoring protection of water quality in the San Pedro River. Out of the 59 respondents who responded to this survey, 44 fell under the category of Very Concerned/ Concerned, and 15 under the category of Somewhat Concerned/ Not Concerned with the majority of those living in a household of 1 -2 individuals. Those showing the most concern frequented the river more often, generally several times a year, and participated in various activities that include hiking, bird watching, horseback riding, picnicking, dog walking, and hunting.

Respondents were asked to rate seven categories for sources of pollution on their impact to the river. Those categories included agriculture run-off, animals, erosion and sedimentation, recreation, urban, wastewater, and lack of riparian buffers. All groups responding were compiled together. Analysis of the pollution ratings revealed a tendency for waste water sources (septic tanks, sewer systems), and

recreation (trash, lack of public toilets), as the biggest areas of concern for all respondents. There was also evidence that those perceiving the health of the San Pedro River in the "Somewhat Concerned/ Not Concerned" group ranked fewer categories as sources of pollution. Trash was viewed as the number one concern causing water quality while several respondents noted that illegal human traffic out of Mexico was the major cause of both trash and human waste (Figure 10).

Figure 4. Resident Survey Results



The most responses for those interested in improving the river's health was in the "Most Concerned/Concerned" group which comprised 44 out of 59 total responses received. Their knowledge of the river's health was based upon personal observations.

The purpose of the survey was to seek resident concerns regarding contributors to water quality. From the responses received, designing messages specifically to increase knowledge of local water quality problems and further explore specific areas is needed. In addition, gaining resident engagement in pollution control along with commitment to sustainable solutions are areas where public support for watershed improvement efforts can be increased.

Conclusions

Public outreach emphasizing education and mechanisms for engaging the communities are needed to strengthen attitudes favoring protection efforts. Further details on the survey data and findings are found in **Appendix B.**

Survey Methods to Identify Pollutant Sources in the River

E. coli exceedances established by ADEQ in its ambient monitoring of 2006 identified background conditions as a need for comprehensive investigations of nonpoint source bacterial contamination. Additional sample collection was determined from multi-layered gathering of information about recreation sites, wildlife and/or livestock watering spots, human foot traffic activity, active and abandoned septic systems, agricultural fields, and waste water treatment plants.

For the purpose of this study, water that flows into the San Pedro is defined seasonally as storm-flow and baseflow. Storm-flow is streamflow that results directly from storm events during the summer monsoon season that typically runs July - October, while baseflow is from intermittent and perennial flow that generally runs from November - June.

Sampling and monitoring of the San Pedro River Watershed had two main components: (1) Monitoring of *Bacteroides* and *E. coli* during one or more storm-flow run-off events and one or more baseflow periods. The objectives of sampling were to quantify exceedances and differentiate among human, cattle and other animal sources of *E. coli*. (2) Provide supporting documentation, including but not limited to flow, turbidity, air and water temperature, climate conditions (ex. precipitation, flooding), pH and specific conductivity measurements, field observations, anecdotal information on land uses gathered from the different communities accessing the watershed, research on records of past and present human habitations, and research on seasonal/meteorological factors affecting all of the above.

The potential sources of fecal contamination causing these impairments can be classified into two groups: point source (from industrial and sewage treatment plants), and nonpoint source (caused by runoff depositing natural and human-made pollutants into lakes, rivers, and wetlands) pollution. The purpose of this study was to determine the nonpoint sources that are diffuse in the environment and could be difficult to identify. Initially, baseline sampling was conducted at four ADEQ sampling sites with the hopes of understanding the origin of fecal contamination as well as identifying the actions necessary to remedy the problem. The sites extended along the San Pedro River from the mouth of the Babocamari to Dragoon Wash in St. David in Cochise County Arizona.

Survey Findings in 2011

Sampling was initially conducted at four sites at which ADEQ had tracked *E. coli* exceedances. ADEQ used four sites as a basis for listing the reach of stream as "impaired due to *E coli*" due to exceedances measured in 2006. These were used as the initial sampling sites. An exceedances of the Full Body Contact (FBC) Surface Water Quality Standard was defined as a single sample maximum of 235 *E. coli* per 100 mL of water sample collected or a geometric mean of the last five samples of 126 *E. coli* per 100 mL of water sample collected.

Table 2. ADEQ Initial Sampling Sites

Site ID	Site Description	Latitude	Longitude	ADEQ Number
SPBBR000.06	BABOCAMARI RIVER MOUTH NEAR FAIRBANK TOWNSITE ON HWY 82	314320.432	1101140.027	103548
SPSPR101.25	SAN PEDRO RIVER - NORTH OF HWY 80	315422	1101448	100276
SPSPR105.49	SAN PEDRO RIVER - AT ESCALANTE CROSSING	315142.4	1101243.2	103674
SPSPR117.97	SAN PEDRO RIVER - AT FAIRBANKS, AZ	314325	1101122	100287

Baseline sampling was conducted on April 17, 2011, at the four initial sampling sites. IDEXX Colilert Quanti-Tray® (IDEXX Laboratories, Westbrook, ME) Colilert was used to evaluate E.coli concentrations according to manufacturer instructions. Results revealed no detection of Coliform E. coli at any of the four locations.

There was little or no flow in the San Pedro River until July 2011, when the monsoon season began. Sampling resumed on July 22, 2011. E. coli exceedences were found at three of the four baseline sampling locations (1) Fairbanks, (2) HWY 80 at St. David Bridge, and (3) BLM North. The Babocomari location (location 4) E. coli levels did not exceed the surface water quality standard for full body contact (FBC) total maximum daily load (TMDL) for E. coli. It was decided by the sampling team that sampling would be conducted again the following day on July 23, 2011, to confirm the exceedence results and to collect samples for Microbrial Source Tracking (MST) using Bacteroides molecular genes analysis. The MST is a group of methods intended to help discriminate against human and non-human sources of fecal contamination. It can also be used to help further differentiate among human, cattle and other animal sources of E. coli.

Dr. Channah Rock, an advisor to this study from the University of Arizona describes the study's sampling methodology:

Microbial Source Tracking (MST) methods are intended to discriminate between human and non-human sources of fecal contamination. MST is an active area of research with the potential to provide important information to effectively manage water sources (Stoeckel et al. 2004). MST based on identification of specific molecular markers (or genes) can provide a more complete picture of the land uses and environmental health risks associated with fecal pollution loading in a watershed than is currently possible with traditional indicators and methods (Jenkins et al. 2009). MST methods have the ability to identify "who" is contributing to the pollution whereas traditional culture based methods only tell you "if" and "when" fecal contamination is present.

The genus Bacteroides contains Gram negative, non-spore-forming, non-motile, anaerobic rod shaped bacteria generally isolated from the gastrointestinal tract (GI-tract) of humans and animals (Smith et al. 2006). An important aspect of Bacteroides biology is their lack in ability to grow in the environment as well as their potential to survive in the environment at a rate directly proportional to the pathogens of concern. Bacteroides depend primarily on temperature and presence of predators, and have been found to survive for up to six days under oxygen stressed conditions similar to other pathogens (Field and Dick 2004). Due to the abundance of this bacterium in human and animal feces, it has allowed for host-related analysis targeting genes present in the Bacteroides genome. Bacteria belonging to the genus Bacteroides have been suggested as alternative fecal indicator to E. coli or fecal coliform bacteria because they make up a significant portion of the fecal bacteria population, have little potential for growth in the environment, and have high degree of host specificity that likely reflects differences in host animal digestive systems.

For this study, the research team used three Bacteriodes based molecular assays to evaluate water quality samples for Bacteroides genes commonly found in Human, Bovine or other host digestive systems and feces.

***Sample collection**. Grab water samples were collected in a one liter sterile polypropylene bottle by our laboratory personnel and trained volunteers from the San Pedro River watershed.*

Conventional Methods:

- ***Escherichia coli.** Were performed following Standard Method #9223B (IDEXX) for the Analysis of Water and Wastewater.*

Molecular Methods:

- ***Sample Water Concentration**. 100 mL of water samples were filtered onto polycarbonate membranes (0.4 μm pore size, 47-mm diameter) (GE Water and Process Technologies, Trevose, PA). The filters were stored at –20°C until DNA extraction.*

- ***DNA extraction**. All DNA extractions were performed using MoBio PowerWater DNA Isolation Kit (Mo Bio Laboratories, Carlsbad, Ca.) according to manufacturer's instructions.*

- ***Quantitative PCR.** Primers sets were obtained according to Seurinck et al 2005 and Layton et al 2006 were used along with SYBR green PCR Master Mix (Applied Biosystems, Foster City, CA); and Shanks et al 2008 were used along with and Universal Master Mix(Applied Biosystems, Foster City, CA).*

All qPCR reactions were performed using the Applied Biosystems StepOnePlus™ Real-Time PCR System.

Figure 5. Three methods used to evaluate water samples for *Bacteroides* genes from Dr. Channah Rock

Assay	Primer	Sequence	Target	BP size	Annealing Temp (°C)	Reference
Allbac296	Allbac 296F	5'-GAGAGGAAGGTCCCCCAC-3'	Total	106	60°C	Layton et al, 2006
	Allbac 412R	5'-CGCTACTTGGCTGGTTCAG-3'				
Hubac183	HF183F	5'-ATCATGAGTTCACATGTCCG-3'	Human	82	60°C	Seurinck et al, 2005
	NDR	5'-TACCCCGCCTACTATCTAATG-3'				
CowM2	Cow M2F	5'-CGGCCAAATACTCCTGATCGT-3'	Bovine	92	60°C	Shanks et al,2008
	Cow M2R	5'-GCTTGTTGCGTTCCTTGAGATAAT-3'				

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The San Pedro River continued to have little or no flow until monsoon rains presented storm-flow conditions on August 2, 2011, and September 10, 2011. Different additional sampling locations were identified during these dates based on the results of the July 23, 2011, *Bacteroides* molecular genes analysis. It was determined that both human and CowM2 *Bacteroides* genes were found at all four initial sampling locations. To rule out contamination from Mexico, the sampling team decided to collect a sample upstream near the United States/Mexico border at Palominas. This sample location served as a "background" sample throughout the study. The Palominas result also showed a positive result for both human and CowM2 *Bacteroides*. Thus, on September 10, 2011, after obtaining access from the landowner, the sampling team collected a sample where the San Pedro River enters the United States from Mexico (LADD1). The site at Fairbanks served as the control during both sampling events. It was determined from *Bacteroides* molecular genes analysis at LADD1 that no human contamination was entering the United States from Mexico. However, there were positive hits for CowM2. (Table 4)

Throughout the initial study period in 2011, *E. coli*, and *Bacteroides* organisms genes had been detected within the study area indicating fecal contamination within the watershed. Microbial levels seemed to fluctuate throughout the watershed indicating that potentially little die-off was occurring as water traveled through the watershed. Slight increases in microbial parameters were seen among the selected sites indicating non-point source contributions to water quality deterioration. Results to date suggested that these fluctuations coincided with extreme storm events and these are a result of overland flow. It is also observed that exceedences measured at the Babocomari ADEQ baseline sampling site likely resulted from backwash from the San Pedro River. Therefore, a new sampling site on the Babocomari was established in 2012.

Of the 12 samples that were analyzed using the *Bacteroides* molecular methods, 7 of the samples assayed, contributions of Human molecular genes were apparent. The following sample locations were positive for the Human molecular genes marker: Fairbanks, HWY 80 Bridge at St. David, BLM North, Charleston, and Palominas. The presence of the *Baceroides* based Human molecular marker genes indicated that human recreation, residuals from recreation, illegal immigrant traffic, possible leaking septic, or sewage discharge could be impacting water quality in the river locations mentioned above.

It was decided by the sampling team that more extensive testing needed to be conducted throughout the following year. The sampling would occur only within the area of impairment within the San Pedro River Targeted Watershed, allowing the sampling team to gather more data and analyze trends. These would include, but were not limited to; analyzing patterns within the data during both seasons of storm flow and intermittent and perennial flow conditions; looking for areas of repeat "hits" of *E. coli* and *Bacteroides*; analyzing overlay land use information with water quality and modeling results; and identifying Best Management Practices (BMP's). Samples analyzed in 2012 were designed to better understand the variations (natural and/or other) that could be evident within the system.

One of the more difficult tasks was gaining access to properties that could be harboring a failing septic system where owners would be unwilling to allow a sampling team through their gates. Completing a field study incurred these same challenges. This situation has not changed. No failing septic systems have been observed and the WIC believes is an area that requires additional study.

Survey Findings in 2012

Sampling was conducted on a monthly bases beginning January - April and again July – September 2012, during both storm-flow and intermittent and perennial flow conditions. At the four initial ADEQ baseline sites from January through April, IDEXX Colilert Quanti-Tray® results revealed no detection of *E. coli* Coliform at any of the four locations. From January to April during intermittent and perennial flow conditions, the Hwy 80 Bridge at St. David location revealed higher levels of *E. coli* prompting samples to be sent for Microbial Source Tracking (MST) using molecular genes analysis. The test showed Human *Bacteroides* genes suggesting possible point source contamination. To try to identify a possible point-source, the sampling team identified two new sampling sites. Samples were collected at two new sampling sites, APNI 1 and APNI 2 in addition to BLM North for MST genes analysis. The results showed both APNI 1 and APNI 2 locations to have both Human and CowM2 *Bacteroides* genes. BLM North showed CowM2 *Bacteroides* genes. Because these samples did not exceed the surface water quality standard for full body contact total maximum daily load (TMDL) for *E. coli*, it was decided by the WIC that sampling would be carefully monitored in this area during storm-flow conditions. Analysis would include looking for elevated levels of *E. coli* that would warrant further bracket sampling upstream and downstream of the sample locations (bracket sampling).

