

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

version 1.05

Appendix A. Survey Design and Site Selection

Selection of monitoring locations involves various procedures specific to each NCPN park unit and wadeable stream. This report describes the rationale for selecting areas for Riparian Monitoring, procedures used to define the target population for monitoring, and procedures used to select monitoring locations.

1 Arches National Park

1.1 Defining the riparian resources for monitoring

Discussions with Southeast Utah Group (SEUG) resource management staff identified Courthouse Wash as the primary focus of riparian monitoring at Arches National Park (ARCH; Figure 1-1). This canyon originates outside of the park to the west and drains an area about the size of the park. Courthouse Wash is one of the main drainages in ARCH, emptying into the Colorado River just south of the park boundary. Courthouse Wash is an intermittent stream that flows after large precipitation events and contains some small perennial reaches. It has fairly extensive alluvial terrace development even though it is mostly surrounded by steep sandstone walls. Monitoring will help us understand natural variability and provide early warning of system degradation due to human disturbances, especially from outside of the park.

1.2 Accessibility

The entire length of Courthouse Wash inside the park (18.7 km) is accessible. The main park road crosses the wash at approximately its mid-point within the park. Courthouse Wash is also accessible from the south via highway 191 and from the west by hiking in Sevenmile Canyon.

1.3 Watershed Area

An analysis of watershed area confirmed that Sevenmile Canyon (Figure 1-1) is a major tributary, contributing 20% of the watershed area of Courthouse Wash. All other tributaries have relatively small watersheds, contributing no more than 3.5% of watershed area.

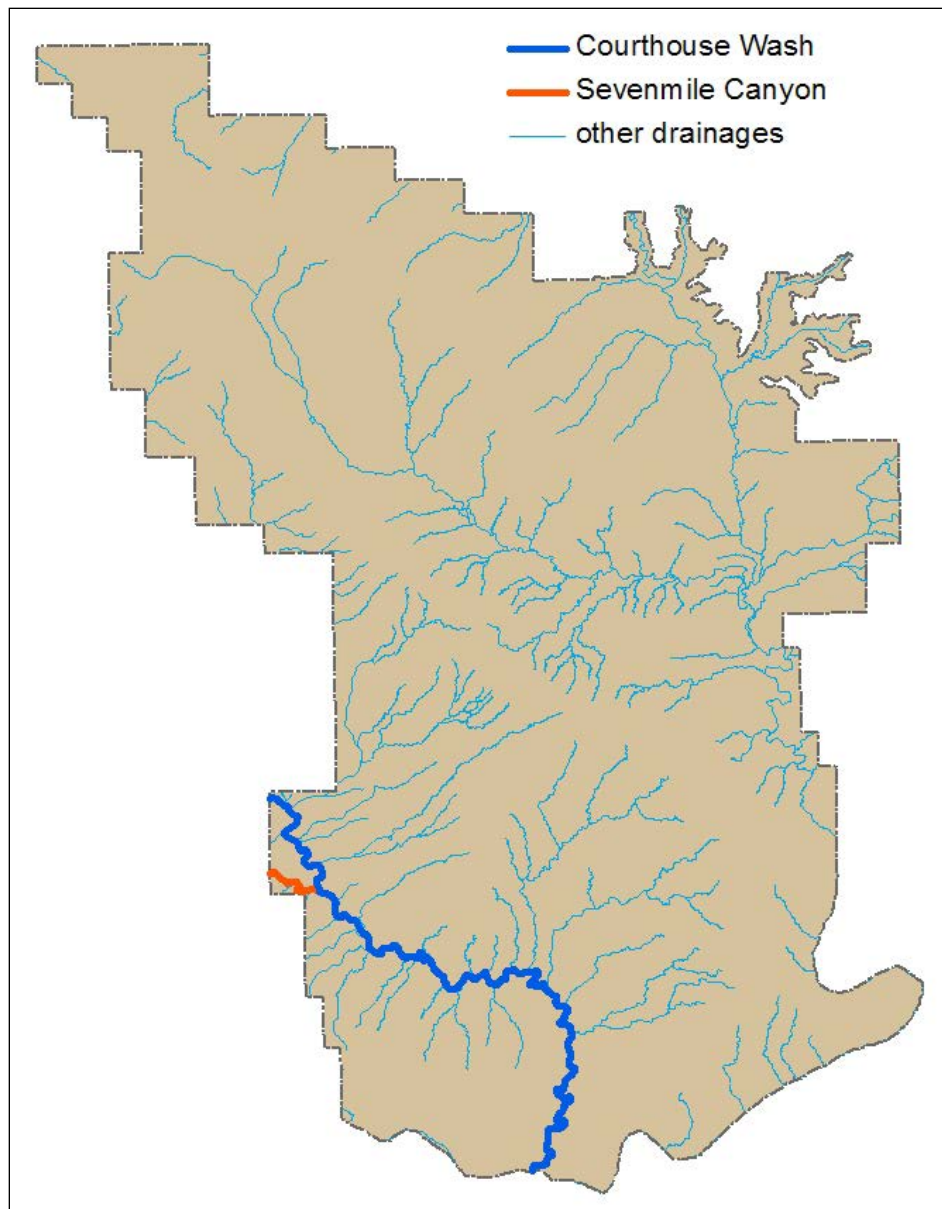


Figure 1-1. Location of Courthouse Wash in Arches National Park.

1.4 Delineating the Target Population

Nearly the entire stretch of Courthouse Wash within ARCH was selected as the target population. NCPN and SEUG staff agreed to limit the sampling frame in Courthouse Wash to below the junction of Sevenmile Canyon since the canyon is narrow and bedrock constricted for much of the area above this point. Sevenmile Canyon also contains a large watershed area, and the hydrologic dynamics are likely to be different in Courthouse Wash above this point. The section of Courthouse Wash in the sampling frame is 15.2 km in length. A few areas in lower Courthouse may also be completely bedrock constricted but these areas will not be removed from the sampling frame. Instead, reaches will be rejected in the field if they contain bedrock-constricted areas.

1.5 Monitoring Site Selection

Monitoring sites were selected using the GRTS (Generalized Random Tessellation Stratified; Stevens and Olsen 2004) function in the spsurvey package (Kincaid and Olsen 2008) in R (R Core Team 2008). GRTS generates a spatially-balanced sample based on the requested number of monitoring locations, and sequentially orders the selected locations (i.e., points) in an output shape file.

GRTS requires the sampling frame to be delineated in an ArcGIS shape file. Line features can be used, but there are instances where the GRTS model will select points adjacent to but not on the imported linear representation of a stream, and reasons for this are unclear. However, a workaround is to rasterize the line used to represent a stream using a 1-m resolution, then convert the raster back to a shape file. This results in the stream being represented as a polygon with a width of 1 m. The minimum grain size generated in the recursive subdivision process of GRTS (the underlying approach used to define sample locations) is 1 m. This workaround results in the selection of locations on the original linear representation of a stream. The polygonal version of the canyon was used in the GRTS site selection procedure.

