TECHNICAL MEMO: Sonoma Watershed Regional Curve Graphics and Data for 319H Project

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TO: Becca Lawton, Sonoma Ecology Center
DATE: 6/30/2013

Bankfull Cross Sectional Area Regional Curve

A correlation of bankfull cross sectional area to drainage area was developed specifically for the Sonoma Watershed for two primary reasons, firstly, to provide information that could help with determining the hydraulic geometry necessary for restoring channel stability, and secondly, to provide the SEC GIS an equation to predict bankfull cross sectional area along any segment of the stream network. Some new data were collected during the 319h Project, however most of the raw data was gleaned from previous projects involving fieldwork in the Sonoma watershed. All data were collected by L. Collins of Watershed Sciences during work on previous projects that included the 2006 Sediment Source Analysis for SEC and the SF Regional Water Quality Control Board, the 2004 Geomorphic Analyses of Processes Associated with Flooding in Schellville for the Southern Sonoma Resource Conservation District (SSCRCD) and the Army Corps of Engineers, the 2013 Sonoma and Carriger Creeks Alluvial Fans Assessment for the SSCRCD and the Sonoma Water Agency, and from 2005 teaching purposes of a class on Applied Fluvial Geomorphology Class for Wildland Hydrology. Matching funds were provided by Watershed Sciences for data reduction, graphing, and analysis during this project and from work on a 2013 concurrent project to develop Regional Curves of Marin and Sonoma Counties for the San Francisco Estuary Project and US EPA. Matching funds were also provided by the San Francisco Estuary Institute to provide metrics on drainage area for 143 data collection sites from their Bay Area Aquatic Resource Inventory (BAARI) maps.

The SFEI BAARI drainage area analysis was reviewed by Watershed Sciences and where some watersheds did not seem to have reasonable drainage areas relative to cross sectional area or appeared as significant outliers, the watershed boundaries and/or stream network were reviewed for differences in interpretation. If a difference was found, the drainage area was redrawn and its new area calculated by Watershed Sciences using Google Earth Pro.

Data on bankfull width and depth had been collected during various field studies and the methods used ranged from direct tape measurement of bankfull width and mean bankfull depth to cross section surveys using either a level line or survey level and rod. Where only bankfull width and mean depth had been measured during earlier studies, the two were multiplied to determine bankfull cross sectional area. When sites were surveyed, a cross section was plotted and the channel area beneath bankfull elevation was calculated.

Data for 143 sites were entered into an Excel spreadsheet and an electronic file provided to SEC. Copies of all data are provided in this technical memo. Figure 1 shows the bankfull cross sectional area plotted against drainage area. A linear regression analyses provided an equation for the trendline and the R^2 value. A Google Earth kmz of the locations of the 143 sites was provided to SEC and Figures 2 through 7 provides Google Earth imagery of the site locations. To view the site locations in detail, the kmz file should be attained from SEC.

When data was available on both width to depth (W/D ratio) and entrenchment ratio (floodprone width divided by bankfull width) it was added to the spreadsheet to determine the Rosgen Stream Class. Floodprone width requires an additional measurement of the channel at twice maximum bankfull depth. Rosgen Stream Classification (Rosgen, 1996) can be used to stratify the data to look at the influences of channel geometry and potential stability. A chart of the Rosgen Stream Classification can be reviewed in Figure 8. A more detailed discussion of regional curves and Rosgen Stream Classification is available in the Collins and Leventhal (2013) report on Regional Curves of Hydraulic Geometry of Wadeable Streams in for Marin and Sonoma Counties, San Francisco ay Area. It is available on the Sonoma Valley Knowledge Base website at http://knowledge.sonomacreek.net/

Figure 1 shows data points with different colors. The data was stratified, when possible, to show the influence of channels with potentially unstable channel geometry as represented by category F and G channels of Rosgen Stream Classification. In particular, definitive G and F channels were highlighted a different color because they are considered highly entrenched and do not have a stable form that can be maintained over a range of flow frequencies. G channels tend to have predominant streambed incision processes making them too deep and narrow, while F channels tend to have predominant bank erosion processes making them too broad and shallow. The standard thresholds for various stream classes can be seen in Figure 8. The threshold error (or variability) for width/depth ratio, as published by Rosgen (1996), is +/- 2.0. Many of the streams analyzed by Rosgen for the development of his Stream Classification system included many channels that are subject to snowmelt. Collins believes that in general, such snowmelt channels are not subject to the higher and often flashier bankfull runoff conditions that occur in coastal California streams. Based upon previous conversations with Dave Rosgen about Bay Area streams, Watershed Sciences modified the standard threshold for W/D ratio to +/- 3.0 instead of 2 because bankfull channel conditions were found that did not fit within the Rosgen Stream Classification System. The Rosgen threshold of +/-0.2 for Entrenchment Ratio was adhered to.

In Figure 1, which shows a plot of bankfull cross sectional area against drainage area, the blue diamond data points represent the following types of conditions: 1) channels that either do not have a determined Rosgen Stream Class from the dataset (because not enough raw data was available from previous studies); 2) channels that could not be definitively separated into definitive F, G, and B stream classes because their thresholds of W/D and entrenchment ratios overlapped (often times this is due to a channel being in a state of adjustment implying that some unstable channels are included); and 3) channels that have relatively stable A, B, C, and E Rosgen Stream Classes. The red diamond data points in Figure 1 are definitively Rosgen Stream Class G channels because their W/D thresholds are ≤9 or their entrenchment ratio is < 1.3 and their W/D is <12. Dark blue box-shaped data points are definitively Rosgen Class F channels with entrenchment ratios of ≤1.3 and w/d ratios ≥15. Grey boxes with asterisks do not fit the defined Rosgen Stream Classes because they have entrenchment ratios between 1.7 and 1.9 but w/d ratios <9. The blue triangles are historically small streams that now have significant storm drainage or agricultural drains from vineyards. Green diamond data points represent 1st order channels with significant headward erosion noted in the field and as mapped previously by Collins (unpublished maps for 2003 Schellville Flooding Project).

Figure 1 shows several different trend lines. The solid black line is the trend line for all the data points. Other trendlines have been added for comparative purposes. The red dashed line is the trendline for the San Francisco Bay Area as published by Leopold and Dunne (1978). Their data set did not include drainage areas smaller than 0.1 sq mi. The pink dash-dotted line is the trend line for Marin and Sonoma counties as reported for Marin and Sonoma Counties by Collins and Leventhal (2013). The solid blue line with arrows at either end is a line fit by eye that falls below the red data points that represent Rosgen Stream Class G channels and above Stream Class F channels. Hypothetically, it might represent the more stable cross sectional area for a given drainage area if the channel is not highly influenced by increased storm runoff or decreased flow from water diversion, however, more research would be needed to stratify data to test this.

Based upon the 2006 Sediment Source Analysis it can be presumed that most of the Sonoma Creek channel network has been modified over the last 200 years by land use activities. Channels in most areas have adjusted their geometry to increased runoff while a few others have adjusted to decreased bankfull flow due to water diversions upstream or in smaller subwatersheds. The dataset represents the best estimates of bankfull geometry in a watershed that is still adjusting its cross sectional area to legacy and modern day impacts. Given enough time, most streams will have a central tendency to develop bankfull features under a stable climatic regime unless they are on unstable features such as alluvial fans that have very dynamic and fluctuating supplies of sediment and water.If a regional curve of historic flow conditions were developed that predated land use impacts, it is likely that it would possibly show a correlation of slightly larger drainage areas to smaller bankfull cross sectional areas.

It is recommended that more research be done on regional curves to start assessing the effects of including stable and unstable channels and stratifying data to reflect local geology, geomorphology, rainfall, and stream stability to test for local or regional influences. Regional curves are highly useful for assessing bankfull geometry in channels that are not gaged and in channels that are not stable and have not formed bankfull indicators. Bankfull geometry is needed by many stream scientists involved in restoration, modeling, and research. If bankfull cross sectional area is known, it can be used in stream restoration to design a more stable configuration applying natural hydraulic geometry. For example if a stable B class channel is suitable for a site, cross sectional area can be used to determine what the width and depth should be within an appropriate range of W/D and entrenchment ratio. By showing the influences of using unstable stream classes in a regional curve analysis it is clear to see how the curve can be greatly influenced by a data set of unstable channels, and how by relying on curves that have unknown information about channel stability could potentially lead to problems with determining stable channel design.

