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Title

Gully incision in Gerbode Creek, Rodeo Lagoon watershed

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LA 227: River and Stream Restoration
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ABSTRACT STATEMENT

The Gerbode Creek drains 947 acres flowing westward to Rodeo Creek and thence to Rodeo Lagoon. The Gerbode valley is located ten miles north of San Francisco, California, in a former U.S. military base now part of the Golden Gate Recreation Area in Marin County. Numerous gullies are present in the watershed, presumably resulting from many years of agriculture, and road construction. In this study I measured the amount of sediment that has eroded in three separate gullies of the Gerbode Watershed and compared the volume of sediment transport to the area of its sub-watershed. I also analyzed aerial photos to see the changes in geomorphic form, riparian vegetation and human impact on Gerbode Valley. I have concluded that the sediment transport is a result of the agriculture and road runoff from this past 150 years. Based on aerial photos the riparian vegetation has been slowly making a comeback.

INTRODUCTION

The Gerbode Creek drains 947 acres flowing westward to Rodeo Creek and thence to Rodeo Lagoon. Gerbode Creek is a tributary of Rodeo Creek. The Gerbode valley is located ten miles north of San Francisco, California in a former U.S. military base now part of the Golden Gate Recreation Area in Marin (Figure.1). Numerous gullies are present in the watershed, presumably resulting from many years of agriculture, and road construction. Tectonic shifts in the geomorphology might have also increased runoff (reference Eric's paper). I measured the amount of sediment that has eroded in three separate gullies of the Gerbode Watershed and compared the volume of sediment transport to its sub-watershed. One gully is located south of the main stem (South Tributary) and two are located north of the main stem (North Tributaries #1 and #2). (Figure 1).

This specific study is part of a larger research project conducted by David Shaw, a graduate student in Environmental Planning, UC Berkeley. He is assessing the hydrology and geomorphology of the Gerbode and Rodeo Creek watersheds in order to make future recommendations on opportunities for ecological restoration and enhancement.

I. BACKGROUND

Gerbode Valley has historically been used for agricultural and military purposes. These uses have affected the hydrology of Gerbode basin. The major impact is ditch excavation for agriculture and road access. Segments of land in the watershed were ditched and partially drained to grow grain and cattle feed. As a result of the increased runoff, channels have incised, gullies have formed and the water table has lowered. This past technique of draining the water table is the primary cause of wetland reduction in Gerbode and Rodeo Valleys (Rodeo Valley Wetland Guidance & Hydrological Assessment, 2003). Aerial photos show that the vegetation on the site has reestablished itself in the past 48 years.

Today the area is part of the Golden Gate National Recreation Area and is primarily used for recreational purposes. Many people visit from nearby urban areas to hike, bike and ride horses on the surrounding trails of the Gerbode Basin. There are two trails that run up along the sides of Gerbode Valley (Map 1). Although the valley basin has no formal trails there are remnants of

old roads that traverse the main stem of Gerbode Creek, including failed culverts. Bobcat Trail runs along the southern side of the valley and Miwok Trail runs along the northern side of the valley. Vehicle traffic is limited on these trails. Both current and past roads have contributed to runoff and erosion. The storm water collection channels constructed to protect the roads have also contributed to erosion and gully formation. According to a report done two years ago there “are a few sites among the old roads where gullying has now occurred and where rapid storm water runoff may be problematic” (Rodeo Valley Wetland Guidance & Hydrological Assessment, 2003).

II. METHODS:

I conducted field surveys and consulted secondary data and references. I estimated the amount of erosion by calculating the volume of the channel using the area of the cross section and the length of the channel. I then compared the volume to the area of the sub-watershed based on United States Geographical Survey (USGS) topological maps. I observed and photographed the riparian vegetation growing on the banks of the creeks to inform the ground water processes taking place. I also analyzed aerial photos to observe the changes in riparian vegetation and human impacts over time.

a. Gullies Selection:

Early in my research I visited the site and chose stretches of Gerbode Creek that have gullies and incisions. To inform the human impacts on the creek, I examined creek conditions and looked for old roads and culverts (Figure 4,5&6).

b. Data Collection:

I measured the depth and the width of numerous gullies to calculate the area of the cross-section. I took measurements where I noted sudden changes in the width and depth of the cross section. I used a measuring tape as my primary tool. I measured the length of one tributary using a measuring tape. I measured the length of the other two tributaries on a USGS topographical map (1inch:24,000 inches).

I also documented cross sections with photographs and sketches. I documented landmarks, like failed culverts, old road structures and changes in riparian vegetation, which might inform why gullies have formed.

c. Area and Volume of Tributaries:

I used the following two equations to calculate the area of the cross section: area of rectangle = height x width, and area of triangle = 1/2 base x height. The results were plotted as cross sections, in Microsoft Excel. I also used the following equation to

calculate volume of the channel: volume = height x width x length (Table 4).

d. Area of Watershed:

I calculated the area of the watershed for each tributary to analyze if there is any correlation between the area of the watershed and the amount of sediment displaced in the gullies (Table 5).

e. Landmarks:

On the USGS map I identified the landmarks that might have caused increased erosion, such as old roads and culverts, and their proximity to the gullies. (See figure 1. and photographs 2-4).

f. Aerial Photographs:

I looked at aerial photographs from 1945, 1960 and 1996 to compare Gerbode Creek at different times. I analyzed the three stretches, North Trib. 1 and 2 and South Trib. to see changes in channel form, riparian growth and old roads that might have impacted the creeks. (Figures 8,9&10)

III. DATA COLLECTION RESULTS

Northern Tributary# 1 of Gerbode Creek

Observations: The Northern Tributary #1 is below the Miwok Trail and runs 400 feet. Riparian vegetation primarily consists of Willow trees. However, there is a stretch in the middle that is less vegetated (Point C) and is covered with Coyote Bush and grasses.

Depth of North Tributary #1: Point A is the source of the tributary and point E is closer to the confluence. Willows stop growing at point B, and give way to Coyote Bush and grasses. By point D they reappear. To see the cross section of each point refer to Appendix I.

Graph 1.

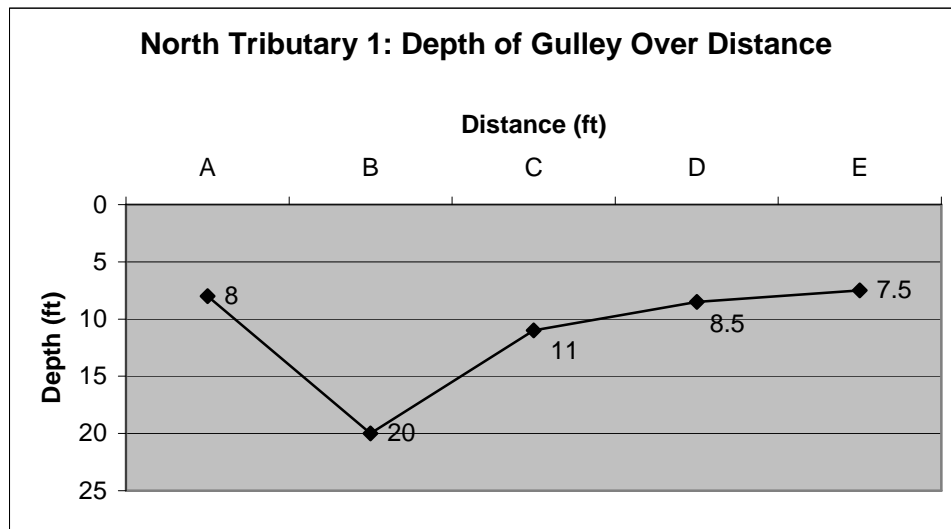


Table 1.