When GRTS selects points along a linear feature, points are often noticeably clumped, suggesting their distribution is random but not spatially-balanced. In order to soundly reject GRTS runs that are not spatially-balanced, Steve Garman (former NCPN quantitative ecologist) developed a program that compares a GRTS run to a random sample. If the GRTS run is not different from a random sample at $\alpha=0.05$, the run is not used for site selection. Three GRTS runs were completed before one was adequately spatially-balanced for riparian monitoring.

Only results from the final GRTS run are reported in this document. GRTS was used to select 14 monitoring locations in Courthouse Wash (Figure 1-2). Seven reaches are anticipated for long-term monitoring. Extra locations were selected to account for rejection of reaches.

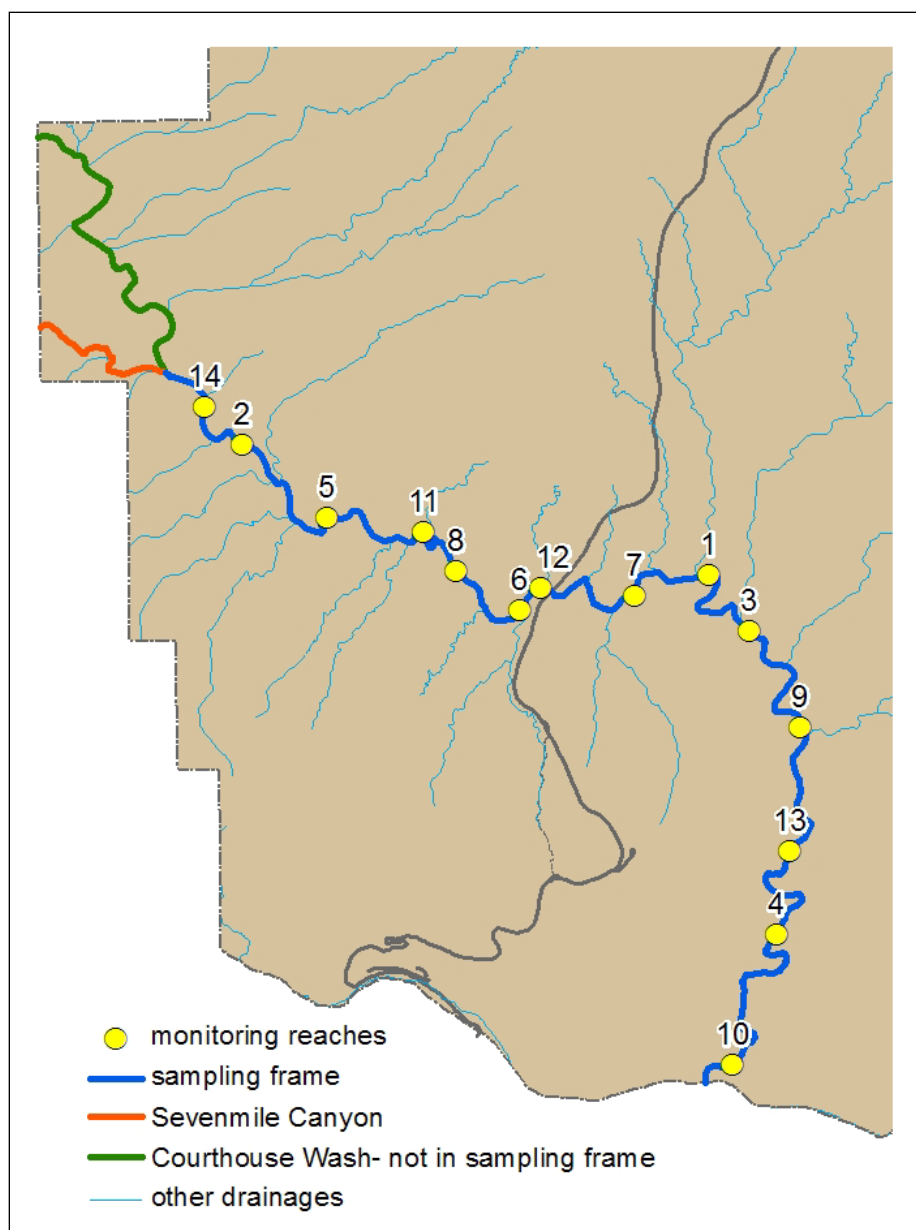


Figure 1-1. Potential reaches for riparian monitoring of Courthouse Wash in Arches National Park.

1.6 Tracking Monitoring Locations

A sequential list of all potential reaches is stored in a shape file (ARCH_riparian_master). The list indicates acceptance or rejection of locations, reasons for rejection, date of reach establishment, and other important tracking information. Attributes of this shape file are described in Table 1-1.

Table 1-1. Attributes of ARCH_riparian_master.shp for tracking riparian monitoring reaches in Courthouse Wash in Arches National Park.

Field	Description
ReachID	The reach number, based on the siteID
panel	Panel that each reach is associated with in the revisit design
PanelYear	Years that panel is sampled (1-7, panel=0 for rejected reaches)
EvalStatus	Ultimate status of a reach (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of reach determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a reach was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
xcoord	UTM E (NAD83, Zone 12)
ycoord	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to the reach in kilometers
Comments	Miscellaneous
siteID	GRTS-assigned ordered unique identifier
stratum	GRTS attribute not used for selection of these sites (None)
mdcaty	Code for stratification of the sampling frame used by GRTS (1 for entire Courthouse Wash sampling frame)
wgt	1/selection probability for each point

1.7 Revisit Design

We decided not to implement pilot monitoring in Courthouse Wash because the number of reaches is more limited by affordable effort and the length of the sampling frame than variability of vegetation. Vegetation at each reach is sampled following a rotating-panel design (Figure 1-3) that samples 2 reaches each year and a total 7 reaches over 7 years. Reaches are sampled 2 years in a row and then rested for 5 years. Every 7 years, the sampling scheme repeats itself. The sampled reaches should represent Courthouse Wash in ARCH below Sevenmile Canyon and excluding bedrock-constrained sections.

1.8 Revisions to the Sampling Design

At the time of protocol publication, a total of 5 reaches were established at ARCH (reaches 1, 2, 4, 5, and 7). Revisiting these established reaches after significant hydrologic events (i.e., large floods) or in response to management concerns is now a higher priority than following the originally proposed revisit design (see section 3.5 in the protocol narrative for additional information).

panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	1	1						1	1	
2		1	1						1	1
3			1	1						1
4				1	1					
5					1	1				
6						1	1			
7	1						1	1		

Figure 1-2. Number of reaches sampled each year based on 7-year rotating panel revisit design for riparian vegetation monitoring in Courthouse Wash in Arches National Park.

1.9 Literature Cited

- Kincaid, T. M. and A. R. Olsen. 2008. spsurvey: Spatial survey design and analysis. R package version 2.0. URL <http://www.epa.gov/nheerl/arm/>.
- R Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>.
- Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

2 Capitol Reef National Park

2.1 Defining the Riparian Resources for Monitoring

Discussions with Capitol Reef National Park (CARE) resource management staff identified several potential streams for monitoring. For the initial effort, however, the Fremont River was selected (Figure 2-1). This stream originates outside of the park to the west. In the park, it runs through the Fremont Gorge, then through orchards and other historically-settled land in the Fruita area, and finally in the canyon beside highway 24. The Fremont River is used to irrigate agricultural land, especially in the broad valleys upstream of CARE.