The first flow in the San Pedro River was not observed until July 5, 2012. The sampling team noted 13 samples collected during storm flow in 2011, showed 92% exceeding the *E. coli* surface water quality standard for full body contact. Because the river flows north, and all samples collected in 2011 at Fairbanks exceeded the FBC TMDL standard for *E. coli,* it was evident that exceedances of *E. coli* were entering the targeted area from up river. Additionally, with bacterial Microbiral levels appearing to fluctuate throughout the watershed, collection of additional

samples through the summer monsoon season was needed to better understand these fluctuations. To accomplish this, three sampling teams were established. One team would conduct sampling every Tuesday from July through August to provide a data baseline of flow regime of the river on a weekly basis through the summer monsoon season. The other two teams would sample during storm-flow events with the goal of collecting four sets of samples in a 48 hour time period approximately every 12 hours. This would provide data for measuring fluctuating levels of *E. coli.* Through careful monitoring, the sampling team would look for consistent "spikes" of *E. coli* warranting further bracket sampling.

Between July 5, 2012, and September 25, 2012, a total of 60 water samples were collected. At each site, water samples were collected at frequencies ranging from once a day, twice a day, to once a week. During intermittent and perennial flow, 100 percent of water samples contained *E. coli* below the state water quality standards (single sample maximum value of 235cfu/100,L). Conversely, during storm-flow 73 percent of the samples contained *E. coli* densities above state water quality standards (single sample maximum value of 235cfu/100mL). Samples collected during the monsoon season showed exceedances of *E. coli* were statistically greater in storm-flow than winter season samples. Furthermore, *E. coli* and turbidity were statistically higher during storm-flow sampling.

Table 3. *E. coli* Sampling Results 2011 - 2012

Hwy 80 Bridge St. David					APNI 2		APNI 1		BLM North				
			01.19.12	10.9								01.19.12	6.3
			03.22.12	86.5								03.22.12	35.5
					04.19.12	39.5	04.19.12	158.6				04.19.12	6.3
		AM	07.05.12	2419.6							AM	07.05.12	920.8
		PM	07.05.12	435.2							PM	07.05.12	55.6
		AM	07.16.12	>2419.6							AM	07.16.12	>2419.6
		PM	07.16.12	194.7							PM	07.16.12	234.8
			07.17.12	>2419.6								07.17.12	>2419.6
			07.18.12	>2419.6								07.18.12	>2419.6
07.22.11	>2419.6								07.22.11	>2419.6			
07.23.11	>2419.6								07.23.11	816.4			
			07.24.12	436.6								07.24.12	>2419.6
			07.31.12	114.7									
												08.07.12	23.7
			08.21.12	101.7								08.21.12	39.3
			08.28.12	1986.3								08.28.12	579.4
			09.04.12	20120	09.04.12	5680	09.04.12	16790				09.04.12	10500
			09.07.12	51720								09.07.12	43520
			09.08.12	34410	09.08.12	32820	09.08.12	48840				09.08.12	31300
			09.11.12	198630	09.11.12	32820	09.11.12	48840				09.11.12	31300
			09.18.12	3930	09.18.12	740	09.18.12	610				09.18.12	3930
												09.25.12	24.1
									12.11.11	4.1			

Fairbanks					Bower's Crossing		Charleston		Palominas		LADD 1	
			01.19.12	5.1	01.19.12	0						
			03.22.12	5.2	03.22.12	3.1						
		AM	07.05.12	>2419.6								
		PM	07.05.12	17.4								
		AM	07.16.12	>2419.6								
		PM	07.16.12	>2419.6								
			07.17.12	121.4								
			07.18.12	>2419.6								
07.22.11	>2419.6											
07.23.11	312.3											
			07.24.12	1733								
			07.31.12	>2419.6								
08.02.11	>2419.6						08.02.11	>2419.6	08.02.11	2420	08.02.11	>2419.6
			08.07.12	51.7								
			08.21.12	344.8								
			08.28.12	36.3								
			09.04.12	19350								
			09.07.12	12590								
			09.08.12	24950	09.08.12	4						
09.11.11	>2419.6		09.11.12	61310	09.11.12	90.8						
			09.18.12	630	09.18.12	10.9						
			09.25.12	770.1								
12.11.11	1											

Table 4 .San Pedro Samples Microbial Source Tracking (MST) using Bacteroides 2011-2012

Site Name	Date Sampled	CFU/PFU/100 mL water†			NTU	Bacteroides molecular genes‡			
		EC	MS	S	Turbidity	All	Hu	Bov	Bov
		E.coli	Male Specific	Somatic		Allbac296	HF183	CF128	CowM2
HWY 80/ St. David	7/23/2011	9100	10	500	11300	+++	+++	-	+++
	3/22/2012	86.5	NT	NT	22	+++	+++	-	-
	7/18/2012	>2419	<10	2590	13400	+++	-	-	-
	8/21/2012	101.7	<1	3	98.4	**+++**	**+++**	-	**+**
	9/11/2012	198630	<1	680	8140	**+++**	-	-	**++**
APNI 1	4/19/2012	158.6	NT	NT	1.26	+++	+++	+	+++
	9/11/2012	48840	<1	670	129100	**+++**	-	-	**++**
APNI 2	4/19/2012	39.5	NT	NT	1.46	+++	+++	+	++
	9/11/2012	32820	<1	590	3080	**+++**	**+**	-	**+++**
BLM North Boundary	7/23/2011	2810	10	620	5580	+++	++	-	+++
	4/19/2012	6.3	NT	NT	0.68	+++	+	+	++
	7/18/2012	>2419	<10	2510	7380	+++	-	-	+
	8/21/2012	39.3	<1	5	3.22	**+++**	-	-	**+**
	9/11/2012	31300	<1	500	5660	**+++**	**++**	-	**+**
Fairbanks	7/23/2011	1299.7	20	530	2290	+++	+	-	+
	8/2/2011	5710	5	3390	6440	+++	+++	-	++
	9/10/2011	NT	10	1220	NT	+++	-	-	+++
	7/18/2012	>2419	<10	2560	8840	+++	-	-	-
	8/21/2012	344.8	<1	768	470	**+++**	**+**	-	**+**
	9/11/2012	61310	<1	810	20900	**+++**	-	-	**+**
Babocamari Bowers Crossing (BC)	7/23/2011	816.4	10	340	646	+++	+	-	+++
	9/11/2012	90.8	<1	15	21.4	**+++**	**+++**	-	-
Charleston	8/2/2011	5810	1	3860	6740	+++	+	-	+
Palominas	8/2/2011	1299.7	17	3900	57.2	+++	+	-	++
LADD 1	9/10/2011	NT	2	15970	NT	+++	-	-	+++

† EC, *E.coli*; MS, Male Specific Phage; S, Somatic Phage.
‡ All, Total; Hu, Human; Bov, Bovine.
§ NT, not tested.
± PA, pending analysis.

*During storm flow events, backflow from the San Pedro River enters the mouth of the Babocomari River. A new sampling site along the Babocomari, Bower's Crossing was created.

Figure 6. Map of Human *Bacteroides* at sampling sites

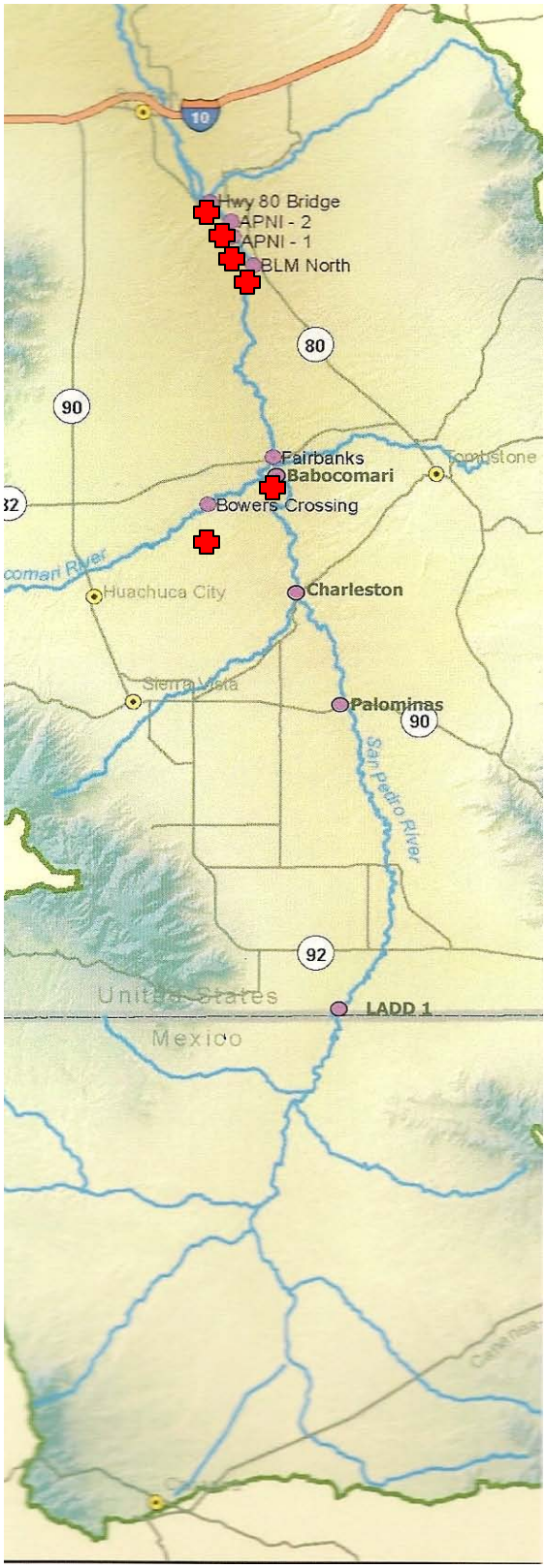


Table 5. Human *Bacteroides* Sampling Results 2011-2012

		CFU/PFU/100 mL water†	NTU	*Bacteroides* molecular genes‡	
Site Name	**Date Sampled**	**EC**	**Turbidity**	**All**	**Hu**
		E.coli		**Allbac296**	**HF183**
HWY 80/ St. David	7/23/2011	9100	11300	+++	+++
	3/22/2012	86.5	22	+++	+++
	8/21/2012	101.7	98.4	**+++**	**+++**
APNI 1	4/19/2012	158.6	1.26	+++	+++
APNI 2	4/19/2012	39.5	1.46	+++	+++
BLM North Boundary	7/23/2011	2810	5580	+++	++
	9/11/2012	31300	5660	**+++**	**++**
Fairbanks	8/2/2011	5710	6440	+++	+++
Bowers Crossing (BC)	9/11/2012	90.8	21.4	**+++**	**+++**

Significant levels of the Human *Bacteroides* were noted at the above sampling sites. Out of 10 samples, 5 did not exceed the TMDL for *E. coli.*

