Santa Rosa Subregional Long-Term Wastewater Project

POTENTIAL STREAMBANK EROSION LAGUNA DE SANTA ROSA AND RUSSIAN RIVER

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa
and
U.S. Army Corps of Engineers

July 1996

Prepared by

DAMES & MOORE
221 MAIN STREET, SUITE 600, SAN FRANCISCO, CA 94105 • 415/896-5858

For

HARLAND BARTHOLOMEW & ASSOCIATES, INC.

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SUMMARY

An analysis of potential streambank erosion along the Russian River and the Laguna de Santa Rosa showed that the proposed discharge of reclaimed water is not expected to significantly increase streambank erosion. The lower reach of the Laguna de Santa Rosa between Mark West Creek and the Russian River nearly exceeded the significance criteria established for determining potential erosion impacts. However, detailed analysis of the data showed that no significant erosion impact is likely to occur. The analysis reviewed hydraulic conditions and erosive forces for typical years with wet, dry and average runoff, and found that increased erosion due to the discharge of reclaimed water would not occur.

PURPOSE

The purpose of this analysis is to estimate the potential for increases in streambank erosion along the Laguna de Santa Rosa and the Russian River due to the discharge of reclaimed water from the three possible discharge points, Delta Pond, Meadow Lane Pond and the proposed discharge point on the Russian River. If the increased flow rate resulting from the discharge could cause significant erosion, mitigation measures would be required.

METHODOLOGY

The potential for streambank erosion in the Laguna de Santa Rosa and the Russian River is related to a parameter know as "stream power" (Dunne, 1978). The formula for stream power is:

$$w = \gamma v d s$$

where w = stream power
(= unit weight of water
v = flow velocity
d = flow depth
s = stream slope

The unit weight of water and the stream channel slope parameters in the stream power equation are the same for flow conditions with and without the reclaimed water discharge. Therefore, when calculating the percentage increase in the stream power between the two conditions, channel slope and the unit weight of water cancel out and are not required in the analysis.

$$\text{Percent Increase} = \frac{v_e\ d_e\ s}{v_d\ d_d\ s} \_ 100 = \frac{v_e\ d_e}{v_d\ d_d} \_ 100$$

Where subscript e is existing conditions and subscript d is conditions with the reclaimed water discharge.

The estimated stream power for each reach along the Laguna de Santa Rosa and the Russian River was calculated for the existing flow conditions and for the projected flow conditions after the discharge of reclaimed water under the proposed 20% discharge alternative. The calculated stream powers for the two conditions were compared to determine whether a significant increase in stream power resulted from the discharge of reclaimed water. A significant increase was defined as greater than 1 percent. If the estimated increase was greater than 1%, it was assumed that a potential erosion impact may occur and that mitigation may be required.

Three representative water years were selected for analysis:

1976 -- dry year
1982 -- wet year
1961 -- average year

Historical streamflow data for these years were adjusted to reflect the flow that would have occurred under existing discharge conditions and under the proposed 20% discharge alternative. The 20% discharge alternative was assumed to be the worst case alternative. Other project alternatives would cause less potential erosion because the discharge rates are lower and, therefore, the increase in the flow rate in the Laguna or the Russian River would be lower.

The Laguna and the Russian River were subdivided into reaches for purposes of the water quality investigation performed by Resource Management Associates (RMA). Appendix A shows the location of each reach. The investigation by RMA produced hydraulic information for each reach and each of the water years listed above. The information provided to Dames & Moore by RMA included average daily flow rates and the corresponding flow velocity and flow depth. (See Appendix B for a sample of the data provided by RMA) These hydraulic properties were provided for both the existing flow conditions in each stream and the increased flow rate corresponding to the 20% discharge alternative. The analysis was conducted for the period October 1st through May 15th, when reclaimed water is discharged to the river system.

Sediment samples from the Laguna and the Russian River were used to estimate the threshold streamflow velocity at which erosion is expected to occur. Below the threshold velocity the sediments will be stable and not subject to erosion. Above the threshold

velocity the hydraulic forces on the sediment are sufficient to lift the particles and move them downstream. The magnitude of the threshold velocity depends on the size of the sediment particles. For example, fine sand will be eroded at a lower velocity than gravel.

Merritt Smith Consulting obtained 14 sediment samples from the bottom of the Laguna and 6 samples from the Russian River. Table 1 summarizes the particle size data. The measured particle size distribution indicates that in the upper reaches of the Laguna, sediments are more susceptible to erosion than in the reaches near the confluence with the Russian River. The Russian River contains more sands and gravels than the Laguna and is less susceptible to erosion.

Table 1

Stream Channel Sediment Particle Size Distribution

	Sediment Volume by Average Particle Size			
Location	**Gravel** 75 - 5 mm	**Sand** 5 - 0.08 mm	**Silt** 0.08 - 0.001 mm	**Clay** 0.08 - 0.001 mm
Laguna de Santa Rosa				
Upper Reaches	0%	30 - 40%	35%	25 - 30%
Lower Reaches (Nos. 7.2, 7.4 and 7.6)	0%	40- 50%	20 - 25%	30 - 35%
Russian River				
Near the Laguna Confluence	3%	70 - 80%	15 - 20%	5%
Near Guerneville	3%	95%	2%	0%

Source: Merritt Smith Consulting

Based on the sediment sampling data, it is apparent that the erosion velocity threshold varies between the Laguna and the Russian River. The finer grained material in the Laguna will erode at a lower streamflow velocity than the coarser material in the Russian River. For the purpose of evaluating potential erosion impacts associated with the discharge of reclaimed water, it was assumed that an increase in the stream power and the potential for erosion was only significant when the average streamflow velocity for the discharge condition was greater than the erosion threshold velocity for the reach. The sediment particle size distribution from Table 1 and typical scour velocities (ASCE, 1995 and Goldman et al., 1986) were used to develop a table of threshold velocities for each reach in the Laguna and Russian River. Table 2 summarizes the estimated erosion

threshold velocities. At velocities less than these values, the stream channel material is assumed to be stable and therefore the increase in the velocity due to the discharge of reclaimed water would not be expected to cause streambank erosion.

Table 2

Estimated Erosion Threshold Velocity

Location	Estimated Erosion Threshold Velocity (feet per second)
Laguna de Santa Rosa	
Upper Reaches	2.0
Lower Reaches	
Reach 7.0	2.0
Reach 7.2	2.0 - 2.5
Reach 7.4	3.0 - 3.5
Reach 7.6	3.0 - 3.5
Russian River	
Near the Laguna Confluence	4.0
Near Guerneville	4.0

Sources: ASCE, 1995 and Goldman et al., 1986

It should be noted that this analysis does not consider localized erosion that could occur at the point of discharge into the Laguna or the Russian River. It is assumed that the discharge pipe outlet and associated structures will be designed with appropriate erosion protection measures to prevent erosion in the immediate vicinity of the discharge point. The analysis herein only considers general erosion along the streambanks downstream from the discharge point.

FINDINGS

The analysis for the three flow conditions (dry, average and wet years) showed that only the lower reaches of the Laguna de Santa Rosa (reaches number 7.0, 7.2, 7.4 and 7.6 between Mark West Creek and the Russian River) experience flow conditions that approach an increase in stream power of more than 1% when the velocity is above the erosion threshold velocity. All reaches on the Russian River and the upper reaches of the

Laguna do not experience conditions that could cause an increase in erosion because either the velocities are less than the threshold velocity or the increase in stream power is less than 1%. A detailed examination of the data and explanation of the results of the analysis for the lower reaches of the Laguna is presented below.