The Fremont River is highly constrained through most of the park, first through the bedrock walls of the Fremont Gorge then by channels and other support structures to prevent damage to park infrastructure.

Monitoring of this stream will provide some indication of natural variability and early warning of system degradation due to human disturbances, especially from outside of the park.

Park resource staff are also interested in monitoring a management issue on the Fremont River. In 1962, when Highway 24 was constructed through the park, the river became channelized, mostly to the north of the highway. At one point, an oxbow was bypassed for ease of construction, creating a small waterfall on the Fremont River. This restricted the river to the north side of the highway, allowing construction crews to avoid building two bridges. More recently, a plan was initiated to restore the flow of the Fremont River to the oxbow, which should help reduce the velocity of flows downstream. The park is interested in monitoring ecological changes in the oxbow and downstream of the oxbow resulting from this project. In order to address these management concerns, the Fremont will be monitored above, below, and within the oxbow, before and after the restoration project.

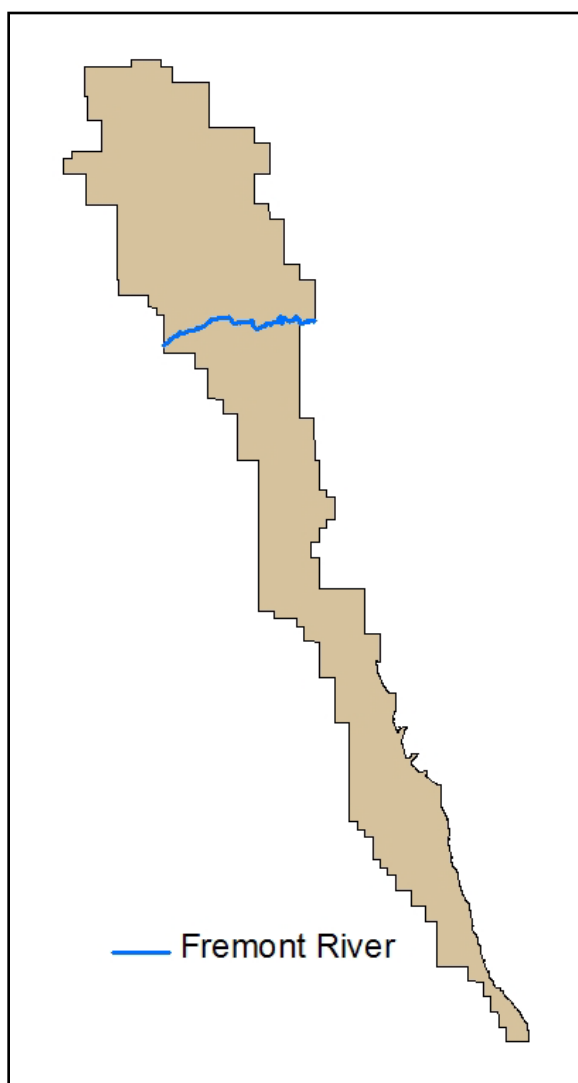


Figure 2-3. Location of the Fremont River in Capitol Reef National Park.

2.2 Accessibility

According to park staff, the entire length of the river inside the park (22.5 km) is accessible. The Fremont Gorge, which runs 5.3 km through the east side of the park, provides the greatest challenge for access. It can be approached by hiking from either side: 1) through the Fruita area inside the park or 2) by roads west of the park. The remainder of the Fremont River inside CARE is easily accessible from park roads.

2.3 Delineating the Target Population

The entire stretch of the Fremont River within CARE was selected as the target population, but it was stratified into sections with similar geology and management in order to look more closely at the management questions (Figure 2-2). The six sections of Fremont River are:

- 1) Fremont Gorge- A relatively natural part of the river running through a deep bedrock-constrained gorge.
- 2) Managed area- The Fremont River flows through wide alluvial valleys that contain orchards, buildings, campgrounds, and other highly-managed areas.
- 3) Above falls- The river flows next to Highway 24 through a canyon constricted by steep sandstone walls.
- 4) Oxbow- The river currently does not flow through this section, but it has been proposed to reroute it through the old stream bed in the near future.
- 5) Below falls- The river flows next to Highway 24 through a canyon constricted by sandstone walls of similar geology to the Above falls section.
- 6) Lower Fremont- The river continues flowing next to Highway 24, but the geology changes to more erodible rock in a wider valley.

The maximum number of reaches in each section depends on the length of the section (Table 2-1).

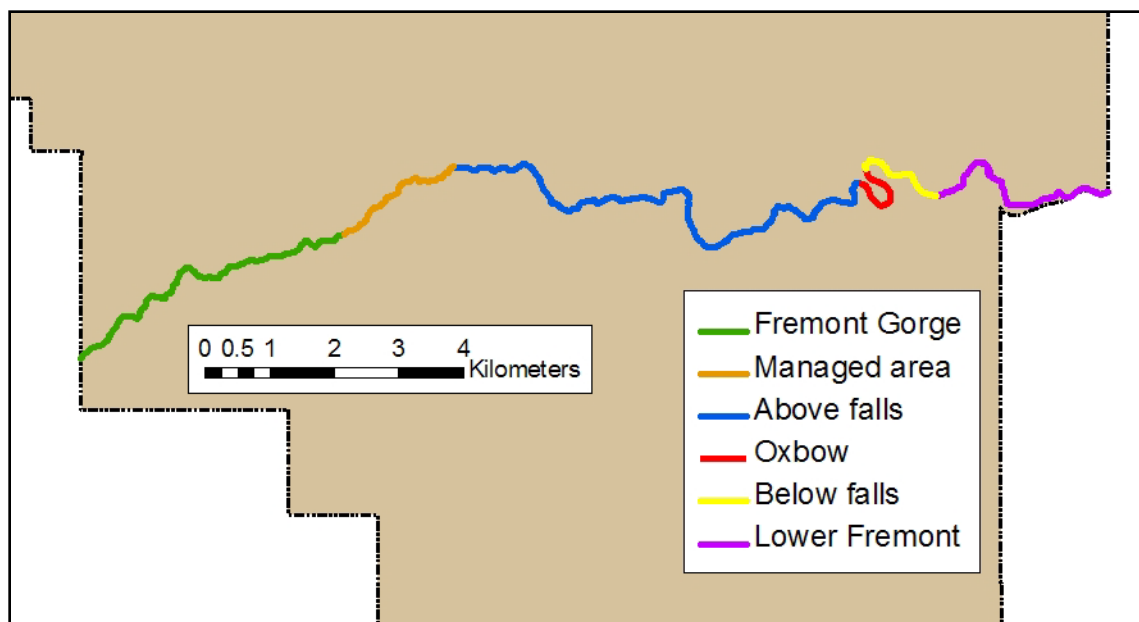


Figure 2-4. Sampling frame for riparian monitoring of the Fremont River in Capitol Reef National Park.

Table 2-2. Length of each section of the sampling frame for riparian monitoring of the Fremont River in Capitol Reef National Park.

Section	Length (km)	Maximum # of reaches
Fremont Gorge	5.3	2
Managed Area	2.2	1
Above Falls	8.6	3
Oxbow	1.4	1
Below Falls	1.5	1
Lower Fremont	3.5	2
total	22.5	10

Before site selection, each section of the sampling frame was buffered on either end to prevent reaches from crossing the boundary between two sections.

