E. coli and Total Coliform Sampling of the San Juan River and Selected Inflows from Blanco to the Hogback, May 10-12, 2005

Methods

Abe Franklin, Scott Clow, Tom Rice, and Meagan O'Donnell floated down the San Juan River from McGee Park (between Bloomfield and Farmington) to Lions Park in Kirtland (downstream of Farmington) on May 10 2005, and from Lions Park to just downstream of the Hogback Diversion on May 12 2005. Along the way, they collected fifty-four samples for bacteria analysis from the river and from selected tributaries, irrigation return flows, and at least one point source. On May 11, samples were collected from three sites on the Animas River, and three sites upstream on the San Juan, to supplement these data. In all, twenty-six samples were collected from the San Juan River, five samples were collected from the Animas and La Plata Rivers, five samples were collected from canyons tributary to the San Juan, twenty-two samples were collected from inflows of relatively clear water to the San Juan most likely associated with off-channel wetlands or irrigation return flow, four samples were collected from conspicuously large inflows to the San Juan River that were thought to most likely be wasteways or other large irrigation return flows, two samples were collected from pipes discharging to the river, and one sample of Farmington tap water was processed for quality control (a blank). Among the above samples, four were duplicates, and two of these were processed by the Colorado Department of Public Health and Environment laboratory in Durango.

Many samples from the San Juan River were collected with the intent of determining the effect on bacteria levels that a tributary or other inflow may have had on the San Juan River. Accordingly, an effort was made to sample the San Juan River at least one hundred meters downstream of the inflow, to permit mixing. Along with each sample a GPS position accurate to approximately five meters was recorded. Samples were kept on ice for less than six hours before they were processed using the IDEXX bacteria enumeration system. The system uses a most probable number method to estimate numbers of total coliform bacteria and *E. coli* per 100 mL of sample. The maximum estimate the system can provide (without dilution, when all but one well is positive) is 2419.6 colony forming units per 100 mL. When all wells are positive, the resulting estimate is greater than 2419.6 cfu/100mL, or too numerous to count.

The weather was clear and sunny during sampling, and weather stations at the Four Corners Regional Airport and at Archuleta recorded no precipitation during the five days previous to sampling[1]. Small precipitation events (0.26" or less falling in a 24 hour period) were recorded at either Archuleta or the airport on several days between April 25 and May 4. The most recent intense rain (0.25" or more falling within an hour) was recorded at Archuleta on April 24, when 0.36" fell within an hour. The U.S. Bureau of Reclamation was increasing releases from Navajo Dam around the time of sampling, and flow in the Animas was slowly increasing in response to snowmelt, such that the San Juan was relatively clear and swift upstream of the Animas, and somewhat more turbid (but still very clear relative to conditions often observed in the fall) and quite a bit swifter

[1] Precipitation data are from precip.fsl.noaa.gov/hourly_precip.html.

downstream of the Animas. The following table lists several recorded flows (in cubic feet per second), included here because they correspond to samples collected nearby.

Table 1: Selected flows, Animas and San Juan Rivers

Date and Time	Gage	Recorded Flow
5/10/05 10:30	San Juan River at Archuleta	3,070 cfs
5/10/05 12:15	Animas River at Farmington	2,480 cfs
5/10/05 12:15	San Juan River at Farmington (below Animas)	4,270 cfs
5/11/05 12:15	Animas River at Aztec	3,040 cfs
5/11/05 13:45	San Juan River at Archuleta	3,030 cfs
5/12/05 12:00	San Juan River at Farmington	5,420 cfs

Results

Table 2 lists the samples collected and the results. Figures 1 – 9 indicate locations for samples collected on or near the San Juan downstream of McGee Park, relative to other features. Sample site descriptions in Table 2 are based in part on field observations, map interpretation, and interpretation of orthophotography prepared by the U.S. Bureau of Reclamation from aerial photography collected on July 12 2001 (available for the San Juan River upstream of the Animas).

Table 2: Sample descriptions and results

Sample Number	Date/Time	Sample Site Description	Total Coliform (cfu/100mL)	*E. coli* (cfu/100mL)
1	5/10/05 10:30	SJR @ McGee Park boat ramp	1299.7	42.0
2	5/10/05 10:45	Gallegos Canyon (inflow from left bank)	> 2419.6	866.4
3	5/10/05 10:50	San Juan River	1299.7	50.4
4	5/10/05 10:57	Inflow from right bank at upstream end of riverside neighborhood	1553.1	71.2
5	5/10/05 11:07	SJR below Bollack Ranch return flow on left bank. Lots of cows in pastures on left bank.	1413.6	54.6
6	5/10/05 11:17	SJR at Bollack Bridge	1732.9	50.4
7	5/10/05 11:20	Inflow from right bank near off-channel lakes/wetlands on Bollack Ranch	> 2419.6	124.6
8	5/10/05 11:33	San Juan River	1732.9	48.8
9	5/10/05 11:45	Inflow from right bank	1986.3	88.2
10	5/10/05 11:50	Inflow from right bank	> 2419.6	307.6
11	5/10/05 11:55	Wetland inflow from right bank	> 2419.6	435.2
12	5/10/05 12:00	San Juan River	1732.9	59.5
13	5/10/05 12:12	Animas River just above confluence	> 2419.6	88.0
14	5/10/05 12:17	Farmington WWTP discharge	> 2419.6	1732.9
15	5/10/05 12:30	SJR @ Bisti Bridge	1203.3	83.6