Gerbode Creek North Tributary #1					
Point	Width 1	*Width 2	Depth	Area	Notes
A	24		9.5	114	Pt. A is at the source
B	30		20	300	Pt. B is in middle of upper willow section
C	35		11	192.5	Pt. C is in the middle of less vegetated section
D	30	14	8.5	187	Pt. D is at the start of the lower willow section
E	26		7.5	97.5	Pt. C is at close to the confluence
Total Area				891	
Average Area				178.2	

(* Width 2 is the bottom of the trapezoidal channel)

North Tributary #2 of Gerbode Creek

Observations: Northern tributary #2, seems to be an old ditch and runs 437 feet along side of Northern Tributary #1. An old road traverses the creek at point D and there are remains of an old culvert (Figure 4&5). The surface of the ditch is covered with grass for the entire stretch. The creek has several gullies that cut through its bed (Figure 6). No grass grows inside gullies

Depth of the North Tributary #2: Point A is the source of the tributary and point G is towards the main stem. The tributary at point A starts at a depth of 4 feet, then lowers to 7 feet before it rises close to grade at 0.75 feet. It then lowers to a depth of 10 feet. To see the cross section of each point refer to Appendix I.

Graph 2.

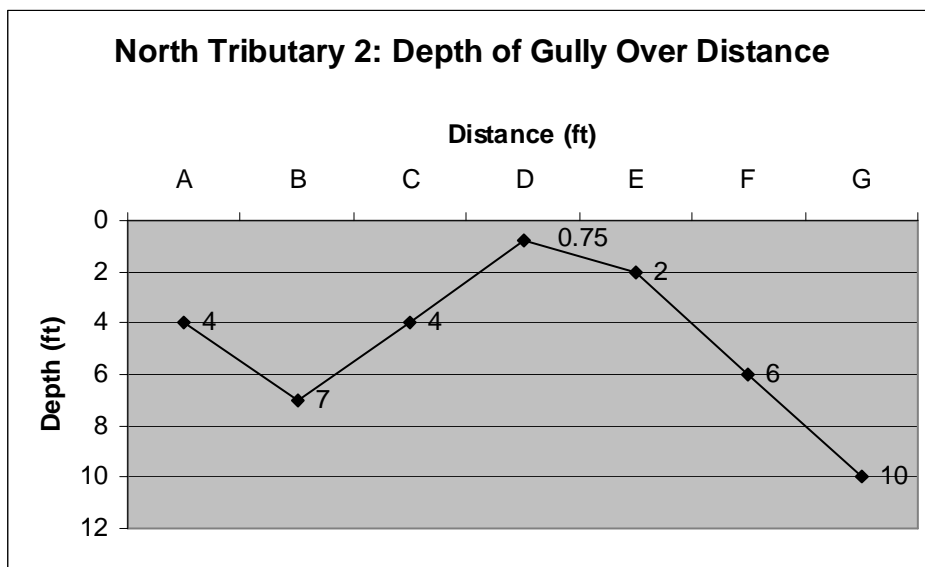


Table 2.

Gerbode Creek North Tributary #2					
Point	Width 1	Width 2	Depth	Area	Notes
A	2		4	4	Pt. A. is at the source
B	12		7	42	65 ft from Pt. A
C	18	8.5	4	53	Trapezoid Channel, 150 feet from Pt. A
D	3		0.75	1.13	61 ft from point E measuring up stream
E	2		2	2	Point E.
F	7.5		6	22.5	35 ft from point E measuring down stream
G	30		10	150	75 ft from point E measuring down stream
Total Area				274.63	
Average Area				39.2	

Southern Tributary of Gerbode Creek

Observations: The Southern Tributary passes through a culvert under Bobcat Trail and has riparian vegetation on its banks for most of its stretch. The majority of its banks are covered with willows. However, the middle section, represented by points C through F, is filled with sediment and covered with wetland grasses and Coyote Bush. An old wooden road structure crosses the tributary over this middle section. Head cuts are forming gullies closer to the confluence at points M, K and H.

Depth of the South Tributary: Point A is close to the source the tributary, before the Bobcat Trail Culvert. Point M is closest to the main stem. Notice that the bottom of the tributary begins at 3.5 feet and decreases to 11 feet and then it increases to 0.6 feet, which is almost grade level. Then the bottom lowers and rises between 2 and 4 feet (approximately, refer to line graph) before it finally lowers to meet the main stem. To see the cross section of each point refer to Appendix I.

Graph 3.

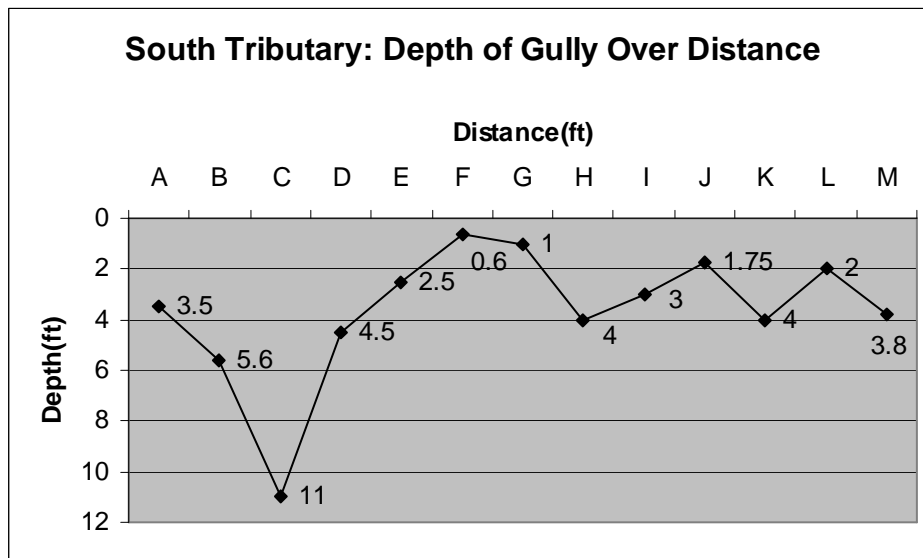


Table 3.