2.4 Monitoring Site Selection

Generalized Random Tessellation Stratified (GRTS; see site selection section for Arches for additional details) was used to select 10 reaches in the sampling frame for the Fremont River (Figure 2-3), and these were divided between the sections according to the distribution in Table 2-1. Twenty extra reaches were selected to account for rejected reaches. Reaches may be rejected if they are bedrock constricted or if a major tributary enters in the middle of a reach.

In order to soundly reject GRTS runs that are not spatially-balanced, they are compared to a random sample (see site selection section for Arches for additional details). The first GRTS run was found to be adequately spatially-balanced for riparian monitoring, probably due to stratification of the Fremont River into sections.

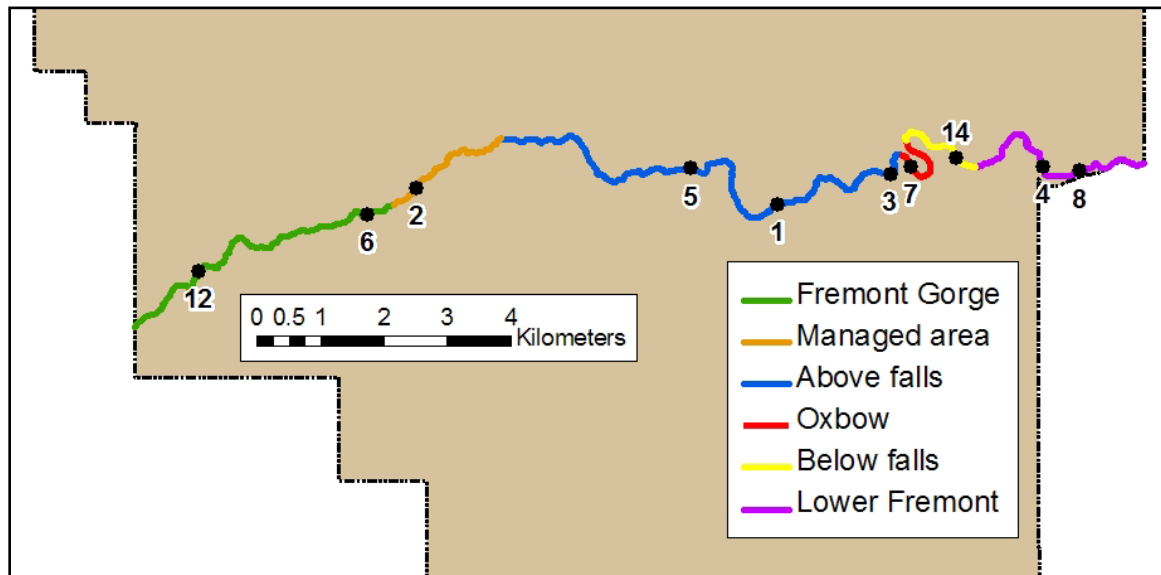


Figure 2-5. Sampling frame and potential reaches for riparian monitoring of the Fremont River at Capitol Reef National Park.

2.5 Tracking Monitoring Locations

A sequential list of the all potential reaches is stored in a shape file (CARE_riparian_master). The list indicates acceptance or rejection of locations, reasons for rejection, date of reach establishment, and other important tracking information. Attributes of this shape file are described in Table 2-2.

Table 2-3. Attributes of CARE_riparian_master.shp for tracking Capitol Reef National Park riparian monitoring locations.

Field	Description
ReachID	The reach number, based on the siteID
panel	Panel that each reach is associated with in the revisit design
PanelYear	Year(s) that panel is sampled
EvalStatus	Ultimate status of a reach (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of reach determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a reach was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
xcoord	UTM E (NAD83, Zone 12)
ycoord	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to the reach in kilometers
Comments	Miscellaneous
siteID	GRTS-assigned ordered unique identifier
stratum	GRTS attribute not used for selection of these sites (originally "None", but changed to represent names of strata in the mdcaty attribute)
mdcaty	Code for stratification of sampling frame used by GRTS (1=Fremont Gorge, 2=Managed area, 3=Above falls, 4=Oxbow, 5=Below falls, 6=Lower Fremont)
wgt	1/selection probability for each point

2.6 Revisit Design

We decided not to implement pilot monitoring on the Fremont River because the number of reaches is more limited by affordable effort and the length of the sampling frame than variability of vegetation. Vegetation at each reach is sampled following a rotating-panel design (Figure 2-4) that samples 3 reaches each year and a total 10 reaches over 5 years.

Reaches are sampled either:

- 1) 2 years in a row and rested for 3 years (panels 1-5) or
- 2) 1 year then rested for 4 years (panels 6-10).

Every 5 years, the sampling scheme repeats itself. The reaches should represent the length of the Fremont River in CARE.

panel	Year (x=1)									
	1	2	3	4	5	6	7	8	9	10
1	x	x				x	x			
2		x	x				x	x		
3			x	x				x	x	
4				x	x				x	x
5	x				x	x				x
6	x					x				
7		x					x			
8			x					x		
9				x					x	
10					x					x

Figure 2-6. Proposed revisit design for riparian vegetation monitoring of the Fremont River in Capitol Reef National Park. This design samples 3 reaches/year and 10 reaches total over a period of 5 years. Every 5 years, the sampling scheme repeats itself.

Table 2-4. Sections of Fremont River sampled each year and ReachID corresponding with Figure 2-3. In Year 6 the rotation begins again sampling Year 1 plots.

	Year sampled				
	1	2	3	4	5
Section sampled (ReachID)	Below falls (14)	Below falls (14)	Fremont gorge (27)	Lower Fremont (15)	Lower Fremont (15)
	Oxbow (7)	Above falls (3)	Above falls (3)	Managed area (28)	Oxbow (7)
	Above falls (1)	Lower Fremont (4)	Fremont gorge (16)	Fremont gorge (16)	Above falls (5)

This design works well for CARE because:

- 1) The park is interested in specific sections of the river (Figure 2-3), and monitoring reaches are divided between these sections approximately by length (Table 2-1).
- 2) Above falls, below falls, and the oxbow are always sampled together for management comparison in year 1, 6, 11, etc. (Table 2-3), but additional sampling could occur before and after river re-route, if necessary.

- 3) Three different sections are monitored each year except for the Year 3, 8, etc. Logistically, it makes sense to visit both Fremont Gorge reaches in the same year.
- 4) The Fremont Gorge can be completed first in years when it is sampled; other reaches can be easily accessed on an additional hitch, if necessary.
- 5) By sampling the managed area once every five years, we can draw inference to the entire length of the Fremont River inside the park, in addition to looking at management comparisons.

2.7 Revisions to the Sampling Design

It became apparent during the 2012 field season that 3 reaches per year were too much to complete in 1 pay period when the oxbow was not one of the 3 reaches. Thus, the following changes were made to the sampling design at CARE.

