2012 Upper Roaring Fork River Aquatic Life Use Assessment

S.K.Mason Environmental, LLC

SUBMITTED: 12/12/13

A Project of The:

ROARING FORK WATERSHED PLAN

Prepared For:

ROARING FORK CONSERVANCY

PO Box 3349
Basalt, CO 81621

Prepared By:

S.K.Mason Environmental, LLC

PO Box 1524
Carbondale, CO 81623

And:

Timberline Aquatics, Inc.

155 West Harvard, Suite 302
Fort Collins, CO 80525

Acknowledgements

Roaring Fork Conservancy would like to thank all partners who contributed to this work in 2012. Funding for this report was provided by Pitkin County Open Space and Trails and City of Aspen. Macroinvertebrate sorting, identification and analysis was performed by Timberline Aquatics, Inc. S.K.Mason Environmental, LLC conducted macroinvertebrate and stream discharge data collection. Reports compiled by S.K.Mason Environmental, LLC, Roaring Fork Conservancy, and Timberline Aquatics, Inc.

Table of Contents

Summary

Stakeholders with an interest in water quality conditions on the segment of the upper Roaring Fork River near Aspen include Colorado Department of Health and Environment (CDPHE), Pitkin County, City of Aspen, Aspen Consolidated Sanitation District, and Roaring Fork Conservancy (RFC). In September of 2012, the Roaring Fork Conservancy, in partnership with City of Aspen and Pitkin County, initiated benthic macroinvertebrate sampling at seven locations near Aspen. This effort compliments past and ongoing water quality monitoring at multiple sites on the upper Roaring Fork by CDPHE Water Quality Control Division (WQCD), RFC, and Colorado Riverwatch volunteers.

In 2011, RFC conducted an extensive basin-wide macroinvertebrate sampling effort. This effort increased existing datasets for several long-term sites, and provided baseline conditions for many previously unsampled sites in the watershed. Subsequently, biomonitoring took place at seven sites on the Upper Roaring Fork River in 2012. Benthic macroinvertebrate communities were sampled and assessed using Colorado's Multi-Metric Index (MMI) and several additional metrics. Scores displayed a clear trend of increasing stress and disturbance from the upstream sites to the most downstream site. MMI scores identified *attainment* of Colorado Water Quality Control Division standards for aquatic life use at the upper five sites, but the lowest two sites near the City of Aspen rated as *impaired*. Impaired scores echoed 2011 sampling results from the Roaring Fork River near Slaughterhouse Park and continue to support the State's 2012 Provisional 303(d) listing of the segment below Hunter Creek.

The MMI assessment methodology does not identify specific causes of impairment; low scores indicate a general stress to macroinvertebrate communities from one or more sources. Suspected stresses to the Roaring Fork in Aspen include regularly occurring summer flow impairment from transbasin and local diversions, and the spectrum of effects associated with urbanization including alteration or destruction of riparian habitat, physical channel alteration, stormwater runoff, and others. In addition, the Roaring Fork River in Aspen may continue to be impacted by legacy effects of past land use practices or pollution. In general, the downstream negative trend in site MMI scores is spatially correlated with increasing flow depletion, urbanization and episodic stormwater inflows. Targeted investigation into these potential disturbances and associated pollutants may help elucidate the reasons for poor macroinvertebrate conditions observed near the City of Aspen.

Based on MMI scores, stream conditions in the James H. Smith and North Star Open Space parcels adequately supported aquatic life. Although previous assessments at these sites are in conflict regarding the geomorphic stability of the area, the presence of healthy aquatic communities indicated that aggressive management actions to improve macroinvertebrate populations may currently be unwarranted.

Importantly, results from this study do not constitute a legal declaration of aquatic life use attainment or impairment on the Roaring Fork River; only the CDPHE may make such designation. Sample results are shared with the Water Quality Control Division to aid their surface water assessment mandate. Under the agency's listing methodology, a segment may be provisionally listed based on one failing sample. However the State may choose to review all other relevant data concerning a particular stream segment before final determination of impairment and 303(d) listing.

1. Introduction

1.1 Purpose and Scope

In 2012, Roaring Fork Conservancy (RFC) conducted biomonitoring at seven sites in the Upper Roaring Fork River to better understand aquatic life conditions in benthic macroinvertebrate communities. Three of the sites were located near the North Star Open Space Parcel (OSP) and four sites were located near the City of Aspen (Figure 1). Plans to revisit the Pitkin County's 2000 North Star Resource Management Plan and 2001 James H. Smith North Star Open Space Interim Management Plan provided motivation for this work. Additionally, the City of Aspen's Stormwater Management Program expressed interest in evaluating macroinvertebrate community condition in relation to stormwater outfalls, waste water treatment outfalls, major streamflow diversion points, and significant tributaries. City of Aspen and Roaring Fork Conservancy hope to better-understand the spatial extent of impaired conditions related to 303(d) listing of the Roaring Fork River below Hunter Creek.

The work described here included a macroinvertebrate community health assessment and collection of ancillary stream flow and substrate data to aid interpretation of results. This effort complimented previous work focused on assessing the condition of aquatic ecosystem health in the Roaring Fork River near the City of Aspen, helped characterize the geographic distribution of impairment on the Roaring Fork River, and provided an assessment of macroinvertebrate community health during a notable low-flow year. Specific questions investigated by this work include:

1. Does 2012 data continue to support the existing provisional 303(d) listing for the upper Roaring Fork River?
2. How does macroinvertebrate community health change with changing land use (i.e. urbanization) near the City of Aspen?
3. Does the spatial arrangement of macroinvertebrate health impairment correspond to suspected point- or non-point source impacts or stressors?
4. What sampling locations are needed to efficiently but adequately detect aquatic life use impacts on the upper Roaring Fork River?

1.3 Project Area Description

This section is not intended as an exhaustive biological and physical description of Upper Roaring Fork River. That information is available at www.roaringfork.org/publications or by direct request from the Roaring Fork Conservancy. Detailed scientific descriptions of both the project area and the entire watershed are provided in the 2012 State of the Roaring Fork Watershed Report (Clarke et al. 2008) and the stream and riparian inventories completed in 2007 for the Stream Health Initiative (Malone and Emerick 2007).

Geology and Hydrology

The upper Roaring Fork River extends northwest from the Continental Divide at Independence Pass downstream to Aspen. The sub-watershed is designated by the 10-digit Hydrologic Unit Code (HUC) 140100040106. Above the confluence with Castle Creek, it drains an area of 154 square miles, with elevations ranging from 7,800' to over 14,000' (USGS StreamStats). Granitic rocks underlie most of the sub-watershed. In the lower part of the sub-watershed, glacial action during the late Pleistocene Epoch (ending about 11,000 years ago) formed a wide, low-gradient valley. Glacial retreat left deep deposits of glacial outwash important in controlling stream and riparian habitat characteristics. On flat alluvial plains, the stream channel developed a sinuous pattern due to low gradient and deep soil profiles. Meander scars indicate the stream's historic highly sinuous shape. Wetlands occurred across much of the valley floor due to shallow groundwater discharge from adjacent slopes and meandering nature. As the Roaring Fork River enters downtown Aspen, the gradient increases and the riverbed is comprised of much larger cobbles and boulders. The channel is more confined below steep-walled banks. In many areas in Aspen, urban and residential development extends to the stream edge, while in other locations the stream is buffered by an intact riparian zone and little floodplain development.

The magnitude, frequency, duration, and year-to-year variation in the natural flow regime has been dramatically altered in the sub-watershed. The combined impact of the transmountain and inbasin diversions (including the senior 1904 Salvation Ditch diversions and several smaller inbasin diversions such as the Wheeler Ditch owned by the City) creates low flows in the late summer and early fall. Peak flows in the spring are also largely decreased, reducing the natural channel-scouring effects and overbank flooding of spring runoff. There is one active stream gage within the study area, which began operation in 1964.

1.3 Human Setting

Protected Lands and Conservation Areas

A majority of the Upper Roaring Fork sub-watershed resides within the White River National Forest. A large portion of the headwaters flow out of federally designated wilderness areas, either in the Hunter-Fryingpan or Collegiate Peaks Wilderness. There are also several protected open space parcels along the Roaring Fork River. Pitkin County Open Space and Trails has management plans in place for two of these properties. Together, the North Star Nature Preserve (North Star) and the James H. Smith North Star Open Space (James H. Smith) total almost 300 acres of protected open space (Pitkin County, 2000 and 2001). Each has experienced various levels human impacts through their former tenure as ranching lands and hayfields. Today, they are managed solely for conservation values including wildlife habitat and limited recreation. The upper portion of the project reach flows through these two protected areas. Further upstream, the Aspen Center for Environmental Studies (ACES) also holds sparsely developed parcels contiguous to James H. Smith

Urbanized Areas

Aspen occupies an area of four square miles, and the Urban Growth Boundary increases this footprint to almost eight square miles. The Roaring Fork flows through the city limits for approximately 4.4 miles along which the condition of the river corridor ranges widely. On some reaches below Hunter Creek, high-quality riparian areas exist. Above the Mill Street Bridge, significant channel alteration including straightening and bank armoring exists, coupled with severely degraded or non-existent riparian areas. These mixed conditions, shared by many urban streams, commonly occur in communities that grew and expanded over a long period of shifting social values towards development, rivers, and human relationships with natural systems.

Riparian Conditions

The Stream Health Initiative (SHI) (Malone and Emerick 2007) inventoried riparian and in-stream habitat throughout the Roaring Fork Watershed. This report classified riparian zone habitat in the James H. Smith parcel as *High Quality* to *Slightly-Modified*. Riparian zones in the North Star parcel were rated as *Severely Degraded* due to channel straightening and widespread destruction of riparian vegetation. A 2011 geomorphic assessment by Miller Ecological Consultants strongly disagreed with this assessment of the North Star segment, concluding instead that the current channel location and plan form has been present at least since the time of settlement in Aspen during the late 19th century. The SHI inventory characterized riparian zones on stream reaches near the Aspen Club as *Moderately Modified*, reaches from the upstream Highway 82 crossing to near Mill Street as *Severely Degraded*, and the segment extending from Mill Street Bridge to Castle Creek as *Slightly-Modified* to *High Quality*. Modification or degradation typically resulted from partial or complete destruction of riparian vegetation to due development, or channel alteration via bank armoring, straightening, or other channel simplification.