Gerbode Creek South Tributary					
Point	Width 1	Width 2	Depth	Area	Notes
A	8		3.5	14	Wet at bottom of channel
B	8	5	5.6	36.4	Wet at bottom of channel
C	30		11	165	Gerbode Creek at point where willows stop growing
D	28	12	4.5	90	Low growing shrubs cover channel surface
E	21	12	2.5	41.25	Grass covers entire channel surface; sediment filled
F	8		0.6	4.8	
G	5.5		1	5.5	
H	3.5		4	14	
I	4.75		3	14.25	
J	1		1.75	1.75	
K	3.5		4	7	
L	1		2	1	
M	12		3.8	22.8	Willows growing in center of channel
Total Area				417.75	
Average Area				32.1	

SEDIMENT VOLUME OF TRIBUTARIES

Table 4.

Gerbode Ck	Cross Section Average Area (ft²)	Length (ft)	Volume (ft³)
North Tributary #1	178.2	2,000	356,400
North Tributary #2	39.2	437	17,043
South Tributary	32.1	2,500	80,250

I calculated the area of each tributaries watershed to compare the size of the watershed to the amount of sediment transport. To calculate the volume of sediment transport at for each tributary I multiplied the average cross section area to the length. The calculations are shown in Table 4. North Trib. #1 and the South Trib. are about the same length, yet the North Trib. #1 transports almost five times more sediment.

WATER SHED AREA

I also calculated the area of each tributary to compare to the volume of sediment transport. The calculations in Table 5 show that the watershed area of South Trib. is greater than the area for North Trib. 1 and 2. In fact the area for South Trib. is almost 1/3 greater that North Trib. 1, yet the volume transported is four times less than North Trib. 1. Although South Trib. has 57% of the total area it only transports 18% of the total sediment volume. On the other hand, North Trib.1 has 34% of the total area yet transports 79% of the total sediment volume. This evidence stimulates the question: why are the sediment loads disproportionate to the area of the watersheds?

Table 5.

Gerbode Ck	Perimeter (ft2)	Watershed Area (ft2)	Volume (ft3)	Area (%)	Volume (%)
North Tributary #1	10,000	6,250,000	356,400	34%	79%
North Tributary #2	5,000	1,562,500	17,043	9%	4%
South Tributary	13,000	10,562,500	80,250	57%	18%
Total	28,000	18,375,000	453,693	100%	100%

COMPARISON OF AERIAL PHOTOS:

I compared the aerial photos from 1940, 1960 and 1996 it seems that riparian vegetation has reestablishing itself along the banks of North Trib. #1 and South Trib. I also looked for changes in channel form and old roads that could have impacted the creek. There was no evidence of changes in channel form. However the 1940 photo shows more agricultural and less riparian vegetation. It also shows remnants of a bridge and road in the vicinity to North Trib. 2. The 1960 photo shows the same type of evidence. All photos show less vegetation on the hills surrounding North Trib. 1 and 2., compared to South Trib. This might be the reason why North Trib.1 has four times more sediment transport than South Trib. (Figures 8,9&10)

Year of Photo	North Trib. 1.	North Trib. 2.	South Trib.
August 1940	Some vegetation in barren section but much less compared to the lower and upper portions of the tributary.	The North Trib. 2 is not visible in this photo, but there is evidence of agriculture and there are visible remnants an old road in the vicinity of North Trib.# 2 and a bridge over Gerbode Creek's main stem.	Very barren in middle section and a lot less vegetation compared to the middle section in North Trib. 1.
April 1960	There is less visible vegetation in this stretch compared to the 1940 photo. The photo was taken after the rainy season so it has less contrast between riparian vegetation and agricultural land	Remnants of the bridge and the road are still visible, but the North Trib. is not visible.	There is a little more vegetation than the 1940. The upper stretch has much more riparian vegetation than the 1940 photo, while the middle section is still barren
April 1996	The entire stretch looks re-established. The middle section has a thin line of green but much more	The bridge and the road are no longer visible, but there are green lines in the landscape that suggest	The vegetation in the upper and the lower parts of the stretch have grown significantly and are

	than the 1960 photo.	where the road might have been in the area of North Trib. 2.	growing towards the middle section. Compared to 1940 and 1960 photos, the riparian vegetation looks re-established.
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DISCUSSION

The graphs for North Trib. 1, 2 and South Trib. show that there is sediment transport through all three stretches. The North Trib. #1 has the deepest incision of 20 feet, followed by South Trib. at 11 feet and North Trib. #2 at 10 feet. I also observed that areas of deep incision have less willows. The data I collected shows that there are two processes occurring at the same time. The elevation on the main stem of Gerbode is propagating upstream while large sediment deposits are migrating downstream. The two processes are meeting in the middle of the tributaries. The Southern Trib. (graph 3) is a clear example. It illustrates that head cuts are migrating up stream as a large sediment load is also migrating down stream. Head cutting is also happening on North Trib. 2 but to a lesser extent.

The sediment volume I calculated indicates that North Trib. 1 has 34% of the total area and transports 79% of the total sediment while South Trib. has 57% of the total area and transports 18% of the total sediment. The North Trib. 1 is transporting 61% more sediment than South Trib. This could explain why North Trib. channel is twice as deep as the South Trib. channel.

The aerial photos I analyzed also showed that the slopes surrounding North Trib. 1 have been less vegetated than the slopes for South Trib. This explains the larger sediment deposit and the greater incision on North Trib 1. The photos I analyzed also showed that there was less riparian vegetation on the banks of North Trib. 1 and South Trib. in 1940 and 1960. However according to the 1996 photos the riparian vegetation is denser. This suggests that riparian vegetation has been slowly reestablishing itself on the banks of both North Trib. 1 and South Trib.

CONCLUSION

According to Dave Shaw, there are three possible explanations for the down cutting in Gerbode Creek. First, the new elevation of the main stem might be caused by natural tectonic uplifts common in the region. The head cuts are a method to readjust all the tributaries to this new elevation. The second explanation is that increased and excessive road and agriculture runoff have caused increased erosion and incision. The third explanation is that the water surface of Rodeo Lagoon has lowered and the head cutting is propagating up stream to compensate for the new surface elevation.

Based on the evidence I provided the tributaries are down cutting because of the increased runoff from the agricultural period. According to aerial photos the hills right above North Trib. 1 and 2 are more deforested than the hills surrounding South Trib. Without dense vegetation the surface is less permeable and this produces more runoff. This explains why there is more

sediment transport in North Trib. than in South Trib. The data I collected show that head cutting is also migrating upstream but the cause has to be further investigated.

