Arizona Department of Environmental Quality

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Gila River

Reach 15040005-022: Yuma Wash to Bonita Creek
Reach 15040002-004: Bitter Creek to New Mexico State Line

Total Maximum Daily Loads

For

Escherichia coli

Arizona Department of Environmental Quality

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LIST OF ABBREVIATIONS

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AgI	Agriculture-Irrigation watering
AgL	Agriculture-Livestock watering
A.R.S.	Arizona Revised Statutes
AUM	Animal Unit Month
AZPDES	Arizona Pollution Discharge Elimination System
A-S NF	Apache-Sitgreaves National Forest
A&Ww	Aquatic and Wildlife-warmwater
BLM	Bureau of Land Management
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
cfs	cubic feet per second
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
ft.	feet
FC	Fish consumption
FBC	Full Body Contact
FSN	Fixed Station Network
G-org	Giga –organisms (billion)
GIS	Geographic Information System
GNF	Gila National Forest
HW	Headwaters
kg/day	kilograms per day
LA	Load Allocation
mg/l	milligrams per liter
mgd	million gallons per day
mi.	miles
$mi.^2$	square miles
MOS	Margin of Safety
NB	Natural background
NEMO	Nonpoint Source Education for Municipal Officials
NEPA	National Environmental Policy Act
NM	New Mexico
NRCS	Natural Resources Conservation Service
PBC	Partial Body Contact
PMP	Probable Maximum Precipitation
POR	Period of Record
ppb	parts per billion
RNCA	Riparian National Conservation Area
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WIP	Watershed Improvement Planning
WLA	Waste Load Allocation
WWTP	Wastewater Treatment Plant

1.0 EXECUTIVE SUMMARY

Reach 15040005-022 (Gila River – Yuma Wash to Bonita Creek) and Reach 15040002-004 (Gila River – Bitter Creek to New Mexico State Line) are listed on Arizona's 303(d) list of impaired waters for exceedances of the state's *Escherichia coli* (*E. coli)* standard. Reach 15040005-022 was first listed for *Escherichia coli* in 2004, and it remains on the state's 303(d) list for the draft 2006/2008 assessment. Reach 15040002-004 was listed for *E. coli* in the draft 2006/2008 assessment. This TMDL was undertaken in late 2006 for both reaches to establish allocations for attainment of Arizona's water quality standard.

Sampling undertaken in 2007, together with previous Arizona Department of Environmental Quality (ADEQ) ambient monitoring data and historic Unites States Geologic Survey (USGS) flow history and *E. coli* data, comprised the data set from which allocations were drafted and reductions were calculated. TMDL sampling covered all parts of the annual hydrograph at a number of sampling locations intended to isolate perennial tributary contributions and contributions from reach subwatersheds and the State of New Mexico. Base flow data and storm flow data for both winter storms and summer monsoons were sampled to obtain a comprehensive picture of the critical conditions affecting *E. coli* loads in the watershed.

Allocations and load reductions were parsed into five categories of flow conditions representing the entire range of flows from flood conditions to historic low flows and summarized in tabular form. Because the geometric mean as used in Arizona's standard is not a conservative value in a mass-balance analysis (Parkhurst, 1998), data sets were also calculated as arithmetic means and reductions. The arithmetic means, amenable to allocation and proration, are the numbers on which subwatershed reductions are presented. A separate analysis on single sample maximums for both reaches was performed evaluating the 90th percentile value of existing loads against load duration estimates using the state's single sample maximum standard by category and site flow histories. Considered together, the two analyses lay out needed reductions for both long-term (mean) and daily (single sample maximum) evaluations of progress towards attaining Arizona's *E. coli* water quality standard.

Analysis determines that mean reductions are needed in the top flow category consisting of high flows for both reaches, with the moist conditions category provisionally flagged for reductions in Reach 004. Single sample maximum reductions are needed in two of the five top flow categories for Reach 15040005-022 and two of the five flow categories for Reach 15040002-004, with another two categories flagged due to insufficient samples. However, for mean reductions, the contributing subwatershed analysis for perennial tributaries consistently found that excessive loading was only occurring in high flow events. An earlier analysis, not detailed in this TMDL analysis, found that almost all exceedance events for the two listed reaches were related to demonstrable flow elevations and hydrograph spikes due to precipitation events. The Gila River - Bitter Creek to New Mexico (NM) subwatershed is disproportionately contributing to *E. coli* loading problems across the span of the flow regime, and the Gila River from Yuma Wash to Bitter Creek, is also contributing to the *E. coli* loading problem based on prorations of existing loads for the cumulative watershed above the USGS Gila near Solomon gauge site. The State of New Mexico, given a load allocation at the state line, is contributing excessive *E. coli* loading in high flow events.

2.0 PHYSICAL SETTING

2.1 Physiographic Setting

The Upper Gila River watershed as defined by ADEQ begins at Coolidge Dam at the San Carlos Reservoir near Globe and includes all Arizona lands draining to this point exclusive of the San Pedro River watershed. The Gila River has its headwaters in the Gila Mountains of New Mexico and also drains a large area of west-central New Mexico. The watershed drains 12,900 square miles total, 7,354 square miles of which are in Arizona. The Central Highlands and Basin and Range physiographic provinces are both represented within watershed boundaries. Elevations range from 2,523 feet at Coolidge Dam to 10,720 feet at Mount Graham in the Pinaleno Mountains above Safford.

The reaches addressed by this TMDL are located in the Gila River Valley near Solomon, Arizona, the Gila Box Riparian National Conservation Area (RNCA) in the vicinity of Bonita Creek, and the Three Way area south of Clifton, Arizona. All may be characterized as being in the Basin and Range province. The Gila Box RNCA, administered by the Bureau of Land Management (BLM), is a popular recreational area for nearby residents with watercraft options, lush riparian corridors, and opportunities for wildlife observation.

The watershed is sparsely populated. Safford is the largest town in the area, with a population of 9,232 (2000). Clifton, county seat of Greenlee County, and Morenci, home of the Freeport-McMoRan (formerly Phelps-Dodge) Morenci copper mine are towns proximate to the study area. Agriculture is practiced in the Gila River Valley near Safford as well as in the Duncan Valley area near the New Mexico state line. Cotton is the principle crop grown in the area.

2.2 Climatic Setting

Hot summers and mild winters characterize the general climate of the Gila River watershed. Higher elevations of the watershed experience harsher winter conditions with winter-long snow cover in normal years. Increased precipitation falls in July through September as a result of high intensity, short duration storms associated with the summer monsoon season. A second rainy season occurs at lower elevations during the winter months (December through March). The winter events are less intense, but longer in duration and larger in extent.

2.3 Hydrology

The Gila River runs intermittently at the New Mexico state line, but portions become perennial between Duncan and Safford. The perennial segments occur where the Gila River takes a northward curve through the more varied topography and geology of the Gila Box area where subsurface water is forced to the surface. After exiting the Gila Box RNCA, the Gila River returns to intermittent status near the town of Solomon. The reaches addressed by this TMDL analysis are perennial reaches, though Reach 15040002-004 is impacted by agricultural diversions.

The Gila River is fed by three major perennial tributaries in the Gila Box area: the San Francisco River near the towns of Clifton and Morenci, Eagle Creek, and Bonita Creek (Figure 1). Approximate watershed areas for these three tributaries are 2,800, 665, and 315 square miles respectively. In the Arizona portion of the upper Gila watershed, perennial streams and stream segments account for approximately 445 river miles exclusive of tribal lands. Intermittent streams and stream segments comprise approximately 970 river miles. Ephemeral tributaries account for an estimated stream mileage of 6305 miles (ADEQ, 2008a).

Two hot springs are located within the study area. Eagle Creek Hot Springs is located downstream of Freeport-McMoRan's water pumping plant on Eagle Creek near an established ADEQ ambient monitoring site. The well-known Gillard Hot Springs on the Gila River upstream of the San Francisco River confluence has the hottest water temperature in the state at approximately 180 degrees Fahrenheit.

The Gila River has an annual mean stream flow at Solomon, based on 84 years of records, of 463 cubic feet per second (cfs) (USGS Water Data for Arizona, 2007). The USGS site on Bonita Creek near Morenci has a mean annual discharge of 12.2 cfs based on 26 years of records. The San Francisco River near Clifton has an annual mean flow of 221 cfs dating from 1911. Eagle Creek has an annual mean flow of 66 cfs at the pumping station near Morenci, based on data since 1943.

2.4 Land Use and Ownership

Land ownership in Arizona's portion of the Upper Gila Basin is split among federal, state, private and Indian reservation lands. BLM administers approximately 23% of land in the basin. The U.S. Forest Service (USFS) also administers 23% as the Apache Sitgreaves National Forest (A-S NF). Native American reservation lands accounts for 29% of land. Arizona State Trust lands comprise 14%, while private ownership accounts for 10%. Military, National Park, and other land ownership classes each account for less than 1% within the watershed boundaries (Figure 2).

2.5 Vegetation

Vegetation types within the watershed vary with elevation. The higher elevations are characterized by Ponderosa Pine, spruce, and montane species. The Central Highlands, located in the center of the watershed, are primarily mixed live oak, mixed Chaparral, and scrub brush. The interior portion of the watershed transitions into the Basin and Range province. Agricultural areas are located along the Gila River in areas suitable for this activity, primarily around Safford, Thatcher and near Duncan.

The vegetation communities within the study area reflect the Sonoran/Chihuahuan deserts plant community associations. Riparian corridors near the perennial waters consist of cottonwoods, Arizona sycamores, and other riparian vegetative communities.

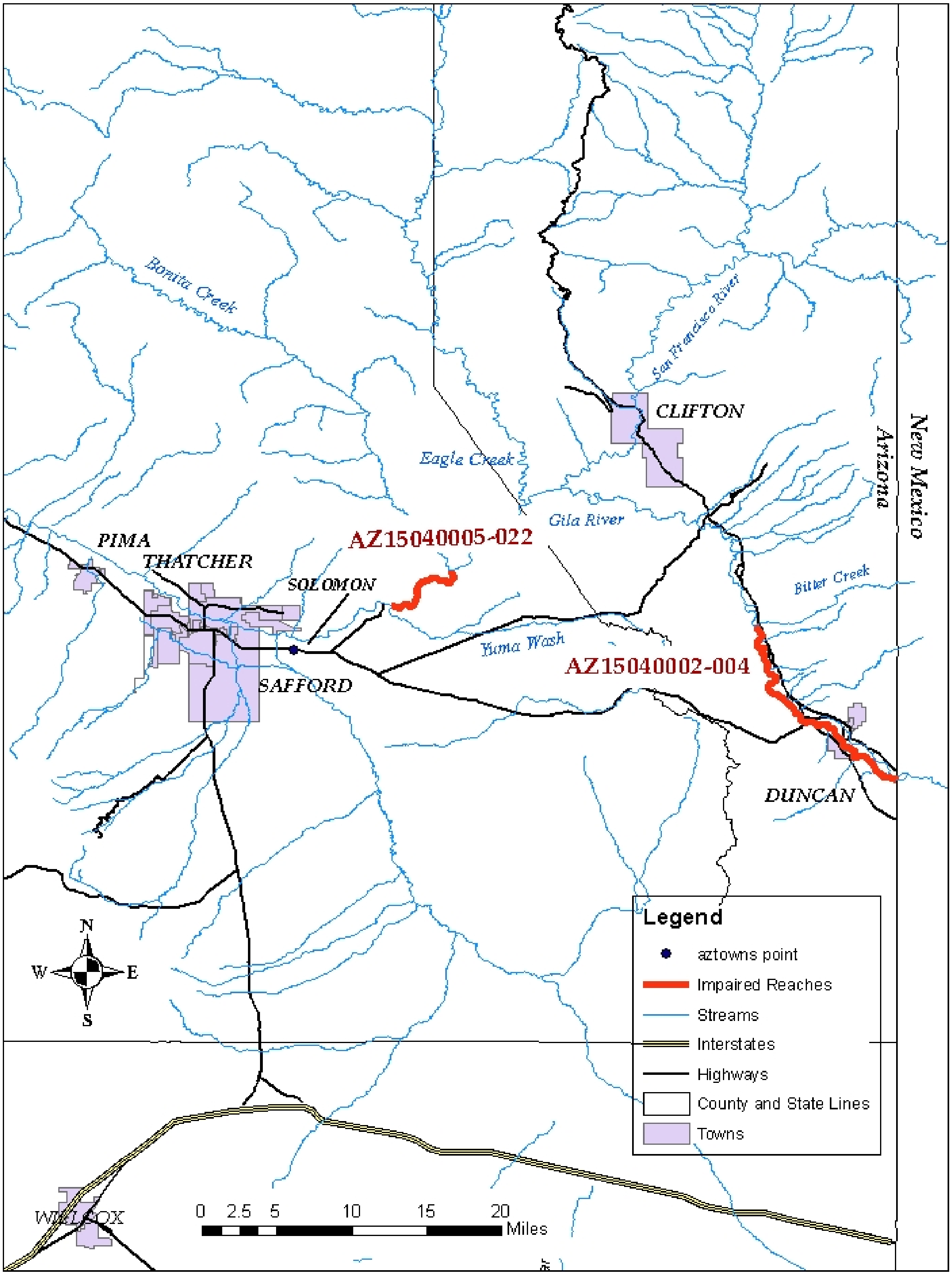

Figure 1. TMDL Project Area

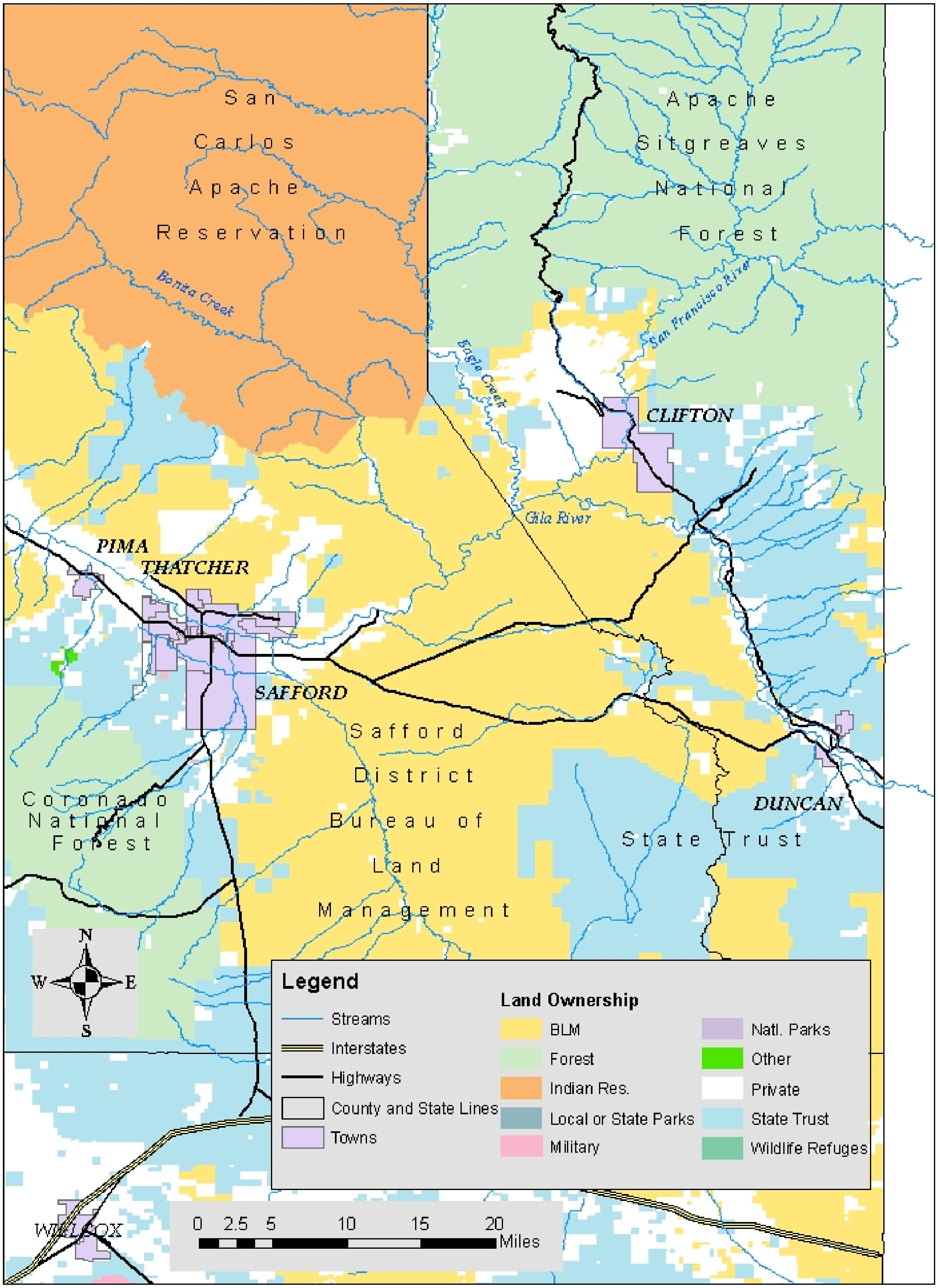

Figure 2. Land Ownership, Gila River Region, Eastern Arizona

3.0 NUMERIC TARGETS

The numeric target values of the TMDLs determined and presented in this document are based upon and calculated from Arizona's geomean (126 cfu/100 ml) and single sample maximum (235 cfu/100 ml) concentrations of *E. coli* for the Full Body Contact (FBC) designated use expressed in Arizona's water quality standards. Concentrations of *E. coli* are expressed in terms of colony-forming units per 100 ml (cfu/100 ml). Loads used in the load duration curve analyses are the product of concentrations and flows with an appropriate conversion factor applied. Loads are expressed in terms of giga (billion)-organisms per day (G-org/day). The conversion factor used to convert from cfu/100 ml to G-org/day is 0.02446.