Sample Number	Date/Time	Sample Site Description	Total Coliform (cfu/100mL)	*E. coli* (cfu/100mL)
16	5/10/05 12:33	Farmington Glade (inflow from right bank)	> 2419.6	328.2
17	5/10/05 12:53	San Juan River	1986.3	58.6
18	5/10/05 12:56	Inflow from right bank at Westland Park	> 2419.6	133.3
19	5/10/05 13:02	La Plata River above confluence	> 2419.6	248.9
20	5/10/05 13:15	Inflow from right bank	1732.9	160.7
21	5/10/05 13:19	Inflow from left bank	184.2	32.7
22	5/10/05 13:33	San Juan River	920.8	77.6
23	5/10/05 13:37	Inflow from right bank from wasteway on irrigation ditch	312.3	93.4
24	5/10/05 13:41	Discharge from pipe on right bank - may be from duck pond or other landscaping	> 2419.6	71.7
25	5/10/05 13:45	Locke Canyon (inflow from right bank)	1046.2	70.6
26	5/10/05 13:57	San Juan River	1299.7	52.8
27	5/10/05 14:03	Inflow from right bank just upstream of sample 28, looks like irrigation return flow	1986.3	35.5
28	5/10/05 14:04	Inflow from right bank just downstream of sample 27, looks like irrigation return flow	1553.1	70.8
29	5/10/05 14:08	Inflow from right bank	> 2419.6	325.5
30	5/10/05 14:15	SJR at Kirtland, Lions Park	1553.1	80.9
31	5/11/05 11:25	Animas River at Jim Young's property between Flora Vista and Aztec (below WWTP), position from topozone.com	> 2419.6	159.7
32	5/11/05 11:55	Animas River at Flora Vista at bridge, position from topozone.com	> 2419.6	141.4
33	5/11/05 12:20	Animas River at Aztec under bridge, position from topozone.com	1732.9	186.0
34	5/11/05 13:45	SJR at Blanco bridge, position from topozone.com	344.1	18.7
35a	5/11/05 14:15	SJR at Bloomfield bridge, position from topozone.com	372.5	25.9
35b	5/11/05 14:15	SJR at Bloomfield bridge, duplicate processed by CDPHE in Durango, position from topozone.com	ND	22.6
36a	5/11/05 14:35	SJR at Lee Acres bridge, position from topozone.com	549.3	38.3
36b	5/11/05 14:35	SJR at Lee Acres bridge, duplicate processed by CDPHE in Durango, position from topozone.com	ND	18.7
37	5/12/05 10:05	SJR at Kirtland, Lions Park	> 2419.6	79.4
38	5/12/05 10:25	San Juan River	> 2419.6	96.0
39	5/12/05 10:30	Inflow from left bank at upstream end of cattle pastures	> 2419.6	68.3
40	5/12/05 10:50	Inflow from left bank. May be backwater rather than inflow (sample spilled).	ND	ND
41	5/12/05 11:00	Inflow from right bank.	> 2419.6	770.1
42	5/12/05 11:20	SJR at Fruitland bridge	2419.6	72.3

Sample Number	Date/Time	Sample Site Description	Total Coliform (cfu/100mL)	*E. coli* (cfu/100mL)
43	5/12/05 11:22	Stevens Canyon (inflow from right bank), sample may be mixed with SJR water.	> 2419.6	866.4
44	5/12/05 11:40	Infow from left bank a short distance upstream of PNM diversion	> 2419.6	143.9
45	5/12/05 12:30	Waterfall probably from a ditch on right bank	> 2419.6	260.3
46	5/12/05 12:33	SJR downstream of PNM diversion	> 2419.6	96.0
47	5/12/05 12:45	Small inflow (trickle) from left bank	> 2419.6	4.1
48	5/12/05 12:52	Inflow from left bank	> 2419.6	209.8
49	5/12/05 13:00	Inflow from left bank near pastures not currently being grazed	2419.6	26.9
50	5/12/05 13:08	Wasteway on right bank, 5-10 cfs	> 2419.6	111.2
51	5/12/05 13:12	San Juan River (no sample collected)	ND	ND
52	5/12/05 13:16	Inflow from left bank	> 2419.6	1732.9
53	5/12/05 13:20	Inflow from left bank	> 2419.6	73.3
54	5/12/05 13:47	San Juan River	> 2419.6	93.3
55	5/12/05 13:50	Small inflow (trickle) from left bank	> 2419.6	2.0
56	5/12/05 14:00	Shumway Arroyo (inflow from right bank)	> 2419.6	1119.9
57	5/12/05 14:12	San Juan River	> 2419.6	95.9
58	5/12/05 14:30	Small off-channel wetland fed by waterfall on left bank	> 2419.6	2419.6
59	5/12/05 14:35	Waterfall on left bank	> 2419.6	> 2419.6
60	5/12/05 14:45	San Juan River	2419.6	93.3
61	5/12/05 15:00	San Juan River at takeout just downstream of Hogback diversion	1986.3	101.7
62	5/12/05 15:00	San Juan River at takeout just downstream of Hogback diversion (duplicate)	> 2419.6	90.6
63	5/12/05 15:00	San Juan River at takeout just downstream of Hogback diversion (second duplicate)	> 2419.6	93.2
64	5/12/05 16:35	Farmington tap water	< 1	< 1