Knickpoints along Sonoma Watershed Streambeds

Additional data on the location of knickpoints has been provided from the previous studies in Sonoma watershed. These data can be used to add to the SEC GIS and to determine if some of the sites should be considered for monitoring or future restoration.

Historical and Present-day Dam Sites in Sonoma Watershed

Data on the location of dams, past and present, has also been added to this memo to add to the SEC GIS and to provide further information on locations of where the stream network might have undergone geomorphic changes due to the influence of instream structures.

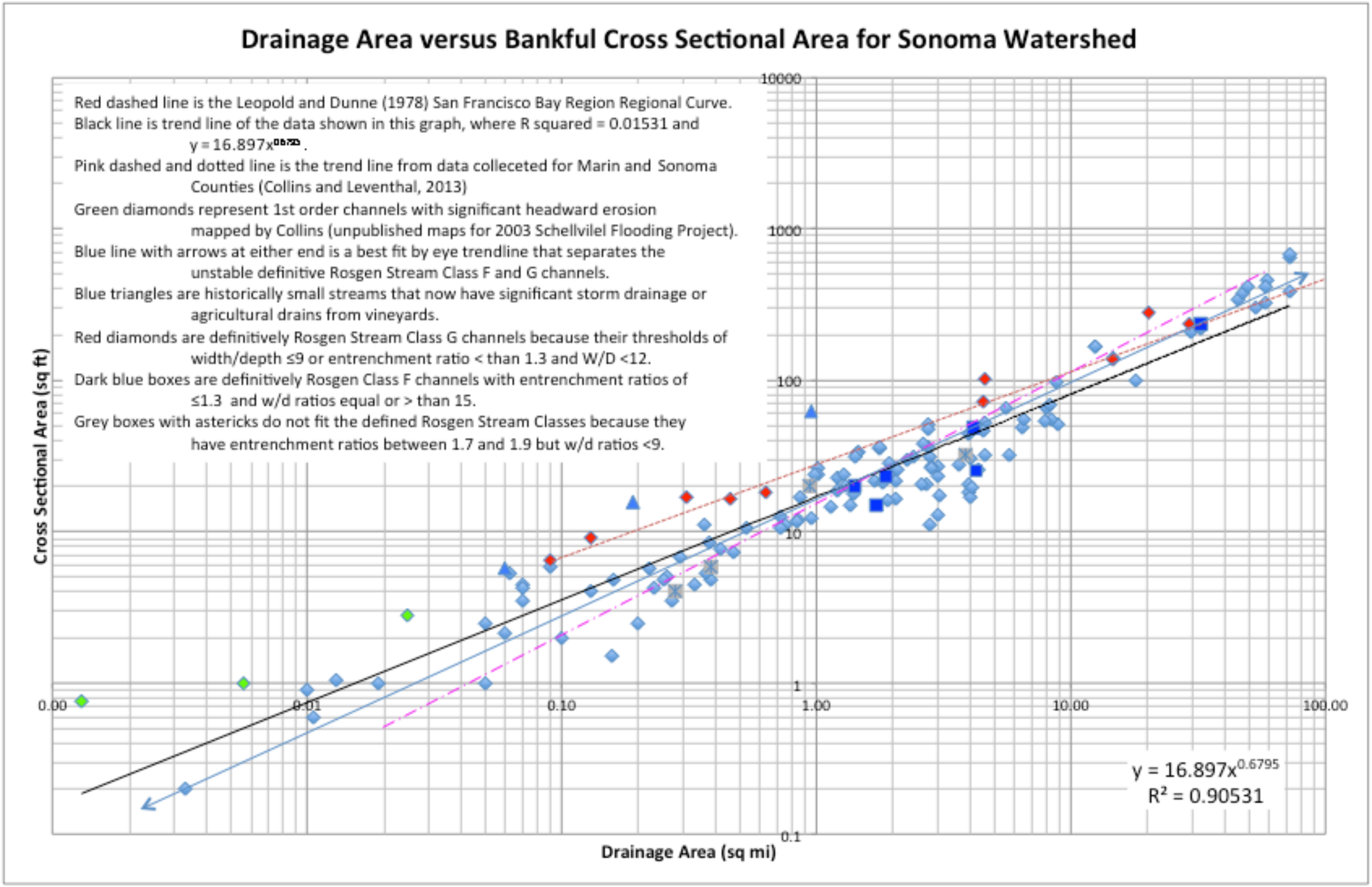


Figure 1. Bankfull Cross Sectional Area Regional Curve for Sonoma Watershed.

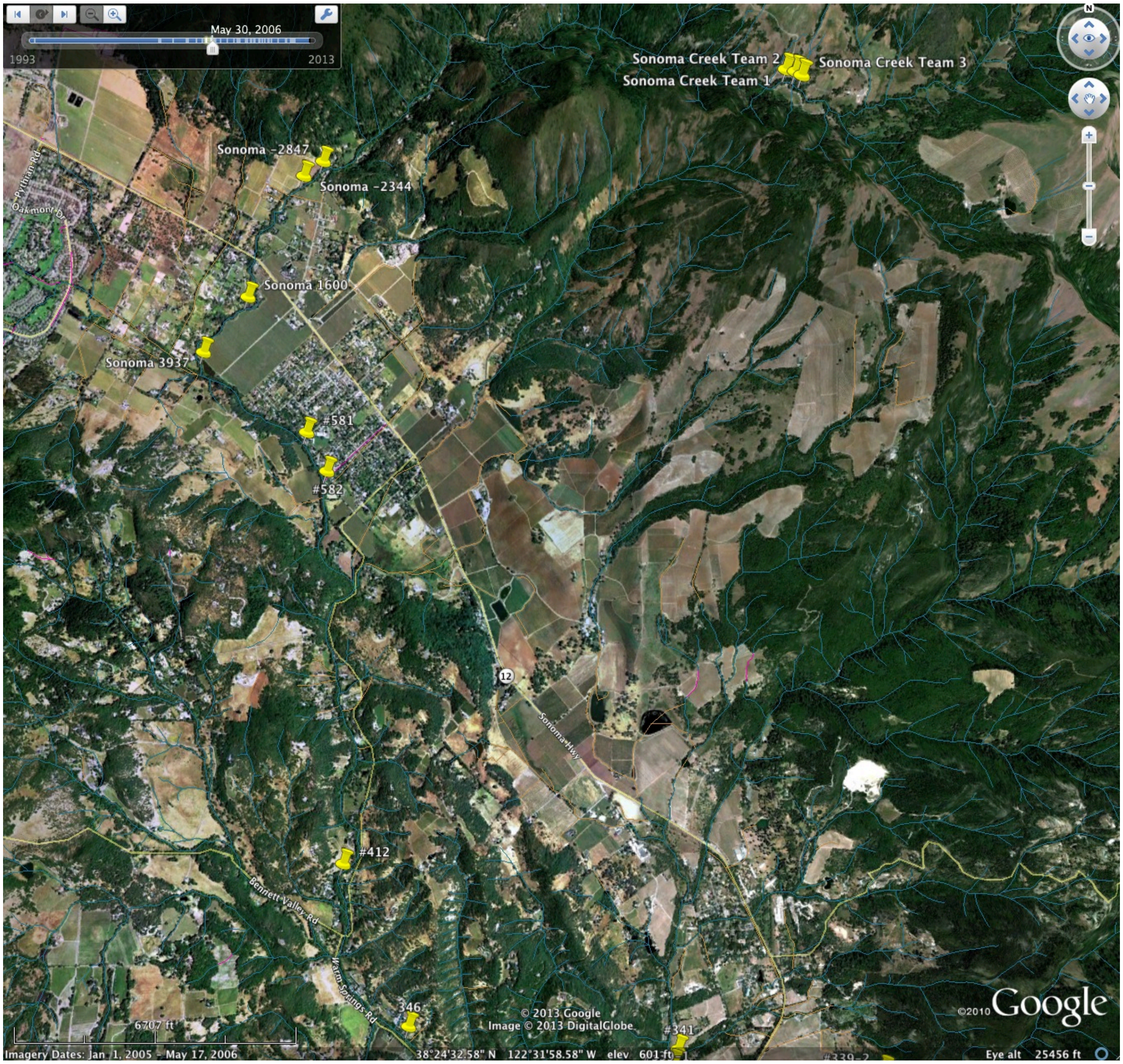


Figure 2. Site locations for northern section of Sonoma Watershed.