REFERENCE

Podlech, M. et al., Some Physical, Chemical and Biological Characteristics of Rodeo Lagoon, Rodeo Lake and Rodeo Creek, Initial Summer Study 1993, Institute of Chemical Biology, University of San Francisco, San Francisco, CA

Rodeo Valley Wetland Guidance & Hydrological Assessment (2003) Draft Document

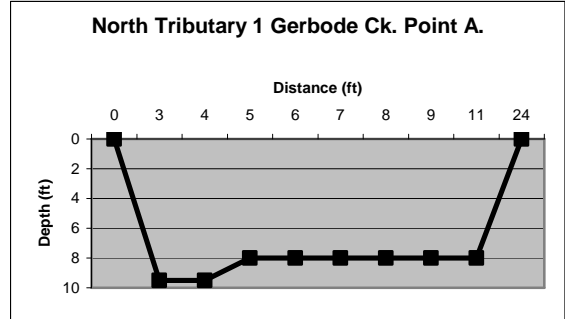
Shaw, David (October/November 2003), Based on conversations with David Shaw, Environmental Planning Graduate Student, University of California, Berkeley.

APPENDIX I: DATA COLLECTION RESULTS

GERBODE CREEK: NORTHERN TRIBUTARY 1

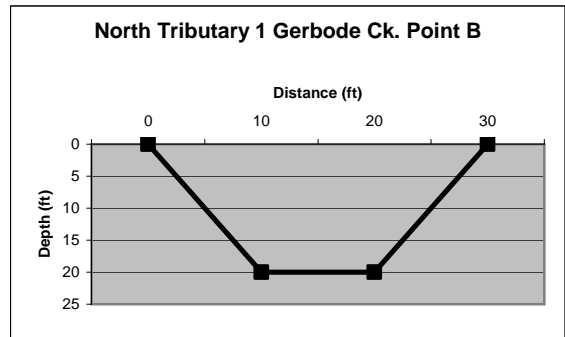
Cross Section A.

The bank full width is 24 feet and the depth is 9.5 feet. There is a deeper channel on the left side. The banks are covered with a combination of Willows, Coyote Bush and grasses.



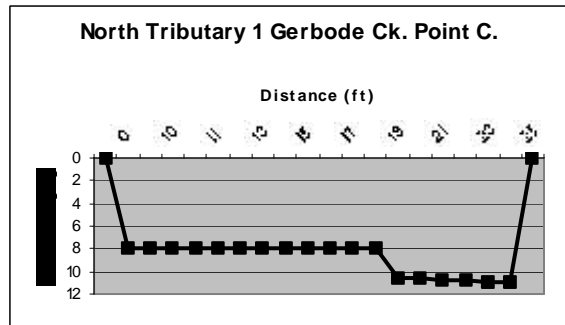
Cross Section B.

Point B is a trapezoidal channel. The bank full width is 30 feet and the depth is 20 feet. Willows cover the banks.



Cross Section C

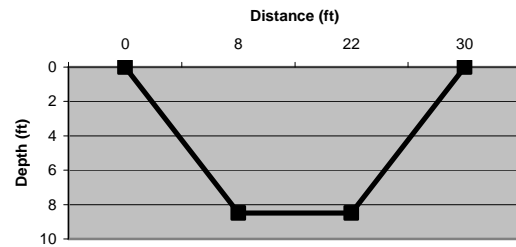
Point C is basically a trapezoidal channel, with a deeper channel on the right side. The bank full width is 35 feet and the depth is 11 feet. Coyote Bush and grasses are growing on the bank. Died horsetail was found on the banks of the creek.



Cross Section D.

There is a trapezoidal shaped channel at Point B. The bank full width is 30 feet, the bottom bank width is 14 feet, and the depth is 8.5 feet. Willows stop growing at this point and Coyote Bush and grasses begin.

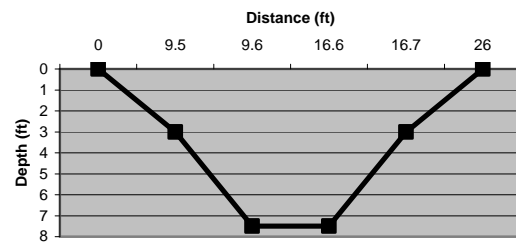
North Tributary 1 Gerbode Ck. Point D



Cross Section E.

The banks at Point E are covered with willows. The bank full width is 26 feet and the depth is 7.5 feet. There is a 3.5 wide shelf on the right bank.

North Tributary 1 Gerbode Ck. Point E.

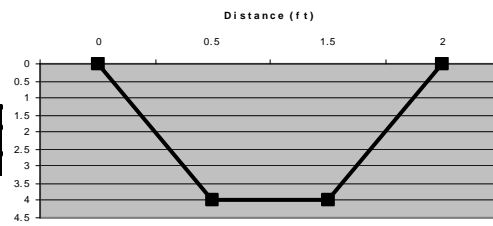


GERBODE CREEK: NORTHERN TRIBUTARY 2

Cross-Section A.

At point A the shape of the gully is an inversed triangle. The top width is 2 feet and the depth is 4 feet.

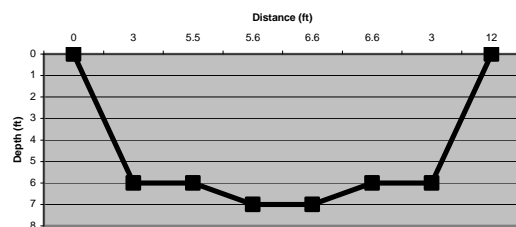
North Tributary 2 Gerbode Ck. Point A.



Cross-Section B.

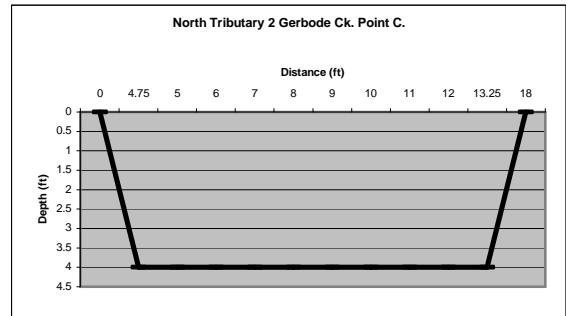
At point B there is trapezoid shaped channel with a smaller incision at the bottom of the channel. The top width of the channel is 12 feet and the depth is 7 feet. This shape is uniform for about 150 feet downstream.

North Tributary 2 Gerbode Ck. Point B.

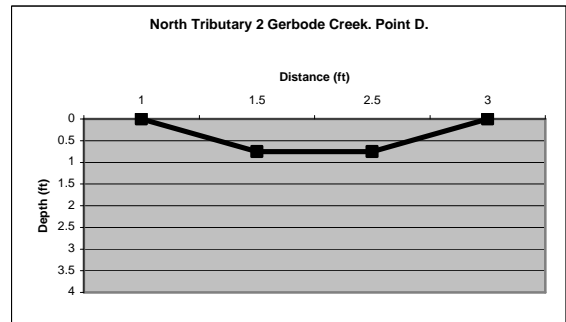


Cross-Section C.

At point C the channel is in the shape of a trapezoid. The top width is 18 feet, the bottom width is 8.5 feet and the depth is 4 feet.