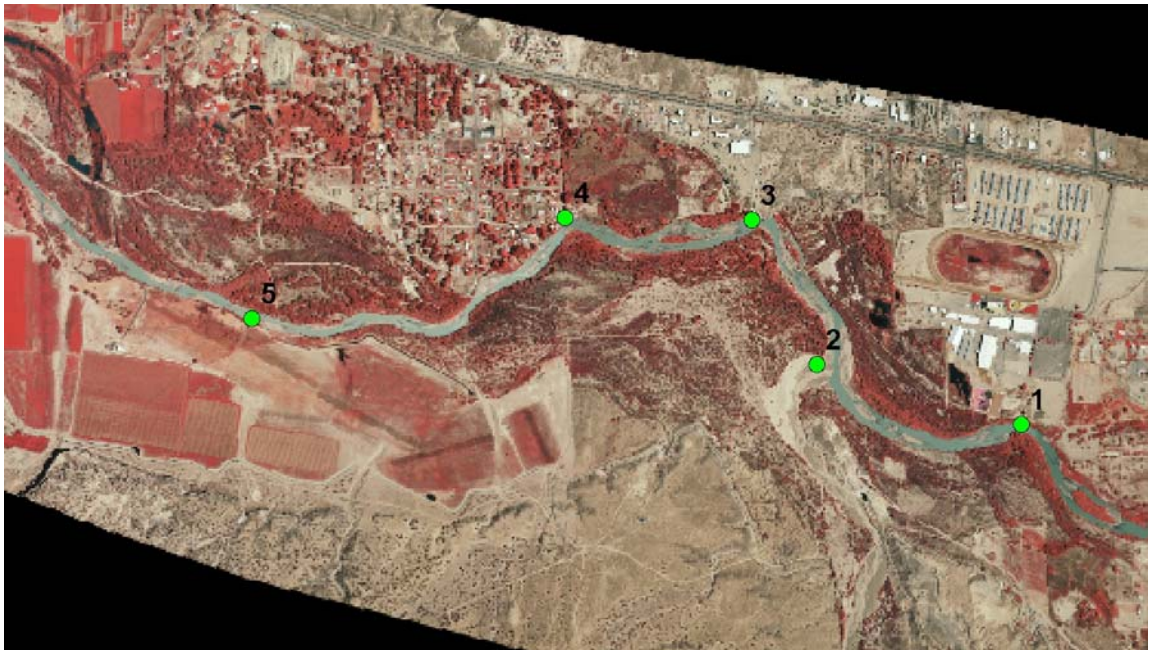

Figure 1: San Juan River, McGee Park to Bollack Ranch reach, *E. coli* sampling sites 05/09/2005. July 2001 orthophoto background.

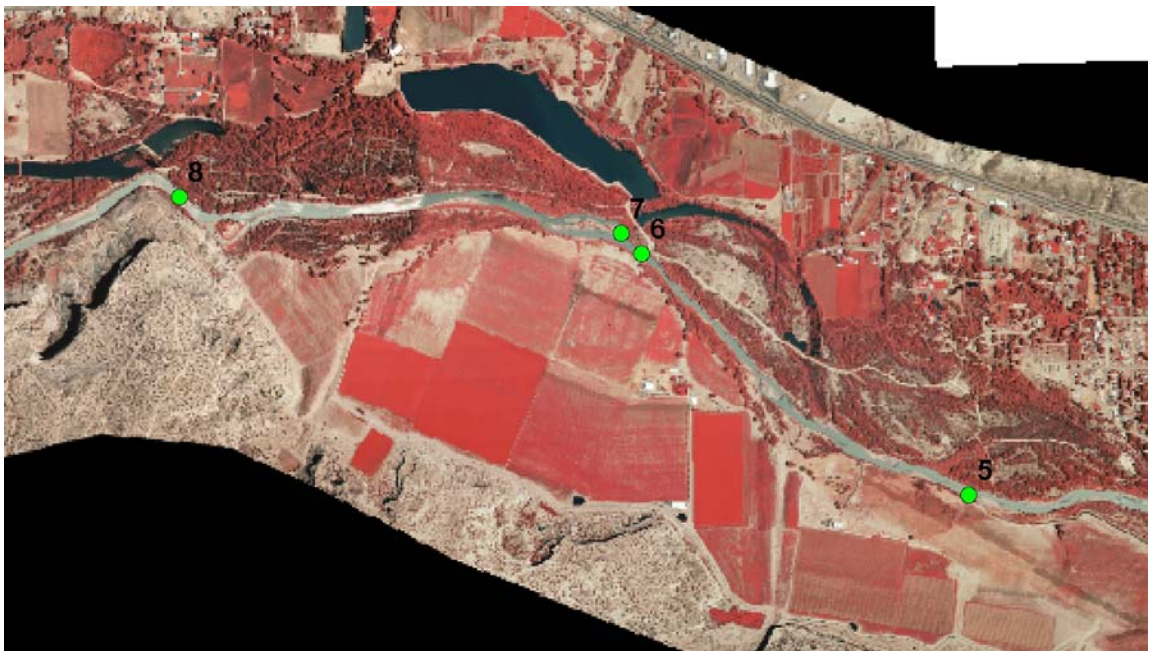

Figure 2: San Juan River, Bollack Ranch reach, *E. coli* sampling sites 05/09/2005. July 2001 orthophoto background.