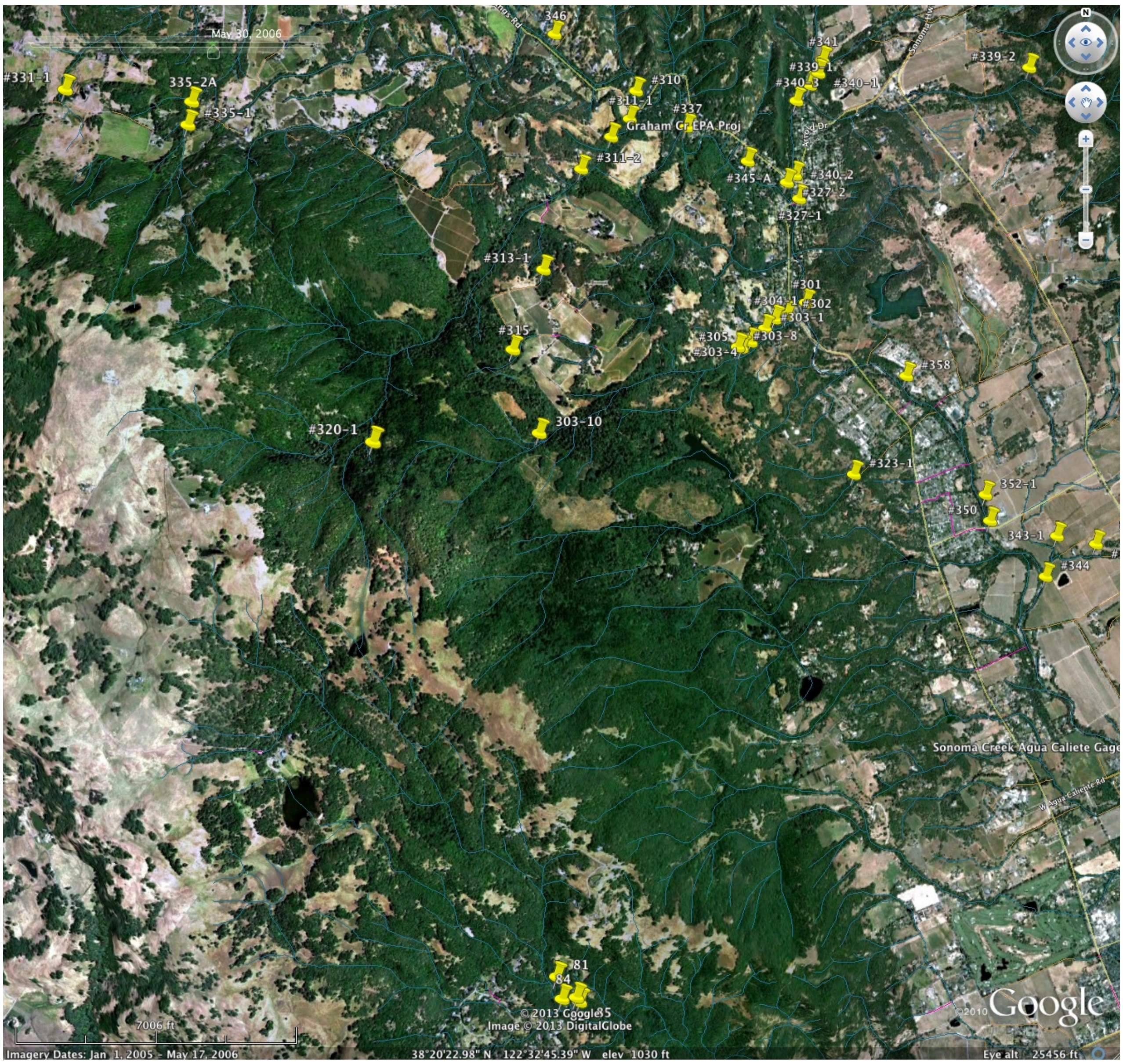


Figure 3. Site locations for central northwestern section of Sonoma Watershed.

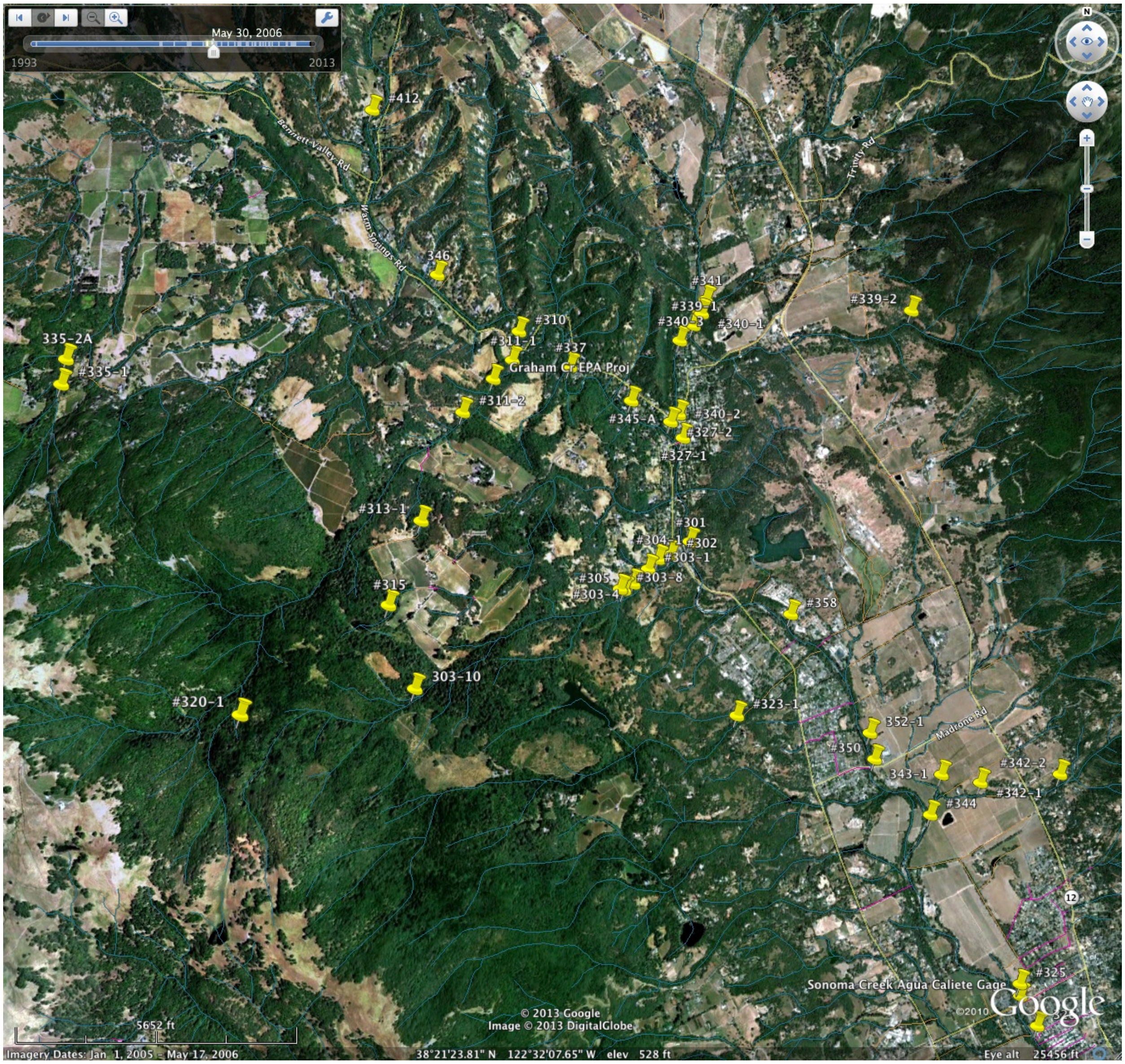


Figure 4. Site locations for central northeastern Sonoma Watershed.