Figure 7. Map of Bovine *Bacteroides* at sampling sites

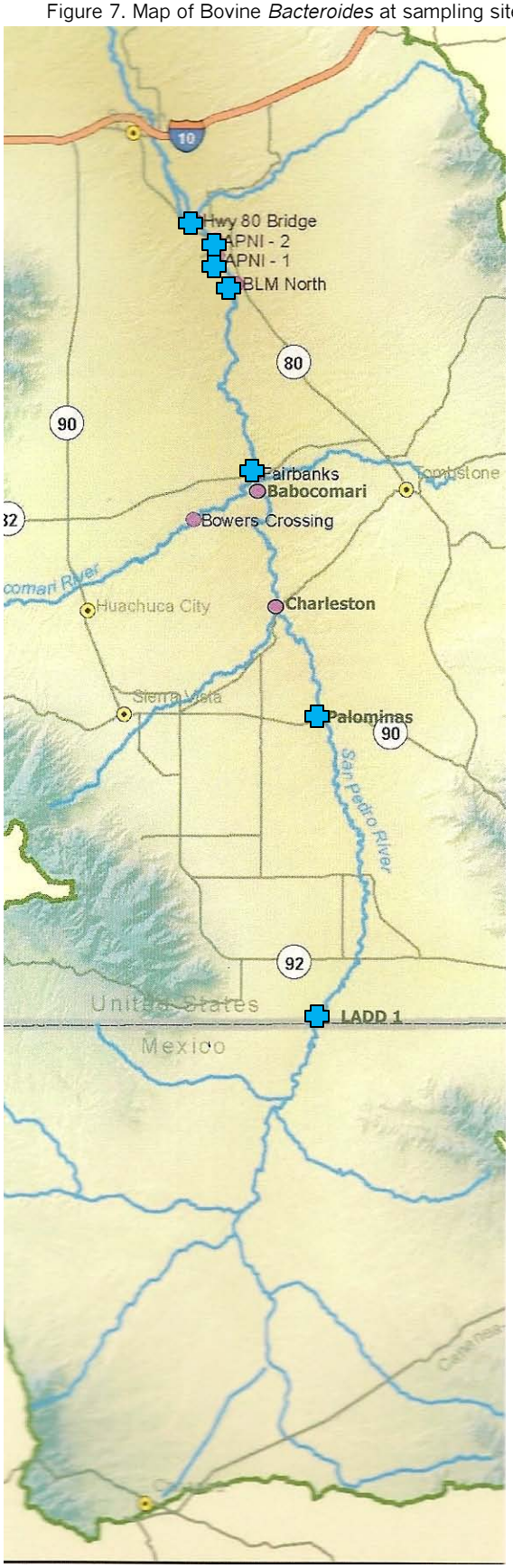
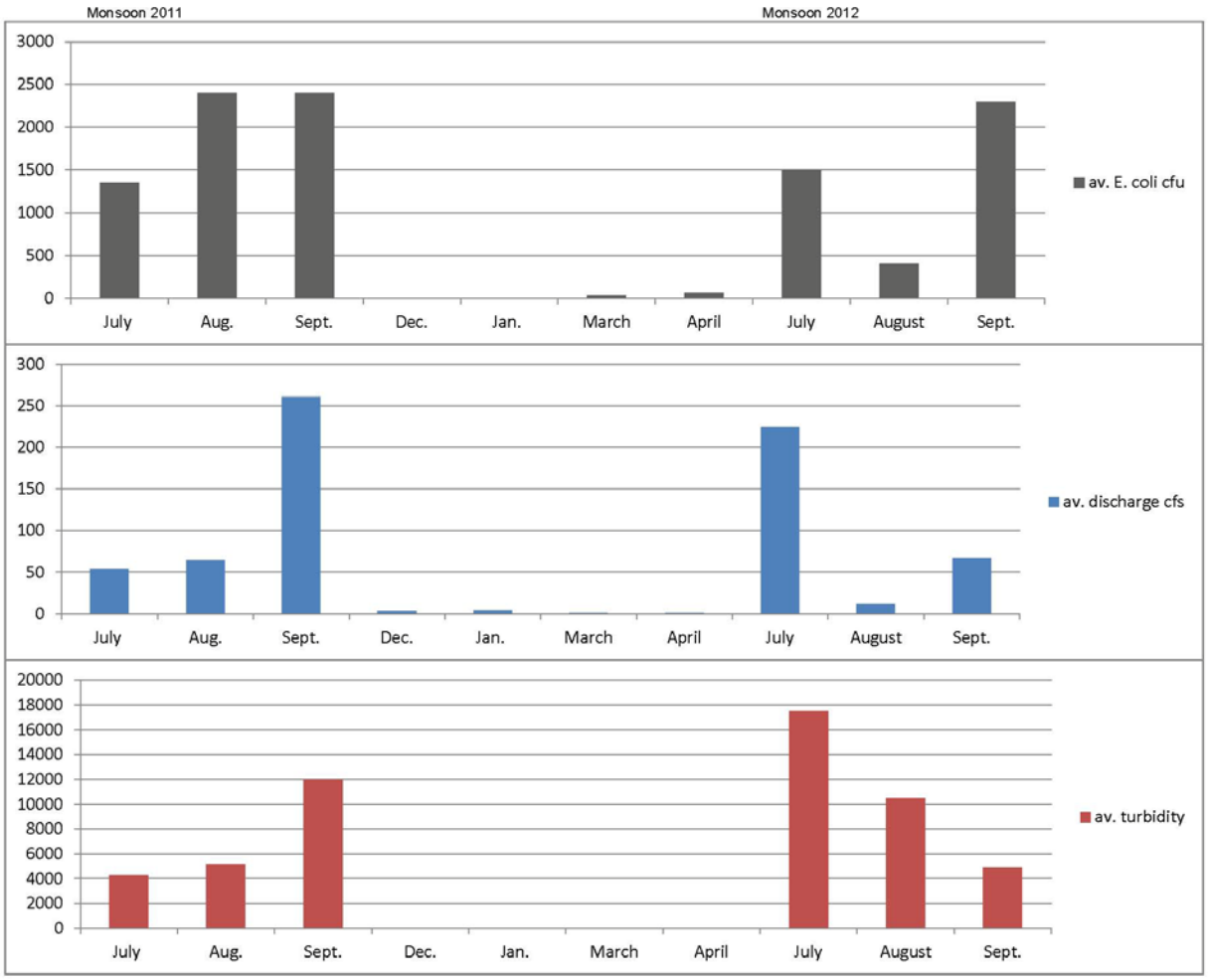


Table 6. Bovine *Baceroides* Sampling results 2011-2012

		CFU/PFU/100 mL water†	NTU	*Bacteroides* molecular genes‡		
Site Name	**Date Sampled**	**EC**	**Turbidity**	**All**	**Bov**	**Bov**
		E.coli		**Allbac296**	**CF128**	**CowM2**
HWY 80/ St. David	7/23/2011	9100	11300	+++	-	+++
	9/11/2012	198630	8140	**+++**	-	**++**
APNI 1	4/19/2012	158.6	1.26	+++	+	+++
	9/11/2012	48840	129100	**+++**	-	**++**
APNI 2	4/19/2012	39.5	1.46	+++	+	++
	9/11/2012	32820	3080	**+++**	-	**+++**
BLM North Boundary	7/23/2011	2810	5580	+++	-	+++
	4/19/2012	6.3	0.68	+++	+	++
Fairbanks	8/2/2011	5710	6440	+++	-	++
	9/10/2011	>2419.6	15300	+++	-	+++
Palominas	8/2/2011	1299.7	57.2	+++	-	++
LADD 1	9/10/2011	>2419.6	17100	+++	-	+++

Significant levels of Bovine *Bacteroides* were noted at the above sampling sites. Out of 12 samples, 3 did not exceed the TMDL for *E. coli. As an anecdotal observation,* there has been minimal grass land restoration on the eastern side of the San Pedro water shed and north of the Babocamari on the western side. The majority of the ranches on the Babocamari water shed (Hayhurst, Babocamari Land Grant, Sands Ranch, and Audubon) have active Conservation Management Plans (CMP) with NRCS restoring grasslands over the last 10 years. The Babocamari River has not seen storm event exceedences that the San Pedro has.

Figure 8. E. coli, Discharge, Turbidity Levels



Conclusions

High turbidity levels are caused from sediment entering the river from overland flow and from tributaries. Turbidity and *E. coli* density were statistically higher during monsoonal flow than during intermittent and perennial flow during the study period. The highest *E. coli* and turbidity densities were typically seen during July – September, and lowest from October – June. Analysis has shown that *E. coli* density in samples is strongly related to turbidity and stream flow during storm events at each of the sampling sites along the San Pedro River.

Summary of the sampling:

- 100% of samples collected October – April 2011 & 2012 did not exceed water quality standards (single sample maximum value of 235cfu/100mL).

- 73% of samples collected July - September 2011 & 2012 exceeded state water quality standards (single sample maximum value of 235cfu/100mL).

- 44% of samples collected using the molecular methods for Human molecular markers were significant. Fluctuations in the presence of Human molecular markers indicate there probably are no failing septic systems. Human recreation or illegal traffic from Mexico may be impacting water quality.

- 75% of samples collected using the molecular methods for Bovine molecular markers were significant. Fluctuations in the presence of Bovine molecular markers indicate a need for rangeland improvement in the uplands as well as riparian buffers in and around St. David.

Results of the analysis indicate a complex system with many variables leading to the impairment of this reach of the river. Research to date has identified varied potential *E. coli* sources within the watershed as indicated by molecular methods analysis sampling results taken on July 18, 2012, and September 11, 2012, which showed significant bacteria levels not represented by either human or bovine markers. 35,603 acres of the SPRNCA lies up river and within the targeted reach of this study. It is home to a variety of mammals, fish, reptiles and birds (BLM GIS Specialist Leslie A. Uhr). Wildlife in some cases can be responsible for excessive *E. coli* loading of streams and rivers. Out of a total of 86 samples collected during this study, 25 were sent in for MST analysis. Areas not investigated for potential *E. coli* sources were from other wildlife, domesticated animals, and water entering the targeted reach through tributaries. Each of these areas deserves further investigation.

CHAPTER 3: WATERSHED IMPROVEMENT STRATEGIES

Watershed Improvement Plan Development

Best management practices (BMP'S) have been developed to address nonpoint source pollution specific to the targeted San Pedro River area. Monitoring of *Bacteroides and E. coli* in the targeted watershed has provided documentation of potential human and bovine sources of fecal contamination contributing to these impairments. Wildlife and domesticated animals could also be possible sources for excessive *E. coli* loading of the San Pedro River. However, these were not investigated for potential *E. coli* sources and are areas that deserve further investigation. Based upon results from this study, the Watershed Improvement Committee (WIC) has determined four BMPs to help restore water quality in the targeted area of the San Pedro River.

Goals and Objectives

The goal of this Watershed Improvement Plan (WIP) is to achieve full-body contact compliance for *E. coli* in the listed impaired reach. The plan's objectives include the following:

1. Identify sources of *E. coli* exceedances.
2. Explain methods of *E. coli* contamination and measures to reduce *E. coli* loads.
3. Recommend Best Management Practices (BMP's) to reduce *E. coli* loads.

Potential Best Management Practices

The WIC has prioritized BMP's by addressing Education & Outreach first, since there was resistance from land owners during collecting samples and implementing a field study. The decision was also based upon comments from the social survey and Rancher's Conference. Human contributions would be ranked above bovine contributions since advisors to the study have stated that human contributions constitute a more serious threat to human health. However, both are important to load reduction overall.

The recommended BMP's are:

1) Education workshops, supported by social survey and the rancher's conference. Education workshop focus will be focused on educating the landowner in land improvement areas.
2) Clean-up of illegal camps shown by evidence of illegal traffic from Mexico through the San Pedro River corridor, supported by public outreach, Cochise County, and US Border Patrol.
3) Signage for trail head locations in the SPRNCA. Signage will promote "Leave No Trace" guidelines.

4) Range improvement practices to decrease the transport of sediment into the San Pedro River. As a part of any good Conservation Management Plan (CMP), brush control, prescribed grazing, fencing, and water wells are possible projects based upon the allotment's location and needs. Each of these projects is supported by NRCS, ranchers, and local National Resource Conservation Districts (NRCD's).

BMP Type 1: Education/ Outreach Workshops

The WIC education and outreach initiatives during the study have only scratched the surface in educating the community in water quality issues.

1. A Rancher's Conference was held February 2012 with 34 interested land owners in attendance. The event was sponsored by ADEQ, Coronado RC&D, Hereford NRCD, and San Pedro NRCD. The premise for the conference being that both NRCD's would continue the event in future years as a service to the communities and to provide on-going education to ranchers and small landowners. NRCS employees and local land owners with rangeland improvement experience served as presenters. Topics covered Riparian and Water Quality, Brush Control Practices on Rangeland, Water Retention Structures, and Conservation Planning. Feedback was received from 47 percent of the participants with an 87 percent approval rating.

2. Two community outreach meetings were held to discuss the progress of the project. The first was held in St. David in 2011, and the second in Benson in 2012. Both community meetings had less than 10 in attendance which demonstrates a need for more education efforts in this area.

3. Dr. Channah Rock, University of Arizona, and an advisor to this study brought her team to Tombstone to work with a class of Future Farmers of America (FFA) group consisting of 33 students. They were given an introduction about the study and water quality issues in the San Pedro River. Training is scheduled with the group in the fall when school resumes for the 2014-2015 school year with the goal having them take over sampling of the targeted reach of the river at Fairbanks.

4. Apache Nitrogen (APNI), a cooperative partner to this study, housed the lab and processed water samples. As part of their community outreach, they will continue sampling at the two baseline sites in St. David to assist with the monthly monitoring process.

5. The Community Watershed Alliance group is a highly effective volunteer community organization whose focus is improving the water quality and environment of the San Pedro River. Members of this group have assisted with the collection of water samples.

6. The social survey conducted during this study demonstrated a need to reach out to more individuals that live and recreate in the area.

Overview

The face of rural Arizona has been greatly changed over the past couple of decades, as population growth continues to go hand-in-hand with the desire to live outside city centers. These changes will continue to present challenges; to cropland agriculture, to ranching and open rangeland, that can directly affect the watershed.

They also present challenges to resource-focused agencies such as Arizona Cooperative Extension (ACE), and the Natural Resources Conservation Service (NRCS). The large number of small rural landowners makes one-on-one assistance difficult, however taken as a group they represent many acres of land. Many landowners want to improve their holdings and need information and suggestions how to do so effectively. Continued education with the small landowner can help reduce *E. coli* exceedances by helping promote better land management and changing the public's perception towards the San Pedro River.

The WIC has created five one-day workshops, with a different workshop to be held monthly. Each workshop will have a different theme and, although each theme can "stand on its own" as an interesting subject, each will also build somewhat on the previous one. In this way the WIC hopes to encourage people to attend each workshop in the series.

Workshops will have a registration fee to cover lunch and refreshment costs.

Apart from the presentations at each workshop, another important objective is to compile a binder of quality handouts, guides, and reference material for each theme and topic presented. These binders can be "built", one section at a time, by those that attend. There is a great deal of excellent material that is available, and the few gaps can be filled in where needed. Finally, each workshop will have a "hands-on" component so that participants can experience the process of each workshop.

Possible Topics for Workshops:

Workshop #1 – Conservation Planning
Workshop #2 – Know Your Soils (Soil Erosion & Soil Quality)
Workshop #3 – Know Your Native Plants
Workshop #4 – Riparian and Water Quality
Workshop #5 - Your Livestock and Your Land

Locations

Each of the planned workshops will be at two different locations on two consecutive days, to make it easier for people to attend. The targeted communities will be St. David/ Tombstone (represented by San Pedro NRCD), and Hereford/Huachuca City (represented by Hereford NRCD).

Associated Costs:

Labor:	Coordination & Research	$5,100.00
	Instructor Honoraria	$3,600.00
Equipment:	PowerPoint Projector	$850.00
	Portable Screen	$220.00
	Laptop Computer	$900.00
Materials/ Supplies:	Binders & Dividers	$160.00
	White Board & Pens	$175.00
	Large Pads	$120.00
	Printing Costs	$200.00
Miscellaneous:	Travel	$700.00
	Advertising	$400.00
	Drinking Water for Field Work	$200.00
Total cost		**$13,125.00**

Resources:

Coronado Resource Conservation & Development (RC&D), University of Arizona Extension, Natural Resources Conservation Service (NRCS), Natural Resource Conservation Districts (NRCD's)

Barriers:

None

Project Schedule & Milestones:

The budget has been created to hold 5 workshops two consecutive days for 5 months.

