RRWPC

Russian River Watershed Protection Committee

Post Office Box 501
Guerneville, CA 95446
(707) 869-0410

May 15, 2001

Matt St. John
North Coast Regional WQCB
5550 Skylane Blvd.
Santa Rosa, CA 95403

Dear Matt:

The intent of this letter is both to respond to David Leland's letter to me of April 6, 2001, and to provide you with data in support of our (RRWPC's) recommendations for further 303(d) listing of the Laguna de Santa Rosa for phosphorus and dissolved oxygen. Please enter this letter into the record for the CWA 303(d) listing process.

First, thank you for your responses to my questions. While most responses were not as detailed as I would have liked and in some cases a bit ambiguous, in general they were satisfactory, but for two. Mr. Leland states that all Russian River tributaries will be included in the *sediment* TMDL. But what about possible temperature, dissolved oxygen, and phosphorus TMDL's that are now being examined and considered for listing by Regional Board staff? This work is primarily under contract with the Sonoma County Water Agency (SCWA) whose main focus is endangered species issues in the main stem of the Russian River. Which perimeters are being considered for the Laguna also? We will make the case that the Laguna should be listed for dissolved oxygen and phosphates.

Secondly, Mr. Leland's response to my question about the 303(d) status of the Laguna de Santa Rosa is quite problematic for us and I'll tell you why.

The process for delisting the Laguna (Laguna de Santa Rosa) for nutrients was never fulfilled in a legal and official way. In fact, it is very strange you would state that it was delisted since Santa Rosa's latest NPDES permit (March, 2000) states on page 6, #26, *"The Laguna de Santa Rosa is listed as an impaired water body pursuant to Section 303(d) of the Clean Water Act and a waste reduction strategy (WRS) has been established....Staff is re-evaluating the City's efforts and the waste reduction goals contained in the WRS....."*

During the Triennial Review of 1998, I was concerned about the fact that the Laguna did not appear on the recommended 303(d) list of impaired water bodies. In response to my inquiries, I was given conflicting stories by staff that concerned me at the time, so I wrote a chronology of events. I am not sure that I ever mailed the enclosed draft letter to Ms. Marcus of the EPA (dated 8-6-'98), but I include it here for your information as evidence that no formal delisting process took place.

Furthermore, I include here the staff report for Dec. 11, 1997, which failed to say one word about the Laguna de Santa Rosa delisting for ammonia and nitrogen, although that water body had been removed from the list included with the staff report. As I recall, I publicly requested an explanation, which I did not get. After the meeting staff gave me a very ambiguous response that neither confirmed or denied that the Laguna was officially removed from the list. It seems as though Santa Rosa's latest permit verifies that it was not. (The fact that the Laguna de Santa Rosa was not listed in the group of water bodies approved at that meeting is not the same as saying that the Laguna was formally delisted according to procedures called for in the CWA. Exactly what was the meaning of the word delisted in your April 6th letter?)

Evidence that Santa Rosa had not even met the goals of the WRS seems to be contained in the *"Update on the Waste Reduction Strategy for the Laguna de Santa Rosa"* on Aug. 27,1997 (included). On page 5 it gives a chart showing that the estimated WRS for winter was 244,932 pounds per year at Trenton-Healdsburg Rd. (Mark West Creek). And yet Santa Rosa's self monitoring reports for 1995-95 show 443,045 pounds generated in the wastewater. The values given for the Spring estimates are also higher in Santa Rosa's Self Monitoring Reports though by a much smaller margin. The report goes on to state, *"The estimates set forth in the WRS strategy are lower than the estimates calculated from the Self Monitoring Reports. Staff tends to place more reliance in the results provided by the Self Monitoring Reports, and proposes to use those values as a basis for comparison in the future."*

What this seems to be saying is that the tmdl strategy is to set goals accommodating the dischargers needs. Who is driving the train here? RRWPC critiqued the tmdl strategy strenuously for several years. In fact, we repeatedly called for a nutrient budget that utilized a mass balance analysis rather than mere guideline *estimates*. This recommendation follows a general trend we've observed over the years: If Santa Rosa can't meet a requirement, then requirements are changed to accommodate their capabilities.