All load target determinations and existing load calculations in the TMDL document are originally derived from either *E. coli* geomean or *E. coli* single sample concentration values, as expressed in the Arizona water quality standards and in data reporting. Consequently, attainment of the total maximum daily loads presented will result in waters that meet water quality standards for concentrations. Conversely, waters meeting the state's water quality standard-based concentration values will be meeting the required total maximum daily loads set forth in this document, except in cases where a prorated load value must be employed at an upstream reach to ensure attainment of the required load at a downstream reach. Additional discussion of this point is presented in Section 7.3. Suggested monitoring and effectiveness evaluation strategies pertaining to evaluations of loads and concentrations for the implementation of these TMDLs is addressed in Section 8.0.

3.1 Applicable Water Quality Standards

Arizona's *E. coli* standard is used as an indicator of bacterial contamination and is designed to protect human health in the case of recreational use of waters with some possibility of small ingestion rates.

Arizona's 2009 water quality standard for *Escherichia coli* reads:

> *The following water quality standards for Escherichia coli (E. coli) are expressed in colony forming units per 100 milliliters (cfu/100 ml) or as a Most Probable Number (MPN):*

E. coli	***FBC***	***PBC***
Geometric mean (minimum of 4 samples in 30 days)	*126*	*126*
Single Sample Maximum	*235*	*575*

Arizona's 2003 water quality standard for *Escherichia coli*, the standard under which this TMDL was drafted, reads:

> *The following water quality standards for Escherichia coli (E. coli), expressed in colony forming units per 100 milliliters (cfu/100 ml) of water, shall not be exceeded:*

E. coli	***FBC***	***PBC***
Geometric mean (four-sample minimum)	*126*	*126*
Single Sample Maximum	*235*	*576*

Calculations, reduction determinations, and assessments of attainment status done in these TMDLs were executed according to the wording of the water quality standard before its modification in 2009, which made no mention of a 30 day averaging period. There are no instances in the sampling record where four samples were collected in a 30 day time frame and only six instances where even two samples were collected in a 30 day time frame. For the Bitter Creek to NM reach (Reach 004), again there were no instances of four samples collected within 30 days, and only three instances of two samples being collected with a 30 day window. Consequently, all historical data for both reaches were aggregated within each category considered and evaluated together with no averaging periods utilized in the analysis. An alternative analysis of geometric means demonstrating that the approach of this TMDL is actually the most protective and most suitable for application is outlined in Section 5.1.

While the geometric mean is clearly listed as an integral part of the water quality standard, in practice, Arizona has lacked the data to determine the geometric mean and evaluated reaches for impairments based upon consideration of single sample maximums alone. Arizona's *E. coli* water quality standard was derived from numbers originating in a series of freshwater beach studies undertaken in the late 1970s correlating *E. coli* bacterial densities with rates of gastroenteritis (EPA, 1986). The Arizona single sample maximum, drafted directly from the freshwater beach studies, originated as a defined point representing a particular confidence level in a cumulative frequency distribution with a geometric mean of 126 cfu/100ml. In practice, however, each incidence of single sample maximum exceedance has been treated as an episode of a violation of an acute criterion. No exemptions are currently permitted in the standard for storm flow exceedances.

3.2 Beneficial Use Designations

ADEQ codifies water quality regulations in Arizona Administrative Code (A.A.C.) Title 18, Chapter 11 (ADEQ, 2009). Designated beneficial uses, such as fish consumption, recreational contact, agriculture, and aquatic biota, are described in AAC R18-11-104 and are listed for specific surface waters in Appendix B of A.A.C. R18-11. For all reaches, including the two which are subjects of this TMDL, the Gila River is currently protected for the following designated uses: Aquatic and Wildlife-warm water fishery (A&Ww); Fish Consumption (FC); Full Body Contact (FBC); Agriculture Irrigation (AgI); and Agriculture Livestock (AgL). *E. coli* standards are addressed under the Full Body Contact use.

3.3 Clean Water Act Section 303(d) List

The Gila River, from Yuma Wash to Bonita Creek (AZ15040005-022) was listed as impaired for *E. coli* on the State of Arizona's 2004 303(d) list according to the provisions of the Clean Water Act Section 303(d) (ADEQ, 2004). The draft 2006/2008 Arizona Water Quality Assessment listed the Gila River from Bitter Creek to the NM state line (AZ15040002-004) as impaired for *E. coli* exceedances. Total Maximum Daily Load (TMDL) allocations must be developed for those waters listed on the 303(d) list. TMDLs determine the amount of given pollutant(s) that the water body can withstand without creating an impairment of that surface water's designated use(s).

Reach 15040005-022 (Gila River – Yuma Wash to Bonita Creek) was originally listed based on three noted exceedances (n = 23) of the state's single sample maximum water quality standard (235 cfu/100 ml) in 1998 and 2000. The 2006/2008 assessment dropped one of the earlier exceedances, but the reach logged an additional exceedance for *E. coli* in August 2004.

Reach 15040002-004 (Gila River – Bitter Creek to NM State Line) was listed in the 2006/2008 assessment for violations of the *E. coli* single sample maximum on two occasions in July and October of 2004. Four additional single sample maximum exceedances have been recorded since the 2006/2008 assessment; all were associated with storm or high flow events. Three of the four exceedances were recorded in the sampling for this TMDL analysis.

4.0 SOURCE ASSESSMENT

The Gila River and its tributaries flow through largely uninhabited areas of western New Mexico and eastern Arizona above the impaired reaches which are the subjects of this TMDL. The watershed is large, comprising 7,874 square miles above the USGS Solomon gauge. Major perennial tributaries of the Gila River in Arizona include the San Francisco River, Eagle Creek, and Bonita Creek. Coniferous forested lands, range or shrub land, and grasslands total 97% of the watershed area. Table 1 breaks down the various land use classifications according the 1992 National Land Cover Data set.

Land Use	Total Area, sq meters	Total area, sq mi	Percentage
Scrubland	9,033,092,100	3487.696	44.29%
Evergreen Forest	8,534,533,500	3295.202	41.85%
Grasslands/herbaceous	2,451,675,600	946.597	12.02%
Mixed Forest	174,973,500	67.558	0.86%
Quarries/strip mines/gravel pits	52,778,700	20.378	0.26%
Pasture/Hay	41,634,900	16.075	0.20%
Bare Rock/sand/clay	38,474,100	14.855	0.19%
Open Water	17,133,300	6.615	0.08%
Row Crops	15,523,200	5.994	0.08%
Deciduous Forest	12,757,500	4.926	0.06%
Small grains	8,098,200	3.127	0.04%
Low Intensity residential	4,181,400	1.614	0.02%
Commercial/Industrial/transport.	3,379,500	1.305	0.02%
Woody wetlands	2,671,200	1.031	0.01%
Orchards/vineyards	1,745,100	0.674	0.01%
Emergent herbaceous wetlands	942,300	0.364	<0.01%
Urban/recreational grasses	690,300	0.267	<0.01%
Total:		7874.277	100.00%

Table 1. Land Use Classification, Gila River watershed above Reach 15040005-022

4.1 Summary of Point Sources

4.1.1 AZPDES and NPDES Permits

The AZPDES permit for the Alpine Sanitary District Wastewater Treatment Ponds near Alpine, Arizona (AZ0025089) in Apache County sets a monthly concentration limit for effluent of 126 cfu/100ml and a daily maximum of 235 cfu/100 ml for *E. coli*. No mass limits are given in the terms of the permit. The monthly concentration limit is expressed as a geometric mean with a four sample minimum. Monitoring is required on a per discharge basis, and sampling is by discrete grab samples. This waste load allocation will not be factored into TMDL calculations because of the existence of a dam at Luna Lake immediately downstream, which effectively disrupts hydrologic continuity and prevents *E. coli* loads from being assimilated with loads from the rest of the San Francisco River and the Gila River watershed.

Two former AZPDES permitted outfalls (both in Permit #AZ0022705) are associated with the Freeport-McMoRan Morenci Mine operation, draining from Chase Creek (Outfall 001) and Gold Gulch (Outfall 002) to the Gila River tributaries of the San Francisco River and Eagle Creek respectively. *E. coli* is not a constituent of concern assessed to have reasonable potential to negatively affect the water quality of Arizona's rivers as a result of mine operations; thus, it was not addressed in the permit. Freeport McMoRan notified ADEQ in December, 2009 of its intention to discontinue AZPDES permit coverage under the Clean Water Act after the draft release of this TMDL, and to rely on Arizona's multi-sector general permit (MSGP) and a Storm Water Pollution Prevention Plan (SWPPP) to monitor and mitigate storm water flows from Freeport property. FMI's AZPDES permit expired on May 18, 2010. Freeport McMoran's stormwater monitoring plan, outfalls, monitoring locations, and area maps have been studied, and data associated with previous documented storm events has been reviewed. *E.coli* found in stormwater samples discharging from Freeport's identified stormwater basins is considered attributable to general watershed processes and will be subsumed under the load allocation for the San Francisco River and Eagle Creek subwatersheds. Section 7.2 discusses the wasteload allocation for Freeport-McMoRan-Morenci in detail.

There are no other AZPDES permits addressing discharges where *E. coli* is a constituent of concern in Graham or Greenlee counties above the Yuma Wash-Gila River confluence apart from the ones discussed in this section, no municipal separate storm sewer systems, and no Superfund sites within the delineated watershed in Arizona.

New Mexico has one permit issued to the Village of Reserve that incorporates terms for *E. coli* limits. Permit NM0024163 sets a 30 day average of 126 cfu/100 ml with a single sample maximum of 410 cfu/100 ml. As it is beyond the scope of Arizona's jurisdiction, the New Mexico point source contributions will be subsumed into a general load allocation to the state of New Mexico.

4.1.2 Multi-sector General Permit, Future Permittees

The purpose of Arizona's multi-sector general permit (MSGP) is to protect the quality and beneficial uses of Arizona's surface water resources from pollution in stormwater runoff resulting from industrial activities for both mining and non-mining operations. Under the Clean Water Act and Arizona Revised Statutes, it is illegal to have a point source discharge of pollutants that is not authorized by a permit, including stormwater runoff from industrial sites to a water of the United States. To protect water quality, the MSGP requires operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff. There will be no standing itemized *E. coli* waste load allocation expressed in terms of organisms per day set aside for MSGP activities in the Gila River watershed that is the subject of this TMDL, as future applicants and permittees cannot be forecast. Where *E. coli* is assessed to be a constituent of concern for discharges resulting from storm events from MSGP applicant locations, the FBC *E. coli* single sample maximum standard of 235 cfu/100 ml is applied as a concentration-based wasteload allocation for each of the individual stormwater outfalls identified in the permittee's approved SWPPP. For each permittee covered under the MSGP, if at a future point anthropogenic sources of *E. coli* are discovered negatively impacting water quality discharged from permitted outfalls, the permittee will be expected to modify BMPs as required by the terms of the general permit to achieve compliance with the *E. coli* water quality standard. Permittees' adherence to these criteria will be considered consistent with the provisions governing the remainder of this TMDL. ADEQ does not expect that stormwater run-off from MSGP sites will persist long enough to determine attainment of the geometric mean portion of the *E. coli* standard.

4.1.3 Concentrated Animal Feeding Operations

Concentrated Animal Feeding Operations (CAFOs) are animal feeding operations or agricultural facilities where animals (other than aquatic animals) are confined and fed for 45 days or more a year. Manure from an animal feeding operation, if not managed properly, can discharge *E. coli* and nitrogen pollutants, which can migrate and pollute surface and ground waters. ADEQ issues two types of water quality permits for CAFOs, the Arizona Pollutant Discharge Elimination System (AZPDES) permit for potential discharges to surface waters, and the Aquifer Protection Program (APP) permit for potential discharges to groundwater. ADEQ's CAFO Inspection program inspects animal facilities for the use of BMPs and unauthorized discharges of manure-contaminated wastewater. (ADEQ, 2008b).

One CAFO exists within the study area. Lunt Dairy, operating near Duncan, Arizona in the Duncan Valley agricultural area, operates under the state of Arizona’s APP Nitrogen Management General Permit. Facilities are allowed to operate under the Nitrogen Management General Permit (A.A.C.R18-9-403) if there is considered little or no potential for run-off, and the facility complies with BMPs outlined in the rule. Currently there are two inspection reports on file from 2001 and 2004. These inspections report a total of 485 animals are on-site. No discharges or overflows have been reported, although inspectors did note concern about a possible lack of capacity of the dairy impoundment to contain a 25 year/24 hour storm event. Were discharges to occur or notice received of the intent to discharge, the APP general permit coverage would be rescinded, and the dairy would be regulated under the AZPDES program instead (Miera, 2008).

4.1.4 Wastewater Treatment Plants

Wastewater treatment plants (WWTPs) adjacent to river courses and permitted to discharge into river systems are obviously possible contributors to *E. coli* loading of a hydrologic system. Arizona facilities discharging to surface waters are regulated by permit and in all cases must comply with the single sample maximum density for *E. coli* of 235 cfu/100 ml.

Facilities in Arizona’s Gila River drainage include the Alpine, Duncan, and Clifton WWTPs. The Alpine facility on the upper San Francisco River is permitted by AZPDES and has a concentration limit equal to the state single sample maximum standard of 235 cfu/100 ml. However, this facility is above a dam at Luna Lake and thus there is no hydrologic continuity with the rest of the Gila River hydrologic system. Consequently, no waste load allocation is necessary for this facility.

Duncan and Clifton are not required to hold an AZPDES permit, as they do not discharge nor intend to discharge to waters of the United States. Both facilities are monitored and regulated under Arizona’s Aquifer Protection Permit (APP) program, which regulates the water quality of discharges to groundwater. The Clifton facility is sited approximately 50 meters from the San Francisco River below Clifton. Clifton’s discharges are pumped to the Morenci mine and re-used in mine operations away from the surface water hydrologic network. The Duncan ponds are located approximately 250 meters from the Gila River below Duncan. Duncan’s discharges are used for agricultural irrigation in fields adjacent to the ponds. Monitoring records for both show no violations of the terms of their respective permits. Both facilities are required to have emergency response plans in place and on-site with personnel aware of and trained in following the emergency response plan. As a condition of both APP permits, permittees are required to act immediately to correct any condition that could pose an endangerment to public health or the environment. Permit conditions for WWTPs administered by the APP program have been considered and are not directly pertinent to any provisions or allocations of this TMDL.

New Mexico has one WWTP in its drainage of the San Francisco River. The Village of Reserve (Permit # NM0024163) requires a 30 day average of 126 cfu/100 ml and a single sample maximum of 410 cfu/100ml. Allocations for this WWTP are incorporated into analysis for load reductions for the San Francisco River. Further refinement of the San Francisco River *E. coli* allocation between the Arizona and New Mexico portions of the watershed will be addressed in a future San Francisco River TMDL for *E. coli*. Additional discussion of this matter is presented in Section 7.2.

4.1.5 Construction General Permits

The purpose of the construction general permit (CGP) is to protect the quality and beneficial uses of Arizona's surface water resources from pollution in stormwater runoff resulting from construction activities. Under the Clean Water Act and Arizona Revised Statutes, it is illegal to have a point source discharge of pollutants, including stormwater runoff from construction sites, to a water of the United States that is not authorized by a permit. To protect water quality, the CGP requires operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff during the construction period. There will be no standing itemized *E. coli* waste load allocation expressed in terms of organisms per day set aside for CGP activities in the Gila River watershed that is the subject of this TMDL, as projects are expected to be small in areal extent, short in duration, and not expected to contribute *E. coli* loads to the hydrologic system in quantities large enough to be appreciable and discernable relative to the size of the Gila River watershed and loads already accounted for. Where *E. coli* is assessed to be a constituent of concern for discharges resulting from storm events from CGP applicant locations, the FBC *E. coli* single sample maximum standard of 235 cfu/100 ml is applied as a concentration-based wasteload allocation for each of the individual stormwater outfalls identified in the permittee’s approved SWPPP. For each permittee covered under the CGP, if at a future point anthropogenic sources of *E. coli* are discovered negatively impacting water quality discharged from permitted outfalls, the permittee will be expected to modify BMPs as required under the terms of the general permit to achieve compliance with the water quality standard. Permittees’ adherence to these criteria will be considered consistent with the provisions governing the remainder of this TMDL.ADEQ does not expect that stormwater run-off from CGP sites will persist long enough to determine attainment of the geometric mean portion of the *E. coli* standard.

4.2 Summary of Nonpoint Sources

4.2.1 Agriculture

Two primary areas of agriculture are identified in the project area; one area northwest of Silver City, New Mexico along the Gila River near the small communities of Gila and Cliff, and the Duncan Valley area extending from Canador Peak, New Mexico to a point east of Duncan, Arizona. Smaller-scale agricultural acreage appears intermittently in the Sheldon-York-Guthrie corridor of Arizona south of Clifton. Isolated small areas of pasture and hay are found near the San Francisco River near Alpine, Arizona, south of Reserve, New Mexico, along the U.S. Highway 180 corridor in New Mexico, and near Redrock, New Mexico on the Gila River. In terms of total watershed area, all agricultural areas comprise 0.33% of total watershed area, or approximately 26 square miles of the 7,874 square mile watershed. The Arizona Department of Water Resources reports:

> *Duncan Valley Basin agricultural irrigation is located southeast of the Town of Duncan in the Duncan Valley and northwest of Duncan in the York Valley area. Principal crops include alfalfa, cotton, corn and wheat and there is some commercial vegetable production. The Franklin Irrigation District, also known as the Duncan Valley Irrigation District, serves farmers in the Duncan Valley. The district boundaries extend into New Mexico and irrigation wells in Arizona and New Mexico are used to irrigate lands in both states (Upper Gila Watershed Partnership, 2004). The District was formed in 1922 and encompasses about 4,700 acres of Gila River bottom land.*
> (ADWR Water Atlas, 2008)

Agriculture in the area can broadly be broken down into two classes: irrigated seasonal cropland, and pasture or forage land. Agricultural areas are generally found within the floodplains of the streams and rivers of the Gila River watershed and thus are considered possible nonpoint source contributors to *E. coli* loads. These areas have the potential to add to *E. coli* loading rates for stream networks due to injudicious applications of manure to acreage.