The managed area and the Fremont Gorge were eliminated from the sampling frame (Figures 2-5 and 2-6). The managed area had the least amount of interest for monitoring from the beginning. The geology in the Fremont Gorge restricts the river much more than in the rest of the park, and we do not think that we will be able to detect changes in geomorphology in the time scale that the NCPN is monitoring. In addition, the vegetation in the Fremont Gorge is very different from the rest of the riparian vegetation along the Fremont River in CARE. Reach 3 in the Above the Falls section was also eliminated due to particularly swift water in this reach, making it unsafe to sample.

This leaves a total of 6 reaches that are sampled with a five-year rotation (Figures 2-5 and 2-6). The five riparian reaches are sampled 2 years in a row, and the oxbow is sampled once every five years as long as flow has not been restored. Two reaches are sampled each year, except for the year that the oxbow is sampled, and three reaches are sampled this year.

At the time of protocol publication, a total of 4 reaches were established at CARE (reaches 1, 4, 7, and 14). Revisiting these established reaches after significant hydrologic events (i.e., large floods) or in response to management concerns is now a higher priority than following the proposed revisit design (see section 3.5 in the protocol narrative for additional information).

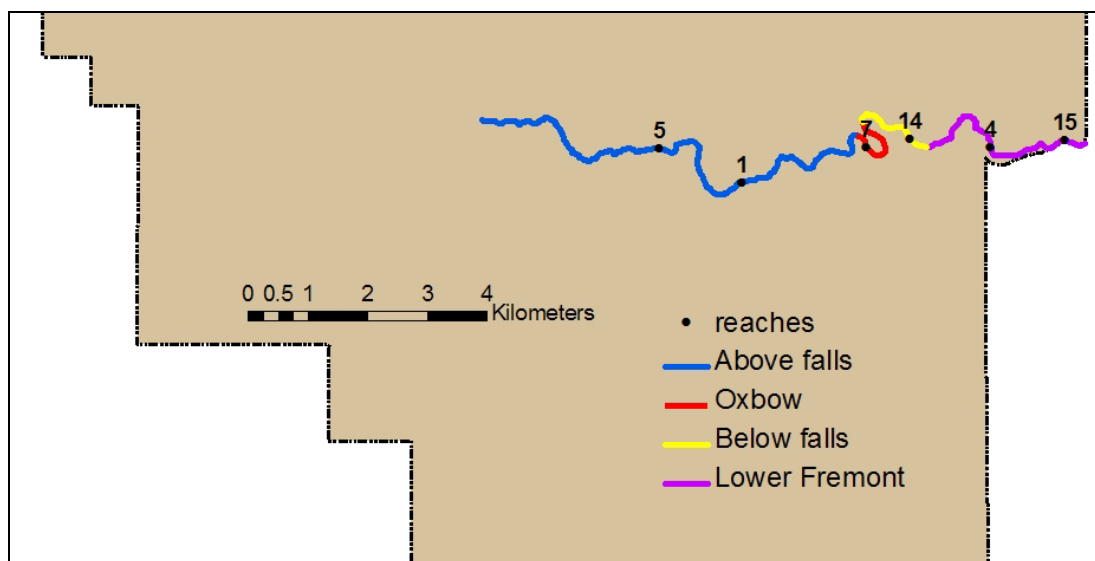


Figure 2-7. Revised sampling frame and reaches for riparian monitoring of the Fremont River at Capitol Reef National Park. The length of the Fremont River sampled in CARE is the area that is expected to change the most and is not highly managed (i.e., we removed the section formerly delineated as the managed area). The Fremont Gorge was also removed from the sampling frame because the geomorphology in the gorge is unlikely to change in the time scale of NCPN monitoring, and the vegetation is very different from the rest of the vegetation along the Fremont in CARE.

		Year sampled				
		1	2	3	4	5
Panel	1	x				x
	2	x	x			
	3		x	x		
	4			x	x	
	5				x	x
	6	x				

Figure 2-8. Revised revisit design for riparian monitoring of the Fremont River at Capitol Reef National Park. Five riparian reaches are sampled two years in a row. The reach in the oxbow is sampled once in 5 years until it is restored. Every 5 years, the sampling scheme repeats itself.

	Year sampled				
	1	2	3	4	5
Section sampled (ReachID)	Above falls (1)	Lower Fremont (4)	Lower Fremont (4)	Lower Fremont (15)	Lower Fremont (15)
	Below falls (14)	Below falls (14)	Above falls (5)	Above falls (5)	Above falls (1)
	Oxbow (7)				

Figure 2-9. Sections of Fremont River sampled each year and ReachID corresponding with Figure 2-5. In Year 6, the rotation begins again sampling Year 1 plots.

3 Natural Bridges National Monument

3.1 Defining the Riparian Resources for Monitoring

Discussions with Southeast Utah Group (SEUG) resource management staff identified several potential areas for monitoring. For the initial effort, however, Armstrong Canyon was selected (Figure 3-1). This canyon originates outside of the monument and drains an area about the size of the monument. Within the park, the Armstrong Canyon empties into White Canyon, a major drainage in southeast Utah ending in Lake Powell. Armstrong Canyon is an ephemeral stream that flows during snow melt in the spring and after large precipitation events and contains some small perennial pools. Armstrong Canyon is susceptible to violent flash-flooding since most of the canyon is bedrock constrained. Due to its relatively small drainage area, flash-flooding in Armstrong Canyon should be less severe than in White Canyon, the other main canyon in Natural Bridges National Monument (NABR).

Although violent flash-flooding will provide unique challenges to riparian monitoring at NABR, there are many clear benefits. Monitoring will help us understand natural variability, especially changes related to flash floods. Monitoring will also provide early warning of system degradation due to human disturbances, especially from outside of the park.

3.2 Accessibility

The entire length of Armstrong Canyon inside the monument (7.4 km) is accessible. Established hiking trails enter the canyon at Owachomo Bridge and Kachina Bridge, providing access to all areas of the canyon with < 3 km hiking distance.