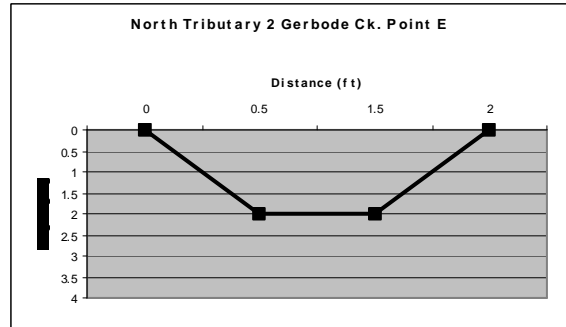


Cross-Section D. At point D the channel is the shape of an inversed triangle. The top width is 3 feet and the depth is .75 feet.



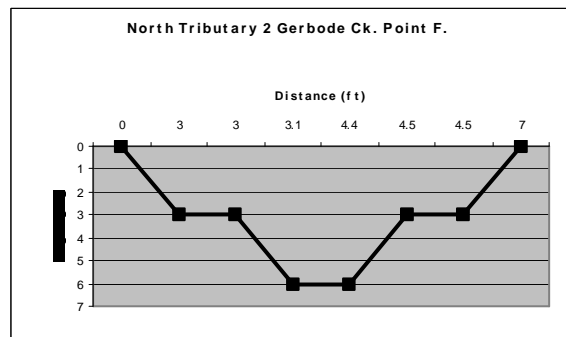
Cross-Section E.

At point E the channel is the shape of an inversed triangle. The top width is 2 feet and the depth is 2 feet.



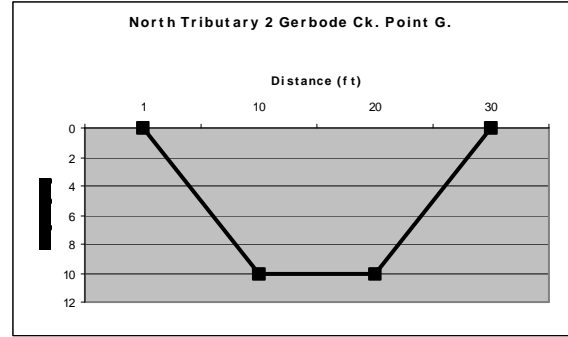
Cross-Section F.

At point F there is trapezoid shaped channel with a smaller incision at the bottom of the channel. The top width of the channel is 7.5 feet and the depth is 6 feet. The width of the small gully at the bottom is 1.5 feet.



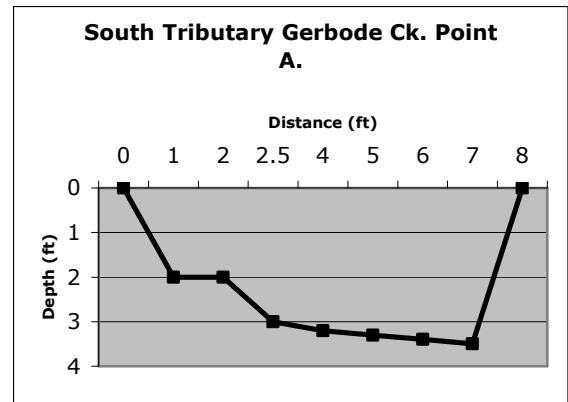
Cross-Section G.

At point G the channel is the shape of an inversed triangle. The top width of the channel is 30 feet and the depth is 10 feet.

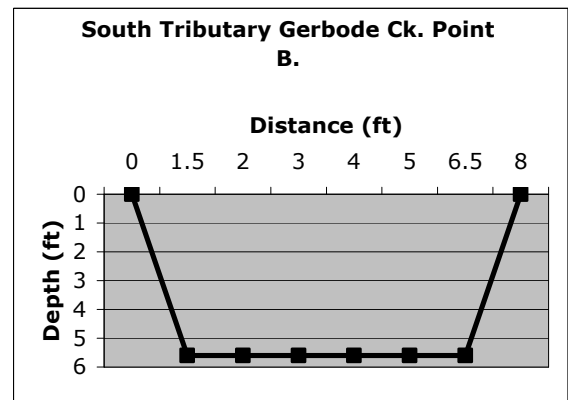


GERBODE CREEK SOUTHERN TRIBUTARY

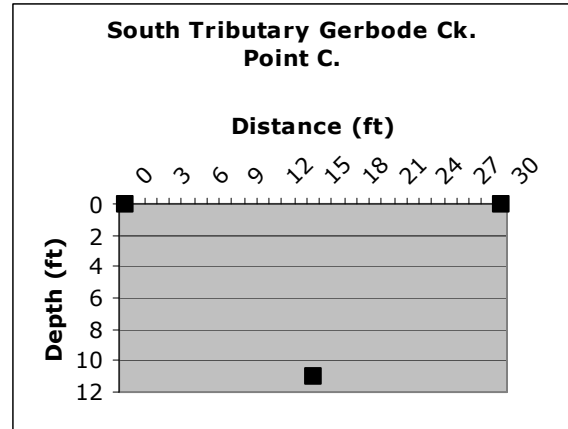
Cross-Section A. This is a cross section of the creek at point A. before it passes through the culvert under the Bobcat Trail/Road. The banks are full of vegetation, mostly Coyote Bush. There is no running water but the soil at the bottom of the creek is moist. As the cross section shows the top width is 8 feet and the deepest part is 3.5 feet. The shape of the cross-section is a trapezoid with a 2foot wide terrace.



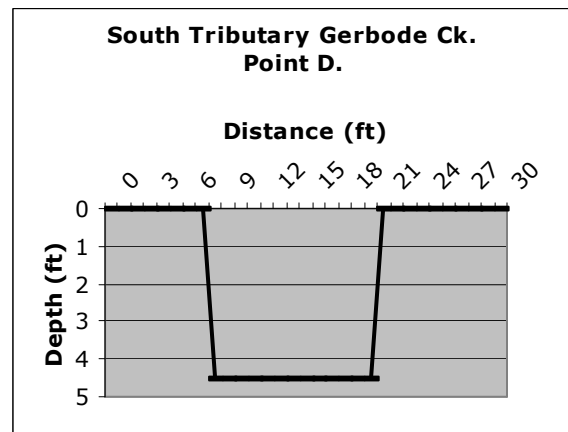
Cross-Section B. This is a cross section of the creek at point B, after it passes through the culvert under the Bobcat Trail/Road. Here the banks are full of vegetation. There is no running water, but the soil at the bottom of the creek is wet. The cross section of the channel is trapezoidal. The top width is 8 feet, the bottom width is 5 feet and the depth of the channel is 5.5 feet



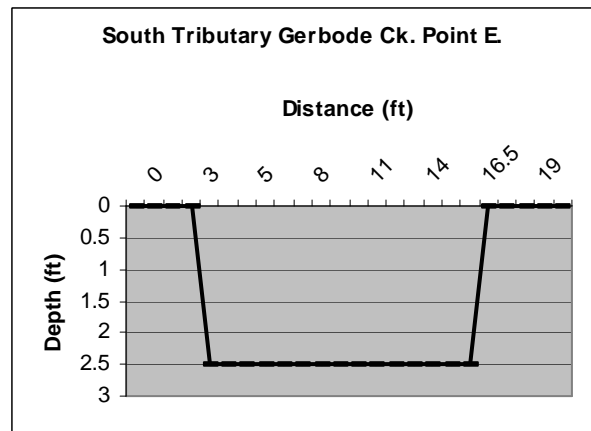
Cross-Section C. At point C, the riparian vegetation dies out and the channel is mostly barren. The shape of the channel is an upside down triangle. The top width of the channel is 30 feet and the depth of the channel is 11 feet. As mentioned above, the vegetation changes at this point. Here the willows give way to wetland type grasses and Coyote Bush and the channel is dry.