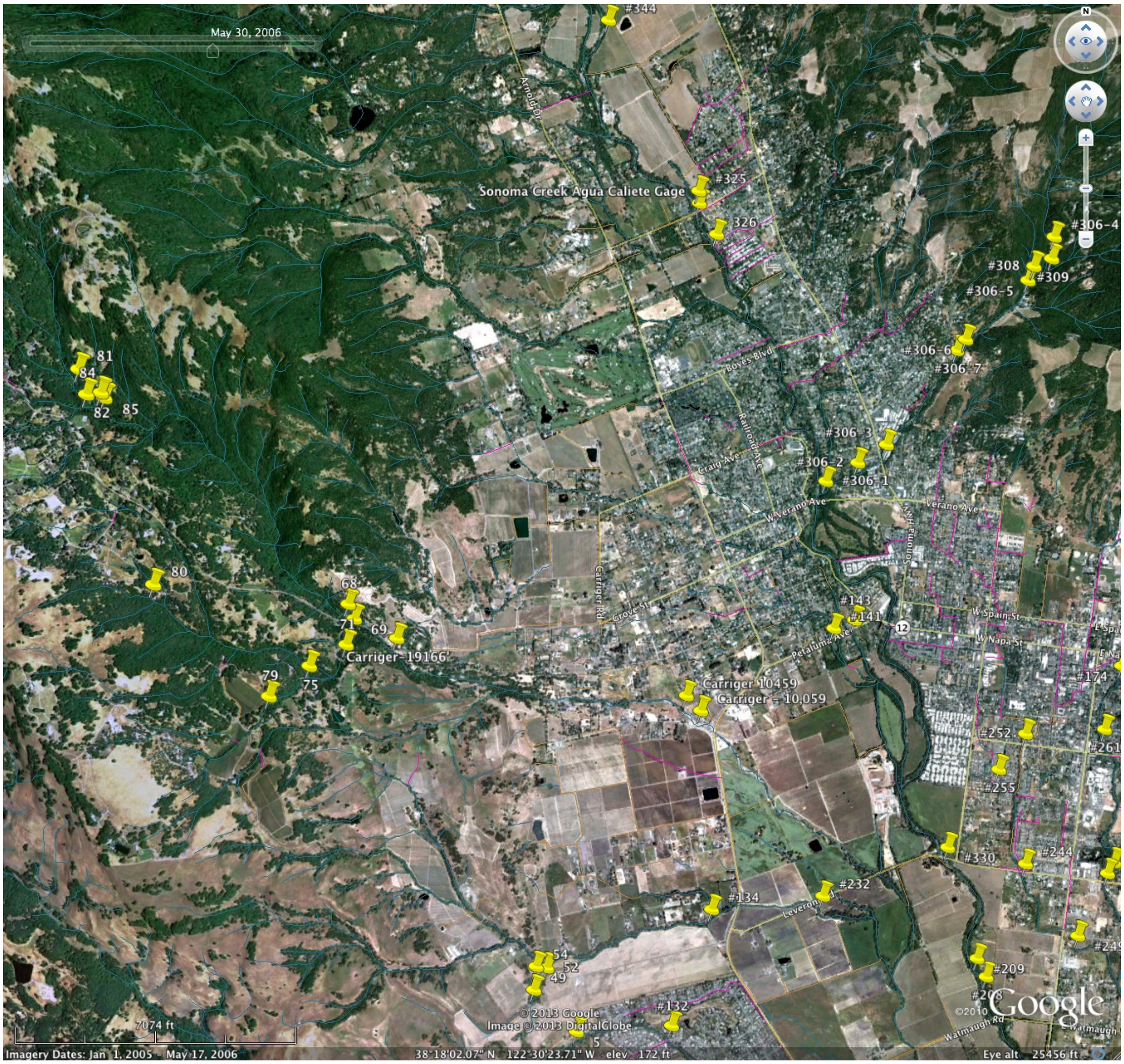


Figure 5. Site locations for central southwestern section of Sonoma Watershed.

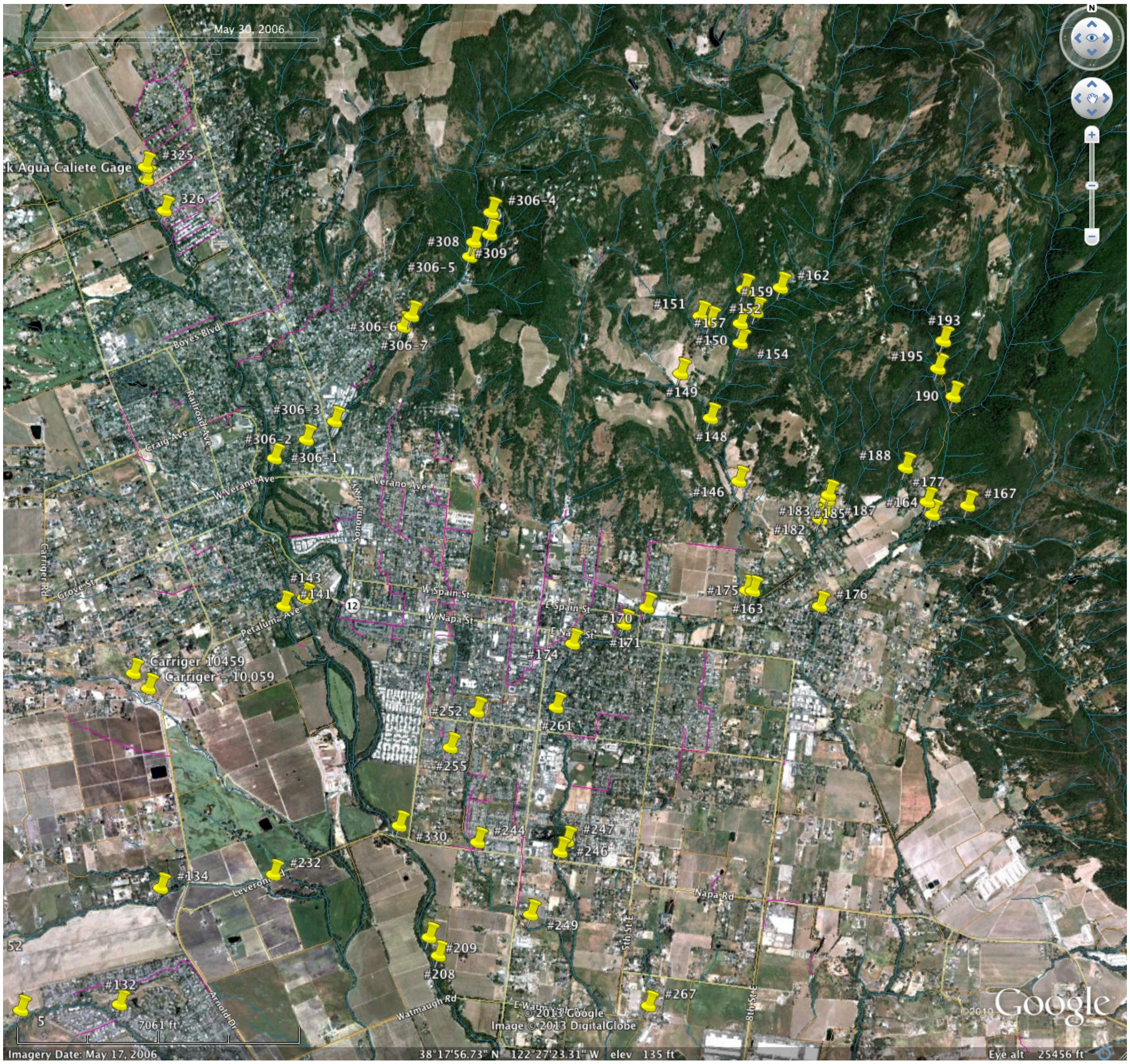


Figure 5. Site locations for central southeastern section of Sonoma Watershed.