Schedule:

- Sites identified and reserved – 1 month
- Speakers identified and scheduled – 1 month
- Advertising completed – 2 weeks prior to each workshop
- Equipment & Supplies purchased – 1 month prior to workshops
- Materials assembled – 2 weeks prior to each workshop

Milestones:

- Participant sign-in sheets completed for each workshop
- Participant and speaker feedback documented for each workshop

Estimated load reduction by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment:

If education/outreach workshops result in a reduction of human or animal fecal material being deposited in the near river environment they can have a significant impact on E. coli loads. E. coli, as member of the intestinal flora, is part of the digestive process and is excreted in feces from most warm blooded animals. The CFU of E. coli in feces averages from 10^7 to 10^9 per gram in humans (Tenaillon et al. 2010) and 6.55 x 10^6 to 7.6 x 10^6 per gram in cattle (Wang et al. 2004). If the education/outreach workshops can reduce the deposition of 1000 kg per year of cow manure into the near river environment the potential load reduction for E. coli would be 6.55 x 10^{12} to 7.6 x 10^{12} CFU per year.

References:

Tenaillon, O., D. Skurnik, B. Picard, and E. Denamur, 2010. The population genetics of commensal *Escherichia coli*. Nature Reviews □ Microbiology 8 (March): 207-217.

Wang, L., K.R. Mankin, and G.L. Marchin, 2004. Survival of Fecal Bacteria in Dairy Cow Manure. Transactions of the ASAE 47(4): 1239-1246.

BMP Type 2: Clean-up of Undocumented Immigrant Camps

Overview

The San Pedro River corridor heading north from the U.S./ Mexico border is a travel corridor for undocumented immigrant foot traffic traveling from Mexico in Southern Arizona.

Ecological impacts from such activity are profound. Figures from the BLM's Southern Arizona Project, aimed at cleaning up public lands from the impacts of immigrant traffic, for FY10 for all of southern Arizona detail the following: over 255 tons of trash, 77 abandoned cars, 364 bicycles, and 787 tires removed. 2583 acres of land were remediated in FY2010 (BLM, 2010).

With increased enforcement of the U.S. Border Patrol, undocumented immigrants use remote pathways leaving behind an estimated 2,000 tons of trash which includes soiled diapers, plastic bottles, and abandoned vehicles. *(Judicial Watch.org)*

Evidence of human waste has been seen along the river banks by the sampling team. These sites are monitored by the U.S. Border Patrol, the BLM, and the help of local residents and ranchers in the area. In addition to the human activity and transient occupancy in the river bed, large storm events can cause the overland flow to potentially move human waste and trash into this reach of the river. This poses a real concern as untreated human waste has the potential to reach large stretches of the river.

In 2008, through a grant received from BLM, Cochise County cleaned up over 30 Undocumented Alien camps (UDAs) using both county resources and community volunteers. During cleanup efforts, hazardous waste materials had not been found and to date has not been a problem.

Locations:

Locations vary determined by Border Patrol monitoring.

Features:

Average cost to clean up an area based on 1 ton of refuse waste is $2,220.96 for an 8 hour day at a location with easy access. Costs are calculated per site.

Associated Costs per site:

Labor:	15 people	$120 per person for 8 hrs	$1,800.00
	1 County Inspector	$ 17.12/hr for 8 hours	$ 136.96
Equipment:	1 Vehicle	$ .56/mi. x 100 miles	$ 56.00
	1 Trailer	$ 50 per day	$ 50.00
Materials/ Supplies:	30 bag ties	$ .20 per tie	$ 6.00
	30 bags	$ 1.00 per bag	$ 30.00
	15 pairs of gloves	$ 1.00 per pair	$ 15.00
	Digital Camera		$ 69.00
	4 G Memory Card		$ 9.88
Miscellaneous:	Porta Potty Rental	$ 75 per day	$ 75.00
	Dumping Fees	$ 52 per ton	$ 52.00
Total cost			**$2,299.84**
Total cost per site	Less digital camera & memory card		**$2,220.96**

Costs have been based upon the following criteria:

- Figures are based on a site within drivable, easy road access.
- Equipment fees are based upon estimates.
- Digital camera and memory card are a onetime purchase to be used at each site for documentation.
- Mileage is estimated depending on cleanup site within easy access.
- One County employee is hired. Volunteer groups may have adult volunteers who do not get paid but observe/supervise.

- Volunteers sign a waiver of liability. No fringe is included in volunteer pay. Rate of pay is based upon $15.00/hour.
- A group of 15 can clean up 1 ton of trash in an 8 hour day.
- Labor costs could possibly be reduced utilizing inmate labor. Additional labor may be assessed if additional officers are required for security.
- Supplies are purchased in bulk to reduce cost.
- Volunteers bring their own food/water.

Resources:

Cochise County, BLM., and U.S. Border Patrol.

Barriers:

Access to sites

Project Schedule and Milestones:

Schedule:

- Contact U.S. Border Patrol for information regarding UDA sites - monthly
- UDA's identified & mapped - monthly
- County contacted to assist with clean-up – monthly
- Volunteers recruited and trained – 2 weeks in advance
- Equipment purchased/ reserved – 2 weeks in advance
- Supplies and Materials purchased – 1 month in advance
- Sites scheduled for clean-up - monthly

Milestones:

- UDA sites identified & mapped
- UDA sites scheduled for clean-up
- Volunteers trained *and* waivers signed
- Photo monitoring for each site documented

Estimated load reduction by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment:

Human fecal material is an important source of enteric pathogenic protozoa and viruses. The concentration of protozoan parasites (Giardia or Cryptosporidium) in feces of infected persons can range from 10^5 to 10^7 per gram and enteric viruses (enteroviruses, adenoviruses, rotavirus) from 10^5 to 10^{12} per gram (Gerba 2000). Consequently, preventing human contamination of water resources is an important water quality management objective. Removal human fecal material from the near river environment through the clean-up program can potentially reduce the level of E. coli loads in the river system. E. coli, as member of the intestinal flora, is part of the digestive process and is excreted in feces. The CFU of E. coli in feces averages from 10^7 to 10^9 per gram in humans (Tenaillon et al. 2010).

Consequently, if 1 kg of fecal material is removed from the river environment through the clean-up program it would result in the potential E. coli load reduction of 1.0 x 10^{10} to 1.0 x 10^{12} CFU.

References:

Gerba, C.P., 2000. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact of water quality. Quantitative Microbiology 2: 55-68.

Tenaillon, O., D. Skurnik, B. Picard, and E. Denamur, 2010. The population genetics of commensal *Escherichia coli*. Nature Reviews □ Microbiology 8 (March): 207-217.

BMP Type 3: Signage in the SPRNCA

Overview

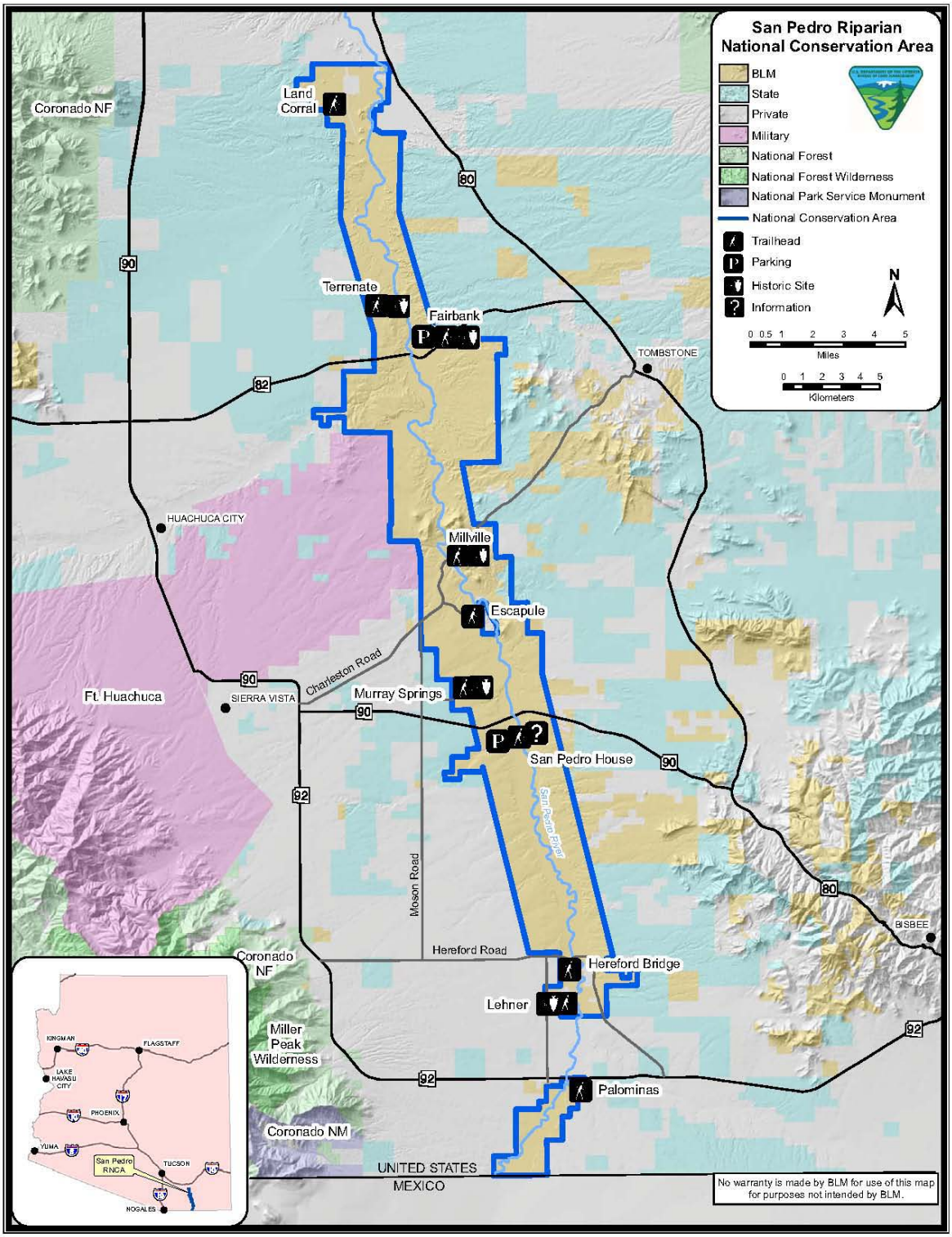
Monitoring of *Bacteroides and E. coli* in the targeted watershed has provided documentation of potential human sources of fecal contamination causing impairments. Human recreation sites occur on federal lands located in the San Pedro Riparian National Conservation Area (SPRNCA) that begin from the border to the cienega located in St. David (Figure 14). Seven of the recreation areas lie upstream from the targeted area of this study. Human recreation along the SPRNCA has the potential to deposit human fecal matter into the San Pedro by surface flows. Recreation in the SPRNCA is managed by BLM with limited restroom and trash facilities. Visitors are strongly encouraged to follow the pack-in/pack-out rule with limited enforcement. Sampling teams have documented occasional visible human fecal inputs along the San Pedro at sampling sites. While open toilet sites are not so easily discovered, data has shown that human fecal inputs are evidenced there.

The Leave No Trace Center for Outdoor Ethics is an organization that is member driven with the purpose to teach people of all ages how to enjoy the outdoors responsibly. It is the most widely accepted outdoor ethics program used on public lands and works in concert with its members to meet their needs. BLM is a member of this organization. The SPRNCA had 118,000 people visit the area in 2012, and are willing to place additional signs along the designated trail sites to help educate visitors about the pack-in/ pack-out guidelines.

Guidelines for pack-in/pack-out can be located on the *Boy Scouts of America* website page (www.scouting.org).

Leave No Trace offers free assistance in tailoring content and providing copywrite information. (*Ben Lawhon (ben@LNT.org), Leave No Trace 1-800-332-4100*)

Figure 9. Map of San Pedro Riparian National Conservation Area.



Used with permission by BLM. The map is subject to change as BLM proceeds with its Resource Management Plan for the SPRNCA.

Associated Costs:

Labor:	Installation	$ 35.00/ hour
Materials/ Supplies:	Digital graphic on .080 alum or ¾" HDO, 3M clear UV overlay for (18" x 24") signs	$ 114 - $144 each
	Frames (dependent upon material used)	$ 102 - $174 each
	Leave No Trace posters (10 or more)	$ 4.00 each
Miscellaneous:	One time art design charge	$ 85.00

Resources:

Wood Product Signs - woodproductsigns.com
Leave No Trace – LNT.org
Bureau of Land Management

Barriers:

Copywrite laws

Project Schedule & Milestones:

Estimated load reduction by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment:

Recreational visitors to the San Pedro Riparian National Conservation Area can be an important source of fecal material to the river environment. Human fecal material is an important source of enteric pathogenic protozoa and viruses. The concentration of protozoan parasites (Giardia or Cryptosporidium) in feces of infected persons can range from 10^5 to 10^7 per gram and enteric viruses (enteroviruses, adenoviruses, rotavirus) from 10^5 to 10^{12} per gram (Gerba 2000). Consequently, preventing human contamination of water resources is an important water quality management objective.

Promoting a pack-in/pack-out program can reduce the level of fecal material in the near river environment. A University of North Dakota study for the U.S. Department

of Agriculture regarding human waste distributions reported the average stool produced by a human adult was 95.5 grams per day and the average number of bowel movements per day by a human adult was 2.54 (Parker and Gallagher 1988). If the new signage program changes the behavior of 100 individuals per year to pack-out their waste materials the potential reduction of fecal material to the river environment would be:

*Fecal Material (kg) = 100 visitors/year * 95.5 g/day * day/2.54 movements * 1 kg/1000 g = 3.8 kg /year*

The Fecal Material estimate is important in regard to E. coli. E. coli, as member of the intestinal flora, is part of the digestive process and is excreted in feces. The CFU of E. coli in feces averages from 10^7 to 10^9 per gram in humans (Tenaillon et al. 2010).