Cross-Section D. At point D, the cross section is trapezoidal. It has a top width of 28 feet, a bottom width of 12 feet and a depth of 4.5 feet. The banks are covered in low growing Coyote Bush. In this section the sediment deposition from up stream is apparent.

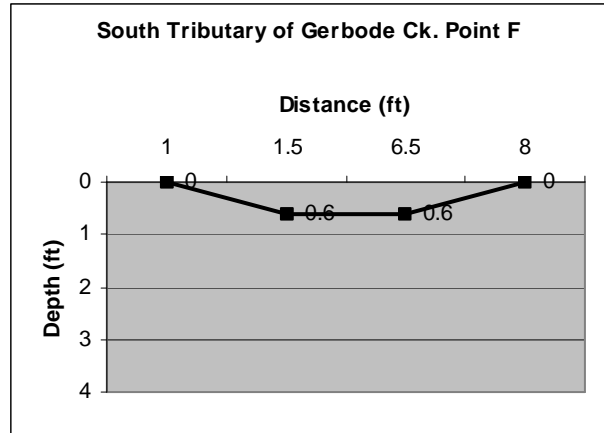


Cross-Section E. At point E, the cross section is trapezoidal. It has the top width of 21 feet, a bottom width of 12 feet and a depth of 2.5 feet. The surface is covered in wetland type grasses. In this section there is increased sediment deposition from up stream.



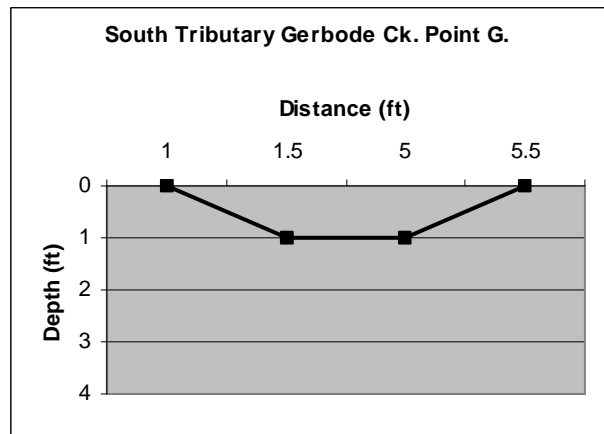
Cross-Section F.

At point F, the cross section is trapezoidal. It has the top width of 8 feet and a depth of 0.6 inches.



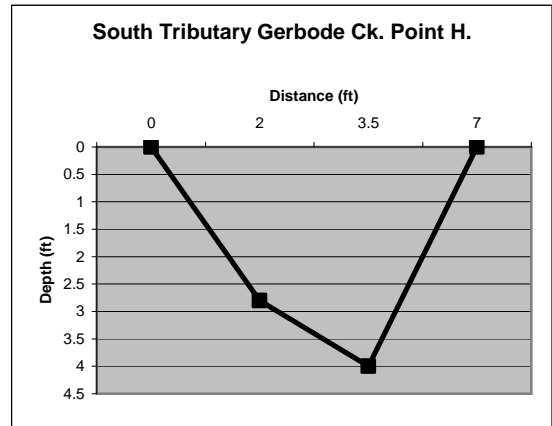
Cross-Section G.

At point G, the cross section is trapezoidal. It has the top width of 5.5 feet and a depth of 1 foot.



Cross-Section H.

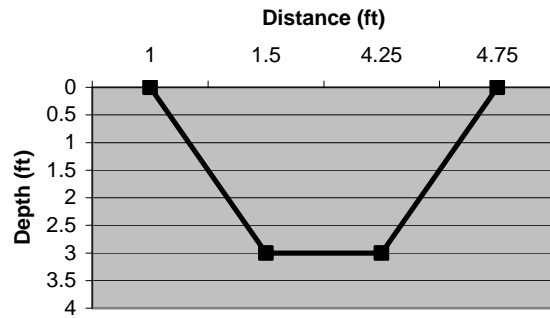
At point G, the cross section is triangular. It has the top width of 4 feet and a depth of 3.5 foot.



Cross-Section I.

At point I, the cross section is trapezoidal. It has the top width of 4.75 feet and a depth of 3 foot.

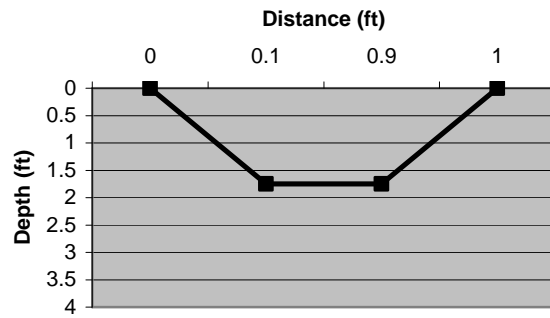
South Tributary Gerbode Ck. Point I.



Cross-Section J.

At point J, the cross section is trapezoidal. It has the top width of 1 foot and a depth of 1.75 feet.

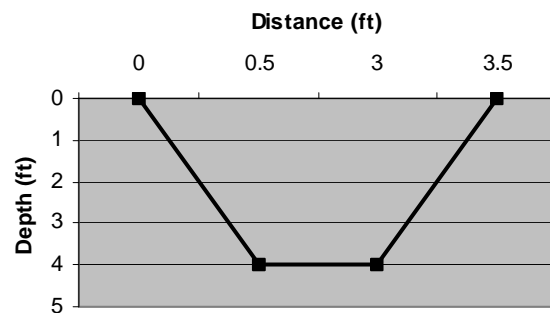
South Tributary Gerbode Ck. Point J.



Cross-Section K.

At point K, the cross section is trapezoidal. It has the top width of 3.5 feet and a depth of 4 feet.

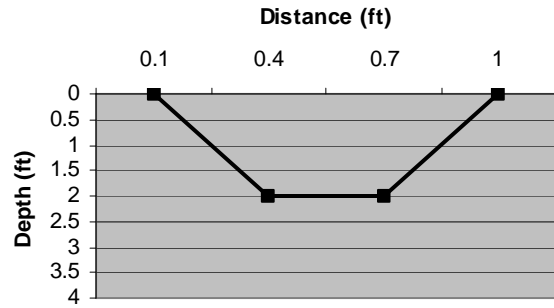
South Tributary Gerbode Ck. Point K.