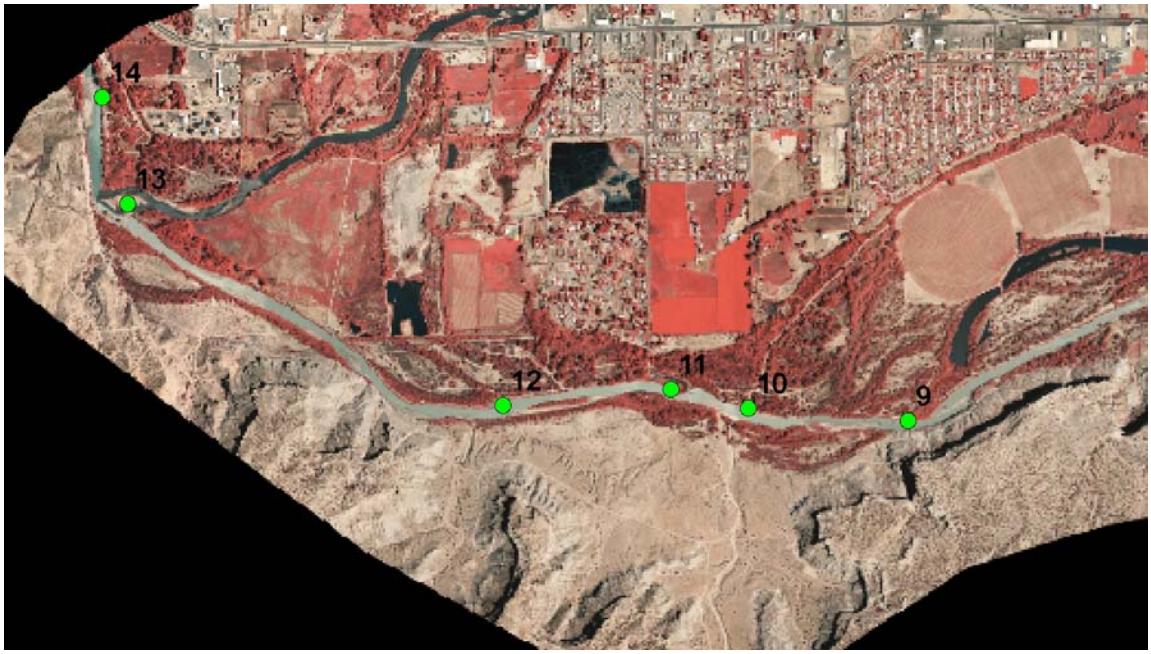

Figure 3: San Juan River, Bollack Ranch to Farmington WWTP reach, *E. coli* sampling sites 05/09/2005. July 2001 orthophoto background.

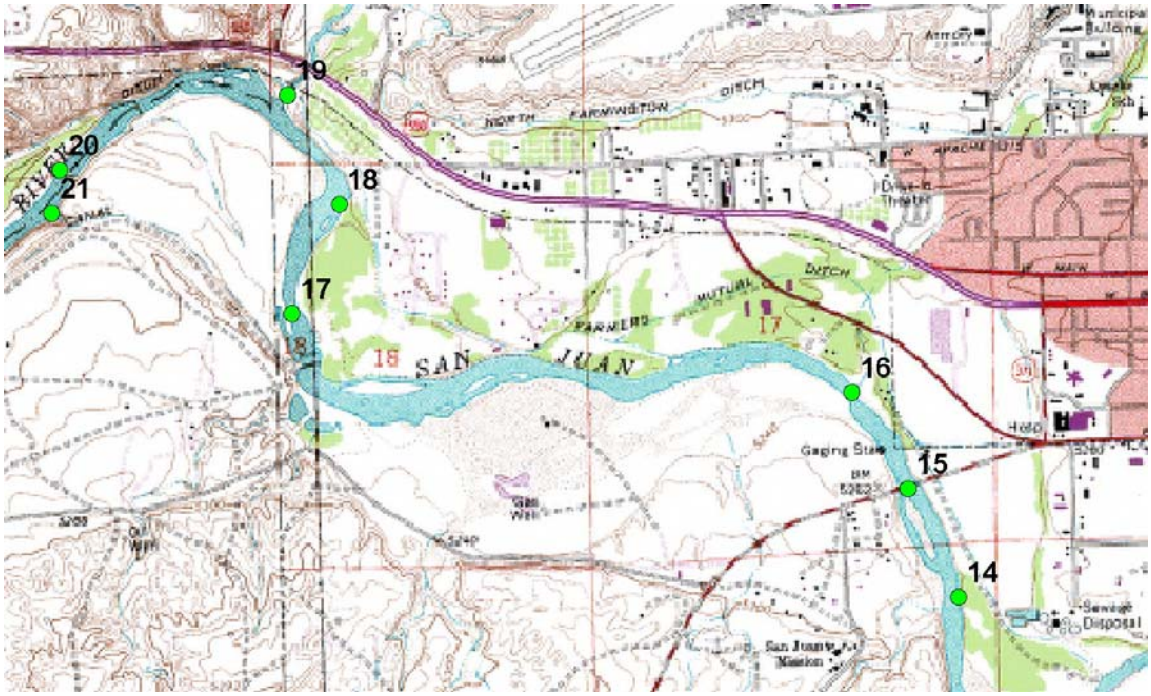

Figure 4: San Juan River, Farmington WWTP to La Plata reach, *E. coli* sampling sites 05/09/2005. USGS 7.5 minute series map background.

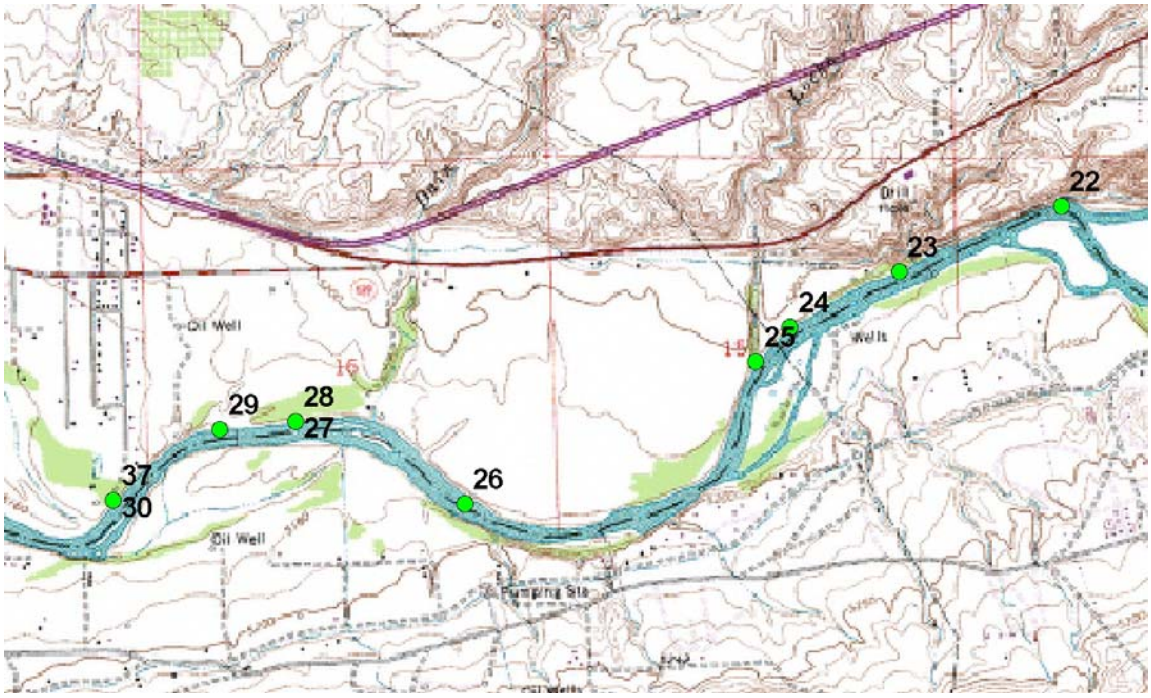

Figure 5: San Juan River, La Plata River to Kirtland reach, *E. coli* sampling sites 05/09/2005 and 05/11/05. USGS 7.5 minute series map background.