Consequently, if 3.8 kg of fecal material is removed from the river environment it would result in the potential E. coli load reduction of 3.9×10^{10} to 3.9×10^{12} CFU per year.

References:

Gerba, C.P., 2000. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact of water quality. Quantitative Microbiology 2: 55-68.

Parker, D. and S. K. Gallagher, 1988. Distribution of human waste samples in relation to sizing waste processing in space. In: The Second Conference on Lunar Bases and Space Activities of the 21st Century, NASA Conference Publication 3166, Vol. 1, pp. 563-568.

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BMP Type 4: Range Improvement Practices

Overview

Analysis throughout this study has shown that *E. coli* density in samples was strongly related to turbidity and storm-flow events at all sampling sites within the targeted San Pedro River. Dr. Guertin, one of our advisors to this study, has stated there is substantial pulsing of sediment into the system as a result of overland flow during monsoon season.

Improper grazing management can contribute to the removal of most vegetative cover, soil compaction, exposure of soil, degradation of soil structure, and loss of infiltration capacity. These impacts can result in soil susceptible to wind and water erosion (U.S. EPA 2003). Livestock also generate microorganisms in waste deposits as they graze on pasture and rangelands (Kress and Gifford 1984). Runoff from grazed land can contain high numbers of indicator microorganisms as fecal material is transport from the grazed areas (Crane et al. 1983).

Dr. Phil Guertin

Thirty-four NRCS land allotments, 374,979 total acres, may impact the targeted area of the San Pedro River. Eight allotments have current active Conservation Management Plans (CMP); nine have initiated the process, leaving seventeen without a CMP with the NRCS (NRCS Willcox 2013). Conservation Management Plan development is a tool used by NRCS to promote agricultural production, forestry, and environmental quality. A CMP can include several practices based upon the goals and needs of the allotment. The practices recommended by the WIC based upon analysis of the study are brush management, prescribed grazing, fencing, water wells, and reseeding. The development and completion of a CMP can take a few months for private lands to 1.5 years for allotments on state and federal lands. While a CMP is not required for funding, it is a requirement when seeking funding through NRCS.

Locations:

Thirty-four land allotments along the San Pedro River equaling 374,979 acres would benefit or continue to benefit from rangeland improvement practices.
Several tributaries empty into the San Pedro River and are located within the targeted reach. These include Slavin Wash, Escalante Wash, California Wash, Clifford Wash, Willow Wash, and Walnut Gulch (Figure 10).

Features:

One of the most striking land cover changes on rangelands worldwide over the past 150 years has been the proliferation of trees and shrubs at the expense of perennial grasses. (NRCS Brush Management as a Rangeland Conservation Strategy)

Creosotebrush is a woody plant species that is abundant on rangeland in Southeastern Arizona. Information taken from a study by Morton and Melgoza measuring changes in herbaceous plant density after treatment of creosotebrush:

As creosotebush increase, forage production decreases. Likewise, when woody plant populations are removed or thinned, forage production increases (Morton et al. 1978, Scifres et al. 1979, Jacoby et al. 1982, Herbel et al. 1983).

As an anecdotal observation, there has been minimal rangeland restoration on the eastern side of the San Pedro watershed and north of the Babocamari on the western side. The majority of the ranches on the Babocamari watershed (Brookline Ranch, Babocamari Land Grant, Sands Ranch, and Audubon) have active CMPs with NRCS restoring rangelands over the last 10 years. The Babocamari River has not seen storm event exceedences of *E. coli* that the San Pedro has.

Two methods for long-term brush control are recommended as part of this BMP. The first is through use of Spike® 20P herbicide which addresses creosotebush and other short rooted woody plant species; the second through cutting and mechanical equipment to address both short rooted and long rooted woody plant species (upland shrub mesquite). Each method helps promote the growth of native grasses. Native grasses create natural buffers that help reduce sediment transport into San Pedro River Watershed.

Spike® 20P is a nonrestricted herbicide product used for long-term woody plant control which allows for sculpting areas based upon land improvement goals. It is applied with calibrated equipment through ground or aerial application during winter months before monsoon season. Activated by rain, it is absorbed by the root system of the woody plant and moved up to the leaves causing brush to defoliate and die encouraging native grasses to grow. The process can take up to two years until all treated woody plants are completely dead roots and all. (*Dow AgroSciences LLC)* In southeastern Arizona, this method of treatment can last 12 - 15 years. (Barry Wallace, Crop Production Services)

The Spike® 20P (Tebuthiuron) specimen label recommends that "*it not be applied to desirable trees or other woody plants, directly to water, to areas where surface waters are present or to intertidal areas below the mean water mark*." Studies on Tebuthiuron for Calculated Estimated Environmental Concentrations (EECS) *"have shown that acute and chronic risk quotients indicate no direct risk to endangered fish, aquatic invertebrate populations, and aquatic vegetation." (*Stavola 2004*)* For these reasons, Spike® 20P is not applied within a 100-200 riparian acre buffer zone. For more information on Spike® 20P and its application visit the Hereford NRCD website http://www.herefordnrcd.com/Brush-Control-Project.html.

Cutting or removal with mechanical equipment is another method used for long term brush control. It works best for the removal of mesquite which have more

complex root systems. It is labor intensive, expensive, and generally only feasible for small or scattered patches. It can take two or three consecutive years of cutting at the proper time to kill most woody species. Reseeding sometimes is used in restoring native grasses. It can last 12-15 years.

Two ranches located within the targeted reach of the San Pedro River with before and after photos of brush control completed in past years are found in Figure 10-12.

Associated Costs Brush Management Using Spike® 20P:

Ground Application*	$21.93 - $31.25 per acre
Aerial Application*	$22.06 per acre

* Costs per acre include time, labor, equipment, and supplies. Estimates based upon information from NRCS for Environmental Quality Incentive Program (EQIP) funding.

Associated Costs Brush Management Using Cutting and Mechanical:

Small shrubs light infestation*	$ 67.26 per acre
Small shrubs medium infestation	$ 82.57 per acre
Small shrubs heavy infestation*	$ 97.89 per acre
Large shrubs light infestation*	$ 183.50 per acre
Large shrubs medium infestation*	$ 300.85 per acre
Large shrubs heavy infestation*	$ 376.76 per acre

* Costs per acre include time, labor, equipment, and supplies. Estimates based upon information from NRCS for EQIP funding.

Associated Costs Reseeding:

Seedbed prep., seed & seeding – native perennial grasses*	$ 251.72 per acre
Seedbed prep., seed & seeding – native perennial warm season grasses*	$ 385.58 per acre
Seedbed prep., seed & seeding – native perennial cool season grasses with legume*	$ 313.69 per acre
Seedbed prep., seed & seeding – introduced perennial warm season grasses*	$ 327.13 per acre

* Costs per acre include time, labor, equipment, and supplies. Estimates based upon information from NRCS for EQIP funding.

Figure 10. NRCS San Pedro River Land Allotments courtesy NRCS Willcox.

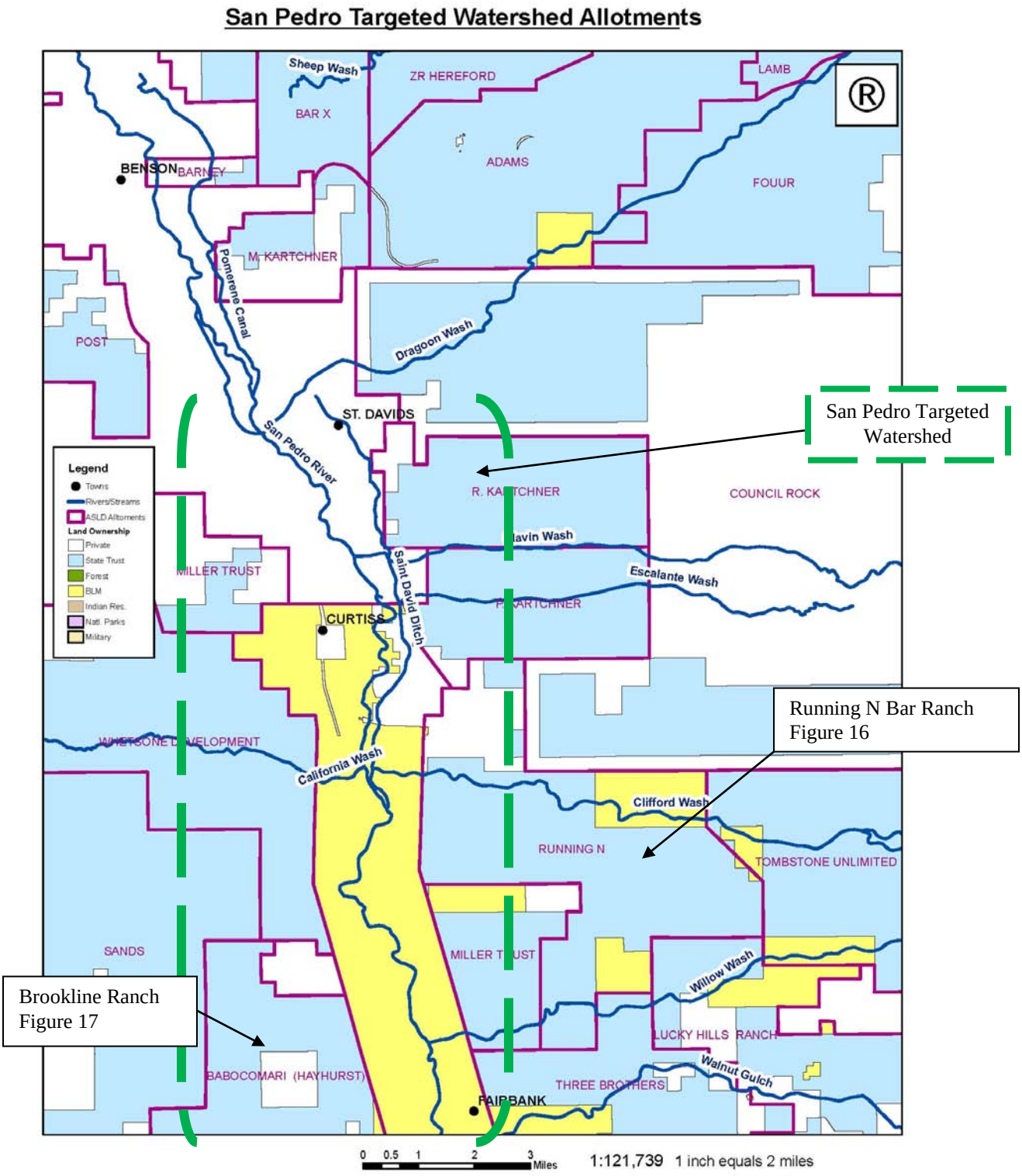

Figure 11. Before and after pictures of mechanical treatment courtesy of Running N Bar Ranch.

Figure 12. Before and after pictures of treatment with Spike® 20P courtesy Brookline Ranch.

Brush control is one practice for rangeland improvement. As part of a CMP the key to the success and control of the treatment is to incorporate other practices such prescribed grazing, fencing and water wells.

Associated Costs Prescribed Grazing:

Range standard ($10,000 cap/yr)*	$ 3.45 per acre
Range intensive (10,000 cap/yr)*	$ 6.36 per acre
Habitat mgt. standard ($10,000 cap/yr)*	$ 3.50 per acre
Habitat mgt. rest rotation ($10,000 cap/yr)*	$ 6.88 per acre
Pasture standard ($10,000 cap/yr)*	$ 9.73 per acre
Pasture intensive ($10,000 cap/yr)*	$ 15.36 per acre
Pasture deferment ($10,000 cap/yr)*	$ 9.89 per acre
Range deferment ($10,000 cap/yr)*	$ 1.12 per acre

* *The cap/year deals with the maximum amount NRCS will pay a producer for applying grazing management. For example, if the payment rate is $5/ac/year and someone comes in and signs up for grazing management on their 20,000 ac ranch the total would come out to $100,000 but NRCS will only actually pay them $10,000. Applying grazing management doesn't cost anything, NRCS simply provides an "incentive" payment in order to entice ranchers into trying a different way of rotating their cows* (NRCS Willcox).

Associated Costs Water Well:

Water Well <=100 feet*	$ 54.77 per foot
Water Well <=100-300 feet*	$ 37.46 per foot
Water Well >300-600 feet*	$ 39.92 per foot
Water Well >600 feet*	$ 45.02 per foot
Water Well remote location*	$ 81.45 per foot

* Costs per foot include time, labor, equipment, and supplies. Estimates based upon information from NRCS for EQIP funding.

Associated Costs Fencing:

Barbed-Smooth Wire	$1.55 per foot
Confinement	$5.50 per foot

* Costs per foot include time, labor, equipment, and supplies. Estimates based upon information from NRCS for EQIP funding.

Institutional and Jurisdictional Consideration

Acquisition of required permits for implementation of Type 2 BMP may require lead time and planning. Permitting requirements differ between practices and land ownership. (Table 4)

Table 4. Permitting requirements for suggested Type 4 BMP
This table provides guidelines for permitting needs and should be considered on an individual project basis.