1.4 Regulatory Setting

Clean Water Act

The State of Colorado is authorized by the U.S. Environmental Protection Agency to administer the Clean Water Act (CWA). The Colorado Department of Public Health and Environment (CDPHE) carries out this responsibility. Under the CWA, all waters are classified according to existing or potential beneficial uses, and those that fail to meet chemical or biological standards assigned to a given use are legally designated as *impaired*. These streams comprise the 303(d) list, referencing the section of the Clean Water Act where the requirement is codified. In Colorado, the 303(d) list is biennially published as Water Quality Control Division (WQCD) Regulation 93. 303(d)

listing triggers certain regulatory responsibilities by WQCD. Causes of impairment must be determined where possible, and action plans such as Total Maximum Daily Loads (TMDL) may be developed to move impaired waters towards attainment of beneficial uses.

The overwhelming majority of previously collected macroinvertebrate samples from the Roaring Fork River indicated use attainment. One site, a WQCD site in Aspen city limits at Cemetery Lane Bridge (WQCD site 12783: *Roaring Fork River below Aspen,* locally known as 'Slaughterhouse Park'), produced scores indicating impairment in 2011, resulting in a provisional 303(d) listing of the segment extending from Hunter Creek to Brush Creek. The provisional listing of the Roaring Fork River indicates that causes of impairment remain unclear. For provisionally listed water bodies, WQCD endeavors to cooperatively undertake additional water quality monitoring and assessment with interested stakeholders. The general goal is to make a final determination of sources of impairment within 10 years of provisional listing (WQCD 2011).

Instream Flows

An instream flow right (ISF) of 32 cfs exists on the Roaring Fork River from Difficult Creek Campground to the confluence with Castle Creek. ISF rights are non-consumptive water rights designated between two specific points to maintain a minimum in-channel flow for the preservation of the natural environment. An ISF may only be held by the Colorado Water Conservation Board (CWCB). The instream flow right on the Roaring Fork is often not met because it is junior to the Independence Pass Transmountain Diversion System (IPTDS) water rights and to many of the in-basin diversions including the Salvation Ditch above town.

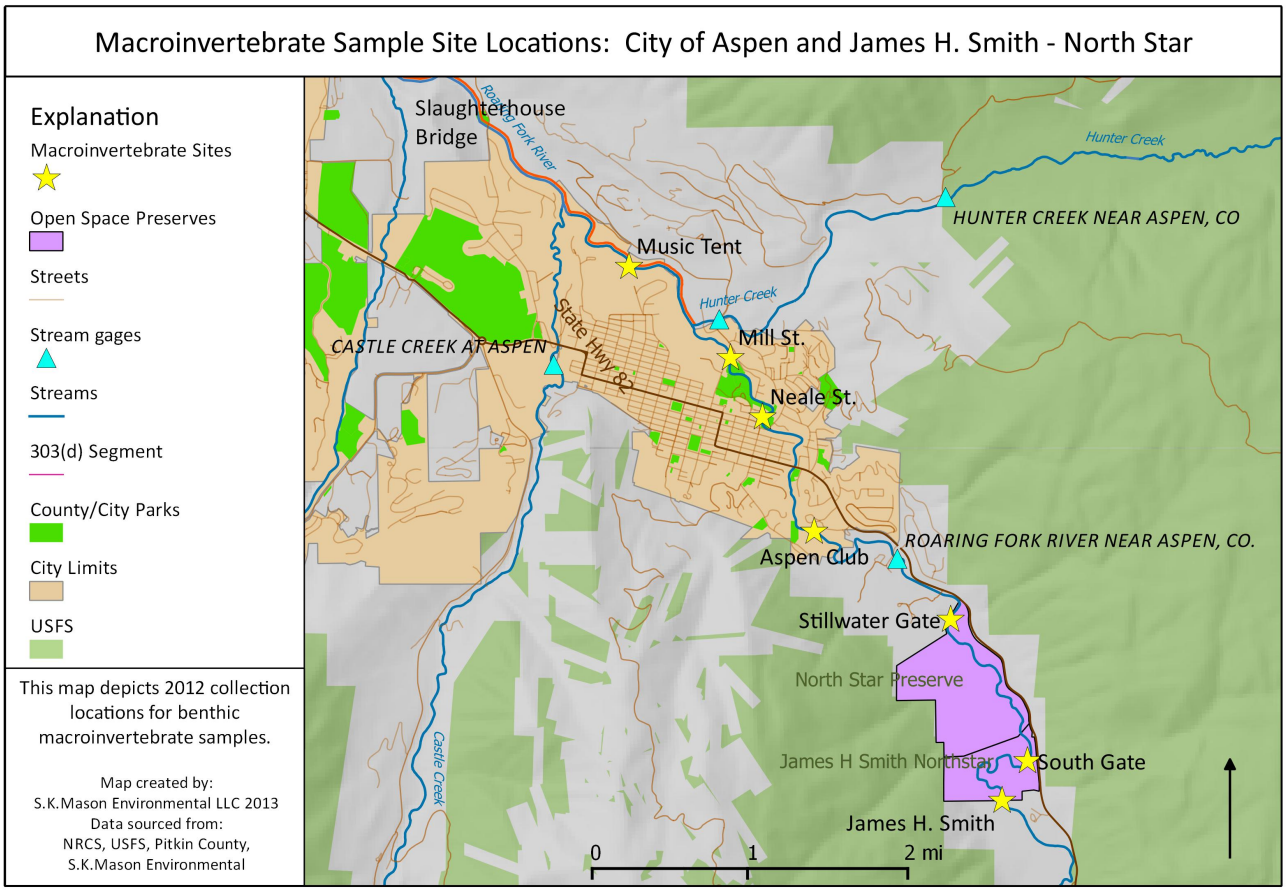
2. Sampling Locations

Sites were selected within Pitkin County Open Space and Trail properties and throughout Aspen to bracket various major land uses and potential point source influences in the watershed, as well as identify any potential gradient in stream conditions (Figure 1, Table 1). Previous macroinvertebrate data for the Upper Roaring Fork River is reported for one of these sites, Mill Street Bridge (WQCD ID 12784, River Watch ID 770), and included in RFC's 2012 report *A Review of Aquatic Life and Stream Health in the Roaring Fork Watershed* (RFC 2012) and in Miller Ecological Consultant's 2011 report *Final Report: Evaluation of River Health Roaring Fork River near Aspen, Colorado* (Miller, 2011).

Table 1. Sample site descriptions

Site Name	WQCD ID	Description	Latitude	Longitude
James H. Smith	NA	Upstream of former Barn site, near Herron preserve	39.16217	-106.792118
South Gate	NA	At North Star and James H. Smith Parcel boundary	39.165194	-106.790436
North Trail Gate	NA	At North Trail Access (Stillwater section float takeout)	39.175640	-106.797070
Aspen Club	NA	Upstream of footbridge behind tennis courts	39.181925	-106.809645
Neale St.	NA	Below Neal St. Bridge at Herron Park	39.190091	-106.814413
Mill St. Bridge	12784 (770)	Downstream of Mill St. Bridge	39.194324	-106.817359
Music Tent	NA	Above footbridge spur from Rio Grande Trail	39.20084	-106.826708

Figure 1. Site location map



3. Methods

3.1 Benthic Macroinvertebrates

Benthic Macroinvertebrate collection utilized a 0.9 ft² Surber Sampler. Samples were collected in August/September 2012 when the best representation of the aquatic insect community is found. At each site, field personnel composited a total of 10 stream bottom samples. This collection methodology is based on White River National Forest macroinvertebrate sampling protocols (Grove 2012) and developed in conjunction with RFC and Timberline Aquatics, Inc. of Fort Collins, CO. It is considered semi-quantitative and admissible for submission ot the State during WQCD data calls. All samples were preserved in ethyl alcohol during transport to the laboratory for sorting and identification. Timberline Aquatics, Inc. counted and identified macroinvertebrate samples and calculated primary and secondary metrics. S.K.Mason Environmental, LLC and RFC provided further analysis and interpretation of results in the context of site-specific concerns on the study reach.

Primary Macroinvertebrate Metrics

Multi-Metric Index (MMI): In the fall of 2010, the CDPHE published specific guidelines for benthic macroinvertebrate sampling and analysis using an MMI (CDPHE 2010). By utilizing 5-6 equally weighted metrics, the MMI combines measures of diversity, abundance, pollution tolerance, community structure, and other factors to generate a normalized score of 0-100 for each sample. Scores may then be compared to reference threshold scores for one of three generalized Colorado biotypes: Transition, Mountains, and Plains & Xeric. Streams in the Roaring Fork watershed are either Transition or Mountain (Biotype 1 or 2). Biotype 1 includes streams in the Transitional Zone between higher elevation and low elevation habitats. Sites within Biotype 2 are higher gradient,

mountain streams. For the two Roaring Fork biotypes, Table 2 displays the range of scores indicating either attainment or impairment for Class I - Cold Water Aquatic Life Use. Timberline Aquatics performed identification and index analysis for macroinvertebrate samples at the firm's facility in Fort Collins, CO.

Table 2. MMI scores for Attainment and Impairment in the two biotypes represented in the Brush Creek Watershed.

Biotype	Attainment Threshold	Impairment Threshold
Transition (Biotype 1)	>52	<42
Mountains (Biotype 2)	>50	<42

Metric scores that fall between the thresholds for attainment and impairment require further evaluation using two auxiliary metrics, the Shannon Diversity Index (Diversity) and Hilsenhoff Biotic Index (HBI), in order to determine if the site is attaining uses or impaired. Auxiliary scores must be less than the HBI threshold *and* greater than the Diversity threshold to achieve an "attainment" designation.

Table 2. Auxiliary metric scores applied to determine Attainment/ Impairment for those sites that initially score in the 'grey zone'.

Biotype	HBI	Diversity
Transition (Biotype 1)	<5.4	>2.4
Mountains (Biotype 2)	<5.1	>3.0

MMI scores detect alteration of biological communities resulting from general stressors such as chemical pollution, habitat impact or destruction, and altered flow regimes. However, MMI scores do not determine a specific stressor or cause. When impairment is determined, sources and causes can be explored with a suite of other tools including additional macroinvertebrate indices, and targeted water quality investigations (WQCD 2011).

Hilsenhoff Biotic Index (HBI): Most of HBI's value lies in detection of organic pollution, but it has also been used to evaluate aquatic conditions in a variety of other circumstances. Although the value indicating a certain water quality rating may vary among regions, comparison of the values produced within the same stream systems should provide information regarding sites impacted by nutrient enrichment. Values for the HBI range from 0.0 to 10.0, increasing as water quality decreases.

Shannon Diversity (Diversity): Diversity values are used to detect changes in macroinvertebrate community structure. In unpolluted waters, Diversity values typically range from 3.0 to 4.0. In polluted waters this value is generally less than 1.0.