In the first part of our comments, we presented a case to show that the Laguna de Santa Rosa was never formally *delisted* for nutrients by your agency, nor had it been demonstrated that nutrient goals had been met (ammonia and nitrogen) and the Laguna should be delisted. It is obvious from low dissolved oxygen and high phosphorus readings and from actual appearances that the water body is still heavily distressed. The Laguna enters the Russian River with a frequent brownish-green plume; most water quality perimeters are more distressed downstream than up. And, while the gradual disappearance of cows from the Laguna Area and improvements at the Laguna Regional Plant probably had lowered ammonia amounts significantly, it has not been amply demonstrated that nitrogen is no longer a problem.

In fact, Dr. Dan Wickham has written a report since that time that seems to indicate that phosphorus is the real bad guy nutrient and that Santa Rosa could go far in reducing its addition into that water body. While I know your staff has been given a complete copy of the report, I include another copy to assure its inclusion in the Triennial Review process.

In regard to the seriousness of the problem, Dr. Wickham includes in his summary that:

- The Laguna de Santa Rosa contains concentrations of phosphates that rank it among the most heavily impacted waterways in the United States.
- Algae blooms resulting in serious degradation of the Laguna are highly correlated with phosphate concentrations but not with nitrate concentrations.
- Attempts to control eutrophication due to nutrient loading by focusing solely on nitrogen cannot be effective if phosphate is not controlled first.
- The City of Santa Rosa releases large enough volumes of phosphate into the Laguna during surface effluent releases that increases in concentration can directly be tracked to their wastewater.
- Data are insufficient to determine what other sources of phosphate load to the Laguna might be significant even though geographical trends in the data point to Santa Rosa as a major source.

- Phosphate from Santa Rosa is loaded during the winter high-flow period, however, a sufficient portion of that is deposited in the sediments so that it becomes available through resuspension processes that lead to heavy algae blooms in the summer.
- Excessive phosphate levels are widely known to change the structure of algel communities in freshwater, allowing nitrogen fixing species to predominate. These communities biologically load the environment with nitrogen from atmospheric sources, negating any infrastructure commitment to control of urban or agricultural nitrogen loading.
- Data on land application of effluent demonstrate the effectiveness of soil filtration for removal of phosphate. This indicates that the Regional board should phase out surface discharges in favor of subsurface forms of releases to freshwater bodies under their control.
- The phosphate signal from the Laguna de Santa Rosa is seen in the Russian River and is the most obvious source in the River. The level of resolution of river samples is 0.1 mg/L. Any further sampling in the river should be at least at the 0.01 mg/L level of resolution to determine the actual load to the river coming from the Laguna de Santa Rosa.

Based on this information, we recommend that the Regional Board begin a serious look at a tmdl listing for the Laguna on phosphates. If this is not pursued, we would appreciate a justification for why it is not.

Similarly, RRWPC has looked at data in Santa Rosa's self monitoring reports (obtained in your office from your files) from 1992 to 1997 that indicates that there is a serious dissolved oxygen (DO) problem in the Laguna. We generated a document (submitted here in rough form) that shows all of the DO readings at as many as 11 different points. The headings are numbered 1 to 9 and represent the following points:

1. Laguna at Llano Rd.
2. Laguna at Todd Rd.
3. Laguna at Highway 12
4. Laguna at Occidental Rd.
5. (A) Santa Rosa Creek at Willowside Rd (B) Santa Rosa Creek at Delta Pond upstream
6. (A) Santa Rosa Creek at Delta Pond downstream (B) Santa Rosa Creek at confluence with Laguna
7. Laguna at LaFranchi pond
8. Russian River at Wohler (upstream of Laguna/Mark West confluence)
9. Russian River at Mirabel (downstream of confluence)

It is clear from the numbers on our chart (included) that the Laguna's DO is severely depressed, often falling below 7.0 We might mention that all of these readings took place at approximately 9 am to 12 pm and do not include diurnal readings for those points which are likely to be far lower than those recorded. Why are no diurnal readings required and included?

Sometime after May, 1997, Santa Rosa began a new system of monitoring that incorporates some improvements but virtually eliminates measurements at the above locations. We will go back and check the data between that date and the current time to be more precise (Since these monitoring reports are in your office filed under *Santa Rosa's Self Monitoring Reports* we hereby incorporate them by reference.)