Cross-Section L.

At point L, the cross section is trapezoidal. It has the top width of 1 foot and a depth of 2 feet.

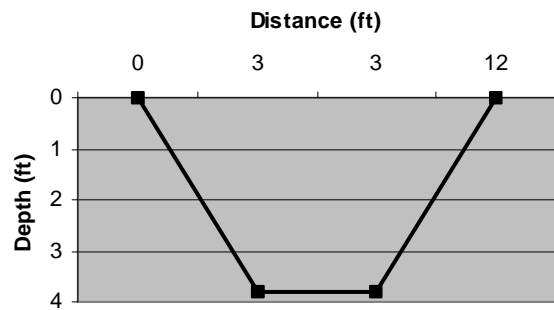
South Tributary Gerbode Ck. Point L.



Cross-Section M.

At point M, the cross section is trapezoidal. It has the top width of 12 feet and a depth of 3.8 feet. Willows grow in the center of the channel.

Southern Tributary Gerbode Ck. Point M.



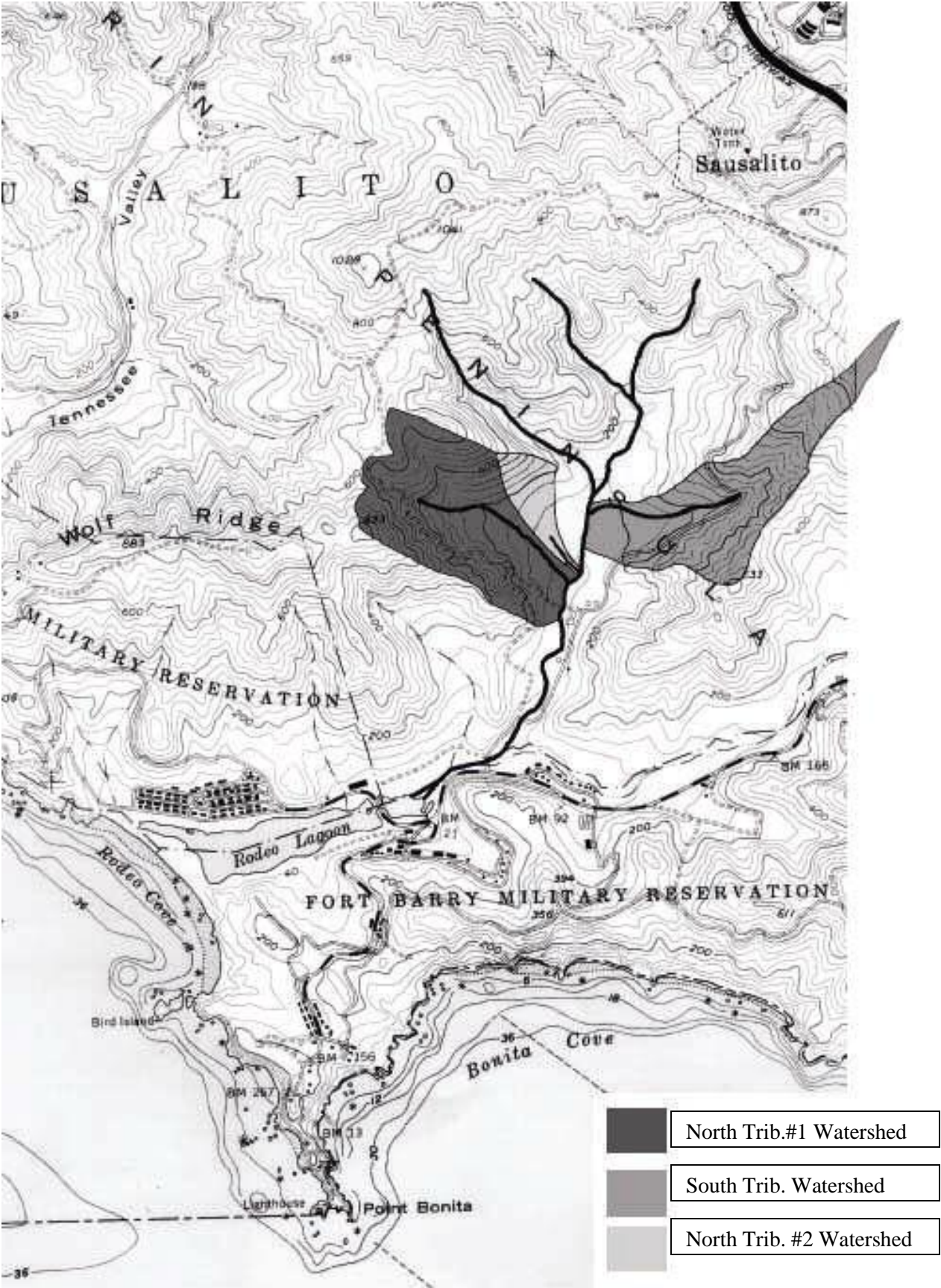


Figure 1. Map of Gerbode Creek with three sub-watersheds outlined.



Figure 2. View the confluence of the North Tributary #1 and the main stem. I took these photos from Miwok Trail looking down into Gebode valley. Notice that the riparian vegetation on the creek in the foreground dies out in the middle and then appears again.



Figure 3. View the riparian vegetation on the South Tributary. The left side is down stream near the confluence and the right side is up stream near the source. Notice the dense riparian vegetation down stream and up stream, while the middle is less vegetated with Coyote Bush and grasses.



Figure 4. David Shaw standing on

remnants of old bridge and culverts
on the North Tributary #2.



Figure 5. David Shaw standing on
remnants of old bridge and culverts
on the North Tributary #2.



Figure 6. An exposed gully North Tributary #2.



Figure 7. David Shaw inside a section of North Tributary #2. The Coyote bush on the bottom right corner shows where the right bank starts. The Coyote Bush on the top left corner shows where the left bank ends. The channel is filled with grass.