Additional Metrics

In order to assist in the evaluation of aquatic life in the study area, Timberline Aquatics compared additional individual metrics among sites. These individual metrics were selected because they are widely used in western streams and could provide additional value. A description of each is provided below.

Taxa Richness: Taxa Richness is used to provide an indication of habitat adequacy and water quality. Taxa Richness, or the total spectrum of taxonomic groups present at a given site, will generally decrease when exposed to declining water quality or habitat degradation (Resh and Jackson 1993). The Taxa Richness measurement is reported as the total number of identifiable taxa collected from each sampling location. This metric is also utilized as part of the Biotype 2 MMI calculation.

Ephemeroptera Plecoptera Trichoptera (EPT): The EPT index is based on the assumption that the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) are generally more sensitive to pollution and environmental stress than other benthic macroinvertebrate orders (Lenat 1988). The value for this metric will naturally vary among river systems, but it can be an excellent indicator of relative disturbance within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Clinger Taxa: This metric is included in both the Biotype 1 and Biotype 2 MMI calculations. Excessive sedimentation, rapid changes in discharge, or excessive algal growth can cause a reduction in this metric value (Hughes & Brossett 2009).

Insect Taxa: The number of insect taxa was used as an individual evaluation tool in this study because it has been found to be effective at detecting stress in Colorado mountain streams (Colorado Department of Public Health and Environment 2010). Insect Taxa is reported as a total count of insect taxa at each site. It is expected that the number of insect taxa will decrease as a response to disturbance. Insect taxa are generally considered more sensitive to disturbance than non-insect taxa..

3.2 Discharge

Discharge was measured concurrently with macroinvertebrate data collection. An ancillary study (Snapshot Assessment of the Roaring Fork Watershed) documented longitudinal patterns in stream flows in the Upper Roaring Fork for the Public Council of the Rockies and Roaring Fork Conservancy (S.K.Mason Environmental, LLC, 2013). For both studies, discharge was measured manually using the velocity-area method described in *USGS Techniques and Methods 3-A8* (Turnipseed and Sauer, 2010) with a handheld Sontek Flowtracker® Acoustic Doppler Velocimeter.

3.3 Substrate

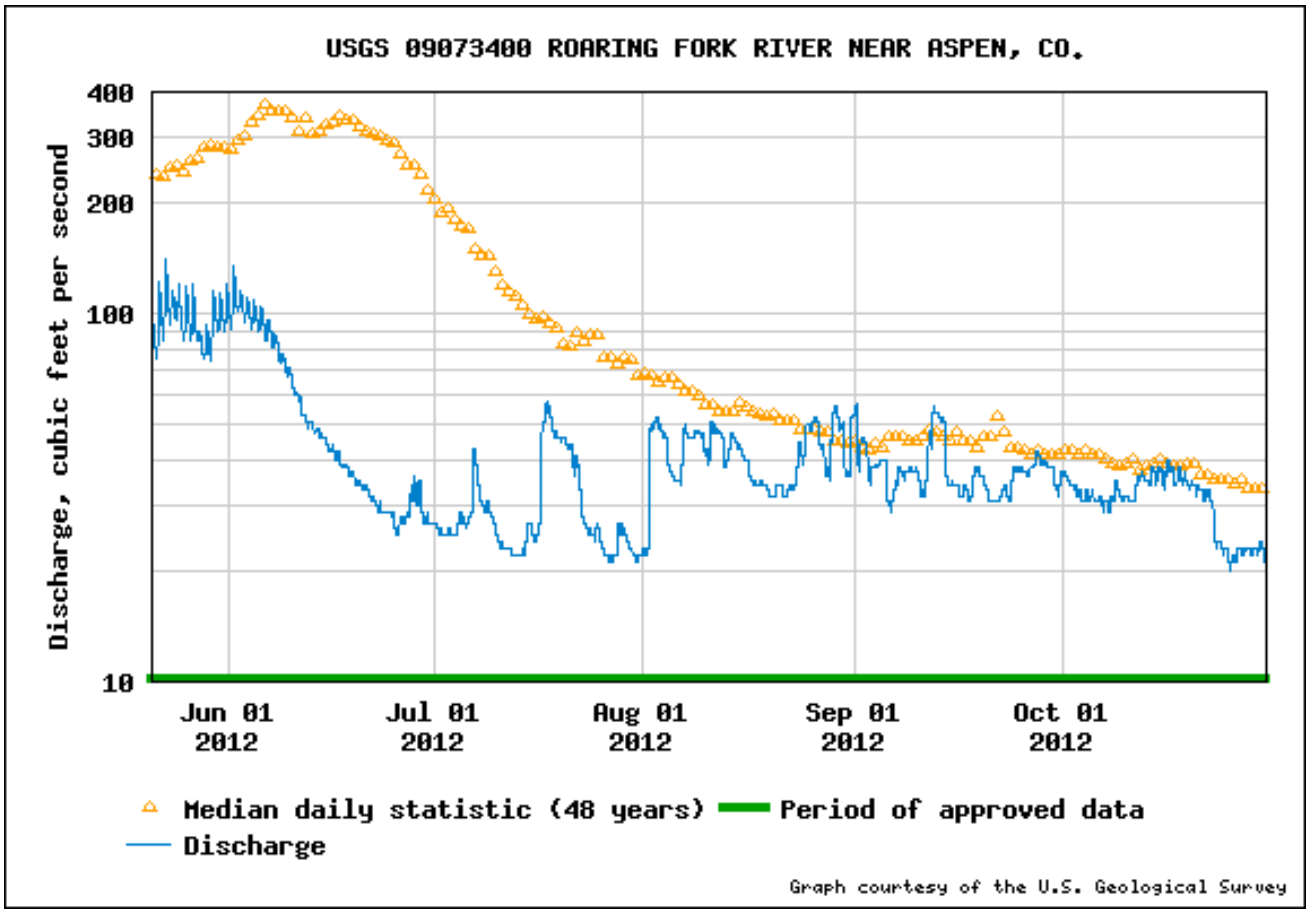
Field personnel used a modified Wolman Pebble Count (Wolman 1954) to characterize substrate size distributions at each sampling location. Pebble counts provided useful site characteristic metadata to help verify that sample collection occurred in appropriate riffle habitat exhibiting a range of substrate sizes (i.e. high habitat diversity). Appendix B contains tabulations of pebble count data.

4. Results

4.1 Discharge

The 2012 Water Year (October 1st 2011 to September 30th 2012) was characterized by low snowpack, a warm spring with early runoff, and statewide drought—conditions contributing to low streamflows in the upper Roaring Fork watershed. Peak runoff at the gage nearest to the study reach (located below the three North Star area sites but above the Aspen town reach) occurred the first week of June and recorded a low of ~12 cfs in July and August (Figure 2). Due to significant senior water diversion rights below the gage at the Salvation and Wheeler ditches, which are in the vicinity of the Aspen Club sampling site, the lower portion of the study reach faced moderate to severe flow depletion, including near-complete dewatering the last week of July when discharge measured at Mill St Bridge approached 6 cfs. Diversions in the upper Roaring Fork were also affected by a call from a large senior water right in the Grand Valley area in western Colorado known as the Cameo Call. When this call came on, diversions from the Roaring Fork headwaters through the IPTDS were curtailed, allowing more water to flow downstream towards the Colorado River. This set the stage for an ironic situation; as water stress increased on downstream diverters, pressure on instream flows in the Upper Roaring Fork actually lessened. The effect of the Cameo Call is easily seen in mid-July and again from the beginning of August through October (Figure 2), when flows increased to between 30 and 50 cfs for nearly 3 months.

Figure 2. Upper Roaring Fork hydrograph, June-September 2012



While the USGS gauge near Aspen provided a picture of flows entering the city, it did not adequately capture what happened along the town reach itself, due to numerous diversions and tributary inputs. In 2012, a concurrent effort by RFC and Public Counsel of the Rockies captured longitudinal discharge profiles of streamflow in a downstream direction to characterize these impacts (Figure 3). That information is fully reported in "Snapshot Assessment of the Roaring Fork Watershed" (S.K.Mason Environmental, LLC, 2013). The reach between the Salvation Ditch diversion point and Castle Creek regularly experienced the lowest flows. Macroinvertebrate sites 4-7 were all located in this segment (Aspen Club, Neale St Bridge, Mill St Bridge, Music Tent). The Mill St site faced the most severe flow impairments over the course of the summer.

Overall, flows for 2012 were consistently below historic averages. Stream discharge fluctuated significantly in the time prior to macroinvertebrate sampling depending on when water was being diverted by the Independence Pass Transmountain Diversion System. By the sampling date, the Cameo Call relieved this stress and provided increased flows throughout the study reach. Table 3 records the actual flows for each site on the dates of sampling.

Figure 3. Longitudinal flow profiles, Aspen town reach 2012. Approximate locations of select macroinvertebrate sample sites are shown by green lines. The profile shows that the most de-watered section of the river extends from below the Salvation and Wheeler ditches to the confluence with Castle Creek. This figure plotted longitudinal changes in streamflow under the assumption that changes in discharge occur at discrete locations where the river experiences tributary inflows or diversions.