	NEPA EIS	ADEQ 401	SHPO	ASLD	ADWR	Army Corp. of Engineers 404
Brush Management Herbicide	X	X		X		X
Brush Management Mechanical	X		X	X		X
Fencing	X		X	X		X
Water Well	X		X	X	X	X
Reseeding	X			X		X

Resources:

Arizona Department of Environmental Quality (ADEQ 401) - http://www.azdeq.gov/environ/water/permits/cwa401.html

Arizona Department of Water Resources (ADWR) - http://www.azwater.gov/azdwr/default.aspx

Arizona State Land Department (ASLD) - http://www.azland.gov/programs/operations/applications.htm
Army Corp. of Engineers 404 - http://www.usace.army.mil/Home.aspx

Bureau of Land Management (BLM) - http://www.blm.gov/az/st/en/prog/grazing.html

National Environmental Policy Act Environmental Impact Statement (NEPA EIS) – http://www.epa.gov/region9/nepa/

National Resource Conservation Services (NRCS) - http://www.az.nrcs.usda.gov/

State Historic Preservation Office (SHPO) - http://azstateparks.com/SHPO/index.html

University of Arizona Extension - http://extension.arizona.edu/programs/rangeland-management

Barriers:

Permitting and costs

Project Schedule and Milestones:

Schedule:

- Develop CMP (if one is not currently available) – up to 1.5 years
- Start Plan – Identify Problems
- Determine Objectives
- Inventory Resource Data
- Formulate Conservation Practice
- Prioritize Order of Installation

Milestones:

- Apply for EQIP if using NRCS funding
- Conservation Management Plan completed if using NRCS funding
- Permits and environmental/archeological clearances completed
- Subcontracts signed for treatment
- Treat acres
- Develop monitoring plan
- Cost-share payment for project completed if using EQIP

Estimated load reduction by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment:

There are 34 grazing allotments within the target reach of the San Pedro River totaling 374,979 acres. Based on Southwest Regional GAP (SWReGap) vegetation data 53.9% (202,000 acres) of the allotments land area are available for brush treatment (30.4% is in Chihuahuan Creosotebush, Mixed Desert and Thorn Scrub

and 23.5% is in Apracherian-Chihuahuan Mesquite Upland Scrub). The prescribe treatment will convert the scrub vegetation types to native grasslands. The treatment effects on runoff and erosion were predicted using the Soil and Water Assessment Tool (SWAT) implemented within the Automated Geospatial Watershed Assessment Tool (AGWA).

If 100% of the scrub vegetation types within the allotments were converted to native grasslands the average sediment yield would be reduced by 1,958 U.S. short ton per year. The pre-treatment average sediment yield was 0.025 U.S. short tons per acre and 0.38 inches of runoff. Post-treatment the Chihuahuan Creosotebush, Mixed Desert and Thorn Scrub vegetation type average sediment yield was 0.015 U.S. short tons per acre (40% load reduction) and 0.31 inches of runoff. Post-treatment the Apracherian-Chihuahuan Mesquite Upland Scrub vegetation type average sediment yield was 0.016 U.S. short tons per acre (36% load reduction) and 0.33 inches of runoff.

The reductions in sediment yield and runoff will assist in the retention of fecal material in the uplands and reduce loads in the stream channels. Given the high levels of impairment for E. coli during the monsoon season decreasing the responsiveness of the watershed should decrease overall E. coli loads.

CLOSING STATEMENT

Results of the analysis indicate a complex system with many variables leading to the impairment of this reach of the river. At the start of this study, the ultimate goal was the delisting of the reach from the EPA impairment list. After two years, it is obvious to the WIC that the San Pedro River is a unique desert river system. The pulsing nature of the watershed during summer storm flow events demonstrates the system is very dynamic. Exceedences of EPA standards for *E. coli* may be unavoidable during these large storm events. Another consideration, research to date has identified varied potential *E. coli* sources within the watershed. Advisors to this study state an expansion of the library for Microbrial markers is needed along with collection of additional data to identify more accurately how desert watersheds act. It is the desire of the WIC that acknowledgement of the very high background level of *E. coli* in this system is taken into consideration, since it may never meet the surface water quality standard for full body contact of E. coli during high flow storm events.

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APPENDIX A: Resident Survey

Dear San Pedro River Watershed Resident…

The Coronado RC&D was funded by a grant, Arizona Department of Environmental Quality (ADEQ), to determine the impairment of the reach of the San Pedro River from the bridge at Fairbanks to the bridge on Hwy 80 in Saint David by the fecal coliform *Escherichia coli (E. coli),* as well as solutions to those problems. The San Pedro Targeted Watershed Improvement Committee was formed in 2010 and currently is working on a Watershed Improvement Plan. As part of the San Pedro River watershed community, you are vital to its economic, recreational and natural future.

We need your help discovering how best to inform other members of the public on ways to protect the San Pedro, and the health of people who use it. This survey is designed to obtain residents' opinions on human behaviors that affect water quality. It will be used to guide projects to improve water quality in the San Pedro River and its tributaries.

The enclosed survey takes approximately 15 minutes to fill out. Please take the time to complete it. Then fold, staple or tape, and either place it in the mail or drop it off at the St. David Water District Office/Drop Box.

The Targeted San Pedro River Project is committed to preserving the integrity of the San Pedro River and recognizes that its stewardship must be a part of the watershed community culture.

We highly value your opinion, and it matters a lot to us! Your time is very much appreciated, and every survey we receive back helps the San Pedro River. ***Thank you for your participation!***

Linda Searle
Program Manager
520.766.3607

Targeted San Pedro River Watershed Residents' Survey

1) **How concerned are you with the health of the San Pedro River Watershed?**
□ Not concerned □ Somewhat □ Concerned □ Very concerned

2) **How many times a year do you visit/recreate along the San Pedro River?**
□ Never □ 1-5 □ 6-10 □ 11-15 □ 16-20 □ 20+

3) **What activities do you undertake while visiting the San Pedro River? Please mark all that apply.**
□ Hiking □ Camping □ ATV □ Swimming □ Hunting □ Dog walks □ Equestrian
□ Other: (Please specify)
_____

4) **Which is the most important source of information affecting your perception of the San Pedro River's health?**
□ Personal observation □ Newspaper □ Radio □ Internet □ State or federal reports □ Local environmental group

5) What sources do you think could be the biggest contributors to the river that can cause human illness? Please number 1, 2 and 3 for your top choices.
__ Litter __ Dog feces __ Baby diapers __ Human feces __ Wildlife feces __ Livestock waste
__ Septic systems __ Sediment __ Storm water run-off __ Waste water treatment plants __ Don't know

6) **How many people live in this household?**
□ 1 □ 2 □ 3 □ 4 □ 5+

Please complete the reverse side, then fold and staple or tape survey closed and mail to Coronado RC&D, or drop off to St. David Water.

7) In your opinion, how much do the following threaten San Pedro River water quality?

0 = not sure 1 = not a problem 2 = slight problem
3 = moderate problem 4 = large problem

Please mark with an X

	0	1	2	3	4
Agricultural runoff					
Livestock manure					
Fertilizers and pesticides					
Animals					
Dog feces that are not picked up and disposed properly					
Wildlife feces					
Livestock					
Erosion and sedimentation due to the following:					
Construction and maintenance of irrigation diversions					
Building and road construction					
Road maintenance					
Low water creek crossings					
Unmaintained “social” trails					
Jeep/ATV use					
Other sources (specify)					
Recreation					
Human feces deposited outdoors					
Trash					
Used and improperly discarded baby diapers					
Lack of public toilet facilities near creek and at trailheads					
Lack of trash receptacles at recreation sites and trailheads					
Urban areas					
Storm water runoff					
Lawn fertilizers and pesticides					
Pet feces not collected from yards					
Wastewater					
Inadequately maintained sewer system					
Improperly built or maintained residential septic systems					
Improperly built or maintained commercial septic systems					
Other					
Lack of riparian buffers (natural vegetation next to the water)					
Other (specify)					

Please, write any comments here:

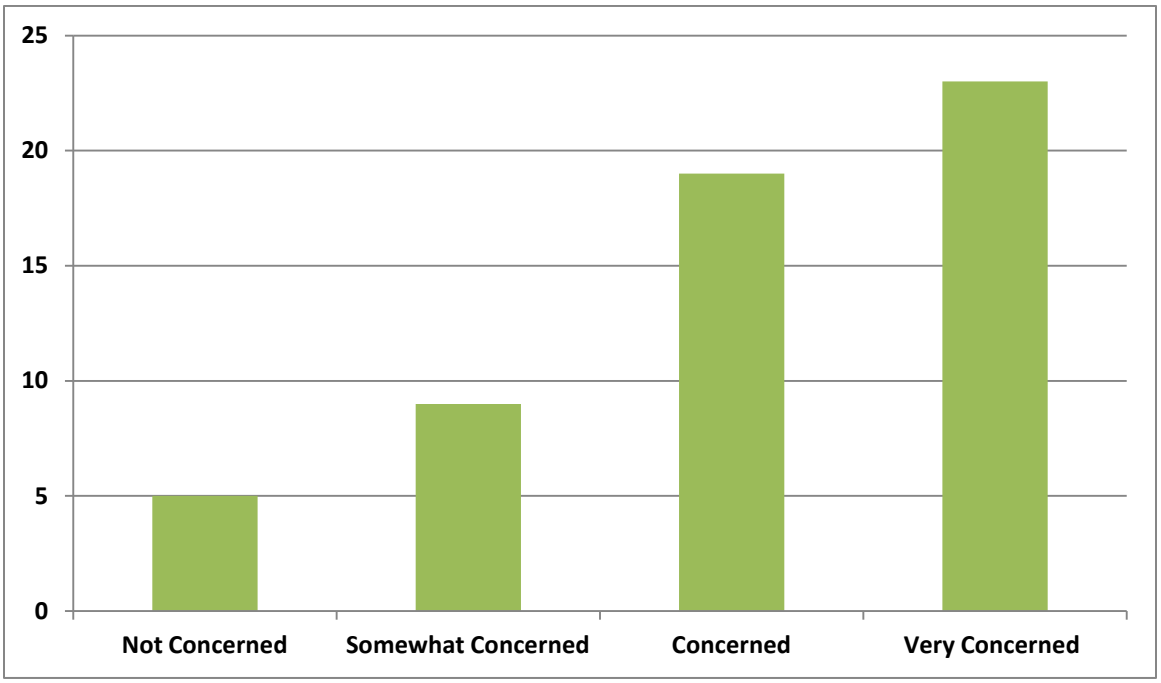
Fold here

Coronado RC&D
450 S. Haskell Ave., Willcox, AZ 85643

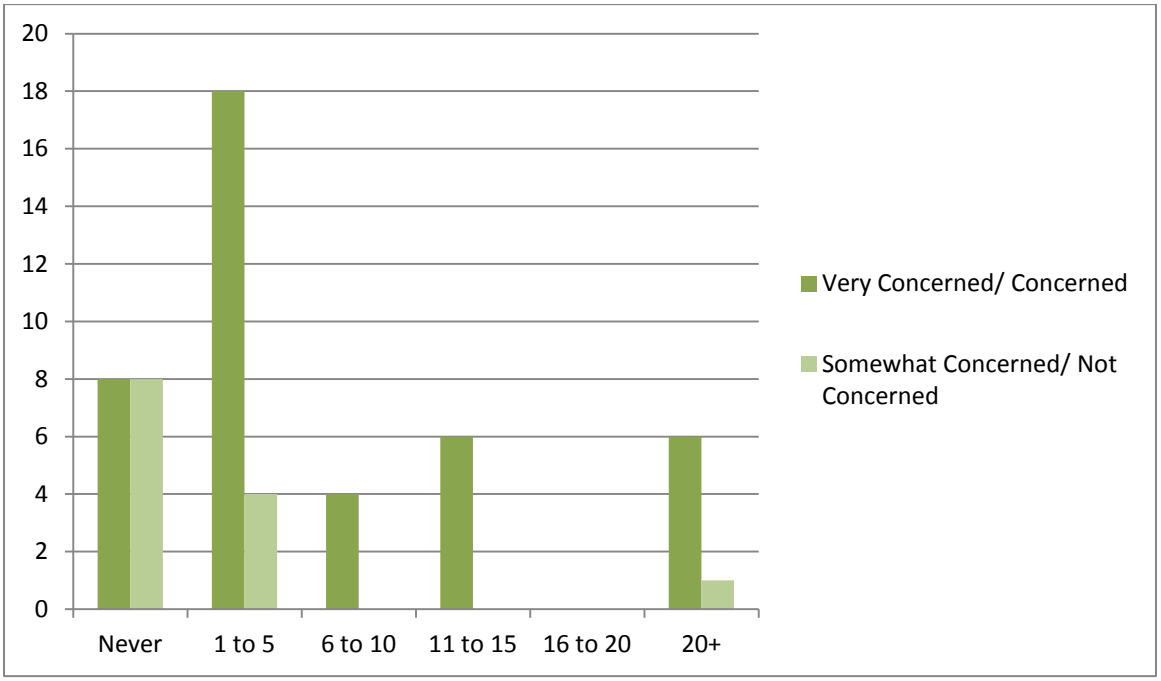
Coronado RC&D
450 S. Haskell Ave.
Willcox, AZ 85643

APPENDIX B: Resident Survey Results

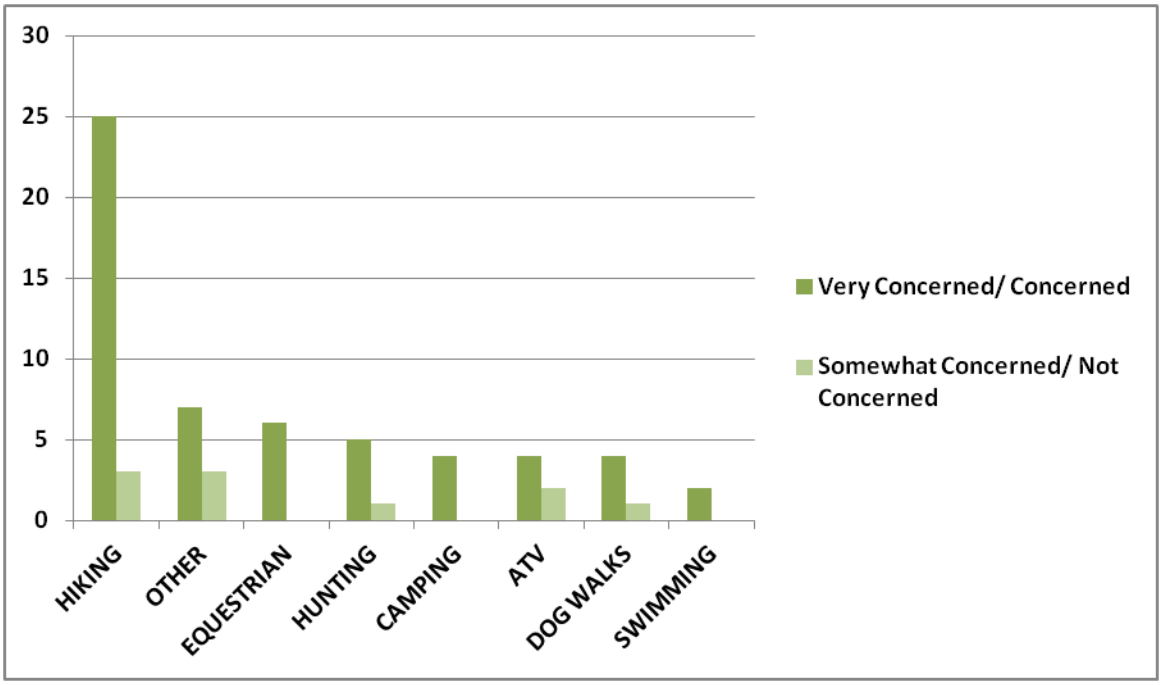
Question 1: How concerned are you with the health of the San Pedro River Watershed?