4.2.2 Urban/Developed

Urban or developed areas can contribute to excessive *E. coli* loading by stormwater run-off from impervious areas, and by concentrations of stormflow in engineered drainage systems feeding into natural watercourses. Minimal impact from lightly developed areas in the Gila River watershed is observed. Three towns in eastern Arizona have the potential to add to *E. coli* problems in the Gila River ecosystem: Alpine, on the upper reaches of the San Francisco River, Clifton/Morenci, situated on the lower reaches of the San Francisco River, and the town of Duncan, on the Gila River near the New Mexico state line. Smaller communities in New Mexico include Gila, Cliff and Reserve. Given the size of the watershed (7800+ square miles), the relative small footprint of each community, and the low intensity of development in the communities, development can be considered a minor contributor to *E. coli* issues in the project area. Developed areas comprise 0.04% of watershed total area, though exceedances near one or more of the towns have been cataloged in the past.

4.2.3 Grazing

The A-S NF and Gila National Forest (GNF) comprise a large part of watershed acreage and have active grazing programs. Additionally, BLM has grazing allotments on the Safford District and the Las Cruces District in New Mexico, both of which exist within the Gila River watershed. Information supplied by the national forests is of a comprehensive character and not restricted only to acreage within the Gila River watershed.

The GNF allots 2.8 million of its total of 3.3 million acres to grazing as a part of fulfilling its multiple use mandate. There are 142 total allotments, with 125 currently active (Pope, personal communication, 2008). In 2007, 206,251 animal use months (AUMs) of grazing were authorized of a total permitted number of 290,326. Total permitted numbers have been on a steady decline for the past fifteen years due to improved livestock management practices, higher costs of livestock production, and conflicts with threatened and endangered species. Authorized numbers fluctuated in recent years dependent upon forage conditions; drought years and low forage production in 2002 and 2003 led to authorized numbers well below the total permitted numbers. National Environmental Policy Act (NEPA) decisions with the implementation of USFS Best Management Practices (BMPs) have been enacted on 102 allotments within the last 15 years. Among these BMPs has been the exclusion of grazing from the riparian corridors of the San Francisco River and Gila River except for small areas. Grazing utilization standards are implemented and monitored on all active allotments on the GNF, with most allotments managed under either a "rest" or "deferred" rotational system where forage is allowed to regenerate during at least two out of three growing seasons.

The A-S NF administers 2 million acres of National Forest land. There were a total of 96 active allotments in 2007 (Jevons, 2008). As with the GNF, the trend on numbers of active grazing allotments has been decreasing in recent years. In 1983, a total of 128 grazing allotments existed; in 2000 the number had declined to 115 being analyzed and having management practices updated under NEPA. The Forest has concentrated in recent years on maintaining satisfactory conditions for wildlife habitat and watershed, riparian and forage vegetation, while recovering from recent major fires and still contending with ongoing drought conditions. Thirteen allotments in 2007 were not used for various reasons. The authorized number of AUMs in 2007 was 127,509. Recent years have seen some fluctuation of authorized numbers, ranging from a high of 187,035 in 2003 to a low of 89,603 in 2004. By rough comparison, permitted (not authorized) numbers in 1983 were 233,932 and 1985 saw permitted numbers of 213,819. Active range condition and trend studies are ongoing. Six allotments were consolidated for more effective resource management under NEPA in 2007. Grazing is permitted for cattle, horse, sheep, and burros.

Semi-arid regions with sparse ground cover, such as those found along the Gila River main-stem in Arizona, are particularly vulnerable to increased *E. coli* loading rates due to the flashy nature of overland flow and the possibility of flash flooding in gullies and ephemeral drainages feeding into perennial waters as a result of intense, short-lived monsoon storms. Overland flow and flash-flooding events in ephemeral drainages carry the potential of washing fecal material from cattle, livestock and domestic animals into perennial water bodies. These characteristics are exacerbated by the natural land surface gradients of the regional topography. The lack of soil cover in low-lying desert and semi-arid steppes contributes to lower infiltration rates and higher run-off discharges with increased velocity in response to precipitation events. Grazing activities, where not properly managed, can add to *E. coli* problems in watercourses. This can occur due to multiple factors, including the denudation of shrubs and vegetative cover, the compaction of soil contributing to lower infiltration rates; and the direct depositing of feces within the stream courses proper, again where cattle and livestock are not managed so as to restrict their access to streams.

The large amount of acreage given over to allotments within the GNF and A-S NF, and the Safford and Las Cruces BLM District offices, coupled with the relatively small areas set aside for wilderness or primitive area protection, suggest that grazing may be a contributor to the cumulative load of *E. coli* in the Gila River watershed.

4.2.4 Wildlife

Wildlife in some cases can be responsible for excessive *E. coli* loading of streams and rivers. Forest and range lands largely unaffected by human activities are home to much of the wildlife population. Federal wilderness areas as designated by Congress are areas where the multiple use mandate in effect elsewhere on National Forest lands is set aside. No motorized travel, no roads, and no permanent human habitation or influence is allowed in a designated wilderness area. The Gila National Forest is home to the 558,000 acre Gila Wilderness Area, the first designated wilderness in the United States, and the 1,200 acre Blue Range Wilderness Area adjacent to the Arizona border. Both areas lie within the watershed of the Gila River. Arizona's A-S NF is home to the Blue Range Primitive Area, a 28,100 acre parcel adjacent to the Blue Range Wilderness Area in New Mexico. Total area of these regions largely unaffected by anthropogenic influence is approximately 918 square miles, or 11.7% of the Gila's watershed above the lowest impaired reach.

Forest areas and rangelands comprise by far the highest percentage of watershed lands, totaling more than 87% of watershed area. Much of this land is under the management of the USFS and the BLM. USFS Region Three Forests within the watershed boundary include the A-S NF and the GNF. BLM lands within the watershed are administered by the BLM's Las Cruces and Safford Field Offices.

While forest lands provide the habitat for wildlife sources that may contribute to *E. coli* loading problems, they may also protect against excessive *E. coli* loading rates by providing a floor layer of litter and duff covers to reduce overland flows.

4.2.5 Septic Systems

Failing septic systems, particularly within the floodplain of a major river like the Gila River, can greatly exacerbate *E. coli* problems. Septic systems can fail or underperform for a number of reasons, including overuse, lack of routine maintenance, unsuitable soils for infiltration in a septic system's leach field, clogging of perforated pipes within the leach field, chemical decimation of the normal flora within a system due to the introduction of industrial or household non-organic waste, river flooding over septic system leach fields, and infrastructure failures/disintegration.

Septic systems are normally found where residences exist outside an incorporated area where sewer service would normally be provided, but may also be found interspersed in areas where sewer systems exist. In the project study area, the Sheldon-York-Guthrie corridor, and individual ranches and household southwards towards Duncan might be at higher risk for this type of stressor on water quality. The number of households affected and their distributions and locations at this time are unknown.

Greenlee County is considering conducting a field survey of residences in the area to gather and record basic septic system information.

In the past, high levels of *E. coli* have episodically been observed at the USGS Gila River near Clifton site downstream of these communities. In a special investigation in 2006 for another purpose, *E. coli* densities sharply spiked from 386 cfu/100ml to 6131 cfu/100ml in this 25 mile stretch of water, suggesting heavy point source loading in this stretch. An anecdotal report from the Greenlee County engineer mentions a trailer park within the Gila River flood plain south of Three Way, Arizona that was known to have had a failing septic system in recent years. The park recently changed owners, and repairs and upgrades have been implemented. Recent sampling at the USGS site has not found similar densities since the 2006 sampling.

4.2.6 Recreational Use

Where waters are used for swimming, wading, and riparian areas for recreational picnic sites, camping, and day-use recreational activities, the chance for increased *E. coli* loading is present. Locations where facilities are not provided and visitation is high carry a proportionately higher risk of *E. coli* contamination of state waters.

Within the project study area, there are two areas of particular concern for this activity. The BLM administers the Gila Box RNCA from the Black Canyon Scenic Back Road to a point south of Bonita Creek. Facilities are provided at some readily-accessible camp sites and day use sites in the area. However, rafting the Gila River through the NRCA is a popular recreational activity, and the remote nature of the river between put-in and take-out locations requires diligent management of human waste along the way during a multi-day excursion. *E. coli* contamination of the Gila River associated with improper disposal of human waste along the route should be considered a possible contributing source for the Gila's *E. coli* problem.

Similarly, the San Francisco River, a major tributary to the Gila River within the study area, has recreational pressures on it both above and below the town of Clifton. These lands are generally not a part of federal land management acreage; most lands adjoining the river in the areas closest to town are privately owned. However, a long tradition of citizen access and use of the San Francisco River on private lands is in place and routine day use activities from fishing to wading and ATV use on and along the extended flood plain terraces carries with it the possibility of recreational contamination of water quality. Unlike the Gila River in the NRCA, no restroom facilities exist along the San Francisco River, and improper disposal of human waste remains a concern.

5.0 LINKAGE ANALYSIS

5.1 Subwatershed Empirical Load Summations

Due to the size of the watershed, the high-order character of the Gila River and its perennial tributaries, the necessarily limited sampling design in both geographic extent and temporal duration, and the relatively undeveloped nature of the watershed, the approach taken to meet Arizona's *E. coli* concentration standard focused upon isolating representative cumulative watershed *E. coli* load contributions at or near the mouth of the major contributing perennial tributaries, at critical points within the impaired reaches where USGS gauge data was available, and near the New Mexico state line. Given the scale of the project area, and the inaccessibility of a sizable portion of the watershed in New Mexico, sampling and modeling for individual ephemeral tributary, source use, source process, or parcel contributions to the total *E. coli* load was impractical and unachievable with resource constraints.

Loadings were allocated amongst the various tributaries and subwatersheds of the Gila based upon relative percentages of subwatershed areas in square miles (Figure 3). Calculations for both load duration analyses and TMDL reductions were made in units of giga-organisms per day. Arizona's *E. coli* water quality standard is expressed both as a geometric mean and a single sample maximum. However, the geometric mean is not a conservative value amenable to allocation in a mass-balance analysis such as a TMDL (Parkhurst, 1998), and as allocations were to be made based on the relative percentages of subwatershed areas, it was necessary to convert existing loads and load allocation values into their corresponding arithmetic means.

For existing loads with established data sets, it is a simple matter to calculate the arithmetic mean from the same data that generated the original geometric means. However, for the establishment of the allocations for the means, an abstraction from the cumulative allowable load calculated from a geometric mean, no inherent relationship exists between arithmetic means and geometric means to inform the setting of the load allocation value. In these cases, the ratio of the logarithms of the geometric mean to the arithmetic mean for the existing data sets were determined across all five categories of flow conditions and applied to each respective category to provide a linking relationship between the arithmetic and geometric means. This linking tool led to category magnitude disparities where the two lower flow categories have higher allocations than the moist condition and mid-range flow categories. This is a function of small data sets for categories 4 and 5 being used to derive the ratios for arithmetic mean determinations. Where data sets are small, geometric means deviate more from arithmetic means, and the consequent ratio between the two becomes smaller as can be seen in the ratios presented in Table 7. These deviations make no material difference in the assessment of categories 4 and 5 as attaining, as the existing values data set for these flows at the lower end of the hydrograph are well within their allocations in the arithmetic mean comparison, and are shown to easily meet the category criteria numerically in the geometric mean comparison.

E. coli concentrations were converted to their associated daily loads (i.e. multiplied by discharge and a conversion factor) and plotted against a standard target load value in a load duration curve. Load allocations for subwatersheds were determined by the relative percentages of total watershed area. Percentages were applied to the total *E. coli* loads, and the loads as broken down by the standard classes of a load duration analysis (<10% exceeds flows, 10%-40% exceeds flows, 40-60% exceeds flows, 60-90% exceeds flows, >90% exceeds flows). Using this empirical linking approach, the sum of the total load allocations of the various subwatersheds is targeted to meet the load allocation necessary to attain the state's *E. coli* concentration standard at the lowest impaired reach on the Gila River. Separate analyses were conducted for geometric means and single sample maximums. The single sample maximum value of 235 cfu/100 ml was converted into a set of corresponding load thresholds. The 90th percentile value of existing loads was compared against the threshold values for subwatersheds where such analysis was possible. The 90th percentile value of existing loads was selected in recognition of the fact that single sample maximums are not intended to be construed as values never to be exceeded (EPA, 2006), but rather represent an implied percentile or confidence level of a frequency distribution. For the original EPA studies from which Arizona *E. coli* standards were derived, the implied percentile for a SSM of 235 cfu/100 ml is the 75th percentile as outlined in EPA guidance (EPA, 1986). However, ADEQ has elected to use the 90th percentile value of existing loads in keeping with the manner in which the agency evaluates acute exceedances of other water quality parameters using a binomial distribution based upon a 10 percent exceedance frequency. Adopting the 90th percentile value for attainment evaluations adds an implicit margin of safety over the 75th percentile level the single sample maximum value was originally drawn from. Two subwatersheds did not permit a subwatershed analysis separate from the cumulative analysis. Separate reduction requirements are presented for the single sample maximum and the geometric mean.

Because an additional impaired reach for *E. coli*, Reach 15040002-004, Gila River –Bitter Creek to NM state line, is nested within the watershed as delineated from Reach 15040005-022, a comparative approach was employed with the objective of identifying the level of protection that allowed both reaches to attain the *E. coli* standard. *E. coli* loads were calculated as simple reductions needed to achieve the allowable loads permitted by the state standard and as reductions needed when multiplied by the percentage of total watershed for the watershed delineated from the downstream end of Reach 15040002-004. It was found that the percentage proration provided the more stringent protection, and also ensured downstream attainment of the standard at Reach 15040005-022. Calculating simple reductions at the upstream reach to attain the water quality standard would not permit the downstream reach to attain the standard. Consequently, the percentage proration method was used to determine allocations for Reach 15040002-004.

An alternative analysis undertaken at EPA's request with rolling geometric means calculated for 4 sample subsets in the historic record for Reach 022 exhibits an overall average geometric mean of 51.87 cfu/100 ml, well under the state's 126 geometric mean standard. Five occurrences of four sample geometric mean exceedances were logged in a set of 50 such geomeans (a 10% exceedance rate); of these, it should be noted that two occurred in conjunction with sets focused upon targeted stormflow sampling not representative of normal frequencies of storm flow on the Gila River (i.e., biased subsets in non-random sampling). When considered alone and independently of the entire set of rolling geomeans, the five subset exceedances require a 14.0% reduction to attain the state's geometric mean standard.

Likewise, for Reach 004, an overall geometric mean average of 78.42 cfu/100 ml was calculated for a set of 22 rolling four sample geometric means. Three exceedances of the 22 values (13.6%) were logged with these four sample subsets; all three were biased subsets focused predominantly on stormflow exceedances undertaken for critical condition determinations for this TMDL's sampling plan. Considered independently, reductions necessary for these three subsets to attain the standard of 126 were 35.2%. This alternative analysis is presented for informational value only; the percentage reductions calculated by aggregating and where necessary averaging the historic data by category without regard to averaging period duration are actually more protective and targeted in terms of percent reductions necessary than the alternative analysis, and the alternative analysis with its implicit requirement that individual flows be considered in some aggregated fashion is not compatible with the load duration curve approach as outlined and executed in this TMDL analysis.

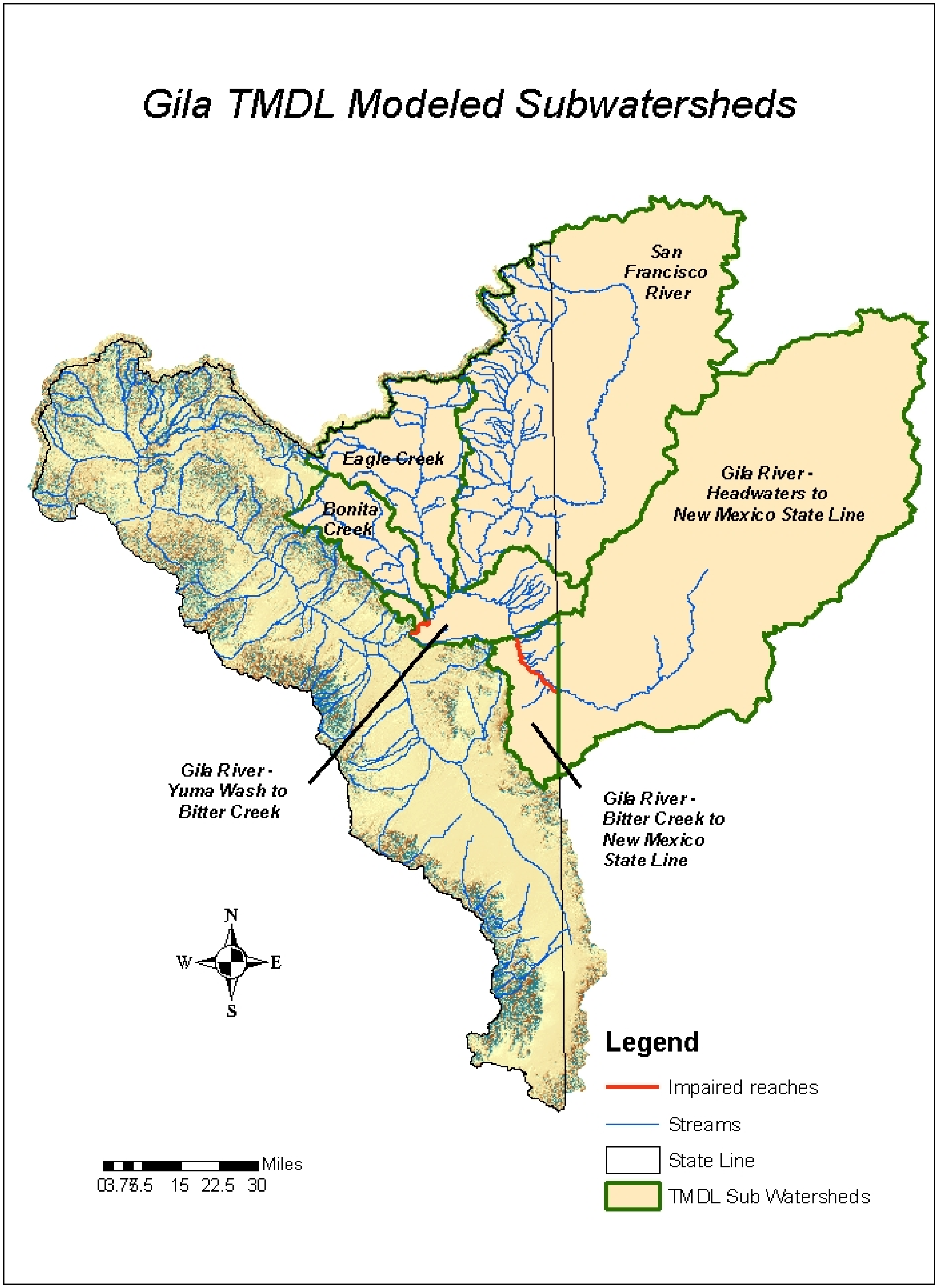

Figure 3. Subwatersheds of the Gila River system for TMDL Analysis

6.0 Modeling and Analytic Approaches

The approaches chosen for modeling *E. coli* loads and calculating the TMDL for reaches 15040005-022 and 15040002-004 consisted of the application of load duration curves. The load duration curve approach was chosen for its flexibility, its capacity to identify and address flow-dependent conditions, and the ability to classify and analyze various data points individually in accordance with the requirements of Arizona's water quality standard for *E. coli*. Long-term USGS streamflow gauges in the watershed permitted in-depth examination of flow histories.