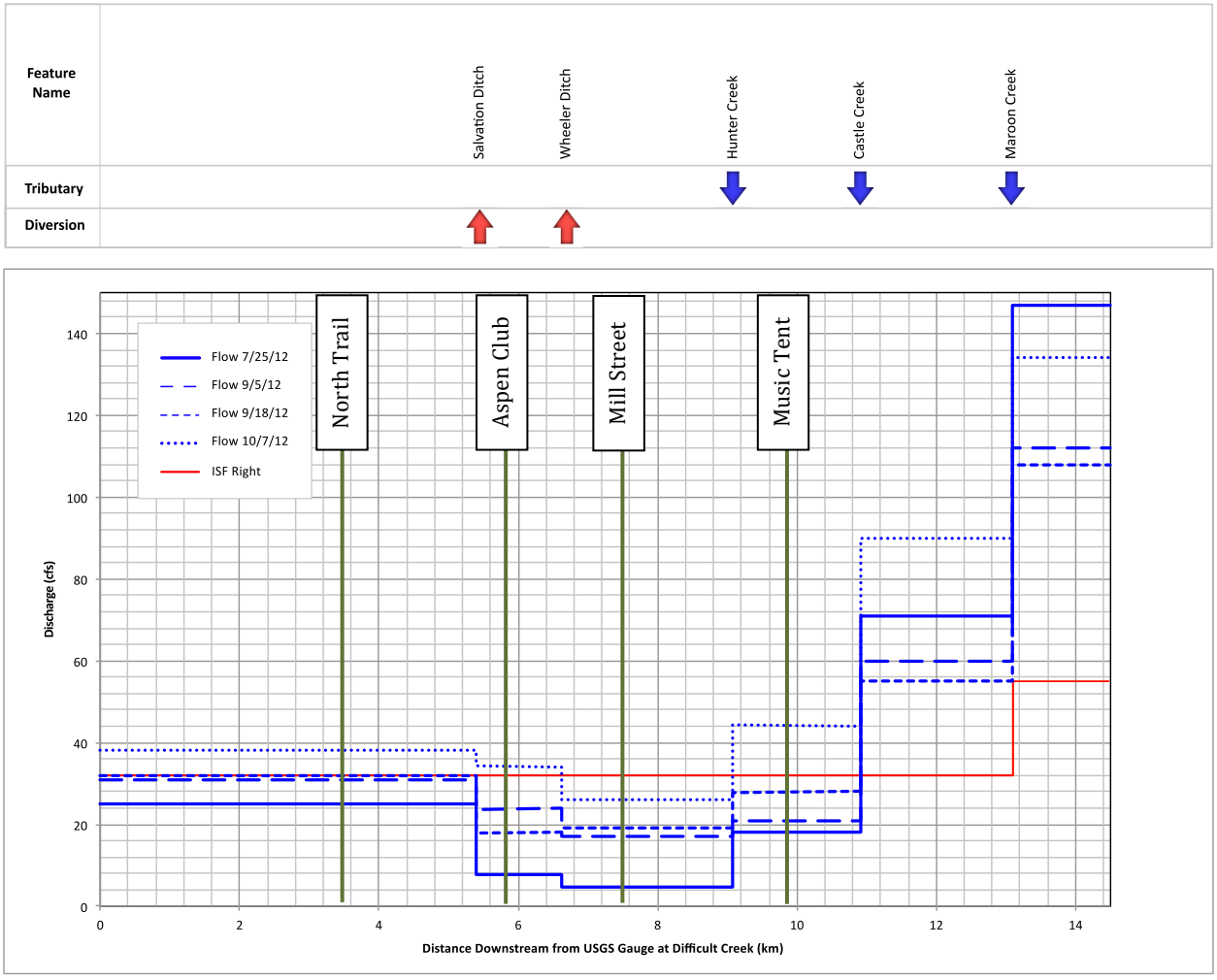


Table 3. Discharge on sampling dates

	James H. Smith	North Gate	North Trail Gate	Aspen Club	Neal St	Mill St	Music Tent
Date	8/30/12	8/30/12	8/30/12	9/6/12	9/6/12	9/6/12	9/6/12
Flow (cfs)	51	51	51	24	13	17	21

3.2 Macroinvertebrates

MMI Scores

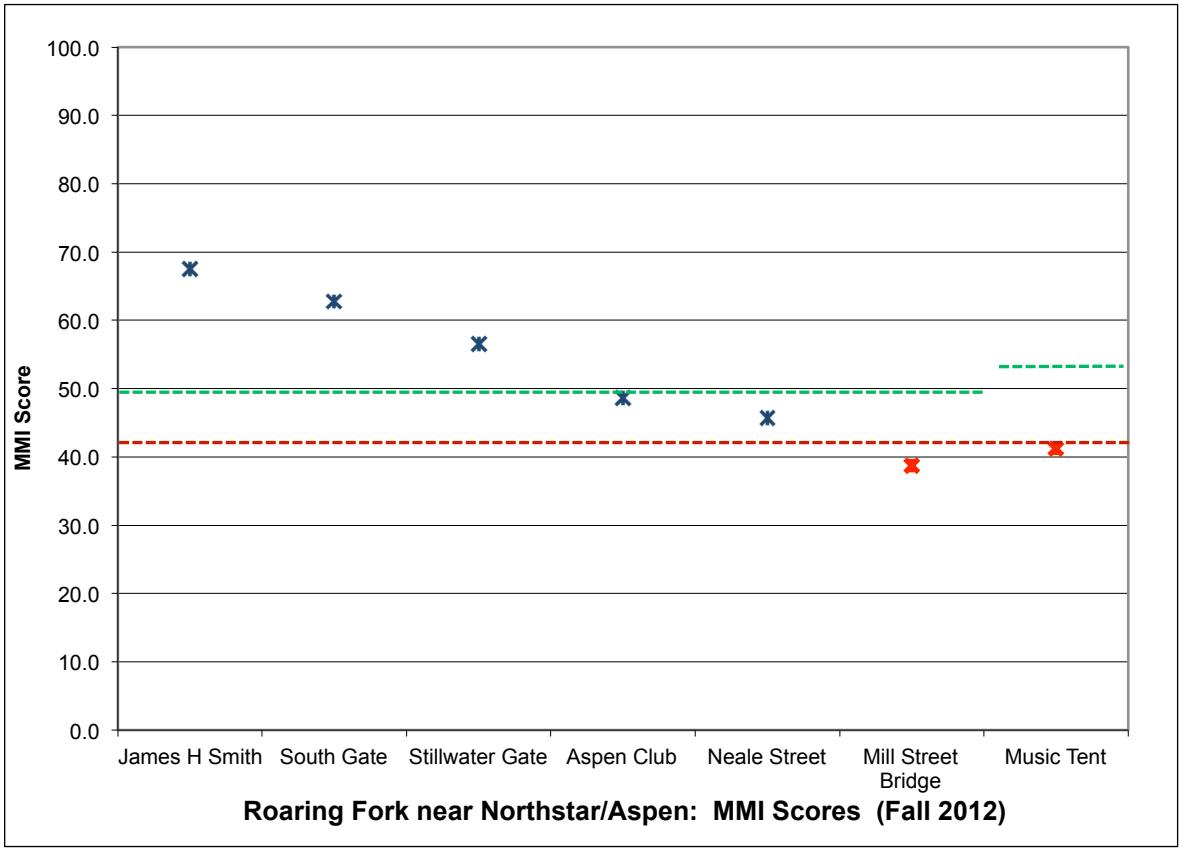
MMI scores are the primary aquatic life data type used in state water quality regulation. However, several additional metrics were employed to assist in this evaluation. These are discussed in the following section. MMI results were split between use attainment and impairment at some sites, with several scoring very near the threshold for use attainment (Table 4, Figure 4). Generally, site scores declined in a downstream direction. Individual sites are discussed in more detail in Appendix 1. The three sites in the protected open space areas (James H. Smith and North Star sites) received MMI scores surpassing the threshold for attainment of aquatic life use. Two sites in the upper portion of the reach flowing through the City of Aspen (Aspen Club and Neale St Bridge) produced MMI scores that fell within the "grey zone" between attainment and impairment. Scores in the grey zone required auxiliary metric calculations to determine final classification, and both of the sites moved to attainment based on HBI and Shannon Diversity scores. The lowest two sites (Mill Street Bridge and Music Tent) scored below the impairment threshold, indicating impaired aquatic life conditions.

Sample sites in the study area spanned two biotypes, with the top six sites in Biotype 2 (Mountains) and the lowest site at the Music Tent in Biotype 1 (Transition). Scores show wide variation among sites; however a clear downstream trend towards increasing impairment is evident (Figure 4). Again, the MMI does not identify individual causes of impairment; scores detect alteration of biological communities resulting from general stressors or disturbances. When impairment is determined, WQCD recommends that sources and causes can be explored with a suite of other tools including additional macroinvertebrate indices, and targeted water quality investigations (WQCD 2011).

Table 4. MMI and auxiliary metric scores by site. MMI scores which did not meet the CDPHE standards for attainment of aquatic life use are reported in red, attaining scores are green . Auxiliary metrics for those sites with non-attainment scores are also reported in red (impaired) or green (attainment).

Area	North Star			Town of Aspen			
Biotype	Biotype 2						Biotype 1
Metric	James H Smith	South Gate	North Trail Gate	Aspen Club	Neale St	Mill St	Music Tent
Taxa Richness	33	34	26	34	27	27	22
EPT	14	15	13	9	6	8	6
Clinger Taxa	11	11	9	10	7	6	8
Insect Taxa	28	31	22	30	22	25	20
Diversity	3.87	3.86	3.03	3.45	3.49	2.95	2.96
HBI	3.72	4.36	2.71	4.05	3.16	3.12	3.29
MMI	**67.5**	**62.8**	**56.6**	**48.6**	**45.7**	**38.7**	**41.2**

Figure 4. MMI scores, 2012. The green dashed line represents aquatic life use Attainment, the red represents Impairment. The change in the attainment threshold at the Music Tents site reflects the shift from Biotype 2 to Biotype 1.



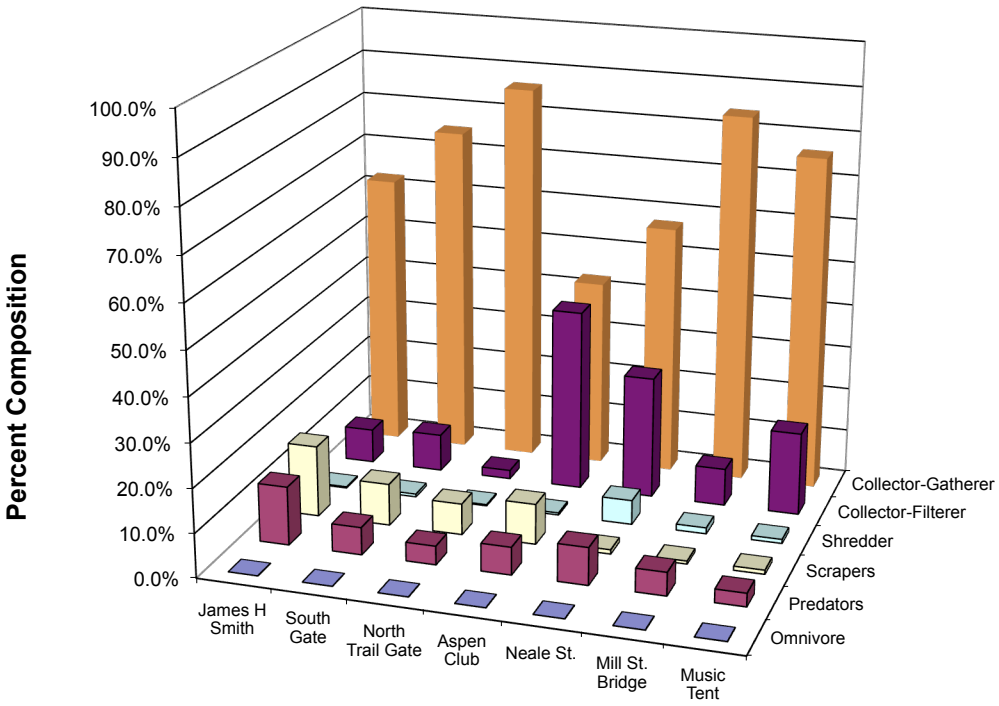
Functional Feeding Group Composition

Results from functional feeding group analysis in the Aspen study area supported the results provided by the MMI and other individual metrics (Table 5, Figure 5). In general, the proportion of resilient taxa increased in a downstream direction in the Aspen study area in 2012 (Table 5, Figure 5). Resilient taxa are more tolerant to disturbances such as pollution. Increased proportions of collector-gatherers and decreased proportions of the more sensitive and specialized groups (shredders, scrapers, and predators) at the farthest downstream sites suggested increased stress or perturbation at those sites. Collector-Filterer groups formed a higher percentage of total populations in the lower town sites than the Open Space parcel sites. The differences in Predator and Shredder taxa between the upstream sites and downstream are an important component driving score differentials. Functional feeding group analysis also reflected a slight improvement in aquatic conditions at the Roaring Fork at Music Tent site; however, the low proportions of shredders and scrapers still indicated disturbance. Like MMI scores, a shift in macroinvertebrate feeding group structure throughout the two study areas (North Star and Aspen) suggests that increased stress to aquatic life occurred in a downstream direction.