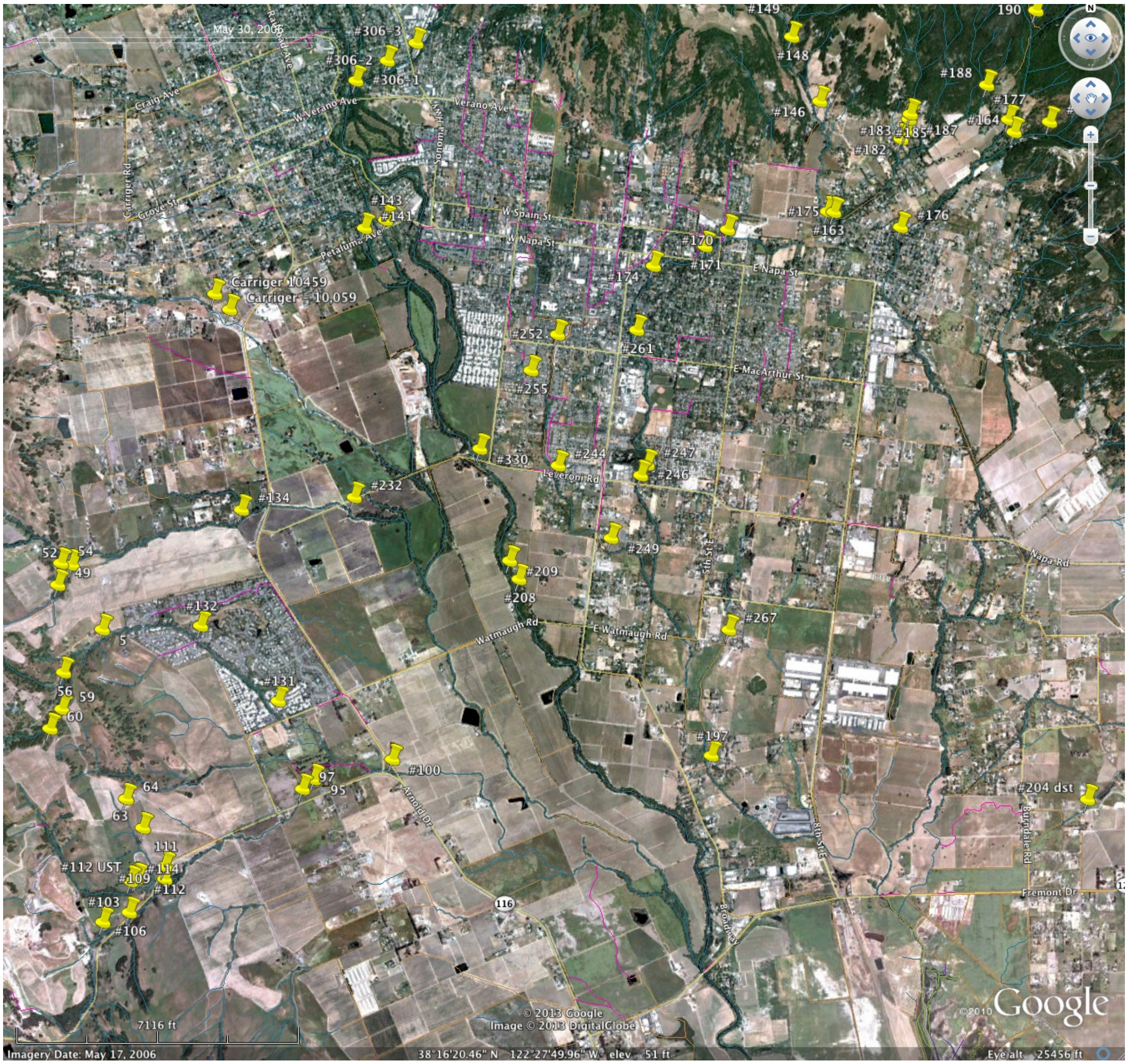
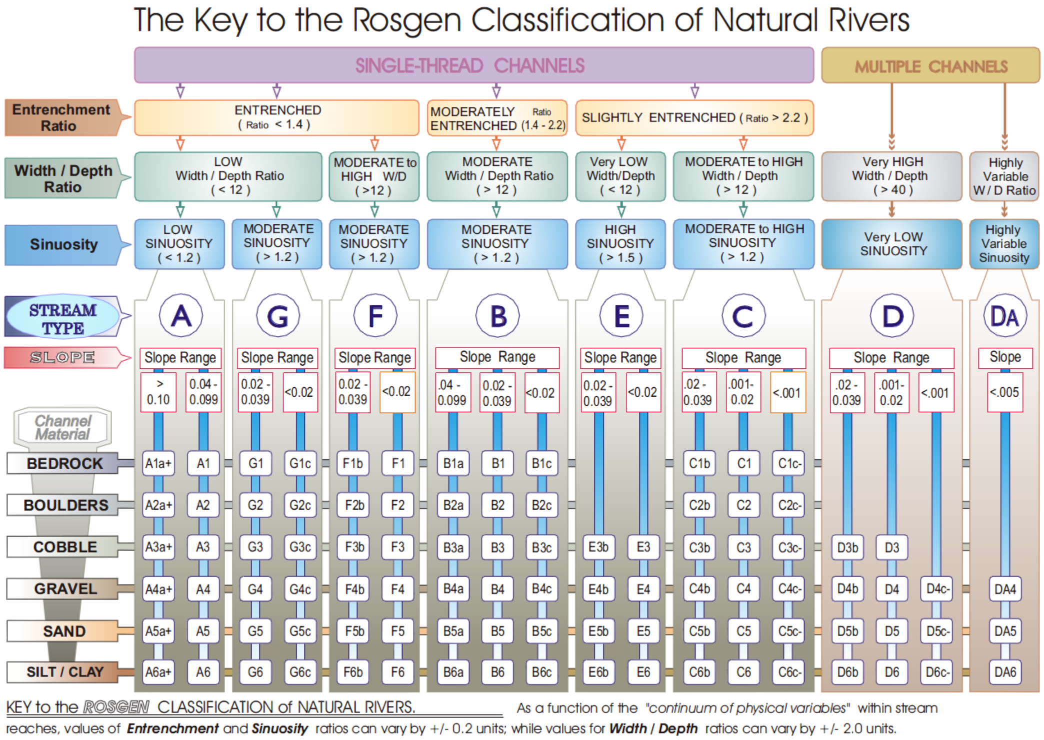


Figure 6. Site locations for southern section of Sonoma Watershed.



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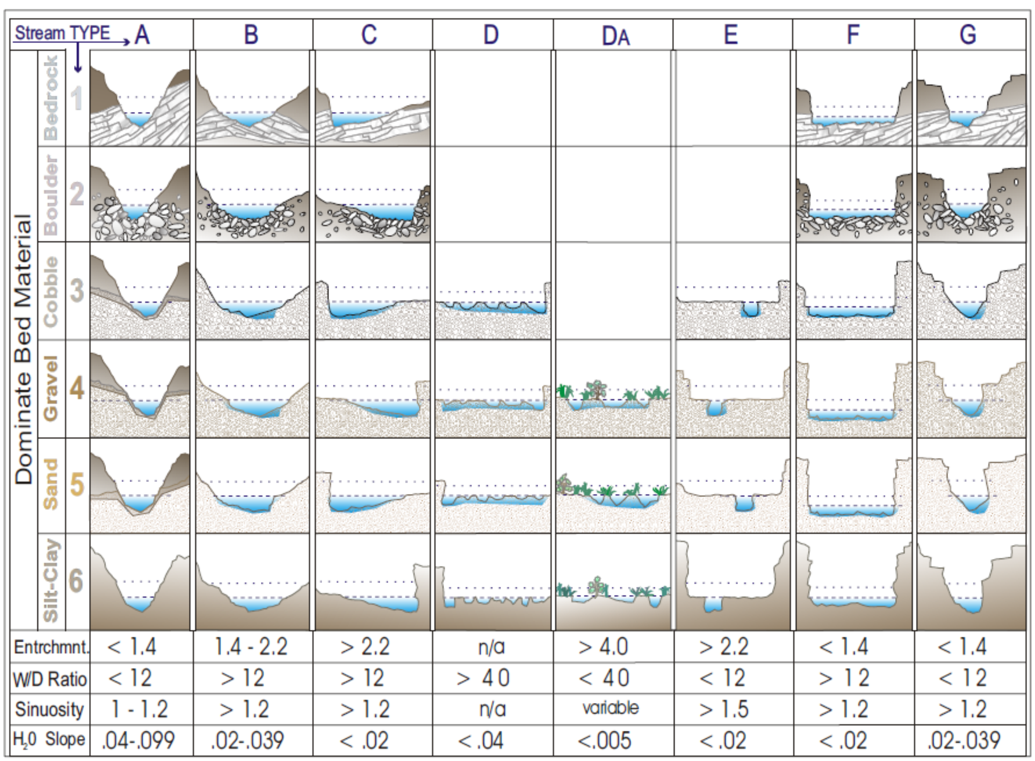

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Figure 8. Rosgen Stream Classification chart from Rosgen (1996).