6.1 Flow and Load Duration Curves

ADEQ has chosen to employ a flow and load duration curve approach in order to determine total maximum daily loads and calculate necessary reductions. Cleland (2003) provides the following discussion on the elements and merits of a load duration curve method:

> *The percentage of time during which specified flows are equaled or exceeded may be evaluated using a flow duration curve (Leopold, 1994). Flow duration analysis looks at the cumulative frequency of historic flow data over a specified period. The duration analysis results in a curve, which relates flow values to the percent of time those values have been met or exceeded. Thus, the full range of stream flows is considered. Low flows are exceeded a majority of the time, whereas floods are exceeded infrequently. …*
>
> *The development of a flow duration curve typically uses daily average discharge rates, which are sorted from the highest value to the lowest. Using this convention, flow duration intervals are expressed as percentages, with zero corresponding to the highest stream discharge in the record (i.e. flood conditions) and 100 to the lowest (i.e. drought conditions). Thus, a flow duration interval of sixty associated with a stream discharge of 82 cubic feet per second (cfs) implies that sixty percent of all observed stream discharge values equal or exceed 82 cfs…*
>
> *…A duration curve framework is particularly useful in providing a simple display that describes the flow conditions under which water quality criteria are exceeded. Stiles (2002) describes the development of a load duration curve using the flow duration curve, the applicable water quality criterion, and the appropriate conversion factor. Ambient water quality data, taken with some measure or estimate of flow at the time of sampling, can be used to compute an instantaneous load. Using the relative percent exceedance from the flow duration curve that corresponds to the stream discharge at the time the water quality sample was taken, the computed load can be plotted in a duration curve format (Figure 4).*
>
> *By displaying instantaneous loads calculated from ambient water quality data and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops, which describes the characteristics of the impairment. Loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show attainment. The pattern of impairment can be examined to see if it occurs across all flow conditions, corresponds strictly to high flow events, or conversely, only to low flow conditions.*

Duration Curve Zones

Flow duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: one representing high flows, another for moist conditions, one covering median or mid-range flows, another for dry conditions, and one representing low flows.
Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect potential nonpoint source contributions. This concept is illustrated in Figure 4. Data may also be separated by season (e.g. spring runoff versus summer base flow). For example, Figure 4 uses a "+" to identify those ambient samples collected during primary contact recreation season (April – October).

Runoff Events and Storm Flows

The utility of duration curve zones for pattern analysis can be further enhanced to characterize wet-weather concerns. Some measure or estimate of flow is available to develop the duration curves. As a result, stream discharge measurements on days preceding collection of the ambient water quality sample may also be examined. This concept is illustrated in Figure 4 by comparing the flow on the day the sample was collected with the flow on the preceding day. Any one-day increase in flow (above some designated minimum threshold) is assumed to be the result of surface runoff (unless the stream is regulated by an upstream reservoir). In Figure 4, these samples are identified with a red shaded diamond.

Similarly, stream discharge data can also be examined using hydrograph separation techniques to identify storm flows. This is also illustrated in Figure 4. Water quality samples associated with storm flows (SF) greater than half of the total flow (SF>50%) are uniquely identified on the load duration curve, again with a red shaded diamond.

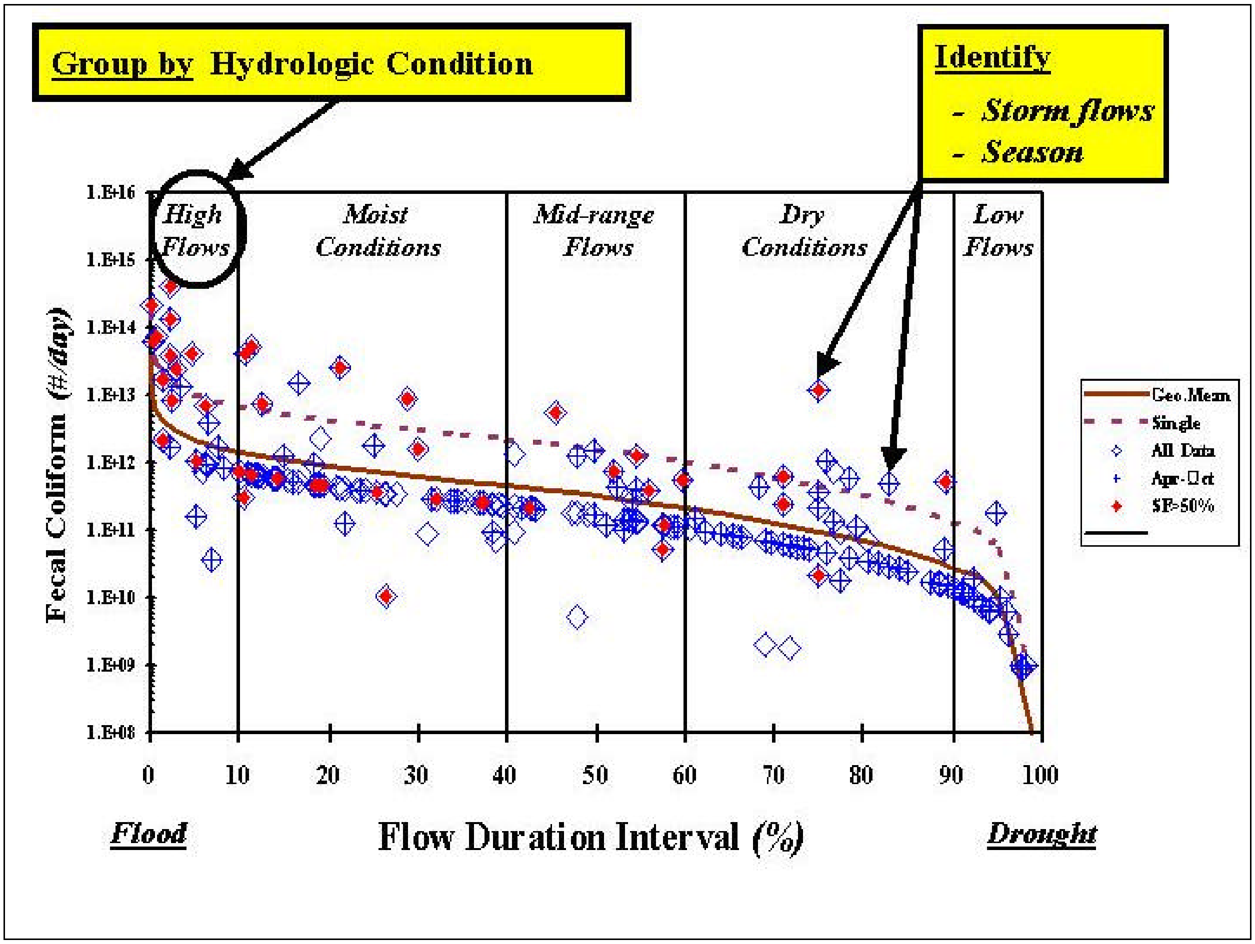

Figure 4. Sample Load Duration Curve

(Illustration courtesy of Cleland 2003).

As outlined above (Cleland, 2003), the subdivision of the flow frequency curve into five zones corresponding to high flows (0-10% Flow Exceeds), moist conditions (10-40% flows exceed), mid-range flows (40-60% flows exceed), dry conditions (60-90 percent flows exceed), and low flows (>90% flows exceed) was executed for analysis and TMDL calculations.

6.2 Natural Background Determinations

Determinations of natural background conditions in the Gila River watershed are complicated due to the size of the watershed, the numerous contributing subwatersheds, the distance of relatively pristine sites selected for analysis from the project area, and the lack of any historical data predating human influence in the watershed. The best available option consists of finding sites near the headwaters of respective watersheds, or on first order perennial tributaries in relatively undisturbed regions, and using these values as the best available approximation of an unaffected natural background value.

Natural background concentrations were determined individually for each of the three perennial Arizona tributaries (Eagle Creek, Bonita Creek, and the San Francisco River) by analyzing selected sites relatively unimpacted by anthropogenic influence within each watershed. For the mean calculations, background was determined as a median concentration for each watershed of *E. coli* concentration values, and then translated into a percentage relative to the state's *E. coli* mean water quality criterion. For the headwaters of the Gila River in the mountains of central New Mexico and all subwatersheds analyzed along the Gila downstream, a value matching the median average concentration of the three subwatersheds (4.0%) was assumed. The median instead of an average was chosen to represent the measure of central tendency for the following reasons:

1) The dataset from which natural background was drawn was not specific for this project, but rather consisted of historic data on first order tributaries throughout the watershed collected in all seasons without screening for storm or high flow events. Extensive field experience affirms that unaffected true natural background concentrations are typically either non-detects or values less than 10 cfu/100 ml on first-order tributaries in relatively unimpacted watersheds. Some of the data incorporated for the analysis consisted of much higher densities than those cited, indicating stormflow influence.
2) The watershed is not a pristine source unaffected by human activities, but rather the best available approximation of lands and water quality unaffected by anthropogenic influences (lands are actively grazed and subject to multiple use USFS management in the area).
3) Flow histories were lacking for natural background sites and the lack of language in the standard permitting exclusion of stormflows prevented a defensible filtering of this data.

For these reasons, using an average value would bias the percentage attributable to natural background high, exceeding 10% of the SSM standard in two of the three subwatersheds. The median values of the dataset provide a more resistant and representative measure of central tendency than the mean in this context.

Cumulative natural background contributions were determined as a weighted average of all contributing subwatersheds using percentages of total watershed area as the weights. Each subwatershed's load allocation was adjusted by apportioning the load allocation between the determined percentage of natural background and the remainder of the calculated load allocation. Table 2 presents details concerning natural background data.

Watershed	***Natural background sites***	***Median E. coli density***	***Percentage, NB Medians to Water Quality Standard***
San Francisco River	UGKPK000.12 UGCMB004.23 UGSFR151.22	5 cfu/100 ml	3.97%
Eagle Creek	UGEAG056.85	3.5 cfu/100 ml	2.78%
Bonita Creek	UGBON000.17 UGBON014.47	8.4 cfu/100 ml	6.67%
Gila River, NM state line to Headwaters	N.A.	N.A.	4.0%
Gila River, Bitter Creek to NM State Line	N.A.	N.A.	4.0%
Gila River, Yuma Wash to Bitter Creek	N.A	N.A	4.0%
Gila River Watershed, Average Median Natural Background	—	—	3.99%

Table 2. Natural Background, *E. coli* Concentrations, median values

Single sample maximum natural background data consisted of the same data set that comprised the median calculation set. 90th percentile *E. coli* densities were determined for watersheds represented by data. As these values are not amenable to subdivision and allocation, a weighted sum for the entire watershed was not performed. Instead, the entire Gila River watershed natural background density was represented by the 90th percentile value of the complete data set. Gila River subwatersheds on the main stem were also represented by this value. Table 3 presents 90th percentile values for this analysis.

It is noted that in keeping with the stochastic nature of the single sample maximum standard, the percentage values supplied in summary tables for single sample maximum analyses is done for the purpose of adhering to the TMDL expression format and is not considered a value subject to arithmetic operations. As such, the natural background percentages should be considered quasi-values and are presented for informational value only. The reader is advised that these values, and loads calculated from them for the traditional TMDL elements of load allocations, natural background, and waste load allocations will not sum to the determined calculated TMDL for the single sample maximum analysis. Section 7.2.1 thoroughly addresses the nature of stochastic elements and their place in a TMDL analysis.

Watershed	***Natural background sites***	***90^{th} Percentile E. coli density***	***Percentage, 90^{th} P-tile to SSM Water Quality Standard***
San Francisco River	UGKPK000.12 UGCMB004.23 UGSFR151.22	89.5 cfu/100 ml	38.9%
Eagle Creek	UGEAG056.85	16 cfu/100 ml	6.81%
Bonita Creek	UGBON000.17 UGBON014.47	106.6 cfu/100 ml	45.34%
Gila River, NM state line to Headwaters	N.A.	N.A.	37.4%
Gila River, Bitter Creek to NM State Line	N.A.	N.A.	37.4%
Gila River, Yuma Wash to Bitter Creek	N.A	N.A	37.4%
Gila River Watershed, 90th P-tile Natural Background	—	88 cfu/100 ml	37.4%

Table 3. Natural Background, *E. coli* Concentrations, 90^{th} Percentile values

7.0 TMDL CALCULATIONS

7.1 Data Used for TMDL Calculations

Data on discharges and *E. coli* measurements were compiled and collected from two sources. Flow histories were uniformly drawn from a series of USGS real-time gaging stations in the watershed, which are summarized below in Table 4. Flow values were supplemented by manual measurements at the time of data collection by ADEQ field personnel. Where USGS collected *E. coli* data, this was incorporated into the data set and included in the TMDL analysis. Periods of record (POR) were generally shorter for *E. coli* data collection, as well as being more episodic in nature.

ADEQ's TMDL program sampled at or near the sites listed for flow and *E. coli* concentrations a total of eight times during 2007. Additional ADEQ samples were taken by the Ambient Monitoring Program in previous years. ADEQ sampling is summarized in Table 5.

Load duration curves were developed for the impaired reaches and for the Gila River near Redrock, New Mexico in order to assist in analyzing and visualizing the patterns of impairment sampling discovered. These load duration curves are presented in Figures 5, 6, and 7.

Site	*USGS Designation*	*Flow Period of Record Beginning Analyzed*	*Flow Period of Record Termination Analyzed*	*USGS Number of E. coli samples*	*E. coli POR Beginning*	*E. coli POR Termination*
Gila at head of Safford Valley near Solomon	09448500	10-01-1920	2-7-2008	45	12-28-1994	8-11-2004
Bonita Creek	09447800	8-1-1981	6-2-2008	--	N.A. (flow only)	N.A. (flow only)
Eagle Creek	09447000	4-1-1944	5-12-2008	--	N.A.	N.A.
San Francisco River	09444500	10-23-1910	5-13-2008	55	12-28-1994	8-16-2006
Gila at Redrock, New Mexico	09431500	10-01-1930	6-30-2008	17	2-5-1998	6-5-2001
Gila at Duncan, Arizona	09439000	11-27-2002	3-13-2008	--	N.A. (flow only)	N.A. (flow only)

Table 4. USGS streamflow gauges and sites for water quality data

Site	ADEQ Designation	Arizona Associated Reach ID	ADEQ Total Number of E. coli samples within reach	ADEQ E. coli POR Beginning	ADEQ E. coli POR Termination
Gila at head of Safford Valley near Solomon	UGGLR448.61	15040005-022*	16	2-14-2007	12-10-2007
Bonita Creek	UGBON000.17	15040005-030	22	1-29-1997	12-8-2007
Eagle Creek	UGEAG011.51	15040005-025	12	11-30-1999	12-9-2007
San Francisco River	UGSFR006.42	15040004-001	54	2-10-1994	12-09-2007
Gila at Redrock, New Mexico	UGGLR515.55**	N.A.**	6	3-27-2007	12-10-2007
Gila at Duncan, Arizona	UGGLR501.45	15040002-004[&]	25	11-9-1999	12-10-2007

Table 5. ADEQ ambient and project sampling locations

* sampled also at UGGLR451.46   ** AZ reach IDs inapplicable in New Mexico. ADEQ sampled at UGGLR515.55
& sampled also at UGGLR 505.96, UGGLR 498.51

The load duration curve modeling approach required values of flows supplied for the midpoint of each category in order to determine the appropriate target load for the class: the 5th percentile for Category 1 (0.1%-10% flows), the 25th percentile for Category 2 (10%-40% flows), the median or 50th percentile for Category 3 (40%-60% flows), the 75th percentile for Category 4 (60%-90%), and the 95th percentile flow exceedance value for Category 5 (90%-99.9% flows). Actual flow values used for calculations are compiled in Table 6. The unit conversion factor used in conjunction with flow in all *E. coli* calculations to convert *E. coli* densities in colony forming units/100 ml into gig-organisms per day was 0.02446. Separate load target curves were established for single sample maximums and geomeans using standards of 235 cfu/100 ml and 126 cfu/100 ml respectively. The flow values for each subwatershed represented in Table 6 were directly used in calculations for single sample maximum target loads. However, only the flow values for the Gila River near Solomon were used for determining mean target loads; subwatershed contributions towards the total mean TMDL value were allocated by a weighting of the total load based upon the percentage area of the subwatershed to the entire watershed above the lowest impaired reach.