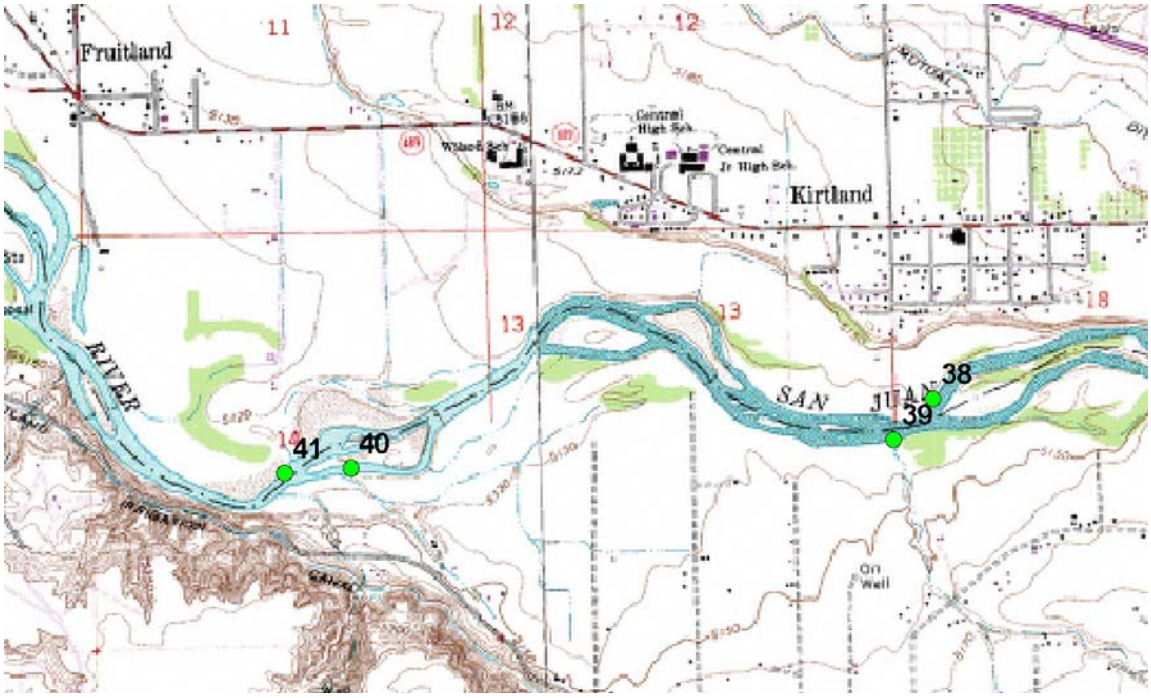

Figure 6: San Juan River, Kirtland and Fruitland reach, *E. coli* sampling sites 05/11/2005. USGS 7.5 minute series map background.

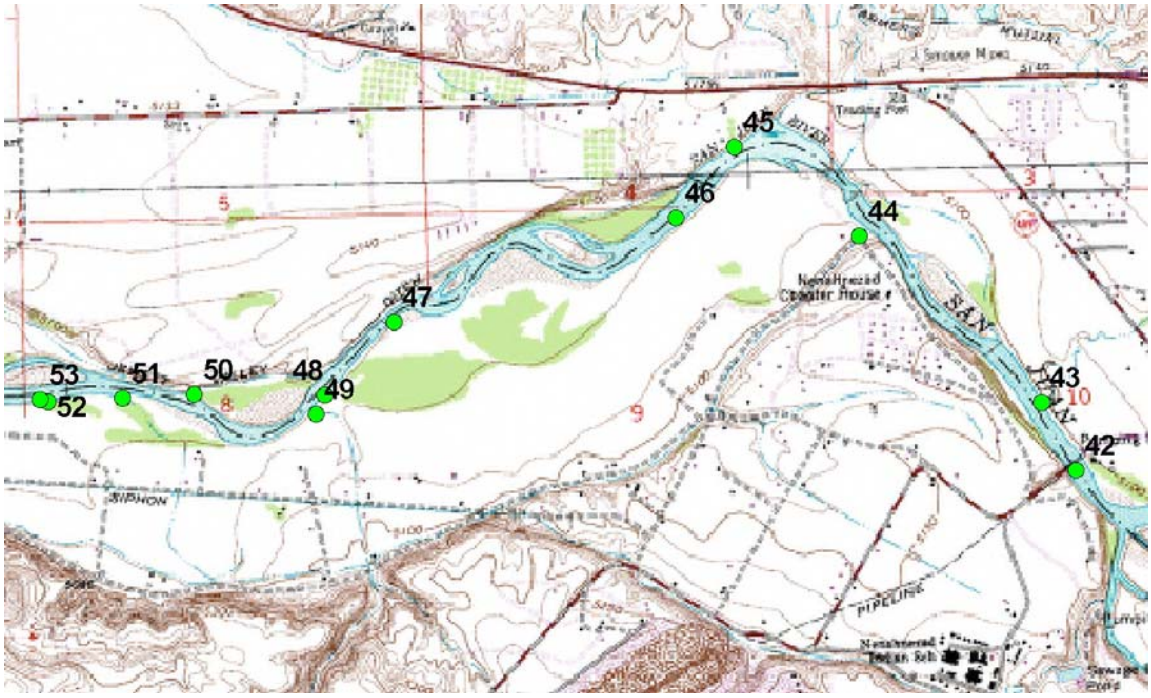

Figure 7: San Juan River, Fruitland to Arizona Public Service Company reach, *E. coli* sampling sites 05/11/2005. USGS 7.5 minute series map background.