TABLE1. DATA FOR REGIONAL BANKFULL CROSS SECTIONAL AREA CURVE FOR SONOMA WATERSHED						
TMDL Analysis Station ID #	**Upstream Drainage Area (sq mi)**	**Cross Sectional Area (sq ft)**	**Notes – associated subwatershed**	**Stream type**	**W/d Ratio**	**Entrenchment Ratio**
49	0.06	5.25	Trib to Felder Cr		2.3	ND
52	0.09	5.85	Trib to Felder Cr	E	3.5	ND
54	0.02	2.8	Trib to Felder Cr	B	5.7	ND
56	0.13	4	trib to Rodgers Cr		4.0	ND
59	0.00	0.2	trib to Rodgers Cr		1.3	ND
60	0.00	0.75	trib to Rodgers Cr		3.0	ND
63	0.05	1	trib to Champlin Cr		4.0	ND
64	0.02	1	trib to Champlin Cr		4.0	ND
5	0.01	1	trib to Rodgers Cr		4.0	ND
68	1.45	33.4	trib to Carriger Cr		8.4	ND
69	1.45	33	trib to Carriger Cr		8.3	ND
71	1.42	31.5	trib to Carriger Cr		7.1	ND
75	0.33	4.5	trib to Carriger Cr	B	5.6	ND
79	0.16	1.5	trib to Carriger Cr		4.2	ND
80	0.10	1.96	trib to Carriger Cr		4.0	ND
81	1.92	24	trib to Carriger Cr		10.7	ND
82	1.93	28.05	trib to Carriger Cr		9.7	ND
84	0.85	12	trib to Carriger Cr	A	12.0	ND
85	2.79	31.2	trib to Carriger Cr		12.2	ND
95	2.05	16.5	Champlin Cr	B/G	7.3	1.6
97	2.04	21.7	Champlin Cr	B	11.1	1.9
100	5.74	32	Rodgers	B	8.0	1.4
103	1.20	22.5	Champlin	B	10.0	1.6
106	1.28	24	Champlin	B/G	6.0	2
109	1.30	20	Champlin	E	1.3	2.8
111	0.53	10.5	Champlin	G or A	4.7	1.1
112	0.39	5.85	Champlin	X	3.5	1.8
112 ust	0.39	4.8	Champlin	B	13.3	1.6
114	0.38	8.4	Champlin	B	17.1	1.8
131	3.01	13	Rodgers	C/B	13.0	3.3
132	2.77	11.2	Rodgers	B	17.5	1.6
134	1.72	15	Felder	F	15.0	1.2
141	0.76	11	trib to Dowdall Cr	G	11.0	1.3
143	1.54		Dowdall = Site is an outlier due to storm drains and drainage area	A or G	8.0	1.3
146	2.70	20.4	Nathonson Creek	B	14.2	1.4
148	2.58	20.4	Nathonson Creek	B	14.2	1.9
149	0.47	7.29	Nathonson Creek	B or G?	9.0	1.5
150	0.28	4	Nathonson Creek	X	6.3	1.7
151	0.01	1.05	Nathonson Creek	E	4.2	2.6
152	0.16	4.8	Nathonson Creek	A	7.5	1.6
154	1.89	16.2	Nathonson Creek	C-G-F-B	16.2	1.2

157	1.41	20	Nathonson Creek	F	31.3	1.3
159	1.39	17.92	Nathonson Creek	X	9.1	1.7
162	1.36	14.8	Nathonson Creek	B	23.1	1.7
163	3.00	23.4	Arroyo Seco	B	16.3	1.5
164	1.20	18.6	Arroyo Seco	B	12.9	1.4
169	1.14	14.69	Arroyo Seco	B-A	8.7	1.4
170	3.95	20.4	Nathonson Creek		7.1	ND
171	3.97	18	Nathonson Creek	B	12.5	12.5
174	4.04	17	Nathonson Creek	E	5.9	2.3
175	0.72	10.5	Nathonson Creek	E or X	4.7	1.9
176	3.01	27	Arroyo Seco Creek	E	8.3	2.1
177	1.70	21.75	Arroyo Seco Creek	A or G	3.5	1.1
182	0.26	5	Nathonson Creek	A or G	5.0	ND
183	0.25	4.8	Nathonson Creek	A or G	7.5	1.4
185	0.20	2.5	Nathonson Creek		10.0	ND
187	0.23	4.3	Nathonson Creek	B	17.2	1.8
188	0.06	2.15	Nathonson Creek	B or E	8.6	2.4
190	0.01	0.6	Arroyo Seco Creek		3.8	ND
193	0.42	7.7	Arroyo Seco Creek	E or X	7.7	1.9
195	0.46	16.25	Arroyo Seco Creek	G	9.6	1.2
197	8.87	51	Schell Creek	F (less likely B)	17.6	1.4
204 DST clv	0.29	6.75	near Knob Hill rd	E or X	3.0	1.9
208	72.47	650	Sonoma Creek		6.5	ND
209	72.47	672	Sonoma Creek		10.5	ND
232	2.40	31.4	Fowler Creek	B or G	7.9	1.4
244	2.07	25.5	Schell Cr	B and G	11.3	1.7
246	4.59	32	Nathanson Cr	G or B	8.0	1.4
247	4.58	52.8	Nathanson Cr	G or B	10.9	1.3
249	2.28	30	Schell Cr	B or G	4.8	1.5
252	1.77	35.1	Fryer	B or G?	10.8	1.5
255	0.19	15.6	West Fork Fryer Creek	B or X	9.2	1.6
261	4.10	19.5	Sonoma Creek	B or G	11.5	1.4
264 UST	18.04	100	Schell Creek	E or G	6.3	ND
267	0.95	62.5	Schell Creek - highly urbanized w storm drains		10.0	ND
301	1.02	26.45	Asbury	E	5.0	2
302	1.01	24	Asbury	G?	10.7	1.2
303-1	0.94	19.8	Asbury	X	8.8	1.7
304-1	0.95	12.16	LB/northern trib to Asbury Creek	A or G	4.8	1.4
303-4	0.98	24	Asbury	A or G	10.7	1.1
303-8	0.86	17	Asbury	A or G	5.9	1.3
305	0.05	2.5	RB/southern trib to Asbury Creek	A or G or B	10.0	1.4
306-1	4.58	101.5	mainstem Agua Caliente Creek	G	8.3	1.3
307-1	0.63	18	northern trib to Agua Caliente	G	8.0	1.1
306-2	4.55	71.25	mainstem Agua Caliente Creek	G	11.4	1
306-3	4.50	46.8	mainstem Agua Caliente Creek	F	14.4	1.3

308	0.07	3.52	western trib to Agua Caliente Cr	A	5.5	1.5

306-4	3.86	32.3	mainstem Agua Caliente Creek	X	8.9	1.7
309	0.07	4.5	eastern trib to Agua Caliente	E	4.5	2.3
306-5	4.04	30.4	mainstem Agua Caliente Creek	E	7.6	2.2
306-6	4.25	25	mainstem Agua Caliente Creek	F	25.0	1.3
306-7	4.34	25.5	mainstem Agua Caliente Creek	B	11.3	1.5
310	29.58	208.44	mainstem Sonoma Creek	E	7.1	2.1
311-1	1.87	23.3	mainstem Graham Creek	F	17.5	1.3
311-2	1.76	36	mainstem Graham Creek	B	11.1	1.7
320-1	0.13	9.12	trib to Graham Creek	G	6.3	1.2
313-1	0.06	5.76	southern trib to Graham Creek - mostly agricultural runoff/w/subdrains	B or X	9.0	1.7
331-1	0.09	6.5	trib to Matanzas Creek	G	3.8	1.3
335-1	0.22	5.67	Matanzas Creek	B or G	7.0	1.5
335-2A	0.37	5.28	Matanzas Creek	E or X	4.4	1.9
303-10	0.36	11	Asbury Creek	X	9.1	1.8
342-1	2.84	27	Hooker Creek	A or G	12.0	1.2
343-1	2.82	26.52	Wilson Creek	F or G	9.2	1.2
344	53.32	300	Sonoma Creek	B	12.0	1.9
340-1 [UST]	8.74	96	Calabazas Creek	G	6.0	1.5
339-1	3.63	27.6	Stuart Creek	B	12.3	1.5
341	0.72	12.65	Calabazas Creek	B	10.5	1.8
337	32.18	227.5	Sonoma Creek	G or B	9.1	1.5
330	72.39	385	Sonoma Creek	B	15.4	1.5
327-2	32.46	218.01	Sonoma Creek	B	11.8	1.6
327-1	45.03	342.72	Sonoma Creek		14.9	ND
326	59.25	451.95	Sonoma Creek	B	9.5	1.9
325	58.03	408.65	Sonoma Creek	B, G, or F	13.5	1.4
323-1	0.84	11.55	Mill Creek	A or G	5.1	1.6
315	0.07	4.2	trib to Kohler Creek	A or G	2.9	1.2
340-2	12.51	165.3	Calabazas Creek	B	19.7	1.5
340-3	12.41	164.5	Calabazas Creek	B	13.4	1.4
345-A	32.44	234.5	Sonoma Creek	F	19.1	1.3
342-2	2.73	36	Hooker	B	9.0	2.1
352-1	0.31	16.8	Sonoma Creek	G	7.5	1.3
358	47.66	372.4	Sonoma Creek	B or F	15.5	1.3
339-2	3.05	17.3	Stuart Creek	B	17.3	2
346	29.06	236.5	Sonoma Creek	G	7.8	ND
338-2	0.01	0.9	Hooker Creek trib	A	3.6	1.7
338	0.27	3.5	trib to Hooker Creek	E	7.1	2
581	14.59	136	Sonoma Creek	G	8.5	1.5
582	14.74	140	Sonoma Creek	F or G or B	11.4	1.2
412	20.21	280	Sonoma Creek	G	5.7	1.3
350	49.49	415	Sonoma Creek	B	16.6	1.6