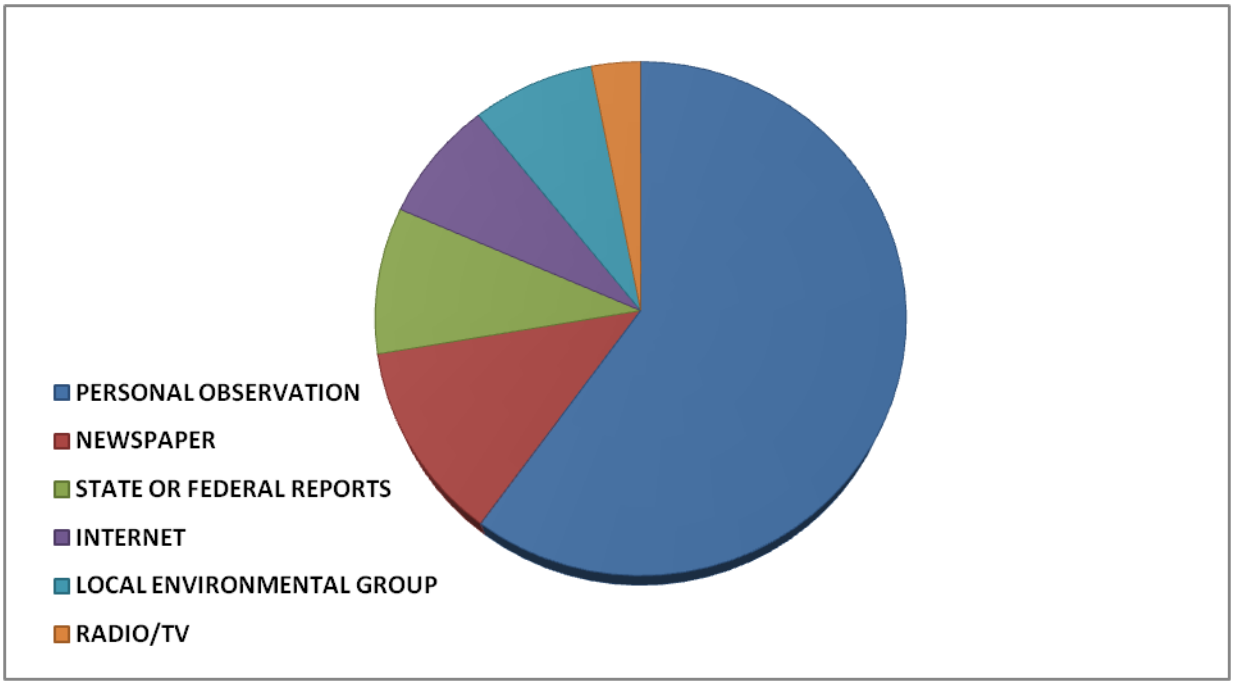
Question 2: How many times a year do you visit/recreate along the San Pedro River?



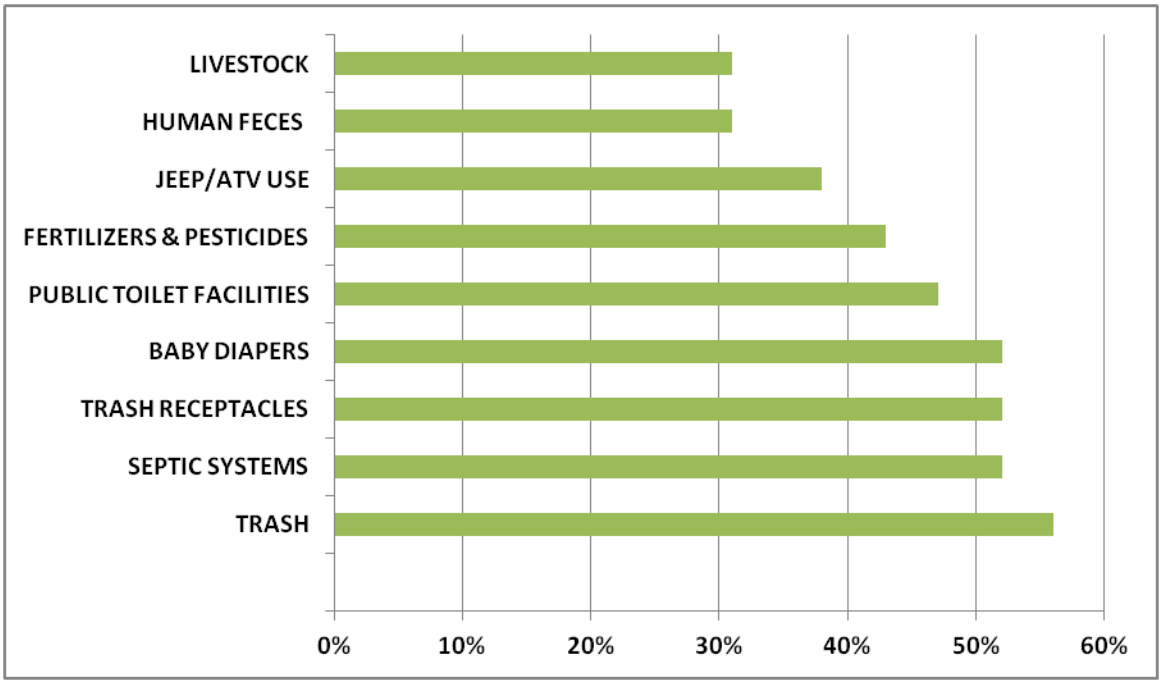
Question 3: What activities do you undertake while visiting the San Pedro River? Please mark all that apply.



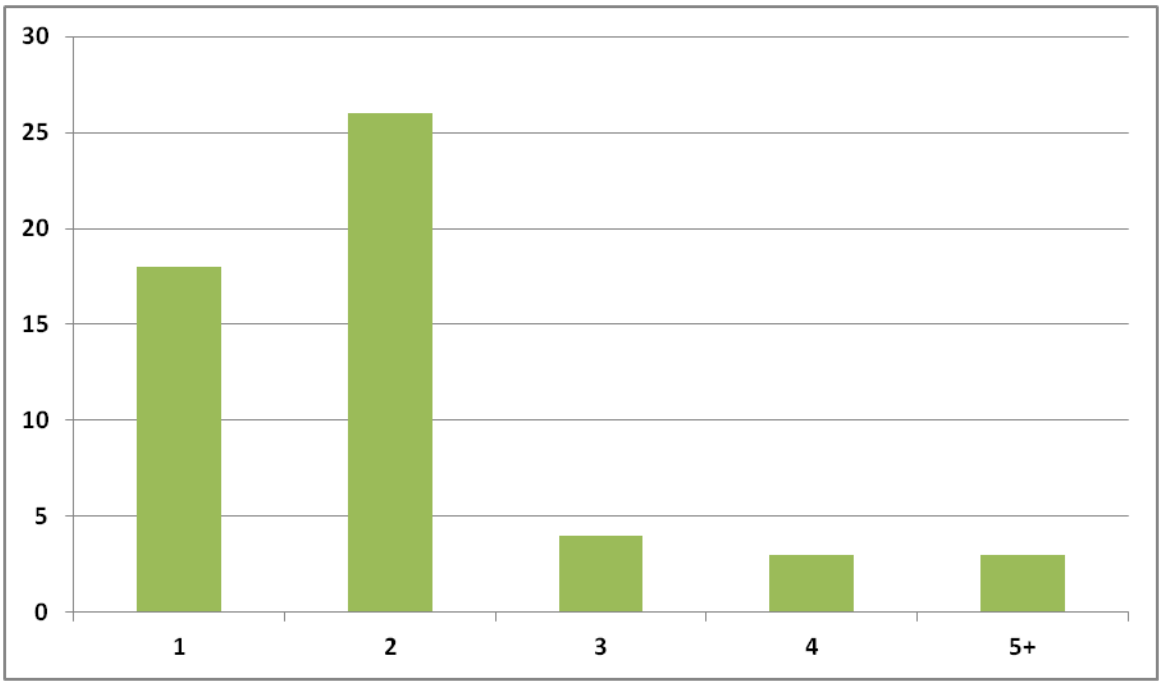
Question 4: Which is the most important source of information affecting your perception of the San Pedro River's health?



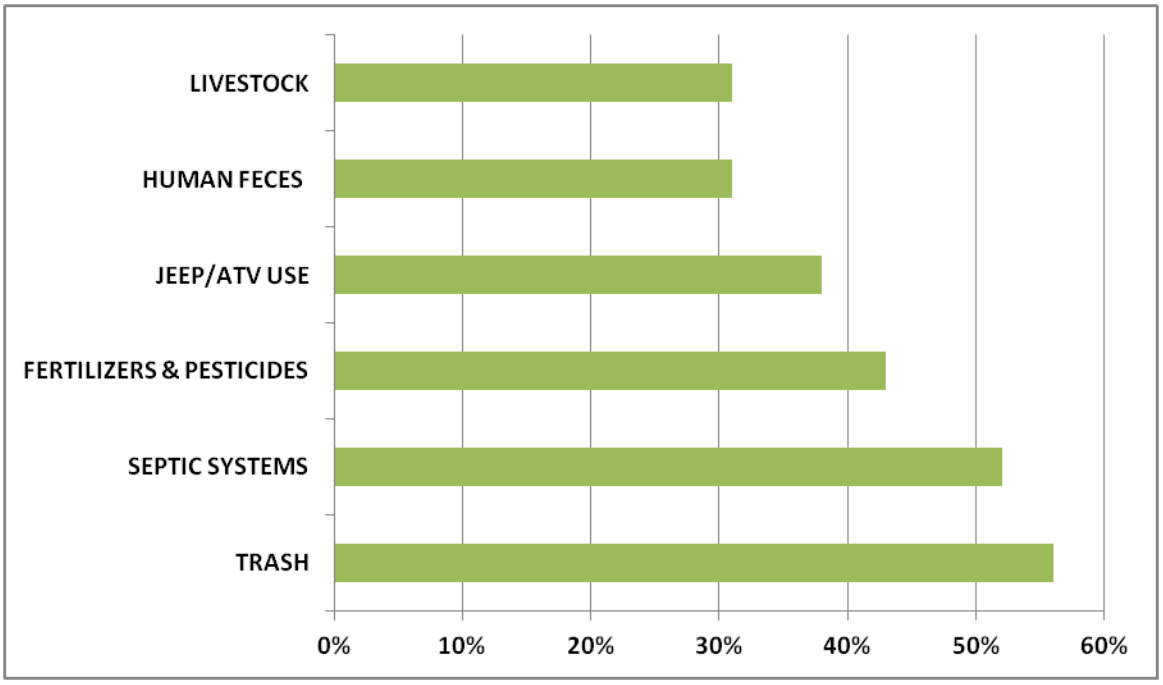
Question 5: What sources do you think could be the biggest contributors to the river that can cause human illness? Please number 1, 2 and 3 for your top choices.



Question 6: How many people live in this household?



Question 7: In your opinion, how much do the following threaten San Pedro River water quality?