Flow Values, cfs	*Flow Exceedance Percentiles*				
	5th	**25th**	**50th**	**75th**	**95th**
Gila at head of Safford Valley near Solomon	1750	361	176	106	49
Bonita Creek	16	5.9	4.2	2.9	1.7
Eagle Creek	155	40	29	20	13
San Francisco River	787	161	75	50	26
Gila at Redrock, New Mexico	777	186	92	60	20
Gila at Duncan, Arizona	929	197	91	46	1.5

Table 6. Flow values used in single sample maximum target load calculations

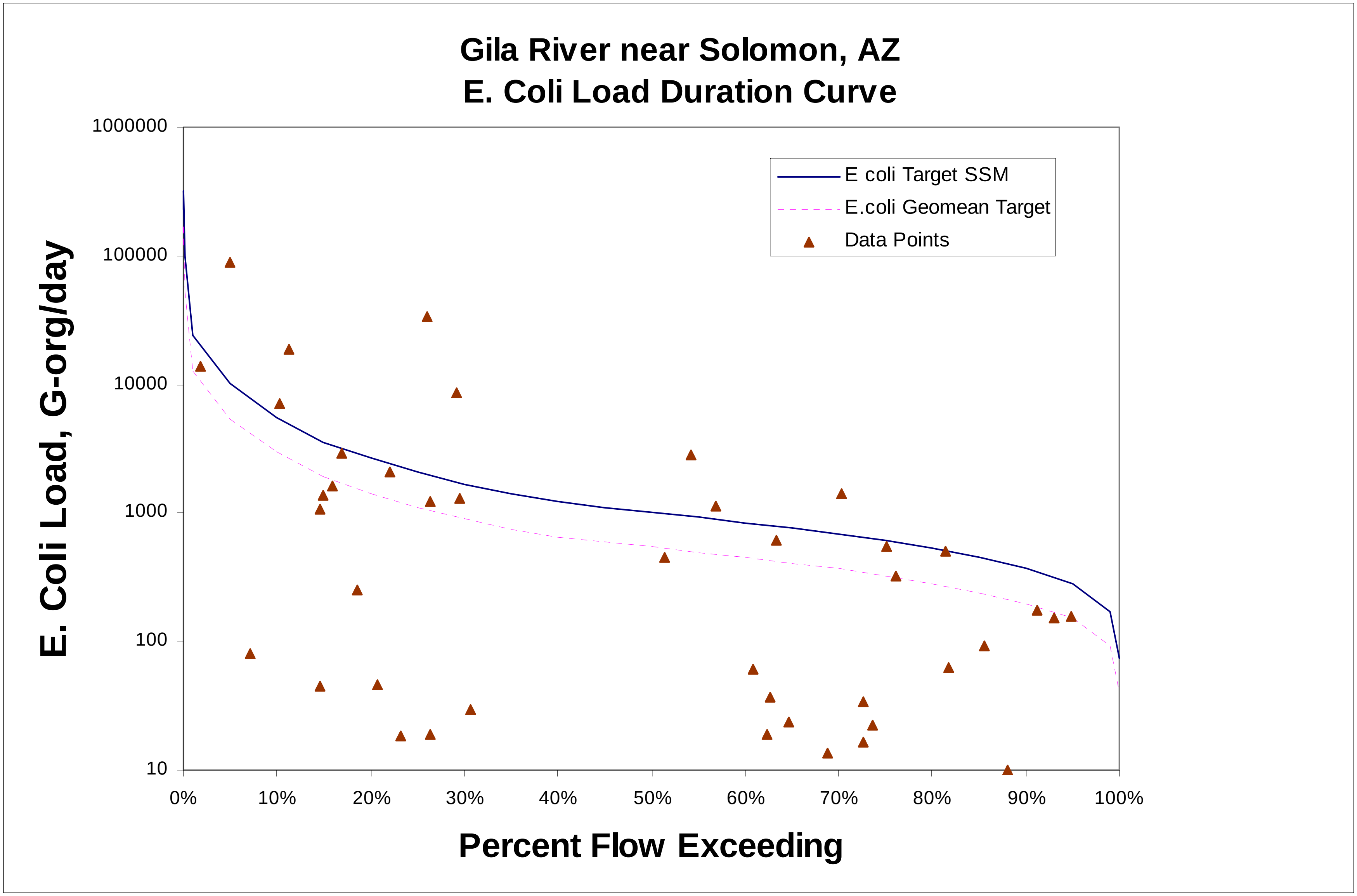

Figure 5. USGS 09448500 Gila River near Solomon, AZ *E. coli* Load Duration Curve (Section 7.1)

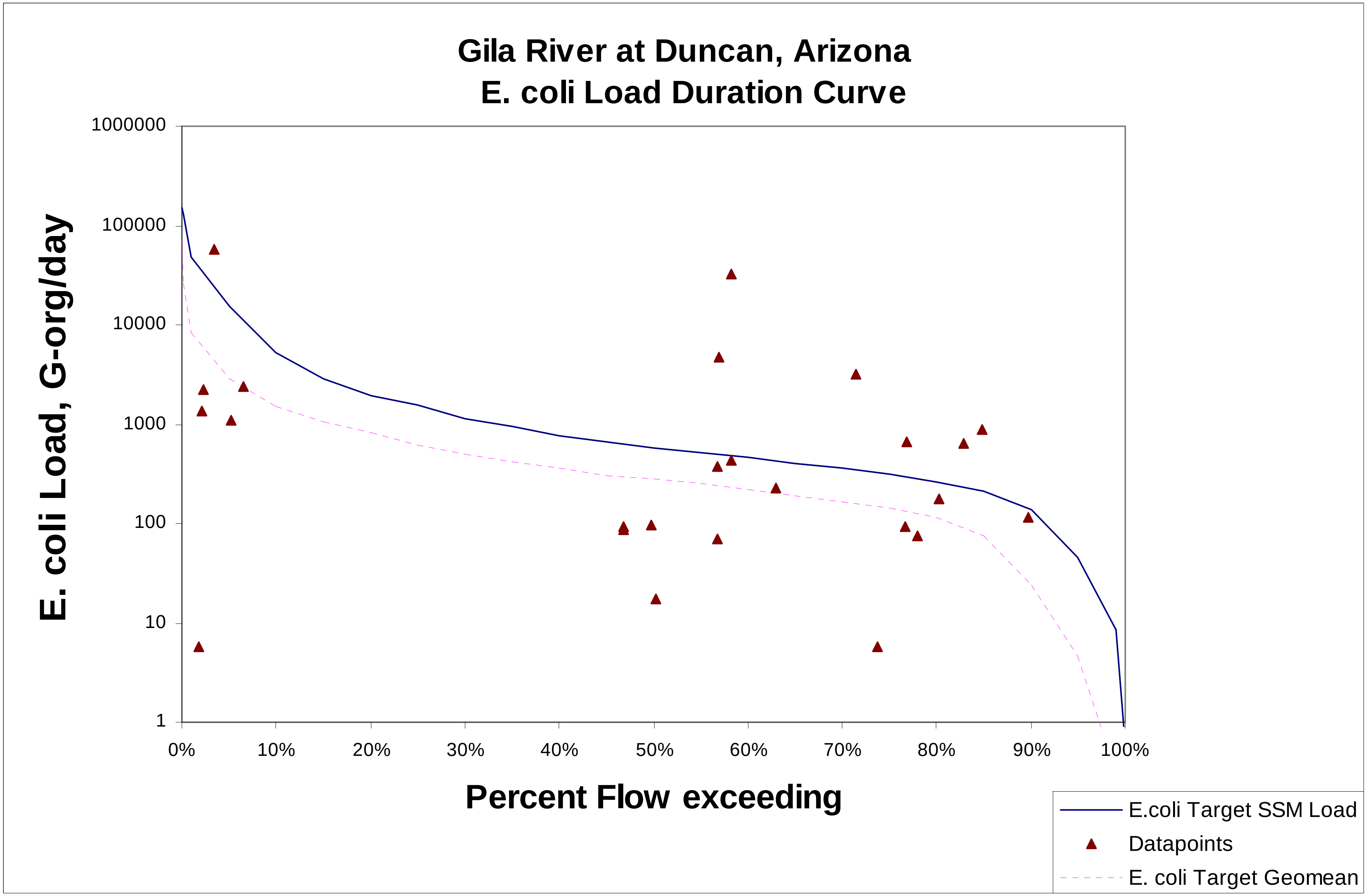

Figure 6. USGS 09439000 Gila River at Duncan, Arizona *E. coli* Load Duration Curve (Section 7.1)

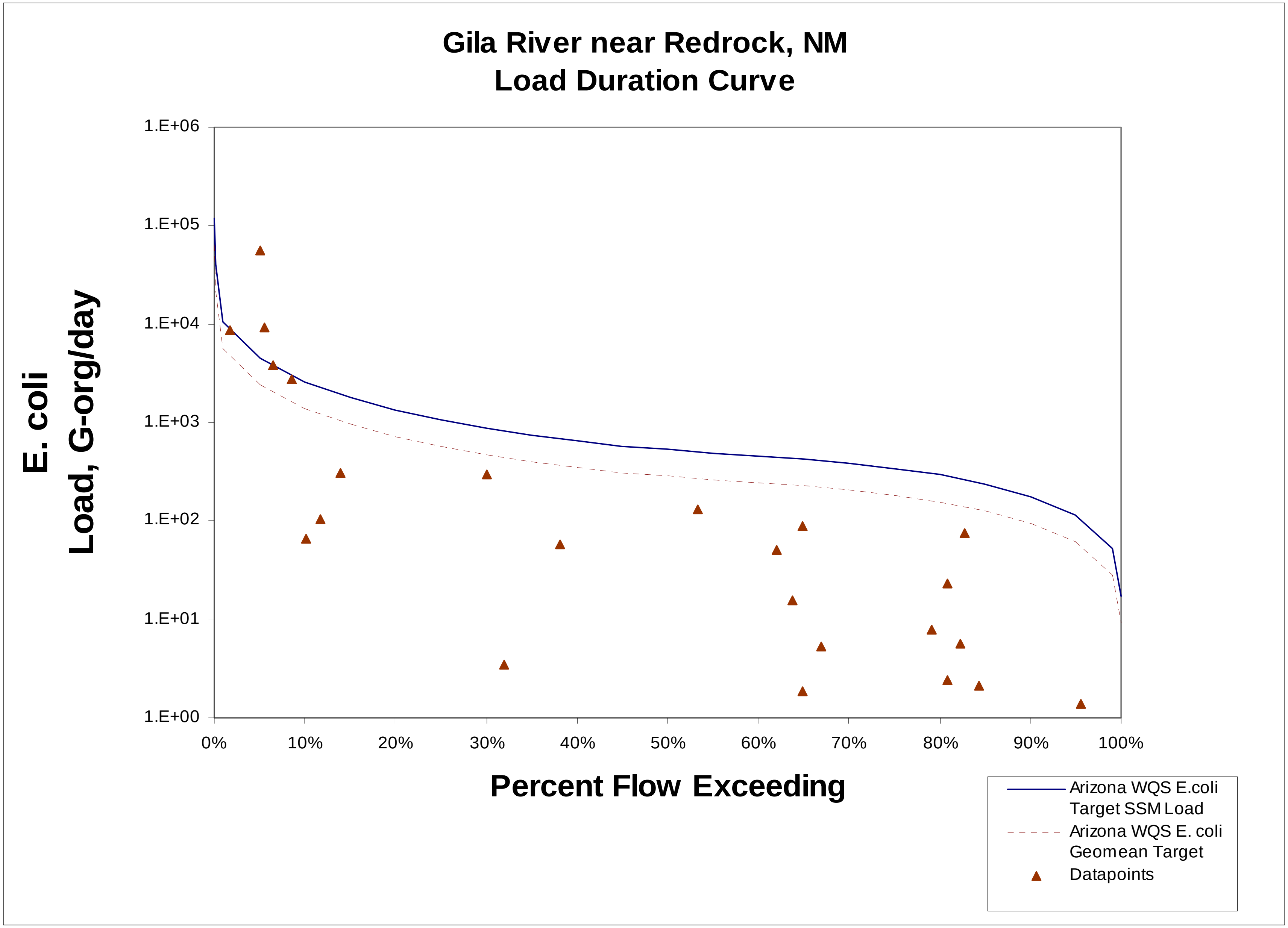

Figure 7. USGS 09431500 Gila River near Redrock, NM *E. coli* Load Duration Curve (Section 7.1)

7.2 Reach 15040005-022 TMDL Allocations

7.2.1 Waste Load Allocations

New Mexico has one WWTP in its drainage of the San Francisco River. The Village of Reserve (Permit # NM0024163) requires a 30 day average of 126 cfu/100 ml and a single sample maximum of 410 cfu/100ml. Using the worst case design flow value of 0.075 mgd, an informational waste load allocation calculation for this permit yields 0.358 G-org/day for the mean value and 1.166 G-org/day for the single sample maximum value. Both of these values are insignificant in relation to the total load allocations as can be seen by referring to Tables 7 and 9. For the San Francisco River, the worst-case mean waste load allocation for the New Mexico permittee comprises less than 0.1% of the most restrictive category load, and the worst-case single sample maximum value comprises less than 1% of the most restrictive category's target value. As they are small relative to the entire load allocation, they are detailed here and noted in the tables, but subsumed under the general load allocation for the purposes of assessment and reduction determinations. It should be pointed out that jurisdictional issues arise in the consideration of determination of waste load allocations for facilities in neighboring states.

Freeport-McMoRan-Morenci has been managed and permitted as a zero-discharge facility under the AZPDES program authorized by the Clean Water Act. However, in December, 2009, FMI notified ADEQ of their intention to discontinue their AZPDES permit under the Clean Water Act effective May 18, 2010, and rely solely upon a multi-sector-general permit (MSGP) to monitor and mitigate storm water discharges from FMI property. *E. coli* is not a constituent of concern from FMI's permitted operations assessed as having a reasonable potential to negatively impact the bacteriological water quality of the Gila River; *E. coli* found in stormwater discharges from the identified stormwater basins under FMI's ownership is considered attributable to normal watershed processes and not due to the activity or operations of the mine. Therefore, *E. coli* loads from these stormwater basins will be attributable to the load allocations of the appropriate receiving waters of either Eagle Creek or the San Francisco River. Consequently, as it is not considered to be a source for *E. coli,* FMI needs no WLA under this TMDL.

The single sample maximum represents an implied percentile value in a frequency distribution and should not be considered apart from the frequency distribution in which it adheres. Distributions of this sort are stochastic in nature, not deterministic, and cannot validly be subject to standard arithmetic operations, as can commonly be practiced for other TMDL analyses. In other words, the 90th percentile value of an *E. coli* load for 25% of the total watershed area is not equal to one quarter of the 90th percentile value for the entire watershed. Likewise, the 90th percentile target value of a waste load allocation cannot be added to the 90th percentile target value of a load allocation to yield the 90th percentile TMDL target value. Consequently, there can be no valid summation of waste load allocations, natural background, and load allocations for single sample maximum loads expressed in mass units per time interval when considered in their proper context as percentiles values of a distribution.

Since the elements of a TMDL analysis require natural background and WLA expressions, non-discrete ("quasi") allocations can be given that are derived from the TMDL value or the load allocations in accordance with the percentage determined by the appropriate ratios (for example, the ratio or percentage of the natural background 90th percentile value relative to the single sample maximum value as exhibited in Table 3), with the understanding that such a percentage is a convention ceded for the purpose of a TMDL expression that is not to be misconstrued as being subject to arithmetic operations. Where non-discrete natural background allocations are presented in Tables 11 and 12, they are presented as line items for informational content to illustrate the relative ranges and relationships, when compared to adjacent values in the table, of the various 90th percentile values presented and expected to be attained, in analogous fashion to the state's single sample maximum standard representation of a threshold or range marker to be considered in conjunction with the state's geometric mean standard. Unlike the presentation of loads in Tables 9 and 10, these values presented in Tables 11 and 12 will not sum to the TMDL value for single sample maximums due to their non-discrete stochastic properties.

7.2.2 Load Allocations and Reductions

E. coli load reductions were calculated for each of the five flow categories of a load duration curve approach for each of the major contributing watersheds. Where the impaired reaches met TMDL targets in particular categories, those categories were not displayed in the subwatershed analysis except for subwatersheds and reaches also listed on the state's 303(d) list for *E. coli*. Target load values and necessary reductions in the mean values for Reach 15040005-022 are shown in Table 7. Table 8 details the specific load reduction calculations made based on existing data for each of the flow classes. Tables 9 and 10 outline the determinations and necessary reductions with calculations for the single sample maximums for Reach 15040005-022. A 90th percentile value was selected as the threshold for comparison for each of the flow categories in keeping with Arizona's water quality binomial assessment methodology that employs the probabilities associated with a 10% exceedance rate to determine impairment.