Table 5. Relative abundance of functional feeding groups. Shredders and scrapers are considered sensitive taxa and make up a small proportion of the macroinvertebrate community at the lower three sites on the Roaring Fork River.

Sampling Area	North Star			Aspen			
Feeding Group	James H. Smith	North Gate	North Trail Gate	Aspen Club	Neale St.	Mill St. Bridge	Music Tent
Collector-Gatherer	62.4%	75.1%	86.4%	42.8%	57.2%	84.1%	76.3%
Collector-Filterer	7.8%	8.5%	2.0%	41.3%	27.8%	8.5%	18.8%
Shredder	0.3%	0.7%	0.3%	0.5%	5.6%	1.4%	0.9%
Scrapers	16.2%	9.5%	7.1%	9.2%	1.0%	0.7%	0.9%
Predators	13.3%	6.2%	4.2%	6.3%	8.5%	5.3%	3.0%
Omnivore	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 5. Functional Feeding Group composition by sampling location. Shredders and scrapers are considered sensitive taxa and make up a small proportion of the macroinvertebrate community at the lower three sites on the Roaring Fork River.



5. Discussion and Recommendations

5.1 Macroinvertebrate Scores

Biomonitoring refers to the systematic use of living organisms to evaluate the aquatic environment (Merritt et al. 2008). In recent years, biomonitoring has become an important tool in assessing the quality of rivers and streams (Plafkin et al. 1989, Barbour et al. 1999, Paul et al. 2005, Hawkins 2006). Biomonitoring programs that utilize benthic macroinvertebrates have advantages that are not realized by physical or chemical water quality monitoring alone (Ward et al. 2002). Through evolution and ecological processes, aquatic macroinvertebrates have become dependent on specific natural environmental conditions. Consequently, macroinvertebrate assemblages are influenced and altered by a wide range of environmental disturbances and/or pollution. Aquatic macroinvertebrates are used more than any other group of organisms to assess impacts from urban areas on aquatic life (Paul and Meyer 2001).

Results provided by consistent sampling practices and accurate identifications can provide valuable information regarding aquatic conditions. Sustained biological monitoring is essential to understanding the effects of long-term influences such as population growth, urban development, and changes in land-use practices (Likens and Lambert 1998, Voelz et al. 2005). Certain taxa can survive or even thrive in the presence of various contaminants, so it is often necessary to employ the use of several biotic indices (metrics) in the analysis of macroinvertebrate data. Bonada et al. (2006) found that the problems associated with individual biomonitoring tools (metrics) can be improved upon by using a multiple metric index (MMI).

Samples at seven sites established a fine resolution picture of aquatic life conditions on the Upper Roaring Fork River near the City of Aspen. Sites bracketed changing land uses, varying levels of instream flow depletion, and suspected water quality influences such as major stormwater outfalls. Results showed the creek attained use standards in 2012 above town in the James H Smith – North Star parcels. Conditions degraded as the river entered the more-developed downtown area. The final two sites at Mill Street and the Music Tent received scores indicating impairment from some cause or combination of multiple causes. The spatial arrangement of scores seemed to parallel increasing areas of urbanization and flow stress. Functional feeding group composition analysis further supported MMI scores. Collector-Filterer groups formed a higher percentage of total populations in the lower town sites than the upper sites in the open space parcels, which is not necessarily indicative of community stress; collector-filterers are moderately sensitive to disturbance. A large change can often be related to a change in food source from tributary or riparian inputs. However, little diversity and balance in feeding group compositions was evident at impaired sites, suggesting that one or more stressors prevented the normal development of community balance and function.

MMI scores cannot speak to a specific cause of impairment; rather they indicate the general presence of one or more perturbations to the stream that result in macroinvertebrate communities that are less functional or balanced than healthy reference streams. In this case, multiple stressors may contribute to stream impairment including: stormwater runoff from the dense urban core and/or heavily landscaped areas of downtown Aspen; physical channel alteration and riparian habitat destruction from years of urbanization; and heavily altered flow regimes from diversion, increased impervious surface area, and drought year flow stress. Considering that an existing macroinvertebrate sampling site at Slaughterhouse Park below the Castle Creek Confluence previously and consistently scored as impaired (RFC 2012), it appears that flow stress is not solely driving impairment to aquatic life in the lower reach.

These scores have regulatory importance to area stakeholders, as they confirm the appropriateness of the Roaring Fork's designation as a 303(d) listed water body below Hunter Creek to at least Maroon Creek. Previous MMI scores within the study area, and further downstream at Slaughterhouse Park/Cemetery Lane lend additional strength to this conclusion. In 2010 the Mill St Bridge Site was sampled by Miller Ecological Consultants (MEC 2010), scoring just above the MMI attainment threshold; however, individual metrics from that sampling event

indicated some form of impairment was likely affecting community numbers and composition. In 2011, Mill Street was again sampled by RFC (Roaring Fork WQCD Site ID 12784) and scored in the grey zone but moved to attainment based on the auxiliary metrics. Because the site consistently scored very near the threshold for impairment in previous sampling, a small amount of additional stress such as increased flow depletion may have been all that was required in 2012 to push the site towards an impaired designation. Additionally, Slaughterhouse Park (WQCD Site 12783) which is the next existing historical sample site downstream of the 2012 Music Tent site had 3 separate samples in 2011 which all scored impaired ratings. When considered together, these scores continue to support an Impaired classification for the lower town reaches and confirm the state's 2012 Provisional 303(d) listing for the lower town reach from Mill St Bridge to at least Slaughterhouse Park.

5.2 Stress, Disturbance, and Macroinvertebrate Response

In the Aspen area, the Roaring Fork experienced varying phases of urbanization in the last century. Urbanization contributes numerous water quality effects through multiple pathways. In a review of the scientific literature covering streams in urban areas, Paul and Meyers (2001) found that researchers consistently linked increases in impervious surface areas to major alterations in flow regimes, as well as physical structure and habitat. Other major factors affecting water quality and aquatic life health result from the increased amount of pollution in urban runoff, which can rapidly transports nutrients, metals, pesticides, pathogens, and other contaminants into water bodies. These combined effects consistently result in a decline to species abundance and richness in perhiphyton, macroinvertebrate, and fish communities (Paul and Meyers 2001).

Urbanization increases the 'flashiness' of runoff, creating periodically intensive alterations to the local hydrologic regime. Rapid runoff also conveys multiple pollutants including sediment, landscaping chemicals, petroleum-based products, and metals. In linking urbanization to aquatic macroinvertebrate communities, Wang et al. (2003) found that increasing gradients of impairment positively correlated with percent impervious area in the watershed. Land uses in the riparian area were especially important to macroinvertebrate community index scores; heavily developed watersheds which maintained functional riparian areas displayed relatively healthier macroinvertebrate communities.

The upper Roaring Fork in Aspen also faces intensive alteration of natural flow regimes from local and transbasin diversions. In a large-sample study of the effects of diversions on sediment and hydraulic regimes on mountain streams in Colorado and Wyoming, Baker et al. (2011) found that reaches downstream of diversions held higher amounts of fine sediment and more slow-velocity habitats. Aquatic macroinvertebrates native to mountain areas in Colorado are adapted to high gradient streams and clear water; they may fair considerably poorer in such altered conditions if habitat and food sources are choked by sedimentation or otherwise altered by low flow effects. In an experimental dewatering of a wetland and associate stream habitat, researchers observed an incremental negative response to a gradient of dewatering stress; however some macroinvertebrate communities were able to bounce back relatively quickly after rapid rewetting (Muehlbauer et al. 2011). Low flows may also contribute to more rapid heat gain in the water column during summer, with subsequent heat stress to sensitive fish taxa.

Although the use of macroinvertebrate community analysis to indicate water quality and general stream degradation is well established, research linking degradation to specific causes lags. In considering land use influences on stream ecosystems Allan (2004) identified several factors contributing to this difficulty, including 1) co-variation between human uses and natural landscape gradients; 2) multiple mechanisms simultaneously exerting water quality influences; 3) non-linear responses of species and ecosystems to stress and disturbance; and 4) separating modern-day influences from legacy/historical impacts. Each of these constitutes a potential issue in linking aquatic life conditions to specific stressors in the Aspen area. Because urbanization contributes stream impacts via multiple pathways; models which applied aggregate measures such as a watershed's percent impervious area or urban land area have met with more success (Allan 2004). At this time, macroinvertebrate community analysis is still best used as an integrative measure which speaks to general stress and disturbance in a stream, but falls short of identifying causes. WQCD's current use of MMI scores in statewide assessments reflects this reality by implementing a 'provisional' 303(d) designation until causes can be further explored.

5.3 Regulatory Implications

Provisional 303(d) listing implies that a stream is impaired by one or more pollutants, or non-human sourced pollution, however those causes are unknown. WQCD must take steps to identify causes and move 303(d) streams towards attainment of designated beneficial uses. Defined uses of the upper Roaring Fork include Aquatic Life Cold I, Recreation E, Water Supply, and Agriculture (WQCD 2012). Based on macroinvertebrate data from 2012 and earlier, the Roaring Fork below Hunter Creek to at least Slaughterhouse Park is not in attainment for Aquatic Life Cold I beneficial use standards. For water bodies which are provisionally listed, WQCD may cooperatively undertake additional water quality monitoring or further investigation and assessment with interested stakeholders to better determine impairment causes. The general goal is to make a final causal determination within 10 years of provisional listing (WQCD 2011).