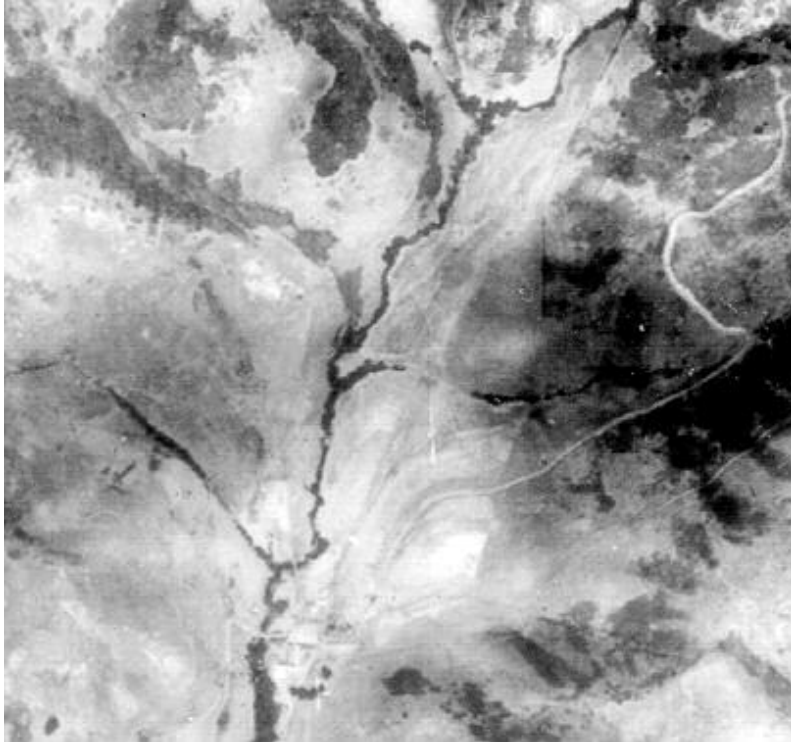


Figure 8. Aerial photo of the site in 1940.

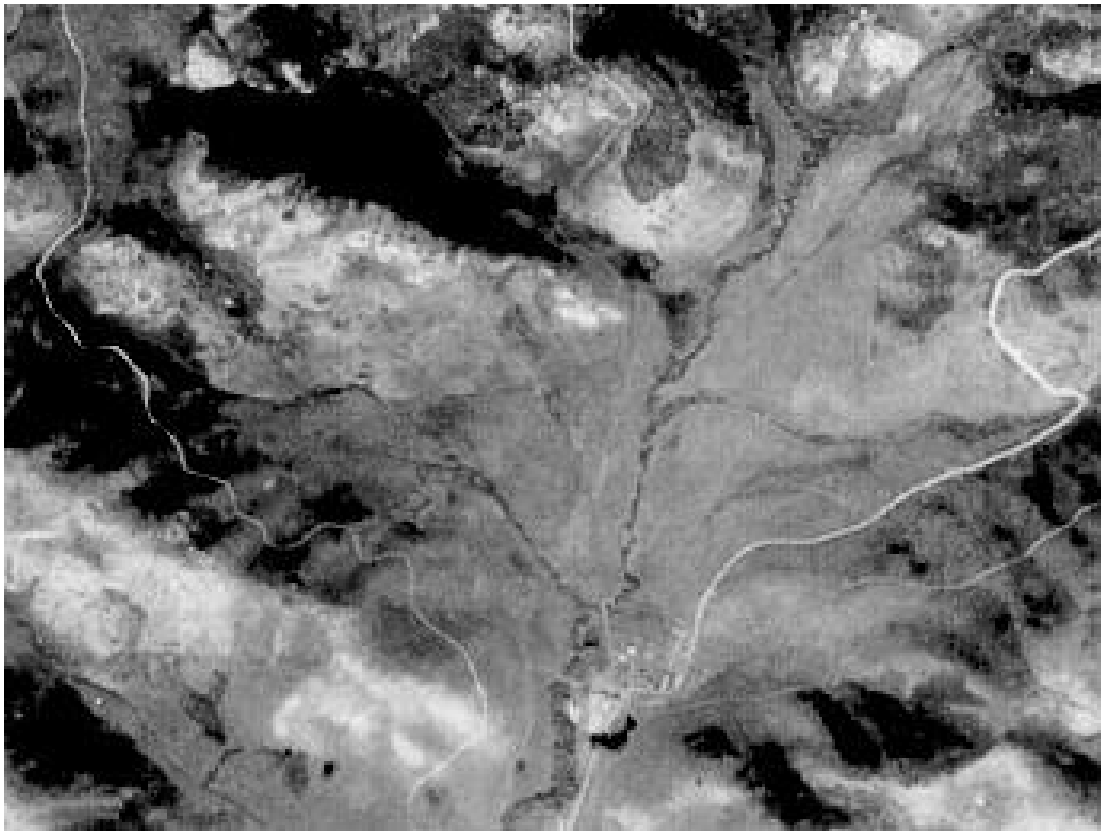


Figure 9. Aerial photo of the site in 1960.

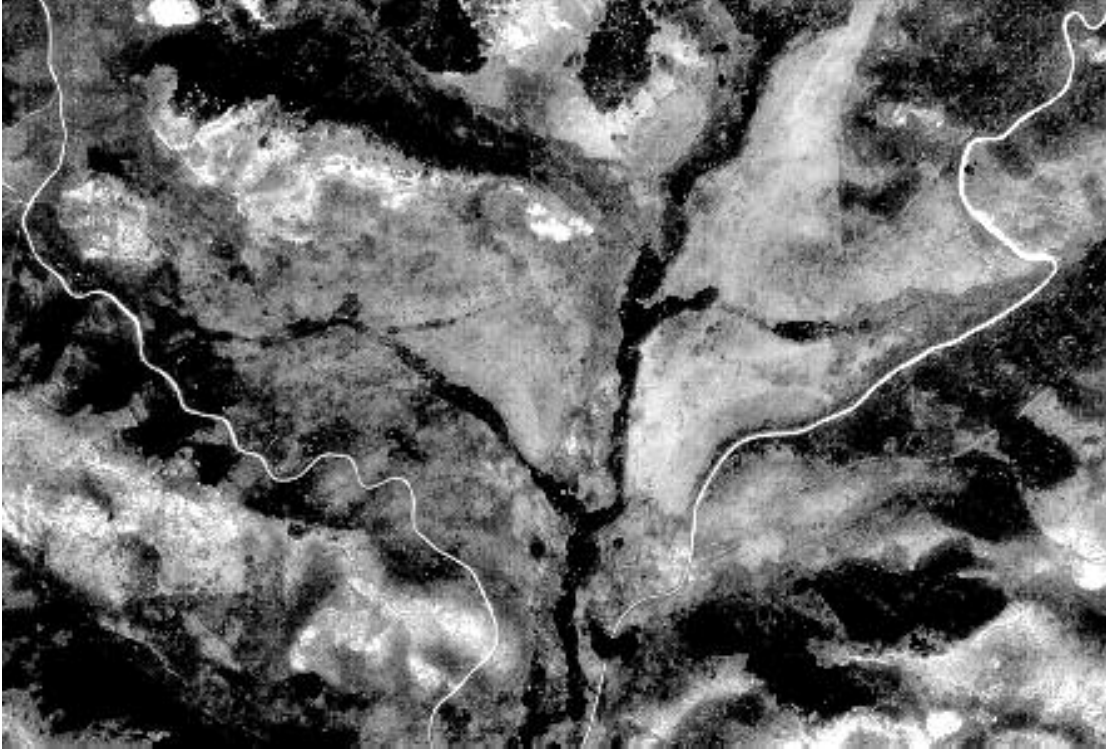


Figure 10. Aerial photo of the site in 1996.