Carriger Cr upstream of Grove	3.98	43.6	Carriger Cr, NOTE: THESE ARE DISTANCE STATIONS UPSTREAM OF THE CONFLUENCE OF CARRIGER CREEK WITH FELEDER CREEK	A or B or X	8.1	1.7
Carriger 20,405' (upper fan)	4.13	48.3	Carriger Cr	F3b	15.6	1.2
Carriger 19,166'	5.57	66.049	Carriger Cr	B	10.0	2.1
Carriger 10.459' (lower fan)	6.45	48.2	Carriger Cr	C	22.8	3.1
Carriger 10,059'	6.51	54.5	Carriger Cr	D	45.9	3.3
Sonoma 2,344' (Fan)	8.03	65	Sonoma Creek Kenwood Fan Project Note; this is the distance upstream of the upstream edge of the Hwy 12 bridge crossing near Adobe Canyon	B4c	17.6	1.7
Sonoma Creek 1600 Lower Fan	8.26	68.7	Sonoma Creek	C4	19.8	5.4
Sonoma Creek 3937 Upst Oakdale conflu	8.39	55	Sonoma Creek	B or G	8.9	1.4
Sonoma Creek - 2847 Aoex fab	7.95	54.2	Sonoma Creek Kenwood Fan Project Note; this is the approximate distance downstream of the downstream edge of the Hwy 12 bridge crossing near Adobe Canyon	B4	25.0	1.6
Sonoma Creek at Agua Caliente Gage	58.02	320.37	Sonoma Creek at the USGS Gage at the Boyes Blvd Bridge crossing - downstream side. Note: Surveyed for Wildland Hydrology class	G4c	10.3	1.4

Sonoma Creek - team 1	2.74	50.8	Sonoma Creek Note: About 100' upstream of upstream edge of bridge near Kiosk at Sugarloaf State Park	B4 or F4	18.9	1.6
Sonoma Creek - team 2	2.73	47.68	Sonoma Creek Note: About 945' upstream of upstream edge of bridge near Kiosk at Sugarloaf State Park	B4 or F4	14.2	1.6
Sonoma Creek - team 3	2.63	37.92	Sonoma Creek Note: About 2000' upstream of upstream edge of bridge near Kiosk at Sugarloaf State Park	B4c	15.2	1.6
EPA Proj Graham Cr	1.83	20.8	Graham Cr	B3a	18.9	1.8

Note - Rosgen Stream Class thresholds for entrenchment ratio were modified to be +/- 3 for width/depth ratio.

Table 2. Knickpoints along Sonoma Watershed streambeds

Station	Helght (ft)		Category
5	5.3	trib not graded	trib conflu
6	3.0	channel steps up 3' over 50' dist	Pet Bdrk
7	5.5	trib not graded	trib conflu
10	2.0	step rises 2' over 50	LWD/bld
14	3.0	trib not graded caused by culv	box or culv
17	2.5	trib not graded	trib conflu
17	3.5	trib not graded	trib conflu
23	15.0	trib not graded	trib conflu
30	3.2	gully discontinuous, clastic volcanic tuff	gully head
38	3.0	gully in tuffaceous clastic material	gully head
44	5.0	Extensive large gully system, very incised beyond gully head	gully head
47	5.0	gully in alluvial material	gully head
51	3.0	sediment stored in over-widened channel	gully head
63	2.5	gully at Champlin Cr	gully head
65	7.0	gully at Champlin Cr	gully head
67	15.0	Qtu unit, drop might be associated with a fault	box or culv
74	5.0	boxculv = fish barrier	box or culv
96	2.0	trib not graded	trib conflu

97	5.5	cobble within a natarually highly cemented layer -might be a fish barrier at some flows?	hardpan/cemented layer
104	2.5	at a 2' diam cmp	box or culv
104	3.0	rb trib not graded	trib conflu
105	6.8	abandoned distributary not graded	trib conflu
105	3.0	3' drop over 60' length	Qtu Form over Volc bdrk
107	5.0	Andesite bdrk	volc bdrk
109	2.0	recently stabilized	Qtu
109	2.0	recently stabilized	distrib in Qtu
110	1.0	distributary channel	distrib in Qtu
110	4.0	distributary channel	distrib in Qtu
153	3.5	boulder dam and fish seen upstrm of this, riffle-run morphology transition to step-pool	
156	2.0	upstream of trib there is another boulder dam with a 2' knickpoint below it	
159	3.0	in rhyolite bdrk	volc bdrk
160	1.8	30' upstrm there is a 1.8' knickpoint	
167	2.0	below cement check dam	sandstone bdrk
170	2.0	knickpoint at end of ~50-long concrete apron	concete apron
177	2.0	upstream of this station there is a step from grade control	grade control
177	3.0	upstream of this station there is a step from grade control	grade control
178	3.0	check dam	grade control
185	2.0	culvert outfall	box or culv
215	1.7	conflu of Agua Caliente to Sonoma creek not graded	trib conflu
234	2.0	2' step over 25',	Huichica bdrk
240	3.0	northfork not graded to south fork Felder Cr	gravel
245	2.0	below box culvert = fish barrier	trib conflu
248	1.4	recent incision caused by culvert	box or culv
248	0.5	recent incision caused by culvert	box or culv
251	5.0	below box culvert	box or culv

259	1.0	below box culvert	box or culv
262	2.0	below box culvert	box or culv
269	3.0	upstream trib not graded	trib conflu
270	2.0	drop at riffle	gravel
303c	8.5	at 8.5 foot knickpoint, photo	
320	8.0	step	
320	3'	step	
331	3.5	UST has a 3.5' knickpoint which is ~40' DST of the culvert	
333	1.8	1.8' knickpoint, cause: culvert and road 32	
333	3.0	knickpoint = 3', cause: road and culvert 81	
334a	7.5	7.5' knickpoint, cause: culvert at redwoods and oak root	roots
335	4.0	4' knickpoint 445	
335	4.0	4' knickpoint 445	

339fa	3.0	contact w/ Glen Ellen drk (GE) and Petaluma? to Bouverie property; ~100' DST knickpoint = 3'	GE bdrk
339f	2.0	at confluence 2' graded step over 30'	
341	4.5	Eastern trib to Calabazas UST of Stuart has a 4.5 knickpoint in Glen Ellen bdrk (GE)	GE bdrk
343y	3.0	knickpoint = 3' in gravel	gravel
343y	4.0	there is a 4' knickpoint	
342b	4.0	end w/ 329' DST and graded 4' knickpoint	
342c	2.3	2.3' step into Glen Ellen (GE) bdrk	GE bdrk
343x	2.5	Photo #7: looking at knickpoint = 2.5' GE bedrock	GE bdrk
343x	2.0	UST knickpoint ~ 20' UST = 2'	
311f	3.5	cause: culvert back eddy, INC in GE bedrock, knickpoint underwater in GE = 3.5'	GE bdrk
354c	6.5	cause: old dam DST has a knickpoint of 6.5' in GE bedrock	GE bdrk
354c	2.0	cause: old dam, ends @ 2' knickpoint in GE	GE bdrk
354c	5.0	cause: concrete ford; ends at concrete ford that has a knickpoint of 5'; Photo #5: looking at it	
354c	1.8	ends at a 1.8' knickpoint @ roots and LWD	roots/lwd
339h	2.2	knickpoint, volcanic flow rock, height = 2.2'	volc flow bdrk
339h	1.5	old debris jam has knickpoint of 1.5' high / photo looking upstream	lwd
339h	1.5	knickpoint, old debris jam = 1.5' at downstream end, fish upstream	lwd
339h	1.5	good measurements to extrapolate a few hundred feet upstream / knickpoint of cobbles, roots + another 1.5' knickpoint upstream / 1924 dam photo looking upstream / knickpoint = 4' , pool depth = 10'	cob
339h	4.0	good measurements to extrapolate a few hundred feet upstream / knickpoint of cobbles, roots + another 1.5' knickpoint upstream / 1924 dam photo looking upstream / knickpoint = 4' , pool depth = 10'	cob
339ka	3.5	knickpoint = 3.5' in volcanic clastic tuff	volc tuff
339ka	3.0	knickpoint height at pool = 3' / pool depth = 3.7'	
339ka	2.0	2' knickpoint, boulders	bld
370k	1.7	Volcanic bedrock in channel; there is a step of about 1.7'	volc bdrk
370k	3.7	Bedrock- volcanic, step of 3.7' and debris jam	volc bdrk
370k	1.5	1.5' step at end	