For the 1976 water year (dry year), reaches 7.2 and 7.4 nearly exceeded the stream power increase limitation for one day during the 230-day discharge period. However, the average velocity in each reach was 2.05 and 3.04 feet per second (fps) respectively, which is at the lower end of the threshold limit for these reaches. (See Appendix C for detailed results of the analysis) Therefore, it was assumed that no erosion impact would occur.

For the 1961 water year (average year), the analysis showed that reaches 7.0, 7.2, 7.4 and 7.6 nearly exceeded the stream power limitation for several days during the 230-day discharge period. Reach 7.0 had an increase in stream power of 1.3% for one day when the average velocity was 2.09 fps compared to a threshold limit of 2.0 fps. Reach 7.2 had an average increase in stream power of 2.9% for eight days when the average velocity was 2.37 fps compared to a threshold limit of 2.0 - 2.5 fps. Reach 7.4 had an average increase in stream power of 3.4% for seven days when the average velocity was 3.48 fps compared to a threshold limit of 3.0 - 3.5 fps. Reach 7.6 had an increase in stream power of 1.1% for one day when the average velocity was 3.37 fps compared to a threshold limit of 3.0 - 3.5 fps. (See Appendix D for detailed results of the analysis). Because the velocities are less than the threshold limits, it was assumed that no erosion impact would occur.

For the 1982 water year (wet year), the analysis showed that reaches 7.0, 7.2, 7.4 and 7.6 nearly exceeded the stream power limitation for several days during the 230-day discharge period. Table 3 summarizes the results of the analysis for these reaches. (See Appendix E for detailed results of the analysis.)

Reach 7.0 had an average increase in stream power of 1.4% for five days when the average velocity was 2.07 fps compared to a threshold limit of 2.0 fps. The average velocity is less than 0.1 fps above the threshold, which is less than the typical error tolerance for estimating stream channel velocities. Therefore, it was assumed that no erosion impact would occur.

Reach 7.2 had an average increase in stream power of 1.4% for seven days when the average velocity was 2.58 fps compared to a threshold limit of 2.0 - 2.5 fps. The average velocity is less than 0.1 fps above the threshold, which is less than the typical error tolerance for estimating stream channel velocities. Therefore, it was assumed that no erosion impact would occur.

Reach 7.4 had a total of 20 days when the velocity was greater than the maximum threshold limit of 3.5 fps. During these 20 days the increase in stream power averaged

1.5% and the velocity averaged 3.83 fps. Although the increase is stream power is greater than 1%, the velocity is only about 0.3 fps greater than the threshold limit. Therefore, because of the short duration, typical tolerances in measuring velocities and variations in sediment gradation, it was assumed that no significant erosion impact would occur.

Reach 7.6 had an average increase in stream power of 1.2% for 16 days when the average velocity was 3.28 fps compared to a threshold limit of 3.0 - 3.5 fps. Because the velocities are within the threshold limits it was assumed that no erosion impact would occur.

Table 3

Summary of Analysis Lower Reaches of the Laguna de Santa Rosa
Wet Year 1982

Reach	Erosion Velocity Threshold (fps)	Velocity Range[1] (fps)	Estimated Average Velocity[2] (fps)	Estimated Stream Power Increase (%)	Number of Days[3]
7.0	2.0	>2.0	2.07	1.4	5
7.2	2.0 - 2.5	2.0 - 2.5	2.14	2.8	25
	2.0 - 2.5	>2.5	2.58	1.4	7
7.4	3.0 - 3.5	3.0 - 3.5	3.17	3.6	16
	3.0 - 3.5	3.5 - 4.0	3.70	1.7	13
	3.0 - 3.5	>4.0	4.12	1.1	7
7.6	3.0 - 3.5	3.0 - 3.5	3.28	1.2	16

Notes:
1. Daily data for each reach was subdivided into selected velocity ranges based on the average daily velocity for the reach.
2. Average velocity for the days during the year where the average daily velocity was within the indicated range and the increase in stream power was more than 1%.
3. Number of days during the year where the average daily velocity was within the indicated velocity range and the increase in stream power was more than 1%.

CONCLUSIONS

The results of the analysis indicate that throughout the Laguna de Santa Rosa and Russian River systems, there is no significant potential for increased streambank erosion due to the discharge of reclaimed water during average and dry years. During very wet years, flow conditions in reaches 7.2 and 7.4 may approach the erosion threshold condition, but based on the analysis presented here, no significant erosion is anticipated. The remainder of the Laguna and the entire Russian River system are not expected to experience any increased erosion due to the discharge of reclaimed water during wet years.

REFERENCES

American Society of Civil Engineers (ASCE), 1995, Hydraulic Design of Flood Control Channels, Technical Engineering and Design Guides as Adapted from the US Army Corps of Engineers, No. 10.

Dunne, Thomas and Luna B. Leopold, 1978, Water in Environmental Planning, W.H. Freeman and Company.

Goldman, Steven J., Jackson, Katharine and Bursztynsky, Taras A., 1986, Erosion and Sediment Control Handbook, McGraw-Hill Book Company

APPENDICES

A. Reach Descriptions
B. Example of Typical Data File
C. Results of Analysis, 1976 -- dry year
D. Results of Analysis, 1961 -- average year
E. Results of Analysis, 1982 -- wet year