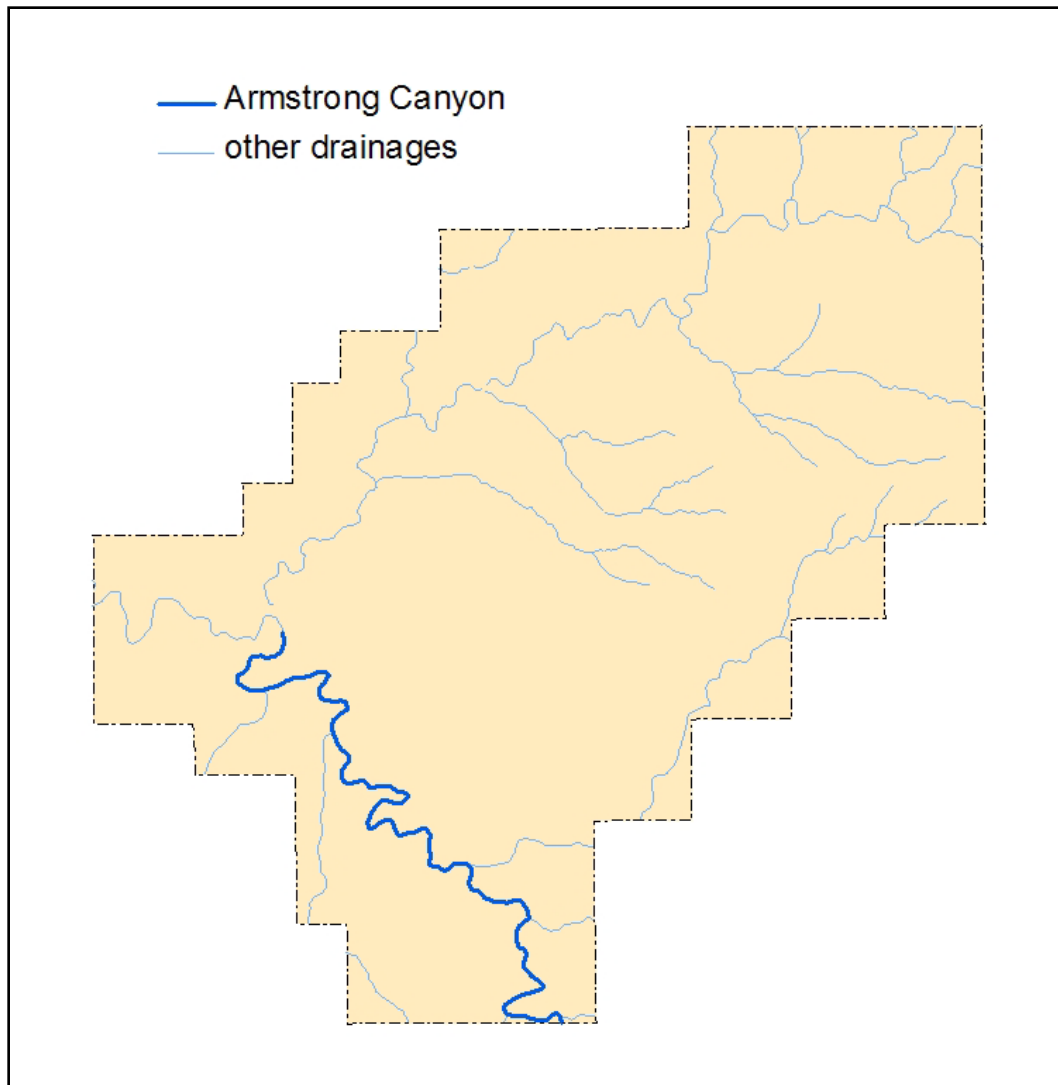


Figure 3-10. Location of Armstrong Canyon in Natural Bridges National Monument.

3.3 Watershed Area

An analysis of watershed area confirmed that all tributaries have relatively small watersheds. The largest tributary is Tuwa Canyon, with a watershed of 1427 ha. We did not find it necessary to stratify Armstrong Canyon above and below certain tributaries based on this watershed area analysis.

3.4 Delineating the Target Population

The entire stretch of Armstrong Canyon within NABR was selected as the target population and sampling frame for Armstrong Canyon.

3.5 Monitoring Site Selection

Generalized Random Tessellation Stratified (GRTS; see site selection section for Arches for additional details) was used to select 10 monitoring locations in the sampling frame for Armstrong Canyon (Figure 3-2). Five reaches are anticipated for long-term monitoring. Extra locations were selected to account for rejection of reaches. Reaches are rejected if they have a bedrock channel or if a major tributary enters in the middle of a reach.

In order to soundly reject GRTS runs that are not spatially-balanced, they are compared to a random sample (see site selection section for Arches for additional details). Three GRTS runs were completed before one was adequately spatially-balanced for riparian monitoring.

3.6 Tracking Monitoring Locations

A sequential list of all potential reaches is stored in a shape file (NABR_riparian_master). The list indicates acceptance or rejection of locations, reasons for rejection, date of reach establishment, and other important tracking information. Attributes of this shape file are described in Table 3-1.

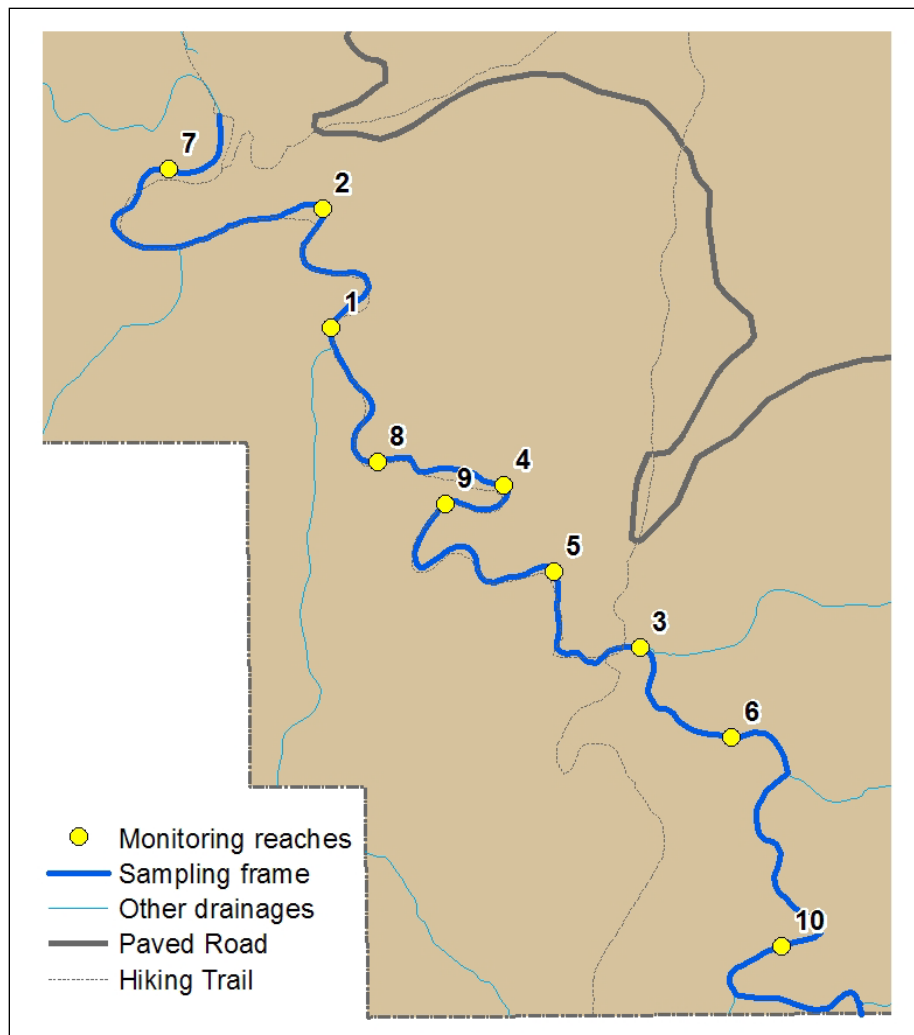


Figure 3-11. Potential reaches for riparian monitoring of Armstrong Canyon in Natural Bridges National Monument.

Table 3-5. Attributes of NABR_riparian_master.shp for tracking riparian monitoring reaches in Armstrong Canyon in Natural Bridges National Monument.