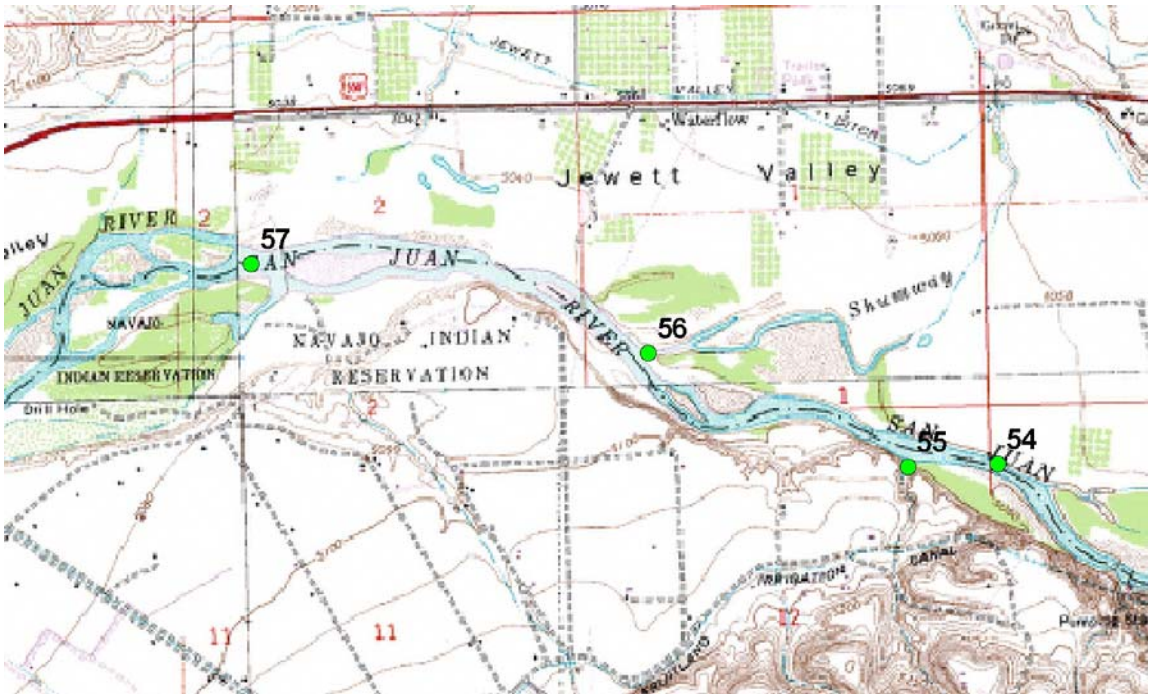

Figure 8: San Juan River, Arizona Public Service Company to Waterflow reach, *E. coli* sampling sites 05/11/2005. USGS 7.5 minute series map background.

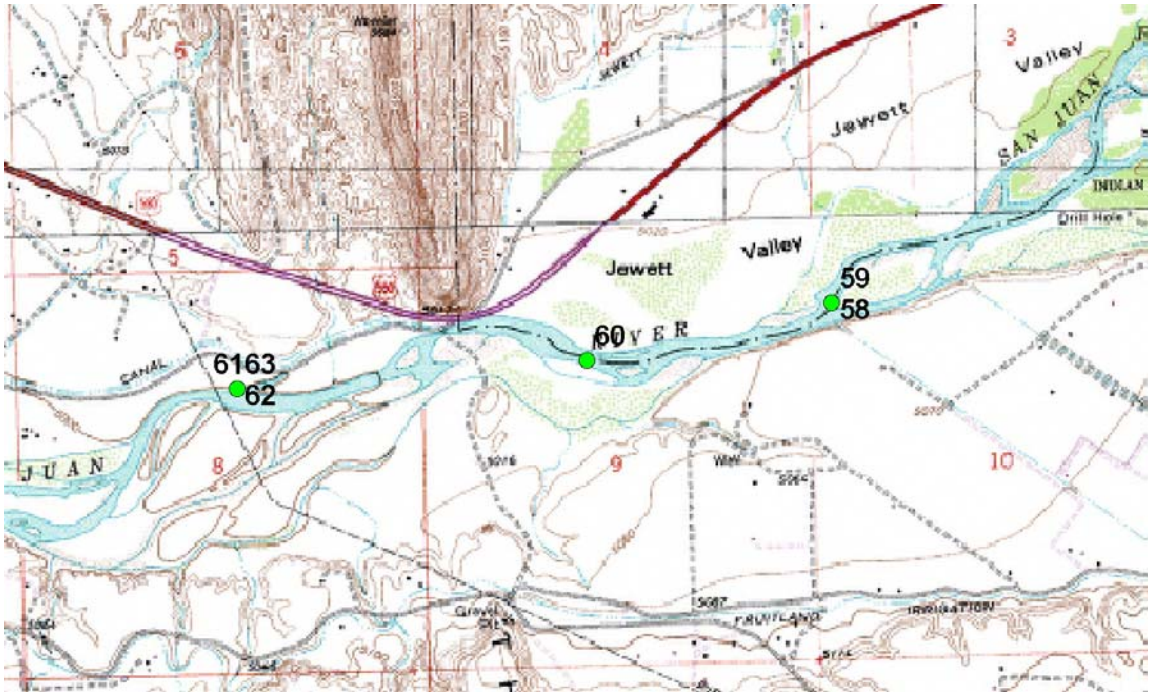

Figure 9: San Juan River, Waterflow to the Hogback reach, *E. coli* sampling sites 05/11/2005. USGS 7.5 minute series map background.