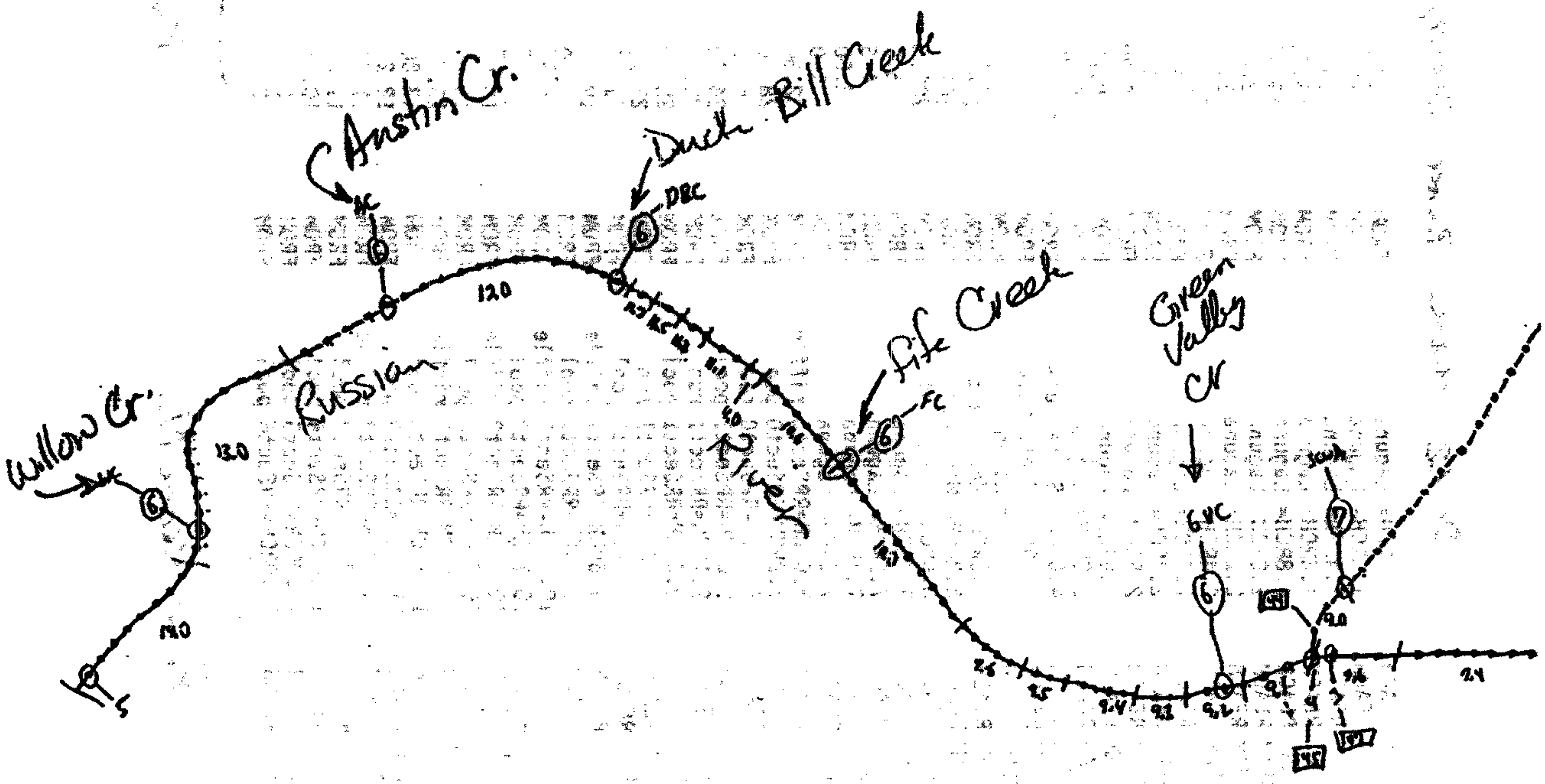
APPENDIX A
REACH DESCRIPTIONS

QUAL2 Model Reach Descriptions

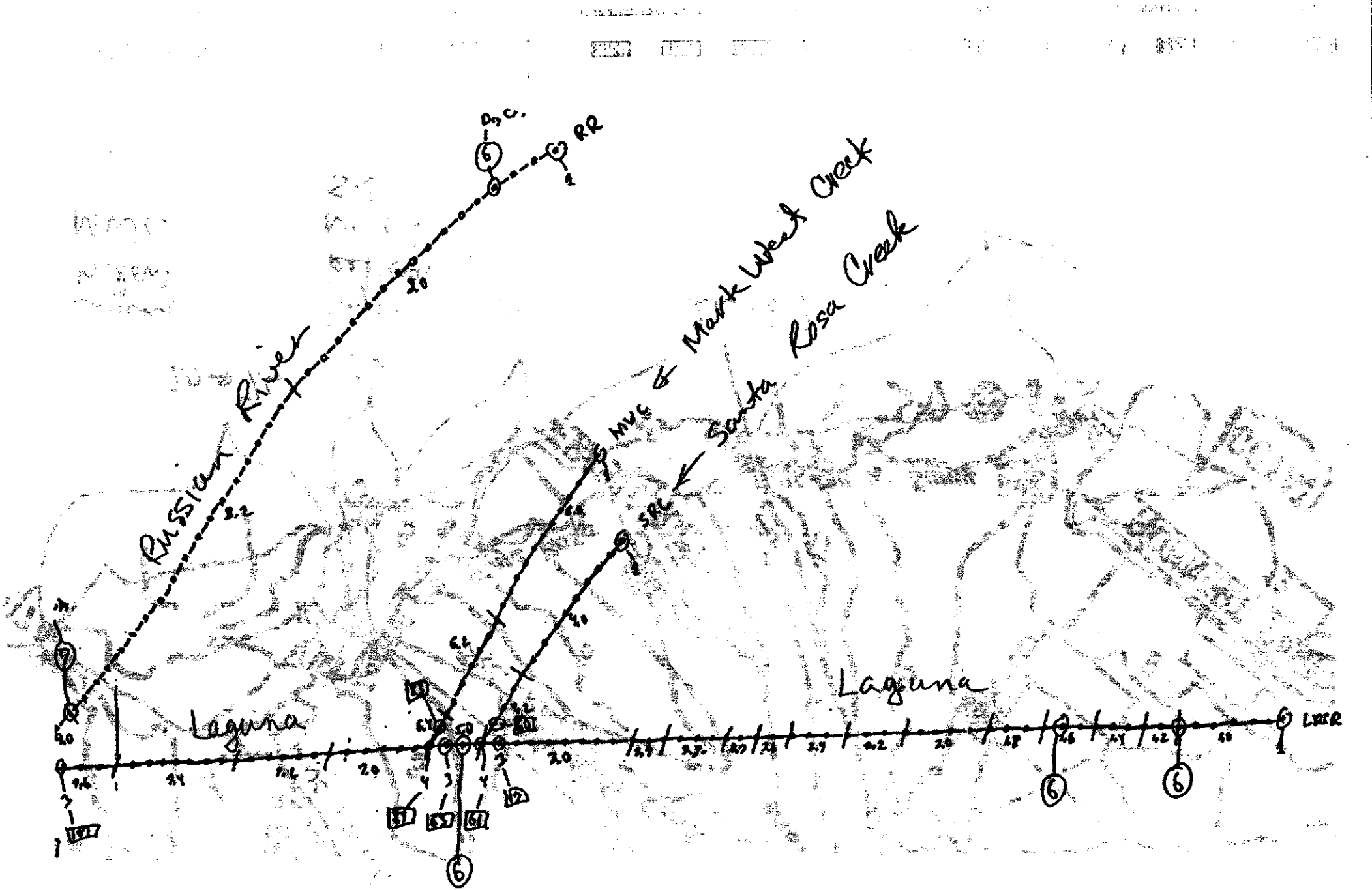
STREAM REACH	1.0RCH= Laguna	FROM	17.5	TO	16.0
STREAM REACH	1.2RCH= Laguna	FROM	16.0	TO	15.5
STREAM REACH	1.4RCH= Laguna	FROM	15.5	TO	14.75
STREAM REACH	1.6RCH= Laguna	FROM	14.75	TO	14.00
STREAM REACH	1.8RCH= Laguna	FROM	14.00	TO	13.25
STREAM REACH	2.0RCH= Laguna	FROM	13.25	TO	12.00
STREAM REACH	2.2RCH= Laguna	FROM	12.00	TO	11.25
STREAM REACH	2.4RCH= Laguna	FROM	11.25	TO	10.5
STREAM REACH	2.6RCH= Laguna	FROM	10.5	TO	10.0
STREAM REACH	2.7RCH= Laguna	FROM	10.0	TO	9.80
STREAM REACH	2.8RCH= Laguna	FROM	9.80	TO	9.20
STREAM REACH	2.9RCH= Laguna	FROM	9.20	TO	9.00
STREAM REACH	3.0RCH= Laguna	FROM	9.00	TO	6.75
STREAM REACH	4.0RCH= Santa Rosa	FROM	103.25	TO	101.0
STREAM REACH	4.2RCH= Santa Rosa	FROM	101.0	TO	100.0
STREAM REACH	5.0RCH= Laguna	FROM	6.75	TO	6.0
STREAM REACH	6.0RCH= Mark West	FROM	205.0	TO	202.0
STREAM REACH	6.2RCH= Mark west	FROM	202.0	TO	200.5
STREAM REACH	6.4RCH= Mark West	FROM	200.5	TO	200.0
STREAM REACH	7.0RCH= Laguna	FROM	6.0	TO	4.5
STREAM REACH	7.2RCH= Laguna	FROM	4.5	TO	3.00
STREAM REACH	7.4RCH= Laguna	FROM	3.00	TO	1.0
STREAM REACH	7.6RCH= Laguna	FROM	1.0	TO	0.0
STREAM REACH	8.0RCH=RRSect0 riffle	FROM	32.50	TO	28.50
STREAM REACH	8.2RCH=RRSect0 pool	FROM	28.50	TO	26.75
STREAM REACH	8.3RCH=RRSect0 pool	FROM	26.75	TO	24.00
STREAM REACH	9.0RCH=RRSect1 pool	FROM	24.00	TO	23.25
STREAM REACH	9.1RCH=RRSect1 run	FROM	23.25	TO	22.50
STREAM REACH	9.2RCH=RRSect1 pool	FROM	22.50	TO	21.75
STREAM REACH	9.3RCH=RRSect1 run	FROM	21.75	TO	21.00
STREAM REACH	9.4RCH=RRSect1 pool	FROM	21.00	TO	19.75
STREAM REACH	9.5RCH=RRSect1 riffle	FROM	19.75	TO	19.00
STREAM REACH	9.6RCH=RRSect1 pool	FROM	19.00	TO	17.75
STREAM REACH	10.0RCH=RRSect2 riffle	FROM	17.75	TO	17.25
STREAM REACH	10.1RCH=RRSect2 pool	FROM	17.25	TO	15.00
STREAM REACH	10.6RCH=RRSect2 riffle	FROM	15.00	TO	13.75
STREAM REACH	10.7RCH=RRSect2 pool	FROM	15.00	TO	13.25
STREAM REACH	11.0RCH=RRSect3 riffle	FROM	13.75	TO	13.00
STREAM REACH	11.1RCH=RRSect3 pool	FROM	13.00	TO	12.25
STREAM REACH	11.3RCH=RRSect3 pool	FROM	12.25	TO	11.75
STREAM REACH	11.5RCH=RRSect3 riffle	FROM	11.75	TO	11.25
STREAM REACH	11.7RCH=RRSect3 pool	FROM	11.25	TO	10.75
STREAM REACH	12.0RCH=RRSect4 pool	FROM	10.75	TO	6.00
STREAM REACH	13.0RCH=RRSect5 pool	FROM	6.00	TO	2.25
STREAM REACH	14.0RCH=RRSect6 pool	FROM	2.25	TO	0.00