APPENDIX C: Sampling Results 2011-2012

ADEQ 12-003 San Pedro Targeted Watershed Sampling Results

ADEQ #	LAT	Long	Location	Date	Time	Discharge cfs	E. coli cfu/100 ml	Dilution	Turbidity	Dilution	Air Temp	Water Temp	pH	TDS mg/L	D.O.	D.O. %	Sp. Cond µs/cm
100287	31 43.389	110 11.631	Fairbanks	07.22.11	7:34	118.65	>2419.6		5232	4:1	23	22.6	8.04	126	7.4	17.5	254
103548	31 43.346	110 11.689	Babocomari	07.22.11	8:01	<1	18.1		314		24	24.7	7.75	224	2.8	7	447
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.22.11	5:22	56.037	>2419.6		5536	4:1	23	23.1	7.71	240	4.9	14.5	475
103674	31 51.672	110 12.605	Escalante	07.22.11	6:22	166.39	>2419.6		5120	4:1	23	22.5	7.85	146	9.5	16.9	296
100287	31 43.389	110 11.631	Fairbanks	07.23.11	11:35	36.11	312.3		5648	4:1	37	29.7	8.22	136	6.6	18.4	273
103548	31 43.346	110 11.689	Babocomari	07.23.11	11:57	pool	3		320		39	33.7	8.43	200	8.1	24.7	394
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.23.11	9:47	32.84	>2419.6		5472	4:1	29	26	8.23	146	8.3	22.1	291
103674	31 51.672	110 12.605	Escalante	07.23.11	10:41	18.198	816.4		6560	4:1	30	29.3	8.28	131	7.4	18.6	267
100287	31 43.389	110 11.631	Fairbanks	08.02.11	7:30	23*	>2419.6		6750	1:1	25	23.4	8.22	119	7.9	19.3	224
	31 63.000	110 17.000	Charleston	08.02.11	6:50	19.6**	>2419.6		7970	1:1	21	22.5	8.27	112	7.4	18.1	222
	31 38.000	110 110.000	Palominas	08.02.11	6:05	21.4***	2419.6		883		20	22.8	8.33	125	7.4	17.3	246
	31 51.770	110 05.437	LADD 1	09.10.11	5:45	136***	>2419.6		17100	100:1	15	15.9	8.35	94	9.5	20.8	195
100287	31 43.389	110 11.631	Fairbanks	09.10.11	7:30	92*	>2419.6		15300	100:1	17	17.4	8.28	76	9.2	21.3	152
100287	31 43.389	110 11.631	Fairbanks	12.11.11	11:10	2.9*	1		6.36		18	10.6	0.68	282	11.6	19.5	608
103674	31 51.672	110 12.605	Escalante	12.11.11	12:00	<1	4.1		0.59		22	17.9	8.1	348	9.7	24.9	686
100287	31 43.389	110 11.631	Fairbanks	01.19.12	15:40	15	5.1		0.49		23	14.1	8.61	254	10.4	20.8	493
	31 41.117	110 13.115	Bowers Crossing (Babocomari)	01.19.12	15:10	<1	0		0.42		19.1	13.6	8.17	309	22	12.1	597
103674	31 51.672	110 12.605	Escalante	01.19.12	16:15	<1	6.3		0.57		23.6	17.7	7.82	341	21.5	10.5	688
100276	31 54.263	110 14.681	Hwy 80/ St. David	01.19.12	16:45	1.5	10.9		0.62		21.4	14.6	8.71	340	10.5	30.8	660
100287	31 43.389	110 11.631	Fairbanks	03.22.12	15:38		5.2		9.09		30.2	23.6	8.77	259	NT	21	518
	31 41.117	110 13.115	Bowers Crossing (Babocomari)	03.22.12	15:10	<1	3.1		1.71		29.8	16.4	7.84	319	NT	20.1	645
	31 51.680	110 12.600	BLM North	03.22.12	16:30	<1	35.5		3.39		30.5	22.7	7.76	376	NT	22.3	756

ADEQ #	LAT	Long	Location	Date	Time	Discharge cfs	E. coli cfu/100 ml	Dilution	Turbidity	Dilution	Air Temp	Water Temp	pH	TDS mg/L	D.O.	D.O. %	Sp. Cond µs/cm
100276	31 54.263	110 14.681	Hwy 80/ St. David	03.22.12	17:00	<1	86.5		22.2		25.8	22.8	8.48	362	NT	21.7	728
	31 53.41	110 17.35	APNI 1	04.19.12	15:35	<1	158.6		1.26		28.7	22.9	8.62	336	NT	17.4	665
	31 53.015	110 13.720	APNI 2	04.19.12	16:09	<1	39.5		1.46		30.2	24.6	8.36	319	NT	17.8	638
	31 51.680	110 12.600	BLM North	04.19.12	14:30	<1	6.3		0.68		31	27.1	7.47	411	NT	20.1	819
100287	31 43.389	110 11.631	Fairbanks	07.05.12	7:17	50.4	>2419.6		7060	10:1	22.6	20.8	8.44	131	7.4	17.5	261
100287	31 43.389	110 11.631	Fairbanks	07.05.12	18:10		17.4		109		29	27.1	8.38	121	7.1	17.3	263
	31 51.680	110 12.600	BLM North	07.05.12	8:27		920.8		946		25.5	23.7	7.73	126	6.9	16.1	275
	31 51.680	110 12.600	BLM North	07.05.12	17:04	<1	55.6		1.55		35	27.4	7.51	125	7.3	17.5	261
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.05.12	9:06		2419.6		2070	10:1	29.5	22.9	8.35	124	7.1	17.1	259
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.05.12	19:10	<1	435.2		270		26	27.8	8.32	119	7.2	17.1	255
100287	31 43.389	110 11.631	Fairbanks	07.16.12	10:25	68	>2419.6		4290	10:1	26.1	25.9	8.22	205	6.3	18.1	232
100287	31 43.389	110 11.631	Fairbanks	07.16.12	16:46	1190*	>2419.6		9970	10:1	23	14.7	8.79	217	8	19.7	133
	31 51.680	110 12.600	BLM North	07.16.12	11:21	80	>2419.6		8390	10:1	33.8	28.4	8.18	105	8.5	22.2	195
	31 51.680	110 12.600	BLM North	07.16.12	17:23	33.1	234.8		1800	10:1	25	27.1	8.1	113	8.1	21.7	230
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.16.12	11:57	pooling	>2419.6		22700	100:1	28.4	26.8	8.14	105	7.5	20.1	210
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.16.12	18:00	High Flow	194.7		2420	10:1	27	26.7	8.2	103	7.9	21	213
100287	31 43.389	110 11.631	Fairbanks	07.17.12	8:43	227*	121.4		24400	100:1	28.2	21.4	8.01	101	8.3	21.7	259
	31 51.680	110 12.600	BLM North	07.17.12	9:19	NT	>2419.6		8090	10:1	34.8	22.5	8.09	105	8.7	22.3	211
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.17.12	10:07	High Flow	>2419.6		9970	10:1	25	21.6	8.18	100	8	21.1	201
100287	31 43.389	110 11.631	Fairbanks	07.18.12	8:17	719	>2419.6		8840	10:1	30	21.3	7.07	107	8.7	22.3	263
	31 51.680	110 12.600	BLM North	07.18.12	9:09	718	>2419.6		7380	10:1	30	22.2	7.73	110	9.3	23.2	223
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.18.12	9:41	1950	>2419.6		13400	100:1	32.5	21.1	7.96	105	8.3	22.7	213
100287	31 43.389	110 11.631	Fairbanks	07.24.12	16:25	99.6	1732.9		642		24.7	23.9	8.63	125	7.2	19.3	264
	31 51.680	110 12.600	BLM North	07.24.12	17:05	94.52	>2419.6		36800	100:1	24	23.7	7.94	119	7.1	17.1	257
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.24.12	17:55	88.27	436.6		86800	100:1	24.1	29.5	8.37	121	7.1	17.3	264
100287	31 43.389	110 11.631	Fairbanks	07.31.12	8:50	13.17	>2419.6		84700	100:1	32.9	22.7	8.52	129	7.7	18.9	257
	31 51.680	110 12.600	BLM North	07.31.12	9:46	14.3	144		22000	100:1	40.7	23.6	8.19	121	7.3	17.7	205
100276	31 54.263	110 14.681	Hwy 80/ St. David	07.31.12	10:14	32.9	114.7		18100	100:1	24.9	22.5	8.19	127	7.3	17.5	212

ADEQ #	LAT	Long	Location	Date	Time	Discharge cfs	E. coli cfu/100 ml	Dilution	Turbidity	Dilution	Air Temp	Water Temp	pH	TDS mg/L	D.O.	D.O. %	Sp. Cond µs/cm
100287	31 43.389	110 11.631	Fairbanks	08.07.12	8:25	1.74	51.7		57.5		31.2	23.6	8.6	79	5.1	17.2	476
	31 51.680	110 12.600	BLM North	08.07.12	9:00	<1	23.7		1.4		35.1	24.8	7.94	89	7.1	16.7	683
100287	31 43.389	110 11.631	Fairbanks	08.21.12	10:14	44.13	344.8		470		33	27.7	8.37	131	8.6	17.3	422
	31 51.680	110 12.600	BLM North	08.21.12	11:11	1.65	39.3		3.22		36.2	30.4	7.92	131	7.7	17.9	680
100276	31 54.263	110 14.681	Hwy 80/ St. David	08.21.12	11:40	1.4	101.7		98.4		34.8	35.1	8.48	119	7.3	18.1	471
100287	31 43.389	110 11.631	Fairbanks	08.28.12	8:15	29.51	36.3		12350	50:1	28.1	22.4	8.48	142	8.9	17.7	461
	31 51.680	110 12.600	BLM North	08.28.12	9:15	4.75	579.4		58100	100:1	33.2	23.8	8.54	161	7.9	19.3	368
100276	31 54.263	110 14.681	Hwy 80/ St. David	08.28.12	10:10	9.15	1986.3		13200	100:1	34.5	24.3	8.4	121	7.4	19.3	455
100287	31 43.389	110 11.631	Fairbanks	09.04.12	7:50	102*	19350	100:1	1240	10:1	20.9	21.2	8.69	105	7.6	16.7	223
	31 51.680	110 12.600	BLM North	09.04.12	8:52	279	10500	100:1	5860	10:1	22.4	21.7	8.6	124	7.1	16.7	251
	31 53.015	110 13.720	APNI 2	09.04.12	9:10	NT	5860	100:1	7670	10:1	22.9	22.1	7.83	125	6.7	16.3	250
	31 53.41	110 17.35	APNI 1	09.04.12	8:30	3.07	16790	100:1	4550	10:1	22.8	20.8	8.03	106	5.9	15.2	214
100276	31 54.263	110 14.681	Hwy 80/ St. David	09.04.12	8:05	NT	20120	100:1	3830	10:1	25.7	20.5	8.4	103	6.2	17.1	200
100287	31 43.389	110 11.631	Fairbanks	09.07.12	8:02	153*	12590	100:1	5490	10:1	20	21.8	8.33	112	5.7	14.3	309
	31 51.680	110 12.600	BLM North	09.07.12	8:49	NT	43520	100:1	1910	10:1	21	22.4	8.3	128	5.8	16.3	245
100276	31 54.263	110 14.681	Hwy 80/ St. David	09.07.12	9:25	NT	51720	100:1	8920	20:1	24	24.2	8.24	111	6.1	15.8	216
	31 41.117	110 13.115	Bowers Crossing (Babocomari)	09.08.12	10:39	<1	4		35		24.5	21.3	7.92	326	5.4	15.8	650
100287	31 43.389	110 11.631	Fairbanks	09.08.12	11:09	627*	24950	100:1	27700	100:1	25.6	22.9	8.3	155	5.3	13.7	313
	31 51.680	110 12.600	BLM North	09.08.12	11:42	180	31300	100:1	5660	100:1	28.6	24.4	8.38	145	5.8	16.3	291
	31 53.015	110 13.720	APNI 2	09.08.12	9:25	115	32820	100:1	3080	100:1	26.1	23.3	8.31	127	5.5	15.5	255
	31 53.41	110 17.35	APNI 1	09.08.12	8:50	115	48840	100:1	12900	100:1	26.8	23.2	8.33	120	5.7	15.1	241
100276	31 54.263	110 14.681	Hwy 80/ St. David	09.08.12	8:13	39.9	34410	100:1	4510	100:1	26.1	23.4	8.37	133	5.7	14.7	267
	31 41.117	110 13.115	Bowers Crossing (Babocomari)	09.11.12	7:49	<1	90.8		21.4		19.3	21.1	7.9	351	5.1	15.2	703
100287	31 43.389	110 11.631	Fairbanks	09.11.12	8:24	266*	61310	100:1	20900	100:1	20.9	20.7	8.37	185	5.5	13.8	372
	31 51.680	110 12.600	BLM North	09.11.12	11:42	180	31300	100:1	5660	100:1	28.6	24.4	8.38	145	5.8	16.3	291
	31 53.015	110 13.720	APNI 2	09.11.12	9:25	115	32820	100:1	3080	100:1	26.1	23.3	8.31	127	5.5	15.5	255
	31 53.41	110 17.35	APNI 1	09.11.12	8:50	115	48840	100:1	129100	100:1	26.8	23.2	8.33	120	5.7	15.1	241

ADEQ #	LAT	Long	Location	Date	Time	Discharge cfs	E. coli cfu/100 ml	Dilution	Turbidity	Dilution	Air Temp	Water Temp	pH	TDS mg/L	D.O.	D.O. %	Sp. Cond µs/cm
100276	31 54.263	110 14.681	Hwy 80/ St. David	09.11.12	7:45	150	198630	100:1	8140	10:1	23.1	20.6	8.53	113	5.9	16.8	226
	31 41.117	110 13.115	Bowers Crossing (Babocomari)	09.18.12	8:02	<1	10.9		32.5		16.6	19.6	7.6	331	4.7	13.8	660
100287	31 43.389	110 11.631	Fairbanks	09.18.12	8:24	18.4	630		53.5		22.3	18.3	8.4	267	5.7	13.6	514
	31 51.680	110 12.600	BLM North	09.18.12	9:11	<1	3930	100:1	1.46		22.6	23.5	7.9	337	5.7	14.9	678
	31 53.015	110 13.720	APNI 2	09.18.12	9:15	<1	740		6.23		23	19.9	8.53	227	5.7	15.3	457
	31 53.41	110 17.35	APNI 1	09.18.12	8:35	<1	610		6.53		27	19.1	8.55	217	5.3	14.7	434
100276	31 54.263	110 14.681	Hwy 80/ St. David	09.18.12	8:00	<1	3930	100:1	7.74		26	17.6	8.52	258	5.7	15.3	516
100287	31 43.389	110 11.631	Fairbanks	09.25.12	11:15	<1	24.1		1.42		30.5	25.2	8.13	350	6.7	13.8	702
	31 51.680	110 12.600	BLM North	09.25.12	10:30	1.07	770.1		7.92		35.4	23.2	8.68	294	6.1	14.3	587