Field	Description
ReachID	The reach number, based on the siteID
panel	Panel that each reach is associated with in the revisit design
PanelYear	Years that panel is sampled (1-5, panel=0 for rejected reaches)
EvalStatus	Ultimate status of a reach (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of reach determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a reach was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
xcoord	UTM E (NAD83, Zone 12)
ycoord	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to the reach in kilometers
Comments	Miscellaneous
siteID	GRTS-assigned ordered unique identifier
stratum	GRTS attribute not used for selection of these sites (None)
mdcaty	Code for stratification of the sampling frame used by GRTS (1 for entire Armstrong Canyon sampling frame)
wgt	1/selection probability for each point

3.7 Revisit Design

We decided not to implement pilot monitoring in Armstrong Canyon because the number of reaches is more limited by affordable effort and the length of the sampling frame than variability of vegetation. Vegetation at each reach is sampled following a rotating-panel design (Figure 3-3) that samples 2 reaches each year and a total 5 reaches over 5 years. Reaches are sampled 2 years in a row and then rested for 3 years. Every 5 years, the sampling scheme repeats itself. The reaches should represent the length of Armstrong Canyon within NABR.

3.8 Revisions to the Sampling Design

At the time of protocol publication, a total of 4 reaches were established at NABR (reaches 1, 2, 4, and 5). Revisiting these established reaches after significant hydrologic events (i.e., large floods) or in response to management concerns is now a higher priority than following the originally proposed revisit design (see section 3.5 in the protocol narrative for additional information).

panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	1	1				1	1			
2		1	1				1	1		
3			1	1				1	1	
4				1	1				1	1
5	1				1	1				1

Figure 3-12. Number of reaches sampled each year based on 5-year rotating panel revisit design for riparian vegetation monitoring in Armstrong Canyon in Natural Bridges National Monument.

4 Zion National Park

4.1 Defining the Riparian Resources for Monitoring

Discussions with Zion National Park (ZION) resource management staff identified several potential streams for monitoring. For the initial effort, however, the East Fork of the Virgin River (East Fork) was selected. This stream originates outside of the park in Long Valley and runs west through the research natural area in Parunuweap Canyon in the southern part of the park (Figure 4-1). The East Fork is approximately 80 km in length, and the majority of the river is located upstream of the park where it is used for irrigation. Within the park, however, the river is relatively unaltered and exhibits ‘natural’ hydrologic function, mainly due to consistently flowing springs in Parunuweap Canyon. The East Fork has comparable flow and geologic settings to the highly altered North Fork Virgin River in the park, and monitoring will help us understand natural variability as well as early warning of system degradation due to human disturbances, especially from outside of the park.

Should resources become available for additional riparian monitoring at ZION, the park is also interested in monitoring North Creek and the North Fork of the Virgin River. The Kolob Fire burned the area around North Creek in June 2006, and this stream would benefit from monitoring recovery after the fire. The North Fork of the Virgin River contains the popular “Narrows” hike and runs through the most heavily managed areas in Zion Canyon. This stream would benefit from riparian monitoring to better understand impacts of management practices and visitor use.

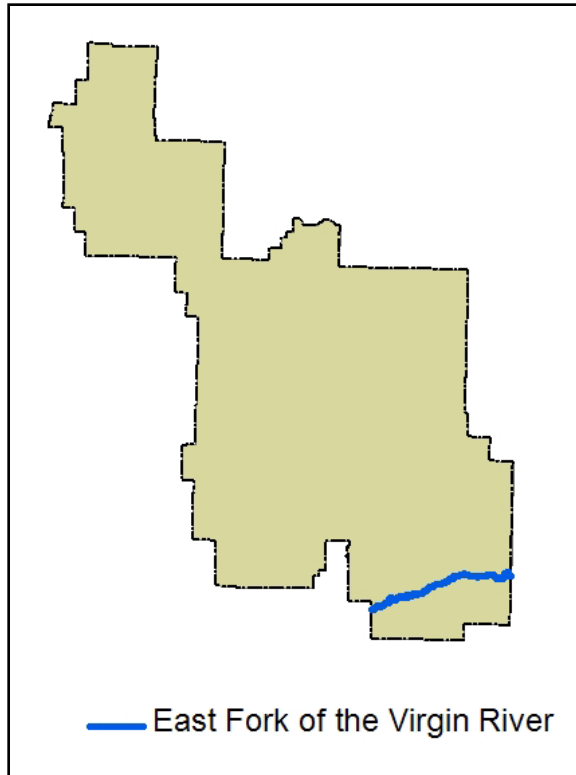


Figure 4-13. Location of the East Fork of the Virgin River in Zion National Park.

4.2 Accessibility

Early discussion with park staff led us to the assumption that the entire length of the stream inside the park (12.3 km) was accessible. In August 2008, NCPN staff attempted to hike the length of the stream and discovered pourovers and large boulders 10.3 km east of the western park boundary that were impassible without advanced climbing moves. This led to a revision of the accessibility map to exclude 2 km of the river near the eastern park boundary (Figure 4-2).

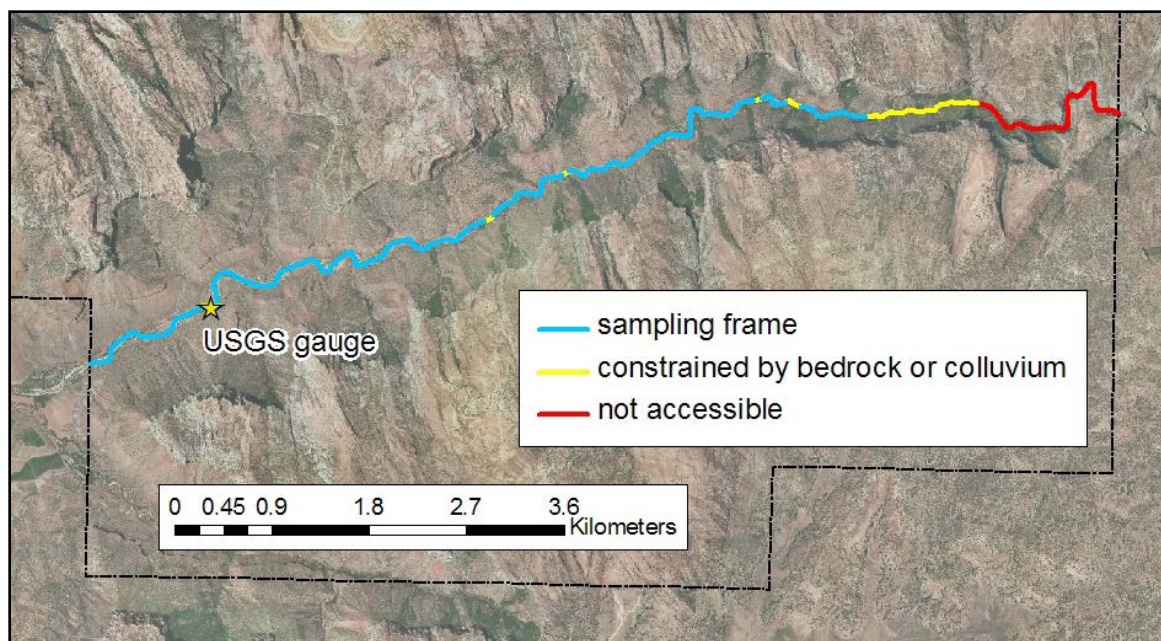


Figure 4-14. Accessible areas and sampling frame for riparian monitoring of the East Fork of the Virgin River in Zion National Park.