370k	2.6	ends with 2.6' step	
370k	2.0	ends w/step of 2' boulders and roots	bld/roots
370k	2.0	2' Cobble boulder step	cob/bld
370m	2.0	Bedrock step 2'	bdrk
370m	3.0	end at 3' boulder step, photo 1 ups, fish in reach	bld
370m	2.4	Bedrock step of 2.4'	bdrk
370m	2.5	ends in 2.5' bedrock step	bdrk
370n	2.8	ends at 2.8' boulder step	bld
370n	2.2	Metal post. Dnstr is oak/bay woodland, upst gets into conifers. Boulder step 2.2'	bld
370p	1.1	Boulder step 1.1' at upst end	bld
370p	2.0	Boulder step 2'	bld
370p	1.5	Boulder step 1.5'	bld
370R	3.0	Boulder step 3'	bld
370R	1.5	1.5' step	
370R	3.5	Boulder step 3.5'	bld
370t	8.0	rhyolitic flow rock this sec, ends with 8' boulder step	bld
370t	12.0	massive boulder step, 12'	bld
370w	4.5	4.5' Boulder step	bld
370w	2.5	2.5' Boulder step	bld
376	9.0	Waterfall- dry, 9' high volcanic flow rock	waterfall
370y	4.0	ends at 4' boulder step	bld
370y	7.0	7' bedrock step	bld
370z	4.0	4' boulder step, dry upst	bld
377	18.0	boulder/ br cascade. Ht 18' over 20	bld
353a	5.0	5' step up, concrete base/culvert	concrt at box or culv
353e	1.7	Channel steps up 1.7' in siltstone bedrock	siltstone bdrk
381	4.0	Gully head 4.4' End sta 353 *(+1838)*	gully head
381	10.0	Channel steps up about 10' at gully head.	gully head
385	3.5	3.5' step in bedrock (GE Tu bedrock)	GE bdrk
311h	8.0	Debris step = 8'	lwd
311h	10.0	Debris jam step = 10', causing significant aggradation.	lwd
311j	4.0	Debris jam step = 4'	lwd
311j	11.0	No Incision (0' incision); boulder step = 11'	bdrk
311j	4.0	Bedrock step = 4'	bdrk
311j	6.0	2 boulder steps total 6'	bld

311j	6.0	2 boulder steps total 6'	bld
311j	2.0	Bedrock step = 2'	bdrk
311j	4.0	ends in woody debris jam step = 4'	lwd
311j	6.5	No Incision (0' incision), ends in woody debris jam step = 4'	lwd
311j	3.0	No Incision (0' incision), ends in woody debris jam step = 4'	lwd
311j	2.5	Bedrock step = 2.5'	bdrk
387a	3.5	2' - 5' step in GE bedrock	GE bdrk
354	2.3	ends at knickpoint halted by tree roots	roots
354	2.0	rip rap in bed; 2' step	rip rap
392	2.2	Boulder step= 2.2'	bld
395d	3.6	Photo #8 UST at knickpoint (3.6')	
395x	3.5	3.5' knickpoint 600	
395y	1.0	knickpoint = 1'	
395y	1.9	knickpoint 1.9'	
396	2.5	Knickpoint = 2.5'	
401a	2.3	step @ is 2.3	
401a	2.9	step is 2.9	
401b	2.5	2.5' step at ust end of culvert	box or culv
401b	4.0	step at 850, 4' high	
405-2	1.6	1.6' step @ 535'	
405-3	3.5	3.5' step @ 555'	
405-7	2.5	knickpoint = 2.5' @ sta 200	
405-8	3.8	dst edge culvert apron, knick pt 3.8' 530	box or culv
405-6d	1.7	LB trib at 507' not graded to channel; steps up approx 1.7'	trib conflu
427a	3.2	step 3.2' - boulders	bld
432a-1	2.5	stepping up 2.5'	
529c	2.3	2.3' step, boulders in bed	bld
529a	2.0	2' step, 4'step = 6' total from big boulders	bld
529a	4.0	2' step, 4'step = 6' total from big boulders	bld
530a	2.5	2.5' step	
581	7.0	roughly 1500 ft downstream of this statin, observed after completion of project. The ~7 ft step extends over possible 50 ft of channel with the step incising into erodible bdrk	
339z	2.5	boulder step knickpoint = 2.5'	bld
339z	3.5	in bedrock, steps up 3.5'	bdrk
339z	4.0	boulder knickpoint = 4'	bld

339y	25.0	boulder knickpoint = 4'	waterfall bld
15-19ME	3.0	lb trib steps up 3 ft	trib conflu
109-107ME	5.0	5' knickpoint	
Data from Schellville Flood Project for Stations < 300. Data From 2013 TMDL Sediment Source Analysis Project Stations >300. See the SEC Sonoma Watersehd GIS maps forstation loction of the nickpoints.			

Table 3. Historical and present-day dam sites observed in Sonoma Watershed

Station	Notes	**Stream**
1	blown out concrete dam	Rodgers
6	blown out concrete dam	Rodgers
12	10' dam = fish barrier	Rodgers
153	boulder dam w/3.5' step	Nathanson
156	upstream of trib there is another boulder dam with a 2' knickpoint below the dam	Nathanson
167	cement check dam with 2' step	Lovall
168	a series of boulder dams with incision	Lovall
177	dam from grade control	Arroyo Seco
177xME	Check dam	Arroyo Seco
176-177ME	dam influences from upstream	Arroyo Seco
183-184ME	reservoir some distance upstream?	Nathanson
148-154ME	downstream of boulder dam	Nathanson
130-120ME	dam	Rodgers
10	blown out dam	Rodgers
3-12ME	incision below dam	Rodgers
339y	8' fish barrier from boulder and LWD debris jam, since 1975	Asbury
339w	concrete dam 10'high	Asbury
512a	ust of gully head caused by diversion dam 205	Redwood

465M	check dam, trapezoidal dst w/ standing water	
435-s6	concrete check dam 75' ust of road	Pytihion
433bx	Dst of Merganser Dam, working toward dnstrm	Pytihion
428d	Note: 428 ends in 2 tribs with no significant sed supply; N confluence observed 150', S confl observed 400'. Apply upper Yulupa trib erosion rate to these channels for pre-dam conditions. Spillway of dam is rock lined.	Frey
423az	old dam site	Pytihion
423az	y = old dam boulder	Pytihion
395y	blown out concrete dam @1330. Photo 4,5 dst @dam	Weaver]
354b	Y cause- channel diversion; FB dam	Yulupa
354a	Possible grade control or dam near here? Blown out?	Yulupa
391	Sonoma Ck trib N of Clever, upst of road x-ing at Michelle Orm's house. INC on Sonoma Ck approx 5.5'. About 500' upst at confl of Clever Ck, there is a dilapidated old dam (may have cut down 5-6' at xsec of dam). Photo 9 looking across at upst confl of Clever Ck. Dnst scour might have been as much as 10.5' before dam blew out.	Clever
353d	Start at old concrete flashboard dam	Snag
370k	Note: old dam remnant H=1-2'; photo 2 upst	Fisher
339x	Dam might account for 1 bankfull width of erosion	Stuart
354c	cause: old dam; ends at DST edge of metal bridge xing 1st UST of Zen Creek confluence	Yulupa
354c	cause: old dam; Photo #4: looking UST at knickpoint at old dam	Yulupa
339fa	possible dam ~340' below Arnold Bridge, cause = dam	Mill
316	Spillway of Bathhouse Lake and trib to Kohler Creek	Graham
Data from Schellville Flood Project for Stations < 300. Data from 2013 TMDL Sediment Source Analysis Project for Stations >300. See the SEC Sonoma Watersehd GIS maps forstation loction of the nickpoints.		

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