Discussion

From the results, the following general interpretations were made:

1. Total coliforms were often too numerous to count. *E. coli* was generally countable, and provides the most useful data for comparisons.

2. *E. coli* numbers in the San Juan, Animas, and La Plata rivers were all well below New Mexico's single sample water quality criterion of 410 cfu/100 mL. Only the results for the La Plata River (sample 19, La Plata River above confluence with San Juan, 248.9 cfu/100mL) and the three sites on the Animas River sampled on May 11 were above the monthly geometric mean criterion of 126 cfu/100mL for those streams.

3. *E. coli* numbers in the San Juan River gradually increased with distance downstream (Figure 10). This increase seemed most pronounced downstream of Bloomfield, and the increase between Blanco and Bloomfield was relatively minor. All but a few inflows to the San Juan River had higher *E. coli* numbers than the nearby San Juan River. Although no single inflow had a dramatic effect on the *E. coli* level in the San Juan River, it is probably true that collectively,

inflows to the San Juan were gradually elevating the *E. coli* levels in the San Juan River.

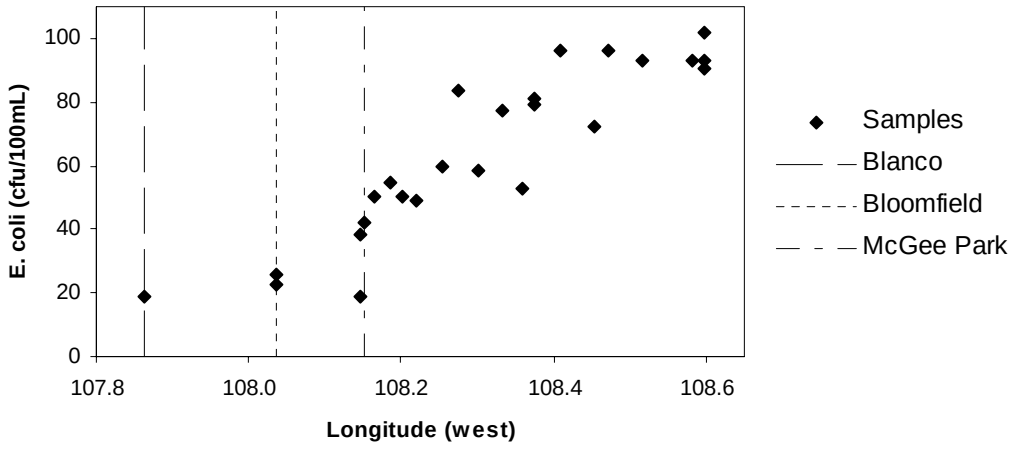

Figure 10: San Juan River *E. coli* results vs. longitude

4. Of the five tributary canyons sampled, four (Gallegos Canyon, Farmington Glade, Stevens Canyon, and Shumway Arroyo) had *E. coli* numbers above 300 cfu/100mL, and one (Locke Canyon) had a result less than the nearby San Juan River.

5. Another category of inflows includes those thought to be from wetlands, irrigation return flow, seepage from leach fields, or some combination of these. Data are available for twenty-one of these. The mean *E. coli* result for these was 344.6 cfu/100mL, although the results vary widely. Three samples had relatively high results (greater than 500 cfu/100 mL). One of these was an inflow from a small wetland fed by a waterfall on the left bank (sample 58, 2419.6 cfu/100mL, see item 6 below). Another was an inflow from the left bank possibly associated with irrigation return flow (sample 52, 1732.9 cfu/100mL), about ¾ mile upstream of the APS diversion. The third (sample 41, 770.1 cfu/100mL), based on map interpretation and the relatively large channel entering the San Juan, appeared to be from a tributary draining the downstream end of Kirtland and the partially developed mesa north of Kirtland (which, according to the map, includes a golf course, trailer parks, and "sewage disposal ponds"). A couple of very small inflows from the left bank (samples 47 and 55) are notable by their very low *E. coli* results.

6. A third category of inflows observed during sampling were larger inflows thought to be flowing directly from irrigation canals. Four of these were sampled. Two were clearly flowing from nearby canals (samples 23, from the Farmers Mutual Ditch, and sample 50, from the Jewett Valley Ditch), and had *E. coli* results somewhat greater than those of the nearby San Juan River. The other two were waterfalls flowing over sandstone bluffs, and were thought to be from irrigation

canals mainly by their size and that they were not flowing down developed channels. One from the right bank (sample 45, 260.3 cfu/100mL) may have been flowing from the Farmers Mutual Ditch, well downstream of its diversion point. Another from the left bank on the Navajo Nation, about one mile upstream of the Hogback (sample 59, >2419.6 cfu/100mL), may have been flowing from the Fruitland Irrigation Canal, and the map indicates a relatively long artificial (straight) channel flowing through a sparsely populated, perhaps agricultural, area (which was not visible from the river).

7. A final category of inflows includes those entering the river via pipes, which may tentatively be thought of as point sources. Two such sources were sampled (the only two observed). One, from the City of Farmington wastewater treatment plant, had an *E. coli* result of 1732.9 cfu/100mL (sample 14). This result, though surprisingly high (in light of other available data such as self-reporting data and the results of compliance inspections), may not be typical. Another, in the vicinity of some large residences, may simply have been conveying irrigation return flow a short distance from a nearby field or duck pond to the river (sample 24, 71.7 cfu/100mL).