Reach 15040005-022: Gila River - Yuma Wash to Bonita Creek
TMDL calculations, Mean values, G-org/day

Total Watershed Area, Sq Mi.	Percentage Watershed Area	**Cumulative *E. coli* Target Values**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
7,902.37	100.000%	Reach 15040005-022					
		Geomeans (G-org/day):	5,393	1,113	542	327	151
		Arithmetic Means (G-org/day):	29,454	3,113	1,742	12,016	10,377
		Ratios, Log geomean to Log mean	0.835021	0.872077	0.843657	0.616247	0.542576
		Load Allocations by Subwatershed					
		(Allocated by Arithmetic Mean Values, G-org/day)					
2,793.68	35.352%	San Francisco River	9,000	951	532	3,671	3,171
3,345.81	42.339%	Gila River- Headwaters to NM state line	10,775	1,139	637	4,396	3,796
664.09	8.404%	Eagle Creek	2,166	229	128	884	763
394.81	4.996%	Gila River, Yuma Wash - Bitter Creek	1,271	134	75	519	448
314.30	3.977%	Bonita Creek	984	104	58	401	347
389.68	4.931%	Gila River, Bitter Creek - NM state line	1,255	133	74	512	442
		Waste Load Allocations	0	0	0	0	0
		Margin of safety: 10%	2,945	311	174	1,202	1,038
		Cumulative Natural Background, G-org/day (3.99%):	1,058	112	63	431	373
		TMDL, Arithmetic Means, G-org/day:	29,453 +	3,113	1,742	12,015 +	10,377

Means Reduction Summary Table	**Reductions Needed:**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
Geometric Mn	Cumulative,	**73.8%**	**Meets**	**Meets**	**Meets**	**Meets**
Arithmetic Mn	Reach 15040005-022	**68.0%**	**Meets**	**Meets**	**Meets**	**Meets**
Arithmetic Mn	San Francisco River	**41.5%**	--	--	--	--
Subwatershed	Gila River- Headwaters to NM state line	**32.8%**	--	--	--	--
Breakdown	Eagle Creek	*	--	--	--	--
	Bonita Creek	*	--	--	--	--
##	Gila River - Bitter Creek - NM state line	**Meets**	*	**Meets**	**Meets**	*
	Gila,Yuma Wash - Bitter Creek	**68.0%**	--	--	--	--

\+ Figure reflects rounding differences from stated target value. Target value above applies as the TMDL
* * Insufficient data: fewer than four data points in the mean. Provisional value/assessment. Reductions not quantified.
\## All categories of loads and targets listed; segment on state's 303(d) list of impaired waters for E. coli.

Table 7. Reach 15040005-022 Mean Load Allocations and Summary of Reductions

TMDL Cumulative Reduction Assessments, Geometric Means, G-org/day		*High Flows*	*Moist Conditions*	*Mid-Range Flows*	*Dry Conditions*	*Low Flows*
Reach 15040005-022 Existing		**17,771**	**542**	**24**	**35**	**8**
Reach 15040005-022 Target TMDL		5,393	1,113	542	327	151
Reach 15040005-022 Target - 10% MOS		4,854	1,001	488	294	136
Reach 15040005-022 Natural Background (composite)	**0.0399**	110	23	11	7	3
Reach 15040005-022 Load Allocation		**4,743**	**979**	**477**	**287**	**133**
Reductions Assessment		**73.8%**	**Meets**	**Meets**	**Meets**	**Meets**
TMDL Reduction Calculations, Arithmetic Means G-org/day						
Reach 15040005-022 Existing		79,447	3,361	333	158	13
Reach 15040005-022 Target TMDL		29,454	3,113	1,742	12,016	10,377
Reach 15040005-022 Target - 10% MOS		26,509	2,802	1,568	10,814	9,339
Reach 15040005-022 Natural Background (composite)	**0.0399**	**1058**	**112**	**63**	**431**	**373**
Reach 15040005-022 Load Allocation		**25,451**	**2,690**	**1,505**	**10,383**	**8,967**
Reductions Needed		**68.0%**	Meets **$**	Meets	Meets	Meets
Contributing watershed calculations, Arithmetic Means G-org/day						
San Francisco River - Existing		**15,376**	--	--	--	--
San Francisco River - Target		9,371	--	--	--	--
San Francisco Natural Background	**0.0397**	**372**	--	--	--	--
San Francisco Load Allocation (-NB)		**8,999**	--	--	--	--
Reductions Needed		**41.5%**	--	--	--	--
Eagle Creek Existing		**8,962 ***	--	--	--	--
Eagle Creek Target		2,228	--	--	--	--
Eagle Creek Natural Background	**0.0278**	**62**	--	--	--	--
Eagle Creek Load Allocation (-NB)		**2,166**	--	--	--	--
Reductions Needed		*	--	--	--	--
Bonita Creek Exisitng		**4 ***	--	--	--	--
Bonita Creek Target		1,054	--	--	--	--
Bonita Creek Natural Background	**0.0667**	**70**	--	--	--	--
Bonita Creek Load Allocation (-NB)		**984**	--	--	--	--
Reductions Needed		*	--	--	--	--
Gila River- Headwaters to NM State Line Existing		**16,039**	--	--	--	--
Gila River- Headwaters to NM State Line Target		11,223	--	--	--	--
Gila HW-NM Natural background	**0.0400**	**449**	--	--	--	--
Gila, HW-NM, Load Allocation (-NB)		**10,774**	--	--	--	--
Reductions Needed		**32.8%**	--	--	--	--
## Gila River - Bitter Creek - HW Cumulative Exisitng		**7,391**	**3,696 ***	**27**	**986**	**13** *
Gila, Bitter-NM State Line, Area weighted Coefficient		0.1043	0.1043	0.1043	0.1043	0.1043
## Gila, Bitter-NM State Line, Existing Prorated		**861**	**430**	**3**	**115**	**1**
## Gila, Bitter Creek - NM State Line Target		1,307	138	77	533	461
Gila, Bitter Creek - NM State Line Natural Background	**0.0400**	**52**	**6**	**3**	**21**	**18**
Gila River - Bitter Creek - NM State Line Load Allocation		**1,255**	**133**	**74**	**512**	**442**
Reductions Needed		**Meets**	*	**Meets**	**Meets**	*
Gila,Yuma Wash - Bitter Creek Existing**		**3,969**	--	--	--	--
Gila,Yuma Wash - Bitter Creek Target		1,324	--	--	--	--
Gila,Yuma Wash - Bitter Creek Natural Background	**0.0400**	**53**	--	--	--	--
Gila,Yuma Wash - Bitter Creek Load Allocation		**1,271**	--	--	--	--
Reductions Needed		**68.0%**	--	--	--	--

* * Insufficient data: fewer than four data points in the mean. Provisional value only. Reductions not quantified.
** Modeled Values - derived from area-weighted percentage of cumulative load.
All categories of loads and targets listed; segment on state's 303(d) list of impaired waters for E. coli.
$ Geometric mean for category meets criteria; Arithmetic mean reduction disregarded

Table 8. Reach 15040005-022 Mean Load Reduction Calculations

Reach 15040005-022: Gila River - Yuma Wash to Bonita Creek
TMDL calculations, G-org/day

90th percentile values	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Reach 15040005-022 Single Sample Maximum Targets (G-org/day):	10,059	2,075	1,012	609	282
90th percentile values by Subwatershed					
San Francisco River	4,524	925	431	287	149
Gila River, NM state line - Headwaters	4,466	1,069	529	345	115
Gila River, Bitter Creek - Headwaters	5,340	1,132	523	264	9
Eagle Creek	891	230	167	115	75
Bonita Creek	92	34	24	17	10
Gila River, Yuma Wash - Bitter Creek	**	**	**	**	**

Reductions Summary Table	**Reductions Needed:**	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Cumulative	Reach 15040005-022	**94.9%**	**78.2%**	**5.8%**	**Meets**	**Meets**
	San Francisco River	**87.7%**	**Meets**	**Meets**	--	--
	Gila River- Headwaters to NM state line	**88.0%**	**Meets**	**Meets**	--	--
	Eagle Creek	*	*	**Meets**	--	--
	Bonita Creek	*	*	**Meets**	--	--
##	Gila River, Bitter Creek - Headwaters	**59.6%**	*	**Meets**	**80.1%**	*
	Gila River, Yuma Wash - Bitter Creek	**See cumulative reductions called for above**				

* * Insufficient data: fewer than four data points in the dataset. Reductions not quantified.
** Subwatershed 90th percentile values cannot be called out independently from cumulative watershed 90th percentile values.
All category loads and targets called out; segment listed on state's 303(d) impaired waters list for E. coli

Table 9. Reach 15040005-022 Single Sample Maximum Thresholds and Summary of Reductions

90th Percentile E. coli Target Values		*High Flows*	*Moist Conditions*	*Mid-Range Flows*	*Dry Conditions*	*Low Flows*
Reach 15040005-022 Existing Data		**176,626**	**8,560**	**967**	**425**	**25**
Reach 15040005-022 Target TMDL		10,059	2,075	1,012	609	282
Reach 15040005-022 Load Allocation		**9,053**	**1,868**	**910**	**548**	**253**
Waste Load Allocation		0	0	0	0	0
Natural Background	$	3,762	776	378	228	105
Reductions Needed		**94.9%**	**78.2%**	**5.8%**	**Meets**	**Meets**

TMDL Reduction Calculations, 90th percentile G-org/day

		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
	San Francisco River - Existing	**36,920**	**179**	**173**	--	--
	San Francisco River - Target	4,524	925	431	--	--
	Natural Background $	1,760	360	168	--	--
	Reductions Needed	87.7%	**Meets**	**Meets**	--	--
	Eagle Creek Existing	**16,057** *	**37** *	**1.6**	--	--
	Eagle Creek Target	891	230	167	--	--
	Natural Background $	61	16	11	--	--
	Reductions Needed	*	*	**Meets**	--	--
	Bonita Creek Exisitng	**9** *	**0.2** *	**8.0**	--	--
	Bonita Creek Target	92	34	24	--	--
	Natural Background $	42	15	11	--	--
	Reductions Needed	*	*	**Meets**	--	--
	Gila River- Headwaters to NM State Line Existing	**37,081**	**302**	**133**	--	--
	Gila, HW-NM, Target	4,466	1,069	529	--	--
	Natural Background $	1,670	400	198	--	--
	Reductions Needed	88.0%	**Meets**	**Meets**	--	--
##	Gila River - Bitter Creek - HW Cumulative Exisitr	**13,206**	**3,696** *	**36**	**1,329**	**22** *
##	Gila River - Bitter Creek - HW Target	5,340	1,132	523	264	9
	Natural Background $	1,997	424	196	99	3.2
	Reductions Needed	59.6%	*	**Meets**	80.1%	*
	Gila,Yuma Wash - Bitter Creek Existing	N.A.	N.A.	N.A.	--	--
	Gila,Yuma Wash - Bitter Creek Target	N.A.	N.A.	N.A.	--	--
	Natural Background		**See natural background values called out above**			
	Reductions Needed		**See cumulative reductions called for above**			

* * Insufficient data: fewer than four data points in the dataset. Provisional value/assessment only.
All category loads and targets called out; segment listed on state's 303(d) impaired waters list for E. coli
N.A Subwatershed 90th percentile values cannot be called out independently of cumulative watershed 90th percentiles
$ Natural background values are percentage extrapolations from TMDL value or LAs and are not amenable to summation.

Table 10. Reach 15040005-022 Single Sample Maximum Load Reduction Calculations

7.3 Reach 15040002-004 TMDL Allocations

The Gila River from Bitter Creek to the New Mexico state line also requires load reductions in *E. coli*. Because of its unique location and status as impaired nested within the larger Gila watershed as delineated from Reach 15040005-022 further downstream, load determinations and allocations must be compared between standard-mandated values for this location and prorated loads originating in the Reach 022 analysis. The more stringent of the two values by category applies to ensure that the downstream reach may still attain its TMDL.

Refer to the comparative analysis in Table 11 of the *E. coli* loads allocated by the state water quality standard within the impaired reach and the *E. coli* loads mandated by the proration of *E. coli* loads allocated in Reach 15040005-022 further downstream. The figures illustrate that in one of the five flow categories, the prorated *E. coli* load value from Reach 022 is more protective of state's designated use. This more protective *E. coli* load target is adopted for the TMDL in the moist condition category. In the other four categories, the *E. coli* load limits as calculated by the state water quality standard in Reach 004 are actually the more protective value. For these categories, the TMDL adopts the *E. coli* target load limit from load duration calculations within impaired Reach 004. Margins of safety are explicitly called out for all categories. A margin of safety of 10% was utilized in the analysis.

The Gila River watershed encompasses parts of both Arizona and New Mexico. This holds true for the two largest subwatersheds in the Gila as well: the Gila River main stem upstream of the San Francisco River, and the San Francisco River watershed. There are no permitted (NPDES) facilities with *E. coli* limits in the New Mexico portion of the Gila River watershed upstream of Reach 004. New Mexico was considered as a single aggregated load allocation on the main stem of the Gila River, with the allocation granted on the basis of the percentage of New Mexico watershed area relative to the watershed area encompassed from Bitter Creek to the Gila River headwaters. For the single category of flow substituted as a result of more stringent Reach 022 prorations, the percentage comparison was adjusted to consider New Mexico's watershed area relative to the entire watershed area from the base of Reach 022. The small portion of the Gila watershed upstream of the Bitter Creek confluence which was not in New Mexico was analyzed as a second load allocation for the mean value. Percentages of *E. coli* loads attributed to each subwatershed are outlined in Table 11. For single sample maximum (SSM) analyses, 90^{th} percentile values and SSM thresholds were determined from cumulative flow histories and load calculations at select sites where flow histories were available and thus are not amenable to subdivision or summations (Tables 13, 14). Consequently, the SSM thresholds are presented for the entire Reach 004 watershed from Bitter Creek to the Gila River headwaters; numbers are not available for the SSM analysis for the subwatershed from Bitter Creek to the New Mexico State Line. If comparison and assessment of contributions in *E. coli* SSM loads from the subwatershed is desired, the two flow histories, 90^{th} percentile values, and assessments from Reach 004 and New Mexico watersheds respectively must be considered independently and contrasted.

Differences in method category selection for *E. coli* target loads likely arise because of the necessity of considering a trimmed flow history for Reach 004. Due to agricultural diversions upstream of Reach 004 and intermittency of flow on the Gila River in the open desert, approximately ten percent of days represented in the flow history were days of no flow at USGS site 09439700 in Duncan. The inclusion of these null flow values in load duration calculations skewed the construction of flow and load duration curves and essentially created a category for low flows that was devoid of almost all populated positive flow values; the 95% flow exceeds value used for calculation of target loads for Category 5 flows was not a positive number. To consider and calculate meaningful numbers and load reductions, only those flows were ranked and given percentile values which showed actual flow at this site. This had the effect of compressing the flow history at Duncan relative to the record at USGS site 09448500 near Solomon, where perennial flow is well-established and a lowest-recorded flow of 31 cfs is on record. By doing so, meaningful load and flow numbers other than zero were generated and used for Reach 004. Thus, while there is a disparity in the construction of the load duration curves between the two reaches, careful analysis and consideration justifies the alteration of the approach and allows for completion of all five categories of load target reductions and assessments.

As with Reach 15040005-022, abstracting arithmetic mean allocation values from geometric means required the application of a ratio of the logarithms of the geomean to the arithmetic mean. Ratios were calculated for all five categories and applied individually to each respective category. Ratios are listed in Table 11. As mentioned previously, it was necessary to present mean allocation targets as arithmetic means, since geometric means are not conservative in a mass-balance analysis. Once again, this linking device led to category magnitude disparities where Category 4 has a higher allocation than Categories 2 and 3. This is a function of a small data set for Category 4 being used to derive the ratios for arithmetic mean determinations. Where data sets are small, geometric means deviate more from arithmetic means, and the consequent ratio between the two becomes smaller as can be seen in the ratios presented in Table 11. These deviations make no material difference in the assessment of Category 4 as attaining, as the existing values data set for these flows at the lower end of the hydrograph are well within their allocations in the arithmetic mean comparison, and are shown to easily meet the category criteria numerically in the geometric mean comparison. Units of analysis in all cases are giga-organisms per day.

For actual mean load reductions necessary for Reach 15040002-004, refer to Table 12. Single sample maximum thresholds and reductions are presented in Tables 13 and 14 respectively.

Reach 15040002-004: Gila River - Bitter Creek to New Mexico State Line
TMDL calculations, Mean Values, G-org/day

Total Watershed Area, Sq Mi.	Percentage Watershed Area	**Cumulative *E. coli* Target Values**	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
		Reach 15040002-004					
		Geomeans (G-org/day):	2,863	N.A.	280	142	5
		Arithmetic Means (G-org/day):	**7,110**	N.A.	**380**	**2,573**	**18**
		Ratios, Log geomean to Log mean	0.897445	N.A.	0.948713	0.63087	0.52607
		Category Target Value based on Reach 15040005-022 proration		**1,447**			
		Arithmetic Means Comparison, Load Determination Methods					
3,735.49	100.000%	Reach 15040002-004 Load Allocations					
		Summations of Load Allocations, Standard mandate	<u>**6,246**</u>	2,631	<u>**334**</u>	<u>**2,260**</u>	<u>**16**</u>
		Summation of Loads prorated from Reach 022	12,230	<u>**1,293**</u>	723	4,989	4,309
		Load Allocations by Subwatershed					
		(Allocated by Arithmetic Mean Values, G-org/day)					
3,345.81	89.568%	Gila River- Headwaters to NM state line	5,502	1,120 ^	294	1,991	14
389.68	10.432%	Gila River, Bitter Creek - NM state line	641	130 ^	34	232	2
		Waste Load Allocations	0	0	0	0	0
		Margin of safety: 10%	711	145	38	257	1.8
		Cumulative Natural Background, G-org/day: (4.0%)	256	52	14	93	0.6
		TMDL, Arithmetic Means, G-org/day:	7,110 +	1,447 +^	380	2,573	18

Mean Reductions Summary Table	**Reductions Needed:**	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Geometric Mn	Cumulative,	**25.7%**	*	**Meets**	**Meets**	*
Arithmetic Mn	Reach 15040002-004	**13.4%**	*	**Meets**	**Meets**	*
Arithmetic Means	Gila River- Headwaters to NM state line	**77.6%**	**Meets**	--	--	--
Subwshed Reductions	Gila River - Bitter Creek - NM state line	**16.9%**	*	--	--	--

+ Figure reflects rounding differences from stated target value. Bolded target values above apply as the TMDL

^ Category figures drawn from more conservative Reach 022 prorations

* * Insufficient data: less than four data points in the mean. Provisional value only. Reductions if necessary not quantified.