We have problems with their current system of data collection. They do not list numbers for any of the monitoring points. Rather they produce a color graph, which is hard to read in color and impossible to read in black and white. We urge you to require the production of specific readings (numbers) at each of the monitoring points.

We did take a look at the data for the winter season of 2000-01 and noticed the significantly low DO levels in Santa Rosa's storage ponds which could indicate a problem for the receiving waters downstream of the discharge:

Alpha: 11-18-00: **4.8**, 11-21-00: **4.5**, 12-6-00: **3.8**, 12-13-00: **4.7**, 12-20-00: **4.1**, 12-28-00: **4.0**: 1-6-01: **3.8**, 1-13-01: **4.7**, 1-20-01: **4.1**, 1-28-01: **4.0**, 2-3-01: **4.6**, 2-10-01: 5.4, 2-17-01: 8.7, 2-24-01: 8.6, 2-31-01: 10.3

Kelly: 11-2-00: 6.1, 11-8-00: 6.3, 11-15-00: **3.0**, 11-21-00: **4.5**, 11-29-00: **4.7**, 12-6-00: **4.4**, 12-13-00: **2.9**, 12-20-00: **3.5**, 12-28-00: **4.7**, 1-6-01: **4.4**, 1-13-01: **2.9**, 1-20-01: **3.5**, 1-28-01: **4.7**, 2-3-01: **4.0**, 2-10-01: 5.8, 2-17-01: 9.2, 2-24-01: 7.5, 2-31-01: 8.8, 3-7-01: 5.6, 3-27-01: **4.9**

Laguna Joint Wetlands: 11-8-00: **4.3**, 11-15-00: **3.4**, 11-21-00: 6.3, 12-6-01: **4.0**, 12-13-00: **3.3**: 12-20-00: **2.8**, 12-28-00: **4.7**, 1-6-01: **4.0**, 1-13-01: **3.3**, 1-20-01: **2.8**, 1-28-01: **4.7**, 2-3-01: **3.0**, 2-10-01: **4.9**, 2-17-01: 8.1, 2-24-01: 6.8, 2-31-01: 9.1

(Values under 5.0 are highlighted since they do not even meet warm water standard.)

We also include a report of Santa Rosa's permit violations of receiving waters between April 1995 through March 2000 for temperature, turbidity, pH, and dissolved oxygen (pages 10-11) generated by Regional Board staff. It is our intention to also examine Santa Rosa's self monitoring data from Oct. 1997 to April 2000 to chart DO readings in their ponds, and where data is available, in the Laguna also. Unfortunately, we cannot get all of that together by the due date of this paper. Since this is data already on file in your office (*Santa Rosa's Self Monitoring Reports*), we reference the information here.

We also want to address a related issue that appears in the First Public Report for the 2001 Triennial Review of the Water Quality Control Plan for the North Coast Region, May 4, 2001. On page 10, under Beneficial Uses, the Report recommends: *"Include the WARM beneficial use designation for the Laguna de Santa Rosa. The Laguna de Santa Rosa historically and presently supports a warm-water fishery. This beneficial use has been erroneously left out of this table."*

We are quite concerned about this item and have been so for many years. We do not believe you can protect a COLD water endangered species (salmon and steelhead) with a WARM listing. We can only surmise that the scene is being set for the further lowering of standards for Santa Rosa's and other discharges.

We include here a page (7-13) from Santa Rosa's Technical Memorandum # L1, published in the early 1990's. Of the 18 species found in the Laguna de Santa Rosa, 10 of them are non-native. In fact, the three most abundant species are non-native. It is hard to fathom how you could manage the Laguna for non-native warm water species without it also causing a TAKING of the listed cold water fish. Please explain. Also, why is coho not listed on these charts (I submit two charts)? I know the City of Santa Rosa has found some coho in their fishery studies.