Traditionally, the development of Total Maximum Daily Load (TMDL) allocations for pollutant loading follows 303(d) listing, and permitted dischargers on a stream reach may be targeted for load reductions. However, in regards to the Roaring Fork in Aspen, with no identified causes and relatively few easily identifiable point sources beyond the municipal wastewater treatment plants and select city stormwater outputs, the traditional work-flow for moving streams towards attainment may not be appropriate. Direct proportional linkages between depressed aquatic life and decreased flows, structural alteration, or urbanization remain difficult to quantify.

Aspen has invested heavily in updated stormwater control measures for some sections of the city, while runoff from other areas remains uncontrolled. Mill Street Bridge and the Music Tent sites both received failing MMI scores in 2012, and another downstream site, Slaughterhouse Park, has consistently scored poorly in the past. The Music Tent is below many of the city's major stormwater outflows. Mill St is below outflows from the new settling ponds and treatment wetlands at Rio Grande Park, but above the Jenny Adair Treatment Pond outflows. While the negative downstream trend in MMI scores visually correlates with the geographic distribution of stormwater loading, it does not identify stormwater as the primary stressor. Further targeted investigation to stormwater loading would be necessary to scientifically support any linkage between the two.

Modern zoning partially prevents excessive riparian zone and floodplain encroachment in new developments; older existing residential and public structures may still heavily encroach upon the stream. Although many of the stressors on the town reach such as increased impervious area, existing riparian zone destruction, and physical channel alteration may be irreversible; creative solutions for improving instream flows, enhancing habitat, continued improvement to stormwater controls, and rehabilitation of physically degraded reaches may all yield dividends in improved aquatic life health over time. Many of the sites scoring as *impaired* are initially in the grey zone or just below the threshold for attainment; multiple small improvements to stream conditions hold the potential to move sites towards attaining State standards.

5.4 Next Steps

Continued Biomonitoring

Long-term monitoring studies are essential for the evaluation of aquatic life in systems with increasing water demands or changes in land use practices (Likens and Lambert 1998, Voelz et al. 2005). Sustained biomonitoring studies also provide a better understanding of impacts from anthropogenic disturbances when compared to natural seasonal and annual variation in benthic communities. Macroinvertebrate sampling in 2012 served to extend the depth of existing data regarding aquatic life use attainment in the upper Roaring Fork River. Continued biomonitoring may occur at fewer locations to optimize program cost. As the length of the dataset increases, statistical comparison of community conditions with flow conditions may show a correlation between MMI scores and the drought conditions of 2012. Conversely, if no correlation exists then flow stress may potentially be ruled-out as a primary impairment stressor. Overall, extended monitoring can illuminate how conditions change over time, either towards improvement or increased degradation.

MMI scores for 2012 continue to support an 'impaired' designation for the segment below Hunter Creek to above Maroon Creek. Yearly sampling in the vicinity of Mill St Bridge down to Slaughterhouse Park is warranted, while a

more extended sampling interval of 3-5 years may suffice for ongoing monitoring of more pristine conditions in the James H. Smith – North Star area to ensure non-degradation of the resource. Recommended sites for continued monitoring on the town reach are at Slaughterhouse and Mill Street Bridge. In 2013, RFC sampled these two sites in conjunction with Colorado Parks and Wildlife's statewide River Watch program; MMI results are anticipated in early 2014.

- **Recommendation: Continued annual macroinvertebrate sampling at Mill Street and Slaughterhouse Park; conduct intermittent sampling of other sites on a longer rotating schedule.**

Flow impairments

The CWCB holds an instream flow right on the town reach for 32 cfs with an appropriation date in 1976. Many other water rights including the IPTDS diversions, Salvation Ditch, and Wheeler Ditch, are senior to the ISF. Cooperative agreements with local diverters hold potential to boost flows in the town reach, which may benefit aquatic life. For example, in June of 2013 the City of Aspen entered a 1 year "non-diversion" pilot agreement with the Colorado Water Trust to not exercise its full right at the Wheeler Ditch when flows on the town reach drop below 32 cfs. Altering diversion schedules from the IPTDS may prove more difficult in light of increasing Front Range water needs and the desire among state water providers to secure or firm-up existing sources in light of climate change and population growth (Driscoll 2011). Because the community of Aspen and Pitkin County have both identified recreation and natural values as important components to resource management decision making, working towards increased flows for aquatic life health may simultaneously satisfy multiple values and goals in the community.

- **Recommendation: Continue current efforts towards supplemental flows and local stakeholder agreements to augment instream flows.**
- **Recommendation: Develop more permanent 'drought year protocols' between area stakeholders that may be implemented when specific low-flow or stream temperature criteria occur.**

Targeted Water Quality Assessments

Once a stream segment is provisionally 303(d) listed, WQCD will cooperatively undertake additional water quality monitoring or further investigation and assessment with interested stakeholders to determine impairment causes. While existing baseline chemistry monitoring programs carried out by RFC, CDPHE, Aspen, and other area stakeholders provide information on long term average water quality conditions, they may miss important influences. Specifically, sampling regimes for stream chemistry and field parameters which occur on a 1x/month, quarterly, or high-flow/low-flow schedule may fail to observe important water quality influences with short durations. Stormwater runoff is one example of a water quality influence which may be missed by these standard monitoring regimes. Monitoring of stormwater runoff events can be logistically difficult and often very expensive. As a result, few entities may regularly or successfully implement such monitoring programs. However, flushes of metals, complex organics, or high TSS inputs may still contribute significant water quality degradation in many urban watersheds like Aspen. Additional water quality studies targeting a specific pollutant or process, rather than baseline monitoring, may shed further light on causes of macroinvertebrate community impairment.

- **Recommendation: Engage appropriate area stakeholders for planning and design of targeted water quality studies for stormwater runoff, organics, and other constituents.**
- **Recommendation: Proactively engage WQCD in causal investigation and any eventual TMDL procedure to keep process locally directed.**
- **Recommendation: Model city run-off sources by location and volume (rather than percent area) for accurate estimates of stormwater runoff loads and locations.**

Channel and Habitat Enhancement

Pitkin County's Stream Health Initiative (Malone and Emerick 2007) divided the reaches of the Roaring Fork through the City of Aspen into three separate segments. The reach from the city limits to just above the E. Cooper Ave (Hwy 82) Bridge was rated as Moderately-Modified to Heavily-Modified in the riparian Zone due to residential development. Furth downstream, riparian and instream habitat rated as Severely Degraded until below the Hunter Creek confluence, primarily due to channel modification, bank armoring, and riparian zone destruction. This is the area of most dense urban streamside development on the Roaring Fork in Aspen. From Hunter Creek to the Castle Creek confluence, habitat quality is rated as Slightly-Modified to High Quality. Most development in this area is set back by open space and recreational corridors on either side of the river, and a hydrologically-connected floodplain and undeveloped riparian buffer are still maintained. While much streamside development may be irreversible in both the short and long term, some improvement may occur over time through city land use policies which promote revegetation of streamside areas, prevention of residential landscaping to the water's edge, increase setbacks if and when re-development occurs, and promote strong BMPs for new development in or near the riparian corridor.

- **Recommendation: Detailed assessment of available locations and project feasibility for geomorphic and habitat enhancement projects in the town reach would be needed before proceeding further.**

James H. Smith – North Star Preserves

While the James H. Smith parcel has been rated for high quality riparian and instream habitat, and supports healthy aquatic communities based on 2012 samples, conflicting assessments of habitat status exist for the North Star segment. The Stream Health Initiative (Malone and Emerick 2007) rated this area as Highly-Modified to Severely-Degraded; while a more recent geomorphic assessment characterized channel form in the area as stable for at least the last century (Miller Consultants 2011). Visually and anecdotally, it seems evident that after cessation of ranching activities and active land management since approximately 1977, the area is returning to a more 'wild' condition than the previous pastureland and hayfields. More definitive conclusions on trajectories of riparian habitat in the area can only be provided by repeated vegetation and habitat assessments over a longer time period. As riparian vegetation matures, in-stream habitat complexity and available instream thermal refugia (i.e. pools, undercut banks, large woody debris, etc.) along this reach may continue to increase in extent and spatial distribution.

Local stakeholders have voiced concern that a diminished hydrologic regime due to transbasin diversions may not be adequately flushing sediment in the stream reach, leading to sediment aggradation and reduced habitat quality. Considering the geologic setting of this segment—a low gradient stream channel on a back-filled lakebed behind a glacial moraine dam—it seems reasonable that the current sand and gravel substrate might consistently persist in the area rather than the larger cobble and boulder substrate found in the steeper reaches found upstream and downstream of this locaiton. Without a more extensive dataset over a longer time period, additional specific conclusions regarding stream channel aggradation are difficult to either support or disprove.

In light of MMI scores showing healthy macroinvertebrate communities in attainment with State aquatic life standards, continued periodic monitoring approach may be warranted. In the event that a significant negative trend in terrestrial habitat or instream conditions becomes apparent from ongoing monitoring, a more active management strategy would be justified. It is possible that in the future, further flow depletions or increased recreational usage might cause such degradation; in the meantime, continued intermittent monitoring of instream conditions may adequately meet the values and stakeholder goals currently identified for management at James H. Smith and North Star preserves.

- **Recommendation: Passive management focus, stream health monitoring every 3-5 years, terrestrial habitat and wildlife monitoring as recommended elsewhere. Establish permanent 'photo points' to visually track changes in riparian cover and type.**

6. References

Baker, D.W. Bledsoe, B.P. Albano, C.M. and Poff, N.L. 2011. Downstream effects of diversion dams on sediment and hydraulic conditions of Rocky Mountain streams. River Research and Applications 27: 388-401. PDF.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Bonda, N.; Prat, N.; Resh, V.H. & Statzner, B. (2006). Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. Annual Review of Entomology, 51: 495-523.

Clarke, S., K. Crandall, J. Emerick, M. Fuller, J. Katzenberger, D. Malone, M. Masone, A. Slap, and J. Thomas. 2008. State of the Roaring Fork Watershed report 2008. Sponsor: Ruedi Water and Power Authority. Lead Consultant: Roaring Fork Conservancy. http://www.roaringfork.org/watershedplan.

Colorado Department of Public Health and Environment. 2010. Aquatic life use attainment: Methodology to determine use attainment for rivers and streams. Policy Statement 2010-1.