4.3 Delineating the Target Population

The entire stretch of the East Fork within ZION was initially selected as the target population, but this was shortened to exclude the inaccessible area on the eastern part of the stream. In addition, we decided to limit monitoring to areas along the stream with alluvial terrace development. This excluded sections of the stream constrained on both sides by bedrock or colluvium. We decided to only monitor alluvial-constrained and alluvial-unconstrained reaches because these are the areas where we could detect change in our time frame for monitoring (50-100 years). Change occurs much more slowly in bedrock- and colluvium-constrained reaches.

A geologic spatial data set exists for Parunuweap Canyon that includes detailed mapping of alluvial terraces in addition to the standard geologic map units. After field testing the accuracy of this data set, we decided to use it to mask out sections of the stream that were bedrock- or colluvium-constrained on both sides (Figure 4-3). This eliminated four small sections within the sampling frame and a longer section upstream of the sampling frame. Details of the eliminated sections are in Table 4-1. The East Fork is constrained completely by bedrock and colluvium from the eastern end of the sampling frame to the eastern park boundary.

The final sampling frame for the East Fork included 9.2 km of the stream starting at the western park boundary. Within this length, a total of 0.4 km was masked out of the four sections mentioned above. This left a length of 8.8 km in the sampling frame which is 85% of the accessible length of the East Fork.

Although the geology data probably masked out most non-target areas, reaches can additionally be rejected in the field if they are found to be bedrock- or colluvium-constrained.

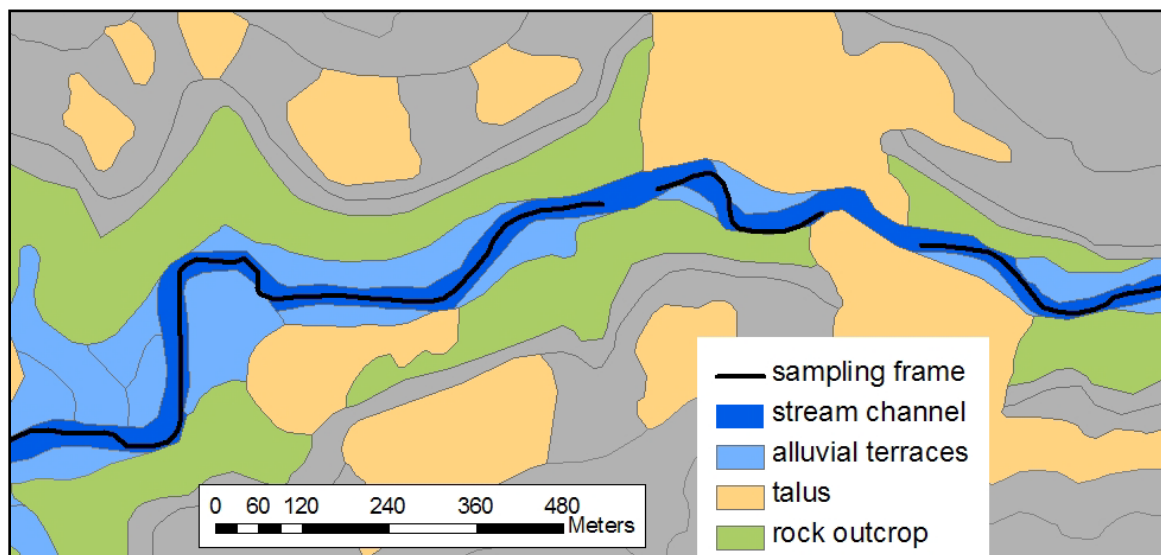


Figure 4-15. Example of geologic map units used in stratification of riparian monitoring on the East Fork of the Virgin River in Zion National Park. Areas where the stream channel was bordered on both sides by talus or rock outcrop were not included in the sampling frame.

Table 4-6. Sections eliminated from the sampling frame for the East Fork of the Virgin River in Zion National Park.

Section*	Length (m)	Reason for omission
1	97	Constrained by bedrock
2	70	Constrained by bedrock
3	77	Constrained by bedrock
4	170	Constrained by colluvium (talus)
5	1091	Constrained primarily by bedrock but also constrained by colluvium on the west side of this section

*Sections run from west to east along the sampling frame.

4.4 Monitoring Site Selection

Generalized Random Tessellation Stratified (GRTS; see site selection section for Arches for additional details) was used to select 15 monitoring locations in the sampling frame for the East Fork of the Virgin River (Figure 4-4). Seven reaches are anticipated for operational monitoring. Extra locations were selected to account for rejection of reaches. Reaches may be rejected if they are bedrock constricted or if a major tributary enters in the middle of a reach.

In order to soundly reject GRTS runs that are not spatially-balanced, they are compared to a random sample (see site selection section for Arches for additional details). Seven GRTS runs were completed before one was adequately spatially-balanced for riparian monitoring.

4.5 Tracking Monitoring Locations

A sequential list of all potential reaches is stored in a shape file (ZION_riparian_master). The list indicates acceptance or rejection of locations, reasons for rejection, date of reach establishment, and other important tracking information. Attributes of this shape file are described in Table 4-2.



Figure 4-16. Potential monitoring reaches for riparian monitoring of the East Fork of the Virgin River in Zion National Park.

Table 4-7. Attributes of ZION_riparian_master.shp for tracking riparian monitoring reaches on the East Fork of the Virgin River in Zion National Park.

Field	Description
ReachID	The reach number, based on the siteID
panel	Panel that each reach is associated with in the revisit design
PanelYear	Years that panel is sampled (1-7, panel=0 for rejected reaches)
EvalStatus	Ultimate status of a reach (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of reach determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a reach was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
xcoord	UTM E (NAD83, Zone 12)
ycoord	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to the reach in kilometers
Comments	Miscellaneous
siteID	GRTS-assigned ordered unique identifier
stratum	GRTS attribute not used for selection of these sites (None)
mdcaty	Code for stratification of the sampling frame used by GRTS (1 for entire East Fork sampling frame)
wgt	1/selection probability for each point

4.6 Revisit Design

We decided not to implement pilot monitoring on the East Fork because the number of reaches is more limited by affordable effort and the length of the sampling frame than variability of vegetation. Vegetation at each reach is sampled following a rotating-panel design (Figure 4-5) that samples 2 reaches each year and a total 7 reaches over 7 years. Reaches are sampled 2 years in a row and then rested for 5 years. Every 7 years, the sampling scheme repeats itself. The reaches should represent the length of the East Fork in ZION that is not bedrock- or colluvium-constrained.

4.7 Revisions to the Sampling Design

At the time of protocol publication, a total of 3 reaches were established at ZION (reaches 1, 2, and 3). Revisiting these established reaches after significant hydrologic events (i.e., large floods) or in response to management concerns is now a higher priority than following the originally proposed revisit design (see section 3.5 in the protocol narrative for additional information).

panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	1	1						1	1	
2		1	1						1	1
3			1	1						1
4				1	1					
5					1	1				
6						1	1			
7	1						1	1		

Figure 4-17. Number of reaches sampled each year based on 7-year rotating panel revisit design for riparian vegetation monitoring on the East Fork of the Virgin River in Zion National Park.