It is questionable as to whether leaving the WARM designation out of the Basin Plan was a mistake, as is stated in the report. The Laguna has changed significantly in recent time as a result of channelization by the Sonoma County Water Agency and the farmers (and consequent speeding of the water to the river exacerbating flooding in the lower river), the denuding of the banks through significant riparian habitat removal by the same, the loss of oak trees, heavy stormwater runoff from increasingly urbanized areas, the growth and development in the Santa Rosa/Rohnert Park 101 Corridor causing a great deal of sedimentation, as well as Santa Rosa's wastewater discharges of 50% to 90% of the Laguna flow. All of these things are artificial, man made causes for increased temperatures in the Laguna. Adding a WARM designation will only serve to lower standards for Santa Rosa's discharge and nonpoint discharges and thereby causing problems to get worse. There are several reports on the Laguna in which these statements may be verified (One be Sonoma State in the 1970's, one by the Laguna Foundation in the 1980's, and one by the City of Santa Rosa in the early 1990's)

Furthermore, we wonder how the Laguna could possibly be treated as both a COLD and WARM water body at the same time. This needs to be fully explained and justified. If it is not designated as COLD and WARM at the same time, it needs to be fully explained when and where it is to be designated as one or the other---in detail. Furthermore, please explained in depth how a WARM water designation could be protective of what's left of the COLD water salmonids.

Furthermore, the contribution, through massive wastewater discharges, of unknown quantities of estrogenic compounds, pharmaceuticals, personal care products, cancer drugs, antibiotics, and other toxins on a regular basis could easily be killing off the COLD water fish and need to be studied. I include several articles about studies conducted in other areas indicating a serious and significant problem. Monitoring data needs to be collected at the least on representative samples of these toxins.

Finally, we have not gotten into the temperature issue directly but believe that it may be of importance. We encourage your staff to further study this perimeter not only in the Russian River but also in the Laguna.

The call for solicitation of water quality information (Mar. 12, 2001) is well and good but an inherent problem exists. Often those who collect information (other agencies and groups) have proprietary attitudes about its dissemination and do not share it readily (unless legally required to do so). Public citizens, on the other hand, usually do not have the means to collect data directly and rely on the agencies to provide this information. It behooves your agency to lobby for as much monitoring funding and information sharing as is politically feasible and to share that information with the public in a meaningful way. We look forward to seeing the results of this work.

Sincerely,

Brenda Adelman

PRELIMINARY

State of California
Regional Water Quality Control Board
North Coast Region

Bruce Gwynne
November 10, 1997

EXECUTIVE OFFICER'S SUMMARY REPORT
8:30 a.m. December 11, 1997
Ukiah City Council Chambers
300 Seminary Avenue
Ukiah, California

ITEM: 6

SUBJECT: Public Hearing to Consider Adoption of the 1998 Water Quality Assessment and Revisions to the Clean Water Act Section 303(d) List of Waterbodies for the North Coast Region

DISCUSSION

Section 305(b) of the Federal Clean Water Act (CWA) establishes a process for reporting on the quality of the nation's water resources to the United States Environmental Protection Agency (USEPA) and Congress. The process requires each state, territory, and interstate commission to develop a program to monitor the quality of its surface and ground waters and to report on the status of water quality every two years to the USEPA on or before April 1st of every even year. This information is then compiled into a biennial report which is submitted to Congress. In addition to Section 305(b), Clean Water Act Section 303(d) requires that lists of water bodies be prepared which describe the status of water quality. States usually include the 303(d) list in the Section 305(b) biennial report.

To comply with the listing requirements of the CWA, the State Water Resources Control Board (State Water Board) developed and adopted the Water Quality Assessment (WQA) for California's surface, estuarine, and ground waters in 1989 and amended the WQA in Fiscal Year 95-96. The North Coast Regional Water Quality Control Board (Regional Water Board) last completed its WQA of the North Coast Region in 1996, and submitted its WQA to the State Water Board for inclusion into the statewide 1996 California Water Quality Assessment Report and California 305(b) Report On Water Quality. Now is the time for the Regional Water Boards to once again prepare biennial reviews and updates to the statewide WQA.

The list of water bodies required by CWA Section 303(d) (303(d) list) describes waters that do not fully support all beneficial uses or are not meeting water quality objectives, and includes a description of the pollutants for each listed water body which limit its use or prevent attainment of its water quality objectives. For such water bodies, the CWA requires the development of Total Maximum Daily Load (TMDL) allocations for the pollutants of concern. A TMDL allocation must estimate the total maximum daily load, with seasonal variations and a margin of safety, for all suitable pollutants and thermal loads, at a level that would assure protection and propagation of a balanced indigenous population of fish, shellfish and wildlife.