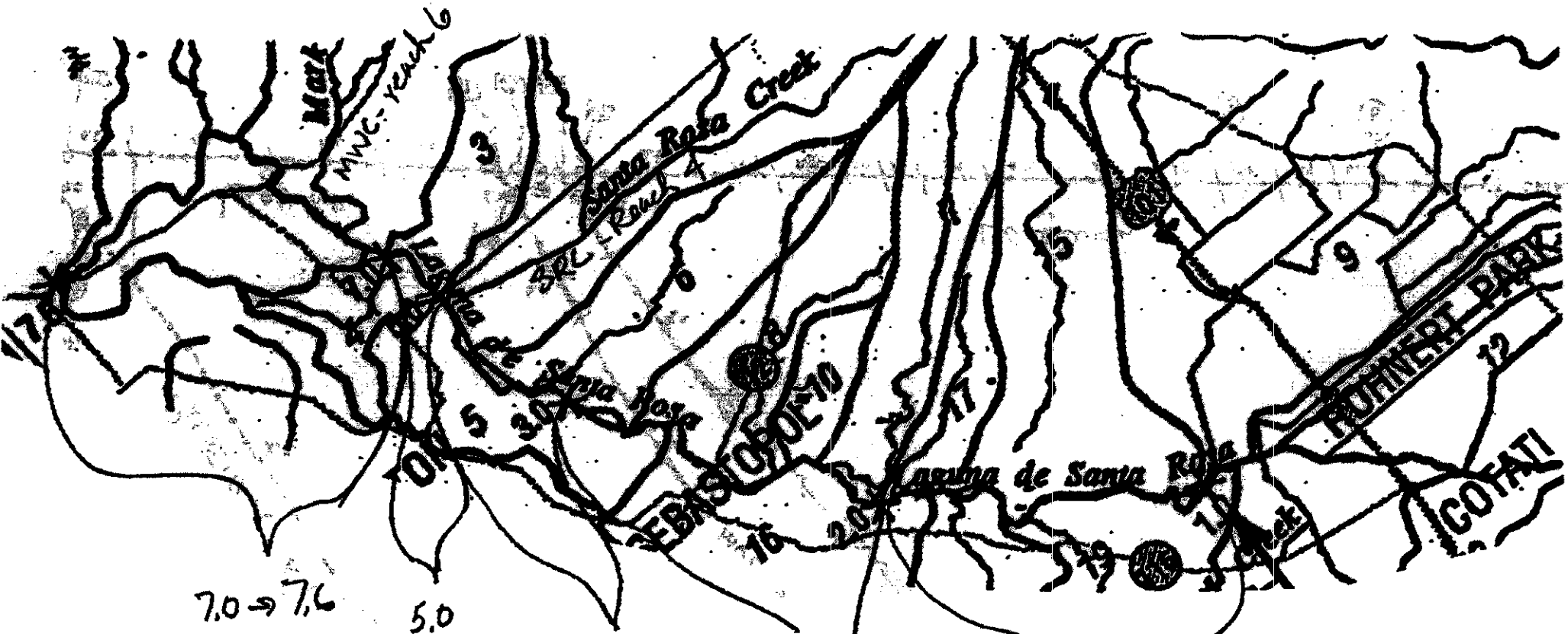
River Reach No.

River Miles



Austin Cr.
Duck Bill Creek
DBC
Willow Cr.
Russian
River
Fife Creek
FC
Green Valley Cr
6 VC
12.0
13.0
14.0
2.4


Russian River
Mark West Creek
Santa Rosa Creek
MWC
SRC
RR
Laguna
Laguna
LWR


Santa Rosa Creek
SRC Road
Laguna de Santa Rosa
REDWOOD DR
RUSSIAN RIVER
ROHNERT PARK
COTATI
MWC-Yeakel
7.0 → 7.6
5.0
3.0
2.0-2.9
1.0-1.8
Laguna below MWC
Laguna between MWC & SRC

APPENDIX B
EXAMPLE OF TYPICAL DATA FILE

REACH	AVERAGE FLOW (cfs)	AVERAGE VELOCITY (fps)	AVERAGE DEPTH (ft)
Elapsed Time Day		===>	1
1	2	0.19	0.97
1.2	2.1	0.19	1.15
1.4	2.7	0.03	2.54
1.6	2.7	0.13	0.72
1.8	3	0.02	1.66
2	3.4	0.04	1.45
2.2	3.5	0.41	0.27
2.4	3.5	0.03	2.12
2.6	3.5	0.43	0.39
2.7	3.5	0.01	4.62
2.8	3.6	0	5.76
2.9	3.6	0.03	2.12
3	3.9	0.32	0.39
4	5.1	0.67	0.31
4.2	12.6	0.87	0.43
5	16.7	0.88	0.62
6	4.3	0.49	0.34
6.2	4.4	0.4	0.39
6.4	4.4	0.52	0.36
7	21.2	0.55	1.26
7.2	21.3	0.77	0.84
7.4	22.9	1.08	0.73
7.6	22.9	0.29	1.5
8	270.1	1.13	2.94
8.2	270.3	0.58	4.94
8.3	270.6	0.58	4.94
9	148.6	0.38	4.88
9.1	171.9	1.49	2.83
9.2	175.1	0.41	5.17
9.3	175.4	1.5	2.87
9.4	176.4	0.42	5.19
9.5	176.7	1.6	1.71
9.6	177.6	0.42	5.2
10	177.7	1.61	1.72
10.1	178.9	0.41	4.92
10.6	182.9	1.07	2.82
10.7	183.2	0.28	6.84
11	183.3	1.07	2.82
11.1	183.6	0.59	3.95
11.3	183.7	0.47	4.44
11.5	183.8	1.07	2.83
11.7	183.9	0.47	4.44
12	197.5	0.31	6.71
13	200.1	0.08	12.51
14	200.2	0.03	17.61