Table 11. Reach 15040002-004 Mean Load Allocations and Summary of Reductions

TMDL Cumulative Reduction Totals, Geometric Means,G-org/day		*Category 1*	*Category 2*	*Category 3*	*Category 4*	*Category 5*
Cumulative E.coli Target Values		*High Flows*	*Moist Conditions*	*Mid-Range Flows*	*Dry Conditions*	*Low Flows*
Reach 15040002-004 Existing		**2,964**	**3,696 ***	**22**	**77**	**3.8** *
Reach 15040002-004 Load Capacity		**2,549**	**526**	**256**	**142**	**4.6**
Reach 15040002-004 Target TMDL (LC-10%)		2,294	473	230	128	4.2
Reach 15040002-004 Natural Background	0.04	92	19	9	5	0.2
Reach 15040002-004 Cumulative Load Allocation		**2,202**	**454**	**221**	**122**	**4.0**
Geomean Reductions Needed		**25.7%**	*	**Meets**	**Meets**	*
TMDL Reduction Calculations, Arithmetic Means G-org/day						
Reach 15040002-004 Existing		**7,391**	**3,696** *	**27**	**986**	**13** *
Reach 15040002-004 Target TMDL		**7,110**	**1,447**	**380**	**2,573**	**18**
Reach 15040002-004 Target - 10% MOS		6399	1302	342	2316	17
Reach 15040002-004 Natural Background (composite)	0.040	256	52	14	93	0.7
Reach 15040002-004 Load Allocation		6,143	1,250	329	2,223	16
Reductions Needed		**13.4%**	*	**Meets**	**Meets**	*
Contributing watershed calculations, Arithmetic Means G-org/day						
Gila River- Headwaters to NM State Line Existing		24,533	128	--	--	--
Gila River- Headwaters to NM State Line Target		5,732	1,186	--	--	--
Gila HW-NM Natural background	0.040	229	47	--	--	--
Gila, HW-NM, Load Allocation (-NB)		5,503	1,139	--	--	--
Reductions Needed		77.6%	**Meets**	--	--	--
Gila River - Bitter Creek - HW Cumulative Exisitng		7,391	3,696 *	--	--	--
Gila, Bitter-NM State Line, Area weighted Coefficient		0.1043	0.1043	--	--	--
Gila, Bitter-NM State Line, Existing Prorated ++		771	386 *	--	--	--
Gila, Bitter Creek - NM State Line Target		668	138	--	--	--
Gila, Bitter Creek - NM State Line Natural Background	0.040	27	6	--	--	--
Gila River - Bitter Creek - NM State Line Load Allocation		641	132	--	--	--
Reductions Needed		16.9%	*	--	--	--

* * Insufficient data: less than four data points in the mean. Provisional value only. Reductions if necessary not quantified.

++ Value calculated as subwatershed area percentage multiplied by cumulative existing load

Table 12. Reach 15040002-004 Mean Load Reduction Calculations

Reach 15040002-004: Gila River - Bitter Creek to New Mexico State Line
TMDL calculations, Single Sample Maximums, G-org/day

90th percentile values	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Cumulative Reach 15040002-004 Single Sample Maximum Targets (G-org/day):	5,340	1,132	523	264	9
90th percentile values by subwatershed					
Gila River- NM State Line to Headwaters	4,466	1,069	529	345	115
Gila River, Bitter Creek - NM State Line	**	**	**	**	**

Reductions Summary Table

Reductions Needed:	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Cumulative Reach 15040002-004	**63.6%**	*	**Meets**	**82.1%**	*
Gila River- NM state line to Headwaters	**88.0%**	**Meets**	--	**Meets**	**Meets**
## Gila River, Bitter Creek - NM State Line	**63.6%**	*	--	**82.1%**	*

** Subwatershed 90th percentile values cannot be called out independently from cumulative watershed 90th percentile values. See cumulative target values.
Reductions for subwatershed are cumulative reductions; reductions cannot be abstracted from flow and load data.
* * Insufficient data; less than four values in the dataset. Reductions not quantified.

Table 13. Reach 15040002-004 Single Sample Maximum Thresholds and Load Reduction Summary

Reach 15040002-004: Gila River - Bitter Creek to New Mexico State Line
TMDL Cumulative Reductions
Single Sample Maximums,G-org/day

90th Percentile E. coli Target Values	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*ategory 5 ow Flows*
Reach 15040002-004 Target TMDL	**5,340**	**1,132**	**523**	**264**	**8.6**
Margin of Safety	10%	10%	10%	10%	10%
Reach 15040002-004 Existing	**13,206**	**3,696** *	**36**	**1,329**	**22** *
Reach 15040002-004 Target TMDL	5,340	1,132	523	264	8.6
Reach 15040002-004 Load Allocation	**4,806**	**1,019**	**471**	**238**	**8.0**
Waste Load Allocation	0	0	0	0	0
Natural Background $	1,997	424	196	99	3.2
Reductions Needed	63.6%	*	**Meets**	82.1%	*
TMDL Reduction Calculations, 90th percentile G-org/day					
Gila River- Headwaters to NM State Line Existing	**37,081**	**302**	--	**72**	**1.0**
Gila, HW-NM, Target	4,466	1,069	--	345	115
Waste Load Allocation	0	0	--	0	0
Natural Background	1,670	400	--	129	43
Reductions Needed	88.0%	**Meets**	--	**Meets**	**Meets**
Gila River - Bitter Creek - NM State Line Existing	N.A.	N.A.	--	N.A.	N.A.
Gila River - Bitter Creek - NM Target	N.A.	N.A.	--	N.A.	N.A.
Waste Load Allocation	0	0	--	0	0
Natural Background $	**See natural background values for entire watershed listed above.**				
Reductions Needed	**See cumulative reductions above**				

N.A.- Subwatershed 90th percentile values cannot be called out independently of cumulative watershed 90th percentiles
See cumulative values listed above

* * Insufficient data: less than four data points in the dataset. Provisional value only. Reductions if necessary not quantified.

$ Natural background values are percentage extrapolations from TMDL value or subwatershed LAs and are not amenable to summation.
See Section 6.2 and Table 5 for complete discussion.

Table 14. Reach 15040002-004 Single Sample Maximum Load Reduction Calculations

7.4 Results and Discussion

Table 15 compiles pertinent data across all supporting tables to present a comprehensive overview of reductions called for in both 303(d) listed reaches. Both geometric mean reduction calculations and SSM reduction calculations are presented, with added discussion on arithmetic means in subwatersheds where appropriate.

Examinations of compiled figures show that cumulative geomean value reductions are called for in the high flow category for Reach 15040005-022. Analysis of contributing subwatersheds by arithmetic means indicates that the high flow category presents load values not consistent with the water quality standard (Table 8), but with percentage reductions needed which are less than the cumulative arithmetic mean percent reduction for contributing subwatersheds. The Gila River to the NM state line, Gila River –Yuma Wash to Bitter Creek, and San Francisco River all show this pattern. Bonita Creek and Eagle Creek had insufficient samples to assess in Category 1. In the other four flow categories of the geomean analysis, existing cumulative loads for Reach 22 met TMDL load allocation values; consequently, analysis by subwatershed is not pursued for these categories. The Gila River Bitter Creek to NM State line subwatershed showed attainment in the high flow category, but is provisionally non-attaining with load allocations in the moist condition category (due to insufficient number of samples). The Gila River subwatershed from Yuma Wash to Bitter Creek followed the load assessments of the larger cumulative watershed, showing non-attainment in Category 1. It should be noted that these values are prorated values from the existing cumulative load for the Gila River at Solomon. In several category instances, assessments and load reductions are only provisionally flagged for either attainment or non-attainment, since fewer than four data points comprise the existing means. Reductions called out for Reach 022 range from 32.8% to 68.0%.

Reach 004 when considered in its own right showed the same larger pattern of non-attainment in Category 1 (high flows), while meeting allocations in the two of the remaining four categories. The other two categories could not be assessed. Analysis of the contributing subwatersheds (Table 12) showed a similar pattern to Reach 022's analysis; the Gila River watershed from headwaters to the New Mexico state line requires reductions only in the high flow category, while quantified high flow reductions were called for in the Bitter Creek subwatershed. Reductions range from 16.9% to 77.6%, but again are not definitively assessed in select categories due to sparse data sets.

For Reach 022, single sample maximum analysis demonstrated substantial reductions necessary in Categories 1 and 2 with marginal reductions necessary in Category 3. Category 1 necessary reductions exceed an order of magnitude at 94.9%. Three of the five contributing subwatersheds for which figures are determinable (Table 10) show reductions necessary in only the high flow category. Reductions approach or exceed an order of magnitude in the high flow category for the San Francisco River, and Gila River from headwaters to the NM state line. The sole subwatershed where problems are evident through a majority of the flow categories is the Gila River- Bitter Creek to headwaters watershed, where quantifiable reductions are called for in two of five categories ranging from 59% to 80% and provisional flags are raised in another two categories. Again, certain categories are not adequately represented by sufficiently large data sets, so some assessments and reductions are not presented.

As Reach 004 single sample maximum loads established by load duration curves are determined by independent analyses for each subwatershed, and are not subject to nesting, proration, or summation, similar percentage reductions are called for in the Bitter Creek to headwaters watershed as for Reach 022 detailed above (Table 14). The difference arises from an application of a 10% margin of safety directly to this reach's targets. Percentage reductions in Categories 1, 2, 4 and 5 range from 63% to 82%.

Reductions from the Gila River in New Mexico are called for in only the high flow category, and approach an order of magnitude in size.

While this analysis has isolated and quantified problematic load contributions from one particular subwatershed (Gila River – Bitter Creek to NM State Line), and to a lesser extent from two others (San Francisco and Gila – NM watersheds), a previous analysis has shown that almost all exceedance events for both listed reaches are attributable to run-off and flow elevations from storm events. The fact that so many high flow categories show reductions of sizable magnitude are necessary while most other categories of flow meet state water quality standards implicitly confirms this analysis. When all assessed data was considered in the aggregate for each listed reach, the geometric mean for each reach attains the state's *E. coli* geometric mean water quality standard under the 2003 standard.

Reach 15040005-022 **TMDL Reduction Assessments, Geometric Means, G-org/day**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
Reach 15040005-022 Existing	**17,771**	**542**	**24**	**35**	**7.9**
Reach 15040005-022 Target TMDL	5,393	1,113	542	327	151
Reach 15040005-022 Target - 10% MOS	4,854	1,001	488	294	136
Reach 15040005-022 Natural Background (composite)	194	40	19	12	5.4
Reach 15040005-022 Load Allocation	**4,660**	**961**	**469**	**282**	**130**
Geomean Reductions Assessment	**73.8%**	**Meets**	**Meets**	**Meets**	**Meets**

Reach 15040005-022 **TMDL Reduction Calculations, 90th Percentile E. coli Target Values**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
Reach 15040005-022 Target TMDL	10,059	2,075	1,012	609	282
Reach 15040005-022 Existing Data	**176,626**	**8,560**	**967**	**425**	**25**
Reach 15040005-022 Load Allocation	**9,053**	**1,868**	**910**	**548**	**253**
Reductions Needed	**94.9%**	**78.2%**	**5.8%**	**Meets**	**Meets**

Reach 15040002-004 **TMDL Reduction Assessments, Geometric Means, G-org/day**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
Reach 15040002-004 Existing	**2,964**	**3,696 ***	**22**	**77**	**3.8** *
Reach 15040002-004 Load Capacity	2,549	526	256	142	4.6
Reach 15040002-004 Target TMDL (LC-10%)	2,294	473	230	128	4.2
Reach 15040002-004 Natural Background	92	19	9	5	0.2
Reach 15040002-004 Cumulative Load Allocation	**2,202**	**454**	**221**	**122**	**4.0**
Geomean Reductions Needed	**25.7%**	*	**Meets**	**Meets**	*

Reach 15040002-004 **TMDL Reduction Calculations, 90th Percentile E. coli Target Values**	*Category 1* *High Flows*	*Category 2* *Moist Conditions*	*Category 3* *Mid-Range Flows*	*Category 4* *Dry Conditions*	*Category 5* *Low Flows*
Reach 15040002-004 Target TMDL	5,340	1,132	523	264	8.6
Reach 15040002-004 Existing	**13,206**	**3,696 ***	**36**	**1,329**	**22** *
Reach 15040002-004 Load Allocation	**4,806**	**1,019**	**471**	**238**	**8.0**
Reductions Needed	**63.6%**	*	**Meets**	**82.1%**	*

* * Insufficient data: less than four data points for consideration. Provisional value/assessment only.

Table 15. CWA 303(d) Listed Reaches Compilation of *E. coli* reductions

8.0 TMDL IMPLEMENTATION

TMDL implementation plans are required by A.R.S 49-234, paragraphs G, H, & J requiring TMDL implementation plans to be written for those navigable waters listed as impaired and for which a TMDL has been completed pursuant to Section 303(d) of the Clean Water Act. This section serves as the implementation plan for the Gila River *E. coli* TMDLs. Implementation plans provide a strategy that explains "how the allocations in the TMDL and any reductions in existing pollutant loadings will be achieved and the time frame in which attainment of applicable surface quality standards is expected to be achieved." The following implementation plan is voluntary for the stakeholders of the region and meant to suggest possible improvements and best management practices that can be employed to improve water quality and guide efforts to remediate water quality on a local scale within the affected watershed.

A basin as large as the Upper Gila watershed, consisting of more than 7800 sq. mi. above the USGS gauge site 09448500 (Gila River at the head of the Safford Valley near Solomon, AZ) and presenting multi-state jurisdictional issues, poses special challenges in the development of a TMDL implementation plan. Actual on-the-ground improvements in water quality will rely upon the voluntary initiative and actions of stakeholder groups and interested individuals employing standard BMPs at a local scale throughout the entire watershed. The scope of the cumulative problem is large enough that ongoing cooperation amongst many stakeholders working within the framework of this TMDL will be necessary to effect long-term improvements over several years. Water quality improvement for the Gila River will ultimately come in incremental steps from many different directions and many different benefactors.

Consequently, the implementation plan in this TMDL provides a general framework for addressing the problem with broad-brush guidance. More focused and region-specific recommendations and guidance for the implementation of more specific improvement measures on a sub-basin scale will be developed as stakeholders and interested parties come forward with proposals. ADEQ also plans to continue its close cooperation with the New Mexico Environment Department, recognizing that both states are partners in the effort to improve Gila River water quality.

Congress amended the Clean Water Act in 1987 to establish the Section 319 Nonpoint Source Management Program. As a result of this federal guidance, states have an improved partnership in their efforts to reduce nonpoint source pollution. The ADEQ Water Quality Improvement Grant Program allocates 319 grant funds from the EPA to interested parties for implementation of nonpoint source management and watershed protection. Under Section 319, state, private/public entities, and Indian tribes receive grant money which support restoration projects to implement on-the-ground water quality improvement projects to control nonpoint source pollution.

8.1 Best Management Practices

Voluntary assumption of responsibility for on-the-ground reduction of excessive *E. coli* loading will rest in large part with the USFS and the BLM, whose acreage in the GNF, A-S NF, BLM Las Cruces District, and BLM Safford District comprise the majority of the total watershed area. Private landowners can also play a role in improving the Gila River's *E.coli* water quality problem, particularly in the

Duncan Valley area, where data indicates excessive loading is occurring. The Safford office of the NRCS stands ready to assist landowners in the area with information and advice on the implementation of land management practices that can improve bacteriological water quality. Improvements in non-point source pollutant problems are typically addressed through the implementation of best management practices (BMPs). BMPs to control nonpoint source pollution problems are a combination of structural and non-structural (management or cultural) practices that landowners or land management agencies decide upon to be the most effective and economical way of controlling a specific water quality problem without disturbing the quality of the environment (NEMO, 2008). BMPs are usually tied to specific land use practices, such as agriculture, grazing, logging, construction, mining, or unimproved road crossings/maintenance, but some are directly related to managing the flow and erosive potentials of the stream course proper. Many BMPs are interdisciplinary in their application and can provide benefits for more than one type of land use or geomorphic process. Land use practices common in the watershed include all discussed in Section 4.0, including agriculture, grazing, and light recreational and residential development. Necessarily, because of the scale of the watershed and the differing state jurisdictions, only broad scope BMPs can be suggested here, and suggestions are not to be construed as an all-inclusive list nor as required measures mandated by this TMDL. In some cases measures have already been rolled out and implemented in the region.

BMPs for grazing activities include fencing of exclusion zones along riparian corridors to keep cattle out of streams and riparian areas, installation of troughs and watering holes away from stream courses for wildlife and cattle, management of cattle use of grazing allotment lands, primarily through rest and rotation grazing strategies, controlled stream crossings where livestock must cross streams, and establishment of riparian buffer zones and filter strips.

Where agricultural activities are concerned, water quality is benefitted through BMPs by the establishment of filter strips and riparian buffer zones, the use of contour plowing and terracing , the management of irrigation by several practices, including the control of tail water return, the engineering of irrigation water control structures such as canals, head gates, and pipelines and small-scale engineering measures such as the installation of brush layers, erosion control fabrics, and willow plantings.

Septic system best management practices include regular maintenance and pumping of systems, siting in areas where soils are relatively permeable for infiltration from leach fields and removed from floodplains and influence from ephemeral drainages, replacement of failing systems, education of residents as to proper waste disposal practices (i.e., prohibition of chemicals from septic systems), adequate sizing for households at construction, prevention of overuse, and other measures.

8.2 Gila River Watershed Improvement Plan and Strategies

The State of New Mexico drafted a comprehensive watershed improvement plan for its portion of the Gila and San Francisco Rivers in 2007 addressing watershed conditions, Clean Water Act Implementation on the Gila River Watershed, Section 319 Funding, TMDLs for portions of the Gila River hydrologic system, and resources available to address the issues in the watershed (NMED, 2007). Numerous maps and summary tables cataloged each of the problem areas identified. The Watershed Improvement Plan (WIP) is a required submission in New Mexico to secure Section 319 funding from the Environmental Protection Agency. Intended as an umbrella document, more specific planning for individual problem areas is called for where necessary. The nine key elements EPA requires for Section 319 funding are addressed in the document. These nine elements include:

a) identify causes and sources of pollution
b) identify specific indicators and quantify targets, including load reductions,
c) identify most effective management practices to achieve targets
d) develop an implementation schedule
e) identify interim milestones to be achieved
f) develop measurement criteria
g) outline a monitoring plan
h) develop an information component
i) outline technical and financial assistance needed for implementation of project components.