To fulfill its role in the 1998 WQA, the Regional Water Board conducted an extended public hearing, on September 25, 1997 in Eureka, California, and on October 23, 1997 in Santa Rosa, California.

Based on the input provided at the public hearing and information which was otherwise readily available, Regional Water Board staff have prepared recommendations for changes to the existing 303(d) list. The recommendations are detailed in Table A which is attached. Table B supplements Table A by providing a summary of information sources and comments received during the WQA public hearing process. Both Tables A and B are further supplemented by Attachments 1 through 52, which contain the detailed information supporting the recommendations. Finally, the information contained in Table A, Table B, and Attachments 1 through 52 were used to prepare an updated 303(d) list which is included as Attachment 1 to proposed Resolution No. 97-132.

Note that Item #1 on Table A describes Lake Pillsbury. The issue of concern for this waterbody is mercury concentrations in consumable portions of fish tissue, based on data gathered in the state wide Toxic Substances Monitoring Program. Because mercury concentrations here consistently exceeded FDA action levels staff is recommending that the Regional Board adopt Resolution No. 97-133, urging the California Office of Health and Hazard Assessment to consider issuance of a Health Advisory for Consumption of Fish from Lake Pillsbury.

PRELIMINARY STAFF
RECOMMENDATIONS:

1) Approve the 1998 Water Quality Assessment shown in Tables A and B.

2) Adopt Resolution No. 97-132, updating the 303(d) list as detailed in Attachment 1 to the Resolution.

3) Adopt Resolution No. 97-133, urging the California Office of Environmental Health and Hazard Assessment to issue a public health advisory for the consumption of fish from Lake Pillsbury

(public1)

Table A: 1998 Water Quality Assessment for the North Coast Region.
Summary of Concern and Staff Recommendations.

Item #	Waterbody	Issue of Concern	Recommendation(s) *	Attachn.
11c	Russian River	Nutrients, low dissolved oxygen levels, lead to impaired fisheries habitat, reduced water quality.	1) Determine if objectives are being met.	41
12	Atascadero Creek	Dissolved oxygen levels do not meet Basin Plan objective. Fisheries habitat is impaired due to low dissolved oxygen levels. Unpermitted discharge industrial waste impacts water quality.	1) Defer further action until Regional Board staff investigate dissolved oxygen levels, waste management, and overall water quality in Atascadero Creek to determine if objectives are met.	41
13a	Green Valley Creek	1) Dissolved oxygen levels do not meet Basin Plan objective. Fisheries habitat is impaired due to low dissolved oxygen levels.	1) Defer further action until Regional Board staff investigate dissolved oxygen levels, stormwater management, and overall water quality in Green Valley Creek to determine if objectives are met.	41
13b	Green Valley Creek	2) Elevated temperatures impact coldwater fisheries.	1) Defer further action until Regional Board staff investigate dissolved oxygen levels, stormwater management, and overall water quality in Green Valley Creek to determine if objectives are met.	NA. Recommendation based on oral testimony
14	Laguna de Santa Rosa	Dissolved oxygen levels do not meet Basin Plan objective. Fisheries habitat is impaired due to low dissolved oxygen levels.	1) Defer further action until Regional Board staff investigate dissolved oxygen levels in Laguna de Santa to determine if objectives are appropriate; or: 2) Add low dissolved oxygen as a limiting factor under Section 303(d) for Laguna de Santa Rosa.	41
15	Mark West Creek	Elevated temperatures impact coldwater fisheries.	1) Defer further action until supporting data are provided.	NA. Recommendation based on oral testimony
16a	Ten Mile River	1) Sedimentation, threat of sedimentation. Ten Mile River is on the 303(d) list as sediment impaired as a result of USEPA action in 1996.	1) Update the existing 303(d) list to accurately reflect current status.	44
16b	Ten Mile River	2) Elevated temperatures impact coldwater fisheries.	1) Defer further action until USEPA staff begins TMDL effort or supporting data are provided; or: 2) Add temperature as a limiting factor under Section 