Elapsed Time Day		===>	2
1	1.9	0.18	0.97
1.2	1.9	0.18	1.15
1.4	2.5	0.02	2.54
1.6	2.5	0.12	0.71
1.8	2.8	0.02	1.65
2	3.2	0.04	1.45
2.2	3.3	0.39	0.26
2.4	3.3	0.02	2.12
2.6	3.4	0.41	0.39
2.7	3.4	0.01	4.61
2.8	3.5	0	5.76
2.9	3.5	0.03	2.12
3	3.8	0.32	0.39
4	4.6	0.64	0.31
4.2	12.3	0.86	0.43
5	16.4	0.88	0.61
6	3.9	0.46	0.34
6.2	4	0.37	0.38
6.4	4.1	0.48	0.36
7	20.6	0.54	1.25
7.2	20.8	0.75	0.83
7.4	22.2	1.06	0.73
7.6	22.3	0.29	1.49
8	273.3	1.13	2.95
8.2	273.3	0.59	4.95
8.3	273.5	0.59	4.95
9	138.5	0.37	4.77
9.1	161.1	1.46	2.73
9.2	164	0.4	5.05
9.3	164.2	1.47	2.76
9.4	165.2	0.4	5.07
9.5	165.4	1.58	1.64
9.6	166.4	0.4	5.08
10	166.6	1.58	1.65
10.1	168.9	0.4	4.83
10.6	173.1	1.07	2.75
10.7	173.7	0.27	6.78
11	173.9	1.07	2.76
11.1	174.6	0.58	3.89
11.3	175	0.46	4.36
11.5	175.4	1.07	2.77
11.7	175.8	0.46	4.37
12	191.7	0.3	6.67
13	194.5	0.07	12.51
14	195.1	0.03	17.61
Elapsed Time Day		===>	3
1	1.8	0.17	0.97
1.2	1.8	0.17	1.14
1.4	2.3	0.02	2.55
1.6	2.3	0.11	0.71

1.8	2.6	0.02	1.65
2	2.9	0.03	1.44
2.2	2.9	0.36	0.26
2.4	3	0.02	2.11
2.6	3	0.38	0.39
2.7	3	0.01	4.61
2.8	3.1	0	5.75
2.9	3.1	0.02	2.11
3	3.4	0.29	0.38
4	4.3	0.61	0.3
4.2	12.4	0.86	0.43
5	16	0.87	0.6
6	3.7	0.43	0.33
6.2	3.7	0.35	0.38
6.4	3.7	0.45	0.36
7	19.7	0.52	1.24
7.2	19.7	0.73	0.82
7.4	21	1.02	0.71
7.6	21.1	0.27	1.49
8	270.1	1.13	2.94
8.2	270.4	0.58	4.94
8.3	270.8	0.58	4.94
9	125.9	0.35	4.61
9.1	147.5	1.42	2.59
9.2	150.9	0.38	4.91
9.3	151.4	1.44	2.63
9.4	153.1	0.39	4.93
9.5	153.6	1.55	1.57
9.6	155.2	0.39	4.96
10	155.5	1.55	1.58
10.1	158.4	0.39	4.75
10.6	162.5	1.07	2.67
10.7	163.1	0.26	6.7
11	163.3	1.07	2.68
11.1	163.9	0.57	3.81
11.3	164.4	0.45	4.27
11.5	164.7	1.07	2.69
11.7	165.1	0.45	4.28
12	180.3	0.29	6.58
13	183	0.07	12.51
14	183.7	0.03	17.61

APPENDIX C
DRY YEAR ANALYSIS
1976 WATER YEAR

APPENDIX C DRY YEAR ANALYSIS – 1976 WATER YEAR

The following table summarizes the results of the dry year analysis. The table is a filtered list of data taken from the entire data base of hydraulic properties for each reach and each day of the October through May discharge period. The table lists only the reaches and days where a potential erosion impact has been calculated based on the hydraulic criteria listed in the following table.

Location	Velocity (fps)	Stream Power Increase
Laguna de Santa Rosa		
Upper Reaches (Nos. 1.0 through 7.2)	>2.0	>1%
Lower Reaches (Nos. 7.4 and 7.6)	>3.0	>1%
Russian River		
Reaches 8.0 through 14.0	>4.0	>1%

Based on this criteria, a potential impact was identified only in reaches 7.2 and 7.4, located on the Laguna de Santa Rosa. (See Appendix A) The other reaches along the Laguna and all reaches on the Russian River would not be impacted based on the criteria described herein.

Erosion Impact Analysis -- Dry Year 1976

Laguna de Santa Rosa and Russian River
Santa Rosa Subregional Wastewater Project

REACH	EXISTING CONDITIONS			20% DISCHARGE			STREAM POWER		
	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	EXIST COND	20% DISCH	INCREASE (%)
7.2	307	2.02	2.66	323.5	2.05	2.73	5.3732	5.5965	4.2%
7.4	339.3	3	2.86	356.2	3.04	2.94	8.5800	8.9376	4.2%

APPENDIX D
AVERAGE YEAR ANALYSIS—1961 WATER

APPENDIX D AVERAGE YEAR ANALYSIS -- 1961 WATER YEAR

The following tables summarize the results of the average year analysis. The table is a filtered list taken from the entire data base of hydraulic properties for each reach and each day of the October through May discharge period. The table lists only the reaches and days where a potential erosion impact has been calculated based on the hydraulic criteria listed in the following table.

Location	Velocity (fps)	Stream Power Increase
Laguna de Santa Rosa		
Upper Reaches (Nos. 1.0 through 7.2)	>2.0	>1%
Lower Reaches (Nos. 7.4 and 7.6)	>3.0	>1%
Russian River		
Reaches 8.0 through 14.0	>4.0	>1%

Based on this criteria, a potential impact was identified only in reaches 7.0, 7.2, 7.4 and 7.6, located on the Laguna de Santa Rosa. (See Appendix A) The other reaches along the Laguna and all reaches on the Russian River would not be impacted based on the criteria described herein.