Arizona recently began a demonstration project intended to produce a similar document cataloging needed improvements watershed-wide. Three Arizona watershed planning groups were invited to submit WIP development proposals for their respective watersheds in September of 2008. The Gila Watershed Partnership, based in Safford, was one of the watershed groups invited to compete. EPA has approved limited Section 319 funding for the planning process and document creation in this demonstration effort, recognizing that inventory and prioritization of projects in a watershed-wide approach should lead to more efficient and productive expenditures of Section 319 funds leading to more water quality improvements and attendant de-listings of water quality impaired reaches.

As of March 2011, the Watershed Improvement Plan for the Gila Watershed Partnership was nearing completion of its two-year time frame. The document is currently in the final stages of its write-up and should provide cataloging and prioritization of projects within the Arizona portion of the Gila River watershed above the impaired reaches. The demonstration project associated with the plan write-up consisted of the construction of sediment retention basins, which were also near completion.

8.3 Healthy Lands Initiative

In 2007, the federal Department of the Interior allocated $21.9 million to a new program called the Healthy Lands Initiative designed to encourage landscape-wide approaches to improving the quality of rangelands in the western U.S. Bill Brandau, former head of the Safford District of the BLM, advocated investigation and use of these resources in the implementation efforts for this TMDL project. BLM releases characterize the program as follows:

> *The Healthy Lands Initiative (HLI) is a central feature of the President's proposed Interior Department budget for Fiscal Year 2009.The overall aim of the Initiative is to improve the health and productivity of the public lands in today's fast-growing West.*

> *The Initiative is characterized by the broad scale of the acreage it seeks to restore and conserve, and the accelerated pace at which results are expected. The Initiative will enable and encourage local BLM managers to set priorities and manage across landscapes and mitigate impacts to an array of resources in ways not previously available to them. The President's budget for Fiscal Year 2009 includes a request for $14.9 million for HLI, an increase of $10 million above the level enacted in Fiscal Year 2008.*
>
> *Demand for a variety of public land uses and products in the U.S. is at an all-time high because of the country's changing demographics and needs. Land health is being affected by pressures such as community expansion, wildfires, unmatched demand for energy resources, ever-expanding recreation uses, and invasive weeds. These pressures often interact to affect large landscapes and ecosystems, particularly those in the growing wildlife-energy interface. A different management approach is urgently needed to meet these challenges. and help avoid restrictions on uses of public lands that would directly affect the nation's energy security and quality of life.*
>
> *The landscape-level approach is the first step, and will be focused so as to realize results in one to three years. The key is keeping resources healthy. Healthy lands support rural and urban economies across the West. The Initiative recognizes that conserving wildlife and habitat is also beneficial to local communities, particularly those whose economies are tied to fish, wildlife, and healthy watersheds. The Initiative gives managers flexibility to identify lands where a particular resource might be emphasized in order to encourage sustained health and balance across a broader landscape or ecosystem.*
>
> *Partnerships are an integral part of the Initiative. Public-private cooperation, incentives for landowners and private industry, and other non-traditional approaches will engauge stakeholders while generating additional funds and resources. (Healthy Lands Initiative National, 2008)*

As of January 2011, Arizona has taken steps to participate in the Healthy Lands Initiative. Rem Hawes of the Arizona BLM states that Arizona currently has two projects within state borders supported by HLI funds, though the project area of this TMDL is not currently included in these efforts to improve rangeland conditions. Projects may originate with the BLM, or stakeholders and other interested parties may come forward with proposals and applications to participate in the effort. The program is overseen by the BLM as a matching program for money, time, or materials, with the intent, but not the requirement that matches be 50:50. BLM has turned the local administration of the HLI over to Arizona's Association of National Resource Conservation Districts (NRCDs) where landowners and stakeholders can apply for funds for specific projects intended to promote rangeland health. The HLI continues to be funded for FY 2010 and 2011, according to Stefani Smallhouse of the NRCD, and currently Arizona's BLM has received approval to participation for a five year period ending at the end of FY 2015, though year to year funding is dependent upon federal budget considerations. Projects in FY 2010 and FY2011 will focus upon the San Pedro watershed and on the Gila River watershed for BLM lands administered by the Safford District Office and for parcels of land located adjacent to BLM lands.

While the Healthy Lands Initiative is targeted to improving the conditions of rangelands in the western U.S, the synergy between this goal and goal of improving bacteriological water quality allow for benefits to be reflected in Arizona's water quality. Healthy rangelands reduce overland flow velocities, allow for more infiltration as a result of precipitation events, and reduce sediment in waterways (often seen in correlation with excessive *E. coli* loading, whether as a correlate or a causative factor). All of these attributes are positive markers for the improvement of bacteriological water quality.

8.4 Time Frame and Future Monitoring

A.R.S. 49-234 mandates that a time frame be established for the implementation plan by which attainment of water quality standards is expected to be achieved. A three to five year time frame is expected before significant improvements will become evident for both Reach 15040005-022 and Reach 15040002-004, assuming that measures to improve *E. coli* loading are implemented expeditiously. Effectiveness monitoring by ADEQ will commence in five years.

For the purposes of implementation and effectiveness evaluations, stakeholders engaged in monitoring activities are encouraged to consider and evaluate monitoring results in terms of concentrations as stated in the Arizona water quality standards. Additionally, the state of New Mexico is asked to consider and reduce their contributions to Arizona's excessive *E. coli* loads where necessary through evaluation of concentration-based determinations at the state line using Arizona's concentrations as benchmarks. As with permittees' monitoring under the MSGP and CGP, *E. coli* densities that meet Arizona's water quality concentration-based criteria will be considered consistent with the provisions governing the remainder of this TMDL and will not be considered as causing or contributing to downstream exceedances. The State's 2009 *E. coli* standard, with a single sample maximum value of 235 cfu/100 ml and a 30 day averaging period for a geomean value of 126 cfu/100 ml is in effect for assessment of results. ADEQ encourages stakeholders to comply if possible with the monitoring requirements of the geometric mean portion of the standard with its 30 day time frame, but recognizes that in meeting the requirements of the averaging period, particular difficulties are posed, with a narrow margin of sampling time discretion available to both establish a set of minimum size four with independence of all samples in the set (samples separated by at least a seven day interval) and to meet the time limit of 30 days for the complete collection of a set. ADEQ anticipates most monitoring results from stakeholders will be evaluated under the single sample maximum provision of the standard.

Where geomean assessment cannot be reasonably performed, it is recommended that sites be sampled for *E. coli* densities quarterly at a minimum in hydrologic conditions that represent all parts of the flow regime, including stormflow, snowmelt, and baseflow conditions, as well as in the irrigation diversion season and outside of it for sites in the Duncan Valley area associated with Reach 15040002-004. For interested stakeholders and other parties doing follow-up monitoring, ADEQ recommends the sites listed in Table 16 to best characterize subwatershed water quality conditions. Sites recommended have been considered for accessibility, suitability for project objectives, and other factors. Where private lands are involved, permission to access and sample from the landowner will be required.

After the TMDL has been completed, ADEQ will review the status of the waterbody at least once every five years to determine if attainment of applicable surface water quality standards has been achieved. If attainment of applicable surface water quality standards has not been achieved, ADEQ will evaluate whether modification of this TMDL implementation plan is required (A.R.S. § 49-234).

ADEQ will continue to monitor the Gila River and its tributaries, both as a routine part of its ambient

Site	*ADEQ Designation*	*Arizona Associated Reach ID*	*Latitude/ Longitude (NAD27)*	*Nearest USGS Site*	*Land Owner / Administrator*
Gila at head of Safford Valley near Solomon	UGGLR448.61	15040005-022*	32°52'06", 109°30'38"	09448500 (co-located)	Private (Clonts property)
Bonita Creek	UGBON000.17	15040005-030	32°53’45” 109°28’45”	09447800 (upstream)	BLM
Eagle Creek	UGEAG011.51	15040005-025	33°03'52" 109°26'30"	09447000 (upstream)	Freeport-McMoRan-Morenci
San Francisco River	UGSFR006.42	15040004-001	33°00'28.3" 109°18'54.2"	09444500 (upstream)	Private (Public access granted)
Gila at New Mexico State Line	UGGLR505.96	15040002-004	32°41'12.6" 109°03'07.8"	09439000 (downstream)	Private (Unknown)
Gila at Duncan, Arizona	UGGLR501.45	15040002-004	32°43'28" 109°05'57"	09439000 (co-located)	AZ DOT (Hwy 75 Right of Way)

Table 16. Recommended Implementation Monitoring Sites

monitoring program on a triennial basis, and for effectiveness evaluations of water quality improvement measures five years from the date of this report. The department will use load evaluation criteria presented in this TMDL document as opposed to the concentration-based criteria recommended to stakeholders to evaluate loading reductions and improvements in the impaired reaches and contributing subwatersheds. As mentioned in Section 3.0, these two approaches are complementary, with loads being derived from concentrations. The more intricate nature of the loading analysis with a nested subwatershed approach, however, makes it more suitable for application to the agency with personnel experienced in the determination, application, and interpretation of loading data in a load duration analysis.

8.5 TMDL Statute Requirements

8.5.1 Environmental, Economic, and Technological Feasibility

Achievement of the load allocations presented in this TMDL on a project-wide scale is environmentally feasible if steps are taken to control nonpoint source *E. coli* loading of the Gila River network in and above the impaired reaches. Natural background loading has been determined to be only a minor percentage of the total load capacity available to attain state water quality standards. Though percent reductions necessary in high flow conditions are relatively high, the high loadings of *E. coli* are a combination of stormflow run-off impairments and possible sediment reservoirs of *E. coli* stored in the channel. Storm flow run-off impairments will respond to improved land management practices in the basin over time. Improvements in excessive sediment loading will also likely yield benefits in improved bacteriological water quality, as reservoirs of *E. coli* liberated within channels and entrained with high sediment loads during high flow events will improve with sediment flushing in due course. Sediment loading is being addressed in a separate TMDL for the same reaches addressed in this TMDL. While improvement in conditions is expected to be incremental and slow due to a number of factors, the prime factors being the size of the watershed and high-order character of the hydrologic network in the impaired reaches, the TMDL has been written to attain water quality standards, with percentage reductions calculated based upon appropriate water-quality targets. Arizona will rely on our sister state New Mexico doing its part to improve water quality in the uplands and drainages in New Mexico; ADEQ has consulted with the NMED throughout the course of this TMDL development and plans to continue working closely with New Mexico once the TMDL is implemented. Long-term improvements in Gila River bacteriological water quality are achievable under the framework of this TMDL.

Regarding the wasteload allocation specific to current and/or future NPDES permittees in the basin, as well as those seeking coverage under the department's MSGP or CGP, ADEQ has established environmentally feasible wasteload allocations consistent to the extent possible with the State's *E. coli* water quality standard. Inasmuch as the premise behind the issuing of each permit to a discharger or potential discharger to Arizona's waters is that water quality standards shall be met, the wasteload allocations set forth in the TMDL are consistent with the permitting considerations governed by the State's water quality standards as well as the standards themselves. While load allocations (LAs) are to be reasonable and minimize uncertainty to the extent possible (EPA, 1991), it is noted that these characteristics are to be considered for the overall loading scheme and not specifically considered for individual wasteload allocations against the allocation scheme as a whole. EPA defines a load allocation in 40 CFR 130.2 (g) as follows:

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

Furthermore, EPA states in the previously cited source:

For traditional water pollution problems, such as dissolved oxygen depletion and nutrient enrichment, there are well validated models that can predict effects with known levels of uncertainty. This is not true for such non-traditional pollution problems as urban stormwater runoff and pollutants that involve sediment and bioaccumulative pathways. Predictive modeling for these problems therefore uses conservative assumptions, but in many cases the degree of certainty cannot be well quantified …For TMDLS involving these non-traditional problems, the margins of safety should be increased and additional monitoring required to verify attainment of water quality standards and provide data needed to recalculate the TMDL, if necessary.

Permittees are being held to a WLA in the TMDL no more stringent than the current water quality standard. Permittees have already accepted this obligation to meet water quality standards in choosing to apply for, accept, and operate under the terms of a permit. The combination of these conditions illustrates that the TMDL criteria of a reasonable allocation plan has been met.

On a project-wide scale, economic feasibility is also considered reasonable; the vast majority of land (approximately 75%) within the Gila River watershed is federal or reservation land, and the costs of addressing nonpoint source pollution on these lands fall to other parties, including the U.S. Forest Service in the Gila and Apache-Sitgreaves National Forests and the Bureau of Land Management. New Mexico acreage makes up more than 2/3rds of watershed area; where federal lands do not exist in the Gila watershed in New Mexico, the state of New Mexico is responsible for addressing costs. State lands in both New Mexico and Arizona comprise a fair percentage of the remaining area. In short, any costs incurred in meeting the allocations of this TMDL are distributed widely, and federal Section 319 grant monies are available to private parties and landowners to assist in defraying costs for voluntarily-implemented measures and projects to improve nonpoint source pollution on a local scale.

For individual permittees in the watershed, economic feasibility has already been established by the premises from which WLAs were drafted. Permittees operating under general permits are already required by the terms of the MSGP and CGP to monitor and/or implement best management practices to safeguard water quality in flows resulting from storm events. Arizona water quality standards serve as the express basis of both the WLA and the general permits. With the TMDL WLA, permittees are being asked to only adhere to the content of Arizona's water quality standard for the *E. coli* single sample maximum in their stormwater discharges. Where inadequate water quality controls become evident, improvement of best management practices already employed is expected to mitigate the issue. Additional costs to the permittees, where incurred at all, are expected to be nominal.

Technological feasibility is also well within means on a project-wide scale, as an extensive set of tested, low-cost, and no- to minimal- engineering control best management practices (BMPs) are available for implementation, many of which have been developed and used successfully by federal land management agencies for years. This knowledge is widely and publicly available. These points have been addressed in Sections 8.0 to 8.3 of the draft TMDL document.

Technological feasibility specific to individual permittees is, as in the larger scale of the project, assessed by the existence and employment of best management practices (BMPs) to mitigate stormwater pollution on a local basis. Permittees operating under a general permit have already agreed to employ BMPs to improve water quality. As mentioned previously, a wide menu of tested and no- to minimal-engineering control BMPs developed largely by federal land management agencies is available in the public domain. Permittees have accepted the responsibility and obligation to monitor and improve BMPs, if necessary, to protect water quality in discharges exiting their respective sites. These additional actions would be required only if BMPs already in place are inadequate to achieve their intended objectives, in which case the permittee is obligated by the general permit to correct or improve. Technological feasibility, then, is built into the permitting framework and nonpoint source implementation measures that are already called for or under employment for permittees in the watershed.

8.5.2 Cost/Benefit Associated with Allocation Achievement

Cost considerations have previously been addressed under the "economic feasibility" factor discussion. For specific permittees in the watershed, little is expected in the way of additional expense to monitor and improve BMPs, if necessary, that permittees are already obligated to perform as a part of the MSGP. As previously mentioned, these additional minimal expenses would be incurred only when BMPs already in place are inadequate to achieve their intended objectives, in which case permittees obligated by their permit to correct or improve. ADEQ expects minimal additional costs to permittees resulting from the application of a WLA. On a project-wide evaluation, extensive discussion has been previously presented regarding cost-sharing between federal agencies, the states involved, private landowners who can apply for Section 319 funds, and tribes.

Benefits resulting from actions improving water quality in the Gila include making the waters of the Gila River compliant with the objectives of the Clean Water Act, i.e. "to restore and maintain the physical, chemical, and biological integrity of the nation's waterways" and ensuring that waterways are "fishable and swimmable." It is salient to note that these goals are not mere abstract objectives devoid of any practical or substantive content; illnesses due to swimmers' exposure to impaired bacteriological water quality on the Gila River have resulted on the San Carlos Apache Reservation within the past five years. The benefits resulting from improved Gila River water quality are benefits that have very real community health and financial values associated with them. It is concluded that the costs possibly incurred in improving Gila water quality are minimal, dispersed in nature, appropriate, commensurate with and offset by the benefits that would accrue to re-establishing the Gila River as an unimpaired waterway.

8.5.3 Pollutant Loading Reductions Previously Achieved

Arizona's TMDL statute requires consideration of any pollutant loading reductions that are reasonably expected to be achieved as a result of other legally required actions or voluntary measures in TMDL analyses. Nonpoint source pollution remediation efforts have been ongoing for a number of years in the Gila River watershed in both Arizona and New Mexico. ADEQ's Section 319 grant program has awarded grant money and tracked the progress of nonpoint source pollution improvement efforts in Arizona since program inception. EPA databases provide information on approved Arizona and New Mexico NPS projects within the Gila River watershed boundaries. However, quantification of these efforts in terms of reduced bacteriological loading has not occurred. Sediment, total nitrogen, and total phosphorus, load reductions attributable through specific projects are available for projects listed in EPA databases, but *E. coli* reductions have not been included.

9.0 PUBLIC PARTICIPATION

Stakeholder and public participation was encouraged and received throughout the development of this TMDL. ADEQ held two public meetings in Safford, Arizona, the first on February 21, 2007 to introduce the Gila River TMDL project and subsequently on April 8, 2009 to present findings and results after sampling and analysis was complete. Stakeholders and interested parties contacted throughout the project timeline included the Gila Watershed Partnership, Safford District of the BLM, Franklin Irrigation District, Greenlee County, Phelps Dodge (now Freeport-McMoRan), Natural Resource Conservation Service – Safford Office, U.S. Geological Survey, and the University of Arizona Cooperative Extension Office in Solomon. Public comment was invited for a 45 day period after the TMDL was submitted to the Arizona Administrative Review. Copies of the final TMDL will be provided to land management agencies including the A-S NF, the GNF, and the Safford and Las Cruces Districts of the Bureau of Land Management.

As the TMDL addresses water quality issues that have interstate implications, collaboration and interaction was solicited throughout the sampling and writing process of the TMDL with the New Mexico Environment Department.

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