Driscoll, G.M. 2011. Front Range Water Supply Planning Update. Ruedi Water and Power Authority, Elk Mountain Consulting.

Grove, M. 2012. Benthic macroinvertebrate sampling plan for White River National Forest. USDA Forest Service.

Hawkins, C. P. 2006. Quantifying biological integrity by taxonomic completeness: Its utility in regional and global assessments. Ecological Applications 16 (4): 1277-1294.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family level biotic index. Journal of the North American Benthological Society 7(1): 65-68.

Hughes, D.L. and M.O. Brossett. 2009. Rapid bioassessment of stream health. CRC Press, Taylor & Francis Group. Boca Raton, FL.

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7:222-33.

Likens, G. E., and Lambert, K.F. 1998. The importance of long-term data in addressing regional environmental issues. Northeastern Naturalist 5: 127-136.

Malone, D.G. and Emerick, J.C. 2007 Catalog of stream and riparian habitat quality for the Roaring Fork River and tributaries, Central Colorado. Roaring Fork Stream Health Initiative. www.roaringfork.org/collaborative/shi. Web. Accessed 9/01/2013

Miller, W.J. 2011. Final report: Evaluation of River health Roaring Fork River near Aspen, Colorado. Contract # 114-2010. Prepared for Pitkin County Attorney. http://www.pitkincountyrivers.com/projects-studies-areas-of-interest.html.

Muehlbauer J.D. Doyle, M.W. and Bernhardt, E.S. 2011. Macroinvertebrate community responses to a dewatering disturbance gradient in a restored stream. Hydrology and Earth System Sciences. 15: 1771-1783. PDF.

Merritt, R. W., K. W. Cummins and M. B. Berg. 2008. An introduction to the aquatic insects of North America. Fourth Edition, Kendall/Hunt. Dubuque, Iowa.

Paul, M. J., J. Gerritsen, C. Hawkins, and E. Leppo. 2005. Draft. Development of biological assessment tools for Colorado. Colorado Department of Public Health and Environment, Water Quality Control Division – Monitoring Unit. Denver, Colorado.

Paul, M.J., and J. L. Meyer (2001). Streams in the urban landscape. *Annual Review of Ecology and Systematics*. 32:333-365

Pitkin County. 2000. North Star Nature Preserve: 2000 resource management plan. http://www.aspenpitkin.com/Portals/0/docs/county/OpenSpace/North Star%20mp2.pdf.

Pitkin County and City of Aspen. 2001. James H. Smith North Star Open Space interim management plan. http://www.aspenpitkin.com/Portals/0/docs/county/OpenSpace/smith_mp.pdf.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA/444/4-89/001.

Resh, V.H. and J.K. Jackson. 1993. Rapid assessment approaches in biomonitoring using benthic macroinvertebrates. In Rosenberg, D.M, V.H. Resh. (Editors). Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York: 195-223.

Roaring Fork Conservancy and Timberline Aquatics. 2012. A review of aquatic life and stream health in the Roaring Fork Watershed. www.roaringfork.org/publications.

S.K. Mason Environmental, LLC. 2013. Snapshot assessment of the Roaring Fork Watershed: A synoptic approach to characterizing low flow conditions on the Crystal and Roaring Fork Rivers in the autumn of 2012. Prepared for Public Counsel of the Rockies and Roaring Fork Conservancy. www.roaringfork.org/publications.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (Also available at http://pubs.usgs.gov/tm/tm3-a8/.)

Voelz, N. J., R. E. Zuellig, S. Shieh, and J. V. Ward. 2005. The effects of urban areas on benthic macroinvertebrates in two Colorado plains rivers. Environmental Monitoring and Assessment 101: 175-202.

Wang, L. and Kanehl, P. 2003. Influences of watershed urbanization and instream habitat on macroinvertebrates in cold water streams. Journal of the American Water Resources Association (WAWRA) 39(5):1181-1196

Wang, L., D. M. Robertson, and P. J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. Environmental Management 39: 194-212.

Ward, J. V., B. C. Kondratieff, and R. E. Zuellig. 2002. An illustrated guide to the mountain stream insects of Colorado. Second Edition. University Press of Colorado. Boulder, Colorado.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35(6) 951-956.

Water Quality Control Division. 2011. 2012 303(d) Listing Methodology. Colorado Department of Public Health and Environment

Appendix A. Macroinvertebrate Site Descriptions

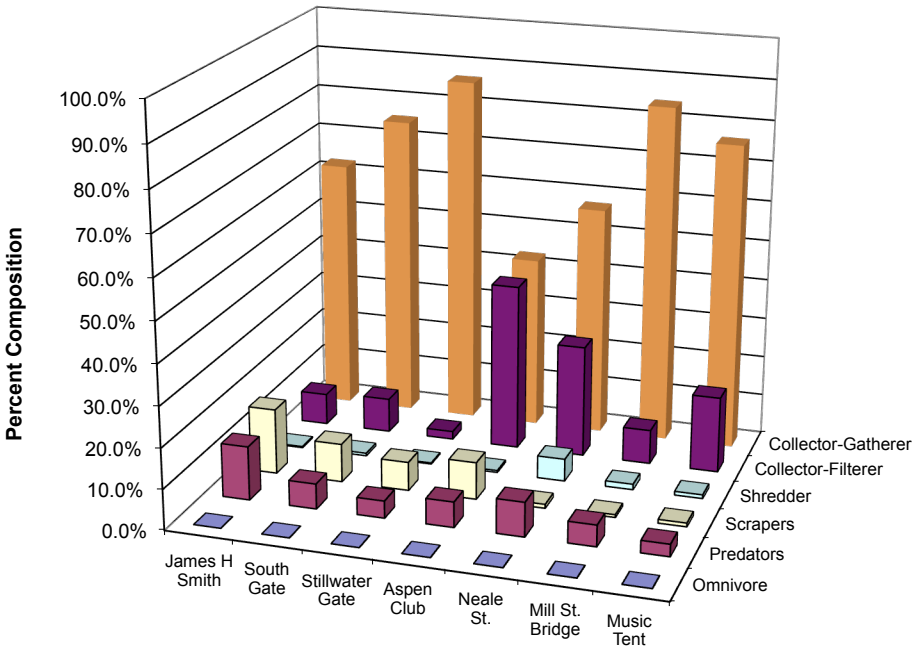
Section Overview

Appendix A includes specific location information and site descriptions for each macroinvertebrate sampling site. A short discussion accompanies each site description, including any previous sampling, and specifically identified stream issues from other reports or expert local knowledge. Macroinvertebrate samples were collected by S.K.Mason Environmental of Carbondale, CO, and analyzed by Timberline Aquatics in Fort Collins, Colorado. Site information is provided by Roaring Fork Conservancy and S.K.Mason Environmental. Table 5 and Figure 5 are reproduced below for quick reference.

Table 5. MMI scores by site.

Area	North Star			Town of Aspen			
Biotype	Biotype 2						Biotype 1
Metric	James H Smith	South Gate	North Trail Gate	Aspen Club	Neale St	Mill St	Music Tent
Taxa Richness	33	34	26	34	27	27	22
EPT	14	15	13	9	6	8	6
Clinger Taxa	11	11	9	10	7	6	8
Insect Taxa	28	31	22	30	22	25	20
Diversity	3.87	3.86	3.03	3.45	3.49	2.95	2.96
HBI	3.72	4.36	2.71	4.05	3.16	3.12	3.29
MMI	**67.5**	**62.8**	**56.6**	**48.6**	**45.7**	**38.7**	**41.2**

Figure 5. Functional feeding group composition by site.



A.1 James H. Smith

River/Stream: Roaring Fork River
Location: above Aspen at North Star James H Smith Preserve
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.162170 W -106.792118

Site Description:
The James H. Smith site is the farthest upstream macroinvertebrate sampling location on the Roaring Fork River. This site has Wilderness and National Forest land located upstream and a riparian corridor of 10 feet on both sides. Highway 81 is located approximately 150-325 feet from the river with potential for some associated impacts.

Benthic Macroinvertebrate Review:
This site, located in Biotype 2, produced an MMI score of 67.5 in 2012 indicating attainment for aquatic life use. Both auxiliary metrics (Diversity and HBI) were also in attainment. Results from all metrics suggest little evidence of perturbation or stress. The Taxa Richness value (33) at this site was one of the highest produced in the Roaring Fork River watershed and indicated that a species-rich macroinvertebrate community was present. Metrics designed to measure sensitive (EPT) and specialized (Clinger Taxa) taxa also produced relatively high values indicating that aquatic stressors had little impact on benthic communities in the fall of 2012 at the Roaring Fork - James H Smith site. The proximity of mostly undeveloped National Forest and Wilderness land to this sampling site likely minimizes anthropogenic influences on the macroinvertebrate communities which resulted in a relatively well-balanced aquatic community.

Site Photos: James H. Smith

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.2 South Gate

River/Stream: Roaring Fork River
Location: above Aspen at North Star Preserve South Gate
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.165194 W -106.790436

Site Description:
The Roaring Fork South Gate macroinvertebrate sampling site is located downstream of the James H. Smith site and above the North Trail Gate site. Highway 82 parallels the reach approximately 150-325 feet from the stream. The riparian corridor is 30 feet on the right and 15 feet on the left bank.

Benthic Macroinvertebrate Review:
This site is in Biotype 2; it produced an MMI score of 62.8 indicating attainment for aquatic life use in 2012. The Diversity and Taxa Richness values (3.86 and 34, respectively) suggested that aquatic conditions at this site were adequate for maintaining a species-rich, well-balanced benthic community. Sensitive and specialized taxa (EPT and Clinger Taxa) were also present in numbers suggesting little impact from stress in 2012. The HBI value (4.36) produced at this site was elevated compared to the upstream site (Roaring Fork - James H Smith), suggesting that nutrients or sedimentation may have provided some negative influence at the Roaring Fork - South Gate site in the fall of 2012 (although not at a level that would cause impairment). Results from the South Gate site appeared to be

mostly influenced by the Wilderness and National Forest land upstream of the North Star Preserve reaches resulting in metric values and an MMI score indicative of relatively healthy aquatic conditions.

Site Photos: North Star, South Gate

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.3 North Trail Gate

River/Stream: Roaring Fork River
Location: North Star Preserve North Trail Gate
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.17564 W -106.79707
Site Description:

The North Trail Gate site is located downstream of the North Gate. This site is found upstream of the City of Aspen and is in close proximity to Highway 82 to Independence Pass (approx. 50-100m). Recreational trails exist on the right bank and the riparian corridor at this site extends 10 feet on both the right and left banks.