Erosion Impact Analysis -- Normal Flow Year 1961

Laguna de Santa Rosa and Russian River
Santa Rosa Subregional Wastewater Project

REACH	EXISTING CONDITIONS			20% DISCHARGE			STREAM POWER		
	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	EXIST COND	20% DISCH	INCREASE (%)
7.2	403.7	2.16	3.03	435.9	2.21	3.15	6.5448	6.9615	6.4%
7.4	447.4	3.24	3.34	480.5	3.31	3.48	10.8216	11.5188	6.4%
7	670.5	2.08	3.88	690.6	2.09	3.91	8.0704	8.1719	1.3%
7.2	684.8	2.46	3.9	704.9	2.47	3.95	9.5940	9.7565	1.7%
7.4	758.3	3.7	4.44	778.4	3.72	4.5	16.4280	16.7400	1.9%
7.2	362.1	2.11	2.89	382.7	2.14	2.96	6.0979	6.3344	3.9%
7.4	399.9	3.14	3.15	420.4	3.19	3.24	9.8910	10.3356	4.5%
7.2	414	2.16	3.04	435.1	2.19	3.12	6.5664	6.8328	4.1%
7.4	460.3	3.23	3.35	481.5	3.27	3.44	10.8205	11.2488	4.0%
7.2	1370.1	2.75	5.29	1391.1	2.76	5.33	14.5475	14.7108	1.1%
7.6	1504.5	3.36	6.16	1525.5	3.37	6.21	20.6976	20.9277	1.1%
7.2	756.4	2.51	4.08	776.5	2.52	4.14	10.2408	10.4328	1.9%
7.4	837.8	3.78	4.68	857.9	3.8	4.74	17.6904	18.0120	1.8%
7.2	398.4	2.16	3.02	419	2.19	3.09	6.5232	6.7671	3.7%
7.4	440.1	3.23	3.32	460.6	3.27	3.4	10.7236	11.1160	3.7%
7.2	742.2	2.49	4.04	755.4	2.5	4.08	10.0596	10.2000	1.4%
7.4	820.8	3.75	4.63	834	3.77	4.67	17.3625	17.6059	1.4%

APPENDIX E
WET YEAR ANALYSIS
1982 WATER YEAR

APPENDIX E WET YEAR ANALYSIS -- 1982 WATER YEAR

The following tables summarize the results of the wet year analysis. The table is a filtered list of data taken from the entire data base of hydraulic properties for each reach and each day of the October through May discharge period. The table lists only the reaches and days where a potential erosion impact has been calculated based on the hydraulic criteria listed in the following table.

Location	Velocity (fps)	Stream Power Increase
Laguna de Santa Rosa		
Upper Reaches (Nos. 1.0 through 7.2)	>2.0	>1%
Lower Reaches (Nos. 7.4 and 7.6)	>3.0	>1%
Russian River		
Reaches 8.0 through 14.0	>4.0	>1%

Based on this criteria, a potential impact was identified only in reaches 7.0, 7.2, 7.4 and 7.6, located on the Laguna de Santa Rosa. (See Appendix A) The other reaches along the Laguna and all reaches on the Russian River would not be impacted based on the criteria described herein.

The second set of tables in this appendix present the same data as the first table except the data are sorted so that the results for each reach (7.0 through 7.4) are presented on a separate table. These tables were used determine averages and to develop statistics to summarize the results of the analysis.

Erosion Impact Analysis -- Wet Year 1982

Laguna de Santa Rosa and Russian River
Santa Rosa Subregional Wastewater Project

REACH	EXISTING CONDITIONS			20% DISCHARGE			STREAM POWER		
	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	AVE FLOW (cfs)	AVE VELOCITY (fps)	AVE DEPTH (ft)	EXIST COND	20% DISCH	INCREASE (%)
7.2	354.2	2.09	2.84	369.3	2.11	2.9	5.9356	6.1190	3.1%
7.4	392.2	3.11	3.09	408.2	3.15	3.16	9.6099	9.9540	3.6%
7.2	478	2.23	3.24	502.9	2.26	3.32	7.2252	7.5032	3.8%
7.4	531.5	3.34	3.61	556.7	3.38	3.71	12.0574	12.5398	4.0%
7.6	1258.7	3.25	5.58	1274.4	3.26	5.62	18.1350	18.3212	1.0%
7.2	1036.9	2.66	4.74	1052.5	2.67	4.77	12.6084	12.7359	1.0%
7.6	1153.2	3.18	5.31	1168.8	3.19	5.35	16.8858	17.0665	1.1%
7.2	822.7	2.56	4.27	838.3	2.57	4.31	10.9312	11.0767	1.3%
7.4	911.3	3.86	4.92	927	3.87	4.97	18.9912	19.2339	1.3%
7.2	741.8	2.51	4.07	757.5	2.52	4.11	10.2157	10.3572	1.4%
7.4	821.8	3.78	4.66	837.5	3.8	4.71	17.6148	17.8980	1.6%
7.4	934.6	3.88	4.99	950.7	3.89	5.04	19.3612	19.6056	1.3%
7.6	933.4	3	4.71	949.4	3.02	4.76	14.1300	14.3752	1.7%
7.2	788	2.54	4.18	807.6	2.55	4.23	10.6172	10.7865	1.6%
7.4	872.8	3.83	4.81	892.3	3.84	4.87	18.4223	18.7008	1.5%
7	628.4	2.06	3.84	648.7	2.08	3.86	7.9104	8.0288	1.5%
7.2	633.1	2.43	3.77	653.4	2.45	3.83	9.1611	9.3835	2.4%
7.4	701.1	3.66	4.27	721.3	3.68	4.34	15.6282	15.9712	2.2%
7	530.8	1.99	3.68	551.3	2.01	3.72	7.3232	7.4772	2.1%
7.2	533	2.33	3.47	553.5	2.35	3.54	8.0851	8.3190	2.9%
7.4	590	3.51	3.9	610.5	3.54	3.97	13.6890	14.0538	2.7%
7.2	525.4	2.32	3.45	546.1	2.35	3.51	8.0040	8.2485	3.1%
7.4	582	3.5	3.87	602.7	3.53	3.94	13.5450	13.9082	2.7%
7	647.9	2.08	3.86	668.7	2.09	3.89	8.0288	8.1301	1.3%
7.2	643.7	2.44	3.8	664.5	2.46	3.86	9.2720	9.4956	2.4%
7.4	713.1	3.67	4.31	734	3.69	4.38	15.8177	16.1622	2.2%
7.2	777.8	2.54	4.16	798.4	2.55	4.21	10.5664	10.7355	1.6%
7.4	861.5	3.82	4.78	882.1	3.84	4.84	18.2596	18.5856	1.8%