Some additional observations may be relevant to interpreting these data. The clarity of the water, the lack of visible particles in the water column, the lack of precipitation in the days preceding sampling, and the similarity of results for samples 30 and 37 (collected from the same location on two different dates) indicate that recent runoff events were not influencing water quality of the San Juan River on the sampling dates. In contrast, samples collected on September 21, 2004 from the San Juan River had *E. coli* results about one third those observed on September 20, including two samples collected from the same location. Resuspension of bacteria in bottom sediments delivered to the river during past precipitation events, suspected as being an important mechanism for sustaining high bacteria levels in September, may have occurred in May, but this effect was not strong between Blanco and Bloomfield, as it was in September 2004, when Largo Canyon was believed to be a major source of bacteria. Largo Canyon was flowing during the September sampling, but not during the May sampling. The data described here seem to indicate many small bacteria sources that are more numerous in the more densely populated, heavily used parts of the San Juan River valley.

Results Relative to Total Maximum Daily Loads

As described in Item 2 (above), water quality criteria were not exceeded during this study. However, it may be instructive to compare the bacteria loading observed during this study, with loading observed in September 2004, relative to the TMDL's established by the New Mexico Environment Department[2]. TMDL's are target loadings (or goals) calculated for stream segments from their water quality criteria and critical low flows. Loading less than or equal to the TMDL ensures concentrations less than the monthly geometric mean criteria, at flows greater than or equal to critical low flows. Table 3

[2] TMDL's were approved by the New Mexico Water Quality Control Commission, but not the U.S. Environmental Protection Agency, as of July 20, 2005. The TMDL documentation is available on the Internet at www.nmenv.state.nm.us/swqb/Projects/SanJuan/TMDL1/Intro-TOC.pdf.

below summarizes the TMDL's for the lower Animas and San Juan Rivers.

Table 3: Summary of Total Maximum Daily Loads for *E. coli*

Stream Segment	Water Quality Criterion (cfu/100mL)	Critical Low Flow (cfs)	Total Maximum Daily Load (cfu/day)
Animas River downstream of Aztec[3]	126	89	2.74×10^{11}
San Juan River (SJR), Hogback to Animas River	126	280	8.64×10^{11}
SJR, Animas River to Largo Canyon	126	374	1.16×10^{12}

The following table lists several calculated loads based on data collected on September 2004 and May 2005.

Table 4: *E. coli* loads calculated from observed *E. coli* concentrations and estimated flows

Site	**Sample date**	**Sample result (E. coli, cfu/100mL)**	**Estimated flow (cfs)[4]**	**Daily load (cfu/day)**
SJR at McGee Park	9/21/04	387.3	302	2.86×10^{12}
SJR at McGee Park	5/10/05	42.0	1,790	1.84×10^{12}
SJR just upstream of Animas River	5/10/05	59.0	1,790	2.58×10^{12}
SJR at Bisti Bridge	5/10/05	83.6	4,270	8.73×10^{12}
Animas River at Aztec	5/11/05	186.0	3,040	1.38×10^{13}
Animas River at Farmington	5/10/05	88.0	2,480	5.33×10^{12}

These calculated loads (Table 4) are all greater than the TMDL's (Table 3). The data in

[3] The TMDL for *E. coli* for the Animas River was not calculated in the TMDL documentation cited above, because there were few enough exceedences of the proposed *E. coli* criterion that the Animas was not designated as impaired based on the data available at that time.

[4] Except as described here, the flows used in this table were recorded at nearby USGS gages. The flow at McGee Park on 9/21/04 was estimated from the daily mean flow at Archuleta (552 cfs), minus an estimated diversion capacity of 250 cfs. The flows of the San Juan at McGee Park and just above the Animas on 5/10/05 were estimated from the flow recorded at the San Juan River at Farmington (4,270 cfs), minus the Animas River at Farmington (2,480 cfs).

Table 4 also remind us that the increase in loading in the San Juan below the Animas is even greater than indicated by the gradual increase in *E. coli* numbers observed with distance downstream; the flow of the Animas River bearing its bacteria load increased the load in the San Juan downstream of the Animas substantially. We can also calculate that the sum of the loads of the Animas at Farmington, and the San Juan just upstream of the Animas, is near the load estimate on the San Juan just downstream of the Animas (at Bisti Bridge).

Future Work

This sampling effort has demonstrated that constant loading seems to contribute most bacteria during spring runoff or dam releases, in the absence of recent precipitation that may increase loading from surface runoff. That *E. coli* numbers were low under these conditions suggests that ingestion of pathogenic bacteria is low among the risks associated with springtime kayaking or rafting in New Mexico's portion of the San Juan Rivers. Though still low relative to the single sample criterion, *E. coli* numbers in the Animas River were higher and may pose more of a concern. Though the *E. coli* levels in the main rivers were low during this study, loading of *E. coli* was great enough that, if sustained during times of lower flow, water quality criteria would be exceeded. There remains a need to assess *E. coli* concentrations and loading during low flow periods, after the high flows of spring recede, yet before the somewhat predictable monsoon season begins, to assess the risk to swimmers during the season when swimming is most popular.

With perhaps one exception (the Farmington Wastewater Treatment Plant), this study has not precisely identified sources of *E. coli*, but has provided information necessary for the next step in identifying sources. The sites corresponding to samples with the greatest *E. coli* results may be the highest priority for developing and testing hypotheses regarding bacteria sources. Samples with results greater than 500 cfu/100mL were collected from Gallegos Canyon, the Farmington WWTP, Stevens Canyon, Shumway Arroyo, a waterfall flowing over a sandstone bluff on the Navajo Nation about one mile upstream of the Hogback, and one additional inflow each from the left and right banks (samples 41 and 52). These samples represent several different types of inflows, with possibly diverse sources of bacteria, and further study of these sites (especially, field inspection and data integration) would greatly inform the process of identifying bacteria sources basin-wide.

This study has shown that Largo Canyon, a source area that was important in September, was less important in May. There may be other seasonal variation in sources, as well as variability of sources that occurs for other reasons, that recent studies were unable to detect. For this reason, sampling a reach already studied in detail may provide useful information about the consistency of sources.