Benthic Macroinvertebrate Review:

North Trail Gate is located in Biotype 2. This site was in attainment for aquatic life use with an MMI score of 56. Both auxiliary metrics, Diversity (3.03) and HBI (2.71), were also in attainment; however, the Diversity value had declined slightly compared to upstream sites. The HBI value (2.71) was much lower than the upstream sites and indicated improvement compared to the Roaring Fork - North Gate site, while other individual metrics (Taxa Richness, EPT, and Clinger Taxa) produced values suggesting that minor additional degradation to aquatic conditions had occurred. The proximity of the North Trail Gate site to Highway 82 and the Town of Aspen may result in increased anthropogenic influences compared to upstream sites, contributing to the score differentials between the upper two sites and the slight decrease at this site.

Site Photos: North Star, North Trail Gate

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.4 Aspen Club

River/Stream: Roaring Fork River
Location: above Aspen at Aspen Club
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.181925 W -106.809645

Site Description:
Located on the Roaring Fork River, the Aspen Club site is above a majority of the development associated with the City of Aspen; however, initially sparse residential development increases in density and proximity to the river through this area. The sample site has only sparse housing on its right bank and a paved footpath on the left bank. A 20 foot riparian corridor exists on the right bank and a 10 foot extension exists on the left bank.

Benthic Macroinvertebrate Review:
Aspen Club site is located in Biotype 2 upstream of the majority of the city. The site produced an MMI score of 48.6 which fell within the "grey zone" for an aquatic life use designation. The auxiliary metrics (Diversity and HBI) both produced values which designated the site in attainment. Additional individual metrics also suggested that this site maintained fairly healthy aquatic conditions. The Taxa Richness metric produced one of the highest values (34) among sites in the Roaring Fork River watershed; however, the EPT value (9) and Clinger Taxa value (10) indicated minor to moderate stress despite the presence of some sensitive and specialized taxa. The somewhat low MMI score produced at this site may have been a result of the influence associated with increasing residential development, stormwater runoff from impermeable surfaces (including the small housing development), or a combination of these potential perturbations. Although the MMI score and other metrics detected some influence of stress, the overall evaluation confirmed that the Aspen Club site maintained a fairly well-balanced and relatively healthy aquatic community in 2012.

Site Photos: Aspen Club

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.5 Neale St

River/Stream: Roaring Fork River
Location: in Aspen near Neale Ave Bridge
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.190091 W -106.814413
Site Description:
Downstream of the Aspen Club site on the Roaring Fork River is the location of the Neale St. site. This site is still above most of the development associated with the City of Aspen, although dense townhomes exist along the left banks. Highway 82 and its associated stressors are also present on the left bank of this site. The riparian corridor is 10 feet on the right bank and 60 feet on the left bank.

Benthic Macroinvertebrate Review:
The Roaring Fork - Neale St site was located in Biotype 2 among much of the development associated with the City of Aspen. In the fall of 2012, the Neale St site produced an MMI score (45.7) that fell within the "grey zone" for aquatic life use (Figure 2, Table 4). The auxiliary metrics (Diversity and HBI) produced values (3.49 and 3.16, respectively) that were well within the range of attainment and subsequently this site was designated as in attainment for aquatic life use (Table 4). Additional individual metrics (Taxa Richness, EPT, Insect Taxa, and Clinger Taxa) detected an increase in stress compared to the upstream Roaring Fork - Aspen Club site; although, the HBI metric value (a measure of nutrient-tolerant taxa) decreased slightly, suggesting that nutrient enrichment was less of an influence to the macroinvertebrate community at Neale St (Table 4). The decline in metric values and MMI score observed at the Neale St. site in the fall of 2012 may also be a result of increased urbanization and the close proximity to a major highway.

Site Photos: Neale Street Bridge

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.6 Mill St Bridge

River/Stream: Roaring Fork River
Location: in Aspen at Mill St Bridge
River Watch Site Name and (Number): Mill Street Bridge (770)
WQCD Site ID: 12784
Coordinates (NAD 83): N 39.194324 W -106.817359

Site Description:
Located on the Roaring Fork River in Aspen just downstream of the Mill Street Bridge, the site is 0.25 mile from Aspen's urban core. Situated in an urban setting, roughly 35% of Aspen's developed area is above this site. This site is above the confluence with most major tributaries in the Aspen area: Hunter Creek, Castle Creek, and Maroon Creek. The river at the sample location is approximately 25 ft. wide and averages 0.75 ft. deep with primarily riffles and runs. The banks have been armored in some locations by boulders. Closer to the bridge channelization narrows and deepens the river. Substrate is predominately cobble and the riparian zone extends 6-7 ft. from either bank.

This stream reach is likely influenced by urban impacts as well as upstream diversions, including the Salvation Ditch and some City of Aspen ditches. The Salvation Ditch can divert 59 cfs. Near the headwaters of the Roaring Fork River, the Independence Pass Transmountain Diversion System divert on average 37% of the Upper Roaring Fork River. The 2006 Roaring Fork Watershed Water Quality Report, placed this reach on the Watch List because of elevated suspended solids levels. Iron exceeded water quality standards once in September 2002 and selenium exceeded once in January and once in July of 2004 (2008 State of the Roaring Fork Watershed Report).

Benthic Macroinvertebrate Review:
The Mill St. Bridge site was located downstream of several major diversions and among much of the urbanization associated with the Town of Aspen. This site is located in Biotype 2 and produced an MMI score of 38.7, indicating impairment for aquatic life use in the fall of 2012 (Figure 4, Table 4). The Insect Taxa value (27) at this site was within a normal range based on surrounding sites on the Roaring Fork River and the HBI value (3.12) appeared to detect minimal impacts from nutrient enrichment. The MMI score was most negatively influenced by the loss of sensitive functional feeding groups (predators and shredders) and the low proportion of mayfly taxa at this site. Other metrics indicating noticeably increased perturbation include the Taxa Richness and Clinger Taxa values (Table 4). Urbanization impacts to aquatic life are a likely source of disturbance at this site due to nearby channelization and this site's proximity to the downtown Aspen area. Additionally, several upstream diversions may reduce water flow through this reach, potentially affecting benthic macroinvertebrate communities by altering the natural flow regime and concentrating constituents found in urban runoff.

This site was also sampled in 2011 when overall macroinvertebrate scores were better, most likely due to higher flow (Table A1). In 2011, the MMI score produced at this site (51.0) fell within the "gray zone" between the thresholds for attainment and impairment; however, both of the auxiliary metrics (HBI and Diversity) produced values indicating the condition of aquatic life was in attainment at this site. Benthic macroinvertebrate communities appeared to be well-balanced, and the relatively low HBI value (3.92) suggested minimal impact from nutrient enrichment. Alternatively, the relatively low EPT metric value indicated that taxa with sensitivity to general perturbations had been reduced.

Table A1. Comparison of values for 2011 and 2012.

Metric	2011	2012
Taxa Richness	28	27
EPT	12	8
Clinger Taxa	10	6
MMI	50.8	38.7
HBI	3.92	3.12
Diversity	3.69	2.95
Flow (cfs)	67	17

Site Photos: Mill Street Bridge

Upstream (2012)

Downstream (2012)

Substrate (2012)

A.7 Roaring Fork – Music Tent

River/Stream: Roaring Fork River
Location: in Aspen at Aspen Institute (Music Tent)
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): N 39.200840 W -106.826708

Site Description:
The Music Tent site is located on the Roaring Fork River downstream of the Mill St. Bridge site in the Town of Aspen. The nearby urban developments are set back from the river and include commercial and residential buildings. Social recreational trails exist on both banks of the river and the macroinvertebrate sample was taken upstream of a footbridge. The riparian corridor extends 30 feet on the right bank and 60 feet on the left.

Benthic Macroinvertebrate Review:
The Roaring Fork - Music Tent site was located farther downstream in the Aspen study area and urban pollutants and stormwater runoff associated within the Town of Aspen were potential sources of impact to the macroinvertebrate communities at this site. This site was located in Biotype 1 and produced an MMI score of 41.2 in 2012, indicating impairment for aquatic life use (Figure 2, Table 4). Both auxiliary metrics (Diversity and HBI) produced values indicating attainment; however, the MMI score at the Roaring Fork - Music Tent site was below the impairment threshold so auxiliary metrics were not considered in the aquatic life use designation (Table 4). Individual metrics applied to data from this site suggested slightly more influence from stressors compared to upstream Roaring Fork River sites, with lower Taxa Richness, EPT, and Insect Taxa values observed (Table 4). Likely sources of perturbation at the Music Tent site on the Roaring Fork River are associated with increased urbanization within the City of Aspen and include: stormwater runoff, residential pollutants, deicing agents, spraying of herbicides/pesticides, etc.

Site Photos: Music Tent

Upstream (2012)

Downstream (2012)

Substrate (2012)

Appendix B. Pebble Count Data

Table B1. Wolman pebble count results. Pebble counts illustrate the differences in substrate composition at each site. Coarse gravels are the dominate streambed sediment in the low-gradient meanders of North Star Area. Large cobbles dominate the streambed in the Town reach.

Site Name		James Smith	North Gate	North Trail Gate	Aspen Club	Neal St.	Mill St.	Music Tent
Date		8/30/12	8/30/12	8/30/12	9/6/12	9/6/12	9/6/12	9/6/12
Size Category	**ranges (mm)**							
Silt/clay	< 0.06		1					
Very fine sand	0.06 - 0.125							
Fine sand	0.126 - 0.125							
Medium sand	0.26 - 0.5						3	
Coarse sand	0.5 - 1				1			
Very coarse sand	1 - 2				5	1		
Very fine gravel	2 - 4	2	9		3			1
Fine gravel	5 - 8	3	8	4	3		2	2
Medium gravel	9 - 16	10	27	13	2		2	4
Coarse gravel	17 - 32	40	28	57	4	1	1	2
Very coarse gravel	33 - 64	28	11	30	13	3	15	11
Small cobble	65 - 90	5	5	1	10	9	14	14
Medium cobble	91 - 128	4	6		9	18	14	10
Large cobble	129 - 180	5	6		17	28	20	23
Very large cobble	181 - 255	3	2		17	25	14	16
Small boulder	256 - 512		1		11	16	15	11
Medium boulder	513 - 1024				3			2
Large boulder	1025 - 2048							4
Very large boulder	> 2048				2			
Bedrock								
Woody debris								
	Total count	100	104	105	100	101	100	100
	Riffles (%)	10	5	5	80	95	90	70
	Runs (%)	20	10	10				
	Pools (%)	70	85	85	20	5	10	30

Dominant substrate sizes highlighted