Wet Year

7	767.1	2.14	4.01	787.7	2.15	4.04	8.5814	8.6860	1.2%
7.2	765.6	2.53	4.13	786.2	2.54	4.18	10.4489	10.6172	1.6%
7.4	849	3.81	4.74	869.6	3.83	4.8	18.0594	18.3840	1.8%
7.4	1234	4.05	5.76	1254.7	4.06	5.81	23.3280	23.5886	1.1%
7.6	1227.7	3.23	5.5	1248.4	3.24	5.55	17.7650	17.9820	1.2%
7.6	1431.8	3.35	6.02	1452.3	3.36	6.07	20.1670	20.3952	1.1%
7.4	1217.3	4.05	5.73	1237.9	4.06	5.78	23.2065	23.4668	1.1%
7.6	1220.9	3.23	5.49	1241.5	3.24	5.54	17.7327	17.9496	1.2%
7.2	1086.4	2.68	4.84	1106.9	2.69	4.88	12.9712	13.1272	1.2%
7.4	1204.8	4.04	5.7	1225.3	4.05	5.75	23.0280	23.2875	1.1%
7.6	1203.2	3.22	5.44	1223.8	3.23	5.5	17.5168	17.7650	1.4%
7.4	1393.4	4.12	6.13	1414	4.13	6.18	25.2556	25.5234	1.1%
7.6	1391.3	3.33	5.92	1411.9	3.34	5.97	19.7136	19.9398	1.1%
7.6	1469.3	3.37	6.11	1489.9	3.38	6.16	20.5907	20.8208	1.1%
7.6	1471	3.37	6.11	1491.6	3.38	6.16	20.5907	20.8208	1.1%
7.4	1247.6	4.06	5.8	1268	4.07	5.85	23.5480	23.8095	1.1%
7.6	1251.2	3.25	5.57	1271.7	3.26	5.62	18.1025	18.3212	1.2%
7.4	1342.5	4.09	5.99	1363.2	4.1	6.04	24.4991	24.7640	1.1%
7.6	1332.6	3.29	5.76	1353.3	3.3	5.81	18.9504	19.1730	1.2%
7.6	1357.5	3.31	5.84	1377.9	3.32	5.89	19.3304	19.5548	1.2%
7.4	1319.6	4.09	5.97	1340.1	4.1	6.02	24.4173	24.6820	1.1%
7.6	1319.3	3.29	5.74	1339.8	3.3	5.79	18.8846	19.1070	1.2%
7.6	1398.6	3.34	5.94	1419.1	3.35	5.99	19.8396	20.0665	1.1%
7.6	1439.2	3.35	6.03	1458.9	3.36	6.08	20.2005	20.4288	1.1%
7.2	661.7	2.45	3.85	669.2	2.46	3.88	9.4325	9.5448	1.2%
7.2	619.6	2.42	3.73	627.1	2.43	3.76	9.0266	9.1368	1.2%
7.2	588.8	2.39	3.64	596.4	2.4	3.67	8.6996	8.8080	1.2%
7.4	629.3	3.56	4.03	636.9	3.57	4.06	14.3468	14.4942	1.0%
7.2	504.2	2.3	3.38	511.8	2.31	3.41	7.7740	7.8771	1.3%
7.4	557	3.45	3.78	564.6	3.47	3.8	13.0410	13.1860	1.1%
7	542.2	2	3.7	553.6	2.01	3.72	7.4000	7.4772	1.0%
7.2	542.3	2.34	3.5	553.1	2.35	3.54	8.1900	8.3190	1.6%
7.4	601.4	3.53	3.94	611.6	3.54	3.97	13.9082	14.0538	1.0%
7.2	474.4	2.26	3.28	491.9	2.28	3.34	7.4128	7.6152	2.7%
7.4	526.3	3.4	3.66	543.8	3.43	3.73	12.4440	12.7939	2.8%
7.2	443.5	2.22	3.18	460.9	2.24	3.24	7.0596	7.2576	2.8%
7.4	492.2	3.34	3.54	509.6	3.37	3.6	11.8236	12.1320	2.6%

Wet Year

7.2	405.4	2.17	3.05	422.8	2.19	3.11	6.6185	6.8109	2.9%
7.4	449.9	3.25	3.37	467.3	3.29	3.44	10.9525	11.3176	3.3%
7.2	377.8	2.13	2.95	395.2	2.16	3.01	6.2835	6.5016	3.5%
7.4	419.4	3.19	3.24	436.8	3.23	3.32	10.3356	10.7236	3.8%
7.2	335.5	2.07	2.8	352.8	2.1	2.86	5.7960	6.0060	3.6%
7.4	372.6	3.09	3.04	389.9	3.13	3.12	9.3936	9.7656	4.0%
7.2	338.5	2.08	2.81	355.7	2.1	2.87	5.8448	6.0270	3.1%
7.4	376	3.1	3.06	393.2	3.13	3.13	9.4860	9.7969	3.3%
7.2	328.4	2.06	2.77	345.6	2.09	2.83	5.7062	5.9147	3.7%
7.4	364.8	3.07	3.01	382	3.11	3.08	9.2407	9.5788	3.7%
7.2	322.6	2.05	2.75	339.8	2.08	2.81	5.6375	5.8446	3.7%
7.4	358.4	3.06	2.98	375.6	3.1	3.06	9.1188	9.4860	4.0%
7.2	311.9	2.04	2.7	329	2.06	2.77	5.5080	5.7062	3.6%
7.4	346.7	3.03	2.93	363.8	3.07	3	8.8779	9.2100	3.7%
7.2	342	2.08	2.82	359	2.11	2.88	5.8656	6.0768	3.6%
7.4	380	3.11	3.08	397	3.14	3.15	9.5788	9.8910	3.3%
7.2	317.6	2.05	2.73	334.3	2.07	2.79	5.5965	5.7753	3.2%
7.4	353	3.05	2.95	369.7	3.08	3.03	8.9975	9.3324	3.7%
7.2	312.7	2.04	2.71	329.3	2.06	2.77	5.5284	5.7062	3.2%
7.4	347.6	3.03	2.93	364.2	3.07	3.01	8.8779	9.2407	4.1%
7.2	295	2.01	2.64	310.6	2.04	2.7	5.3064	5.5080	3.8%
7.4	327.9	2.99	2.84	343.5	3.02	2.91	8.4916	8.7882	3.5%
7.2	297.8	2.02	2.65	312.1	2.04	2.7	5.3530	5.5080	2.9%
7.4	330.9	2.99	2.85	345.4	3.03	2.92	8.5215	8.8476	3.8%

Erosion Impact Analysis -- Wet Year 1982									
7	628.4	2.06	3.84	648.7	2.08	3.86	7.9104	8.0288	1.5%
7	530.8	1.99	3.68	551.3	2.01	3.72	7.3232	7.4772	2.1%
7	647.9	2.08	3.86	668.7	2.09	3.89	8.0288	8.1301	1.3%
7	767.1	2.14	4.01	787.7	2.15	4.04	8.5814	8.6860	1.2%
7	542.2	2	3.7	553.6	2.01	3.72	7.4000	7.4772	1.0%

Erosion Impact Analysis -- Wet Year 1982									
7.2	354.2	2.09	2.84	369.3	2.11	2.9	5.9356	6.1190	3.1%
7.2	478	2.23	3.24	502.9	2.26	3.32	7.2252	7.5032	3.8%
7.2	1036.9	2.66	4.74	1052.5	2.67	4.77	12.6084	12.7359	1.0%
7.2	822.7	2.56	4.27	838.3	2.57	4.31	10.9312	11.0767	1.3%
7.2	741.8	2.51	4.07	757.5	2.52	4.11	10.2157	10.3572	1.4%
7.2	788	2.54	4.18	807.6	2.55	4.23	10.6172	10.7865	1.6%
7.2	633.1	2.43	3.77	653.4	2.45	3.83	9.1611	9.3835	2.4%
7.2	533	2.33	3.47	553.5	2.35	3.54	8.0851	8.3190	2.9%
7.2	525.4	2.32	3.45	546.1	2.35	3.51	8.0040	8.2485	3.1%
7.2	643.7	2.44	3.8	664.5	2.46	3.86	9.2720	9.4956	2.4%
7.2	777.8	2.54	4.16	798.4	2.55	4.21	10.5664	10.7355	1.6%
7.2	765.6	2.53	4.13	786.2	2.54	4.18	10.4489	10.6172	1.6%
7.2	1086.4	2.68	4.84	1106.9	2.69	4.88	12.9712	13.1272	1.2%
7.2	661.7	2.45	3.85	669.2	2.46	3.88	9.4325	9.5448	1.2%
7.2	619.6	2.42	3.73	627.1	2.43	3.76	9.0266	9.1368	1.2%
7.2	588.8	2.39	3.64	596.4	2.4	3.67	8.6996	8.8080	1.2%
7.2	504.2	2.3	3.38	511.8	2.31	3.41	7.7740	7.8771	1.3%
7.2	542.3	2.34	3.5	553.1	2.35	3.54	8.1900	8.3190	1.6%
7.2	474.4	2.26	3.28	491.9	2.28	3.34	7.4128	7.6152	2.7%
7.2	443.5	2.22	3.18	460.9	2.24	3.24	7.0596	7.2576	2.8%
7.2	405.4	2.17	3.05	422.8	2.19	3.11	6.6185	6.8109	2.9%
7.2	377.8	2.13	2.95	395.2	2.16	3.01	6.2835	6.5016	3.5%
7.2	335.5	2.07	2.8	352.8	2.1	2.86	5.7960	6.0060	3.6%
7.2	338.5	2.08	2.81	355.7	2.1	2.87	5.8448	6.0270	3.1%
7.2	328.4	2.06	2.77	345.6	2.09	2.83	5.7062	5.9147	3.7%
7.2	322.6	2.05	2.75	339.8	2.08	2.81	5.6375	5.8448	3.7%
7.2	311.9	2.04	2.7	329	2.06	2.77	5.5080	5.7062	3.6%
7.2	342	2.08	2.82	359	2.11	2.88	5.8656	6.0768	3.6%
7.2	317.6	2.05	2.73	334.3	2.07	2.79	5.5965	5.7753	3.2%
7.2	312.7	2.04	2.71	329.3	2.06	2.77	5.5284	5.7062	3.2%
7.2	295	2.01	2.64	310.6	2.04	2.7	5.3064	5.5080	3.8%
7.2	297.8	2.02	2.65	312.1	2.04	2.7	5.3530	5.5080	2.9%

Erosion Impact Analysis -- Wet Year 1982									
7.4	392.2	3.11	3.09	408.2	3.15	3.16	9.6099	9.9540	3.6%
7.4	531.5	3.34	3.61	556.7	3.38	3.71	12.0574	12.5398	4.0%
7.4	911.3	3.86	4.92	927	3.87	4.97	18.9912	19.2339	1.3%
7.4	821.8	3.78	4.66	837.5	3.8	4.71	17.6148	17.8980	1.6%
7.4	934.6	3.88	4.99	950.7	3.89	5.04	19.3612	19.6056	1.3%
7.4	872.8	3.83	4.81	892.3	3.84	4.87	18.4223	18.7008	1.5%
7.4	701.1	3.66	4.27	721.3	3.68	4.34	15.6282	15.9712	2.2%
7.4	590	3.51	3.9	610.5	3.54	3.97	13.6890	14.0538	2.7%
7.4	582	3.5	3.87	602.7	3.53	3.94	13.5450	13.9082	2.7%
7.4	713.1	3.67	4.31	734	3.69	4.38	15.8177	16.1622	2.2%
7.4	861.5	3.82	4.78	882.1	3.84	4.84	18.2596	18.5856	1.8%
7.4	849	3.81	4.74	869.6	3.83	4.8	18.0594	18.3840	1.8%
7.4	1234	4.05	5.76	1254.7	4.06	5.81	23.3280	23.5886	1.1%
7.4	1217.3	4.05	5.73	1237.9	4.06	5.78	23.2065	23.4668	1.1%
7.4	1204.8	4.04	5.7	1225.3	4.05	5.75	23.0280	23.2875	1.1%
7.4	1393.4	4.12	6.13	1414	4.13	6.18	25.2556	25.5234	1.1%
7.4	1247.6	4.06	5.8	1268	4.07	5.85	23.5480	23.8095	1.1%
7.4	1342.5	4.09	5.99	1363.2	4.1	6.04	24.4991	24.7640	1.1%
7.4	1319.6	4.09	5.97	1340.1	4.1	6.02	24.4173	24.6820	1.1%
7.4	629.3	3.56	4.03	636.9	3.57	4.06	14.3468	14.4942	1.0%
7.4	557	3.45	3.78	564.6	3.47	3.8	13.0410	13.1860	1.1%
7.4	601.4	3.53	3.94	611.6	3.54	3.97	13.9082	14.0538	1.0%
7.4	526.3	3.4	3.66	543.8	3.43	3.73	12.4440	12.7939	2.8%
7.4	492.2	3.34	3.54	509.6	3.37	3.6	11.8236	12.1320	2.6%
7.4	449.9	3.25	3.37	467.3	3.29	3.44	10.9525	11.3176	3.3%
7.4	419.4	3.19	3.24	436.8	3.23	3.32	10.3356	10.7236	3.8%
7.4	372.6	3.09	3.04	389.9	3.13	3.12	9.3936	9.7656	4.0%
7.4	376	3.1	3.06	393.2	3.13	3.13	9.4860	9.7969	3.3%
7.4	364.8	3.07	3.01	382	3.11	3.08	9.2407	9.5788	3.7%
7.4	358.4	3.06	2.98	375.6	3.1	3.06	9.1188	9.4860	4.0%
7.4	346.7	3.03	2.93	363.8	3.07	3	8.8779	9.2100	3.7%
7.4	380	3.11	3.08	397	3.14	3.15	9.5788	9.8910	3.3%
7.4	353	3.05	2.95	369.7	3.08	3.03	8.9975	9.3324	3.7%
7.4	347.6	3.03	2.93	364.2	3.07	3.01	8.8779	9.2407	4.1%
7.4	327.9	2.99	2.84	343.5	3.02	2.91	8.4916	8.7882	3.5%
7.4	330.9	2.99	2.85	345.4	3.03	2.92	8.5215	8.8476	3.8%

Erosion Impact Analysis -- Wet Year 1982									
7.6	1258.7	3.25	5.58	1274.4	3.26	5.62	18.1350	18.3212	1.0%
7.6	1153.2	3.18	5.31	1168.8	3.19	5.35	16.8858	17.0665	1.1%
7.6	933.4	3	4.71	949.4	3.02	4.76	14.1300	14.3752	1.7%
7.6	1227.7	3.23	5.5	1248.4	3.24	5.55	17.7650	17.9820	1.2%
7.6	1431.8	3.35	6.02	1452.3	3.36	6.07	20.1670	20.3952	1.1%
7.6	1220.9	3.23	5.49	1241.5	3.24	5.54	17.7327	17.9496	1.2%
7.6	1203.2	3.22	5.44	1223.8	3.23	5.5	17.5168	17.7650	1.4%
7.6	1391.3	3.33	5.92	1411.9	3.34	5.97	19.7136	19.9398	1.1%
7.6	1469.3	3.37	6.11	1489.9	3.38	6.16	20.5907	20.8208	1.1%
7.6	1471	3.37	6.11	1491.6	3.38	6.16	20.5907	20.8208	1.1%
7.6	1251.2	3.26	5.57	1271.7	3.26	5.62	18.1025	18.3212	1.2%
7.6	1332.6	3.29	5.76	1353.3	3.3	5.81	18.9504	19.1730	1.2%
7.6	1357.5	3.31	5.84	1377.9	3.32	5.89	19.3304	19.5548	1.2%
7.6	1319.3	3.29	5.74	1339.8	3.3	5.79	18.8846	19.1070	1.2%
7.6	1398.6	3.34	5.94	1419.1	3.35	5.99	19.8396	20.0665	1.1%
7.6	1439.2	3.35	6.03	1458.9	3.36	6.08	20.2005	20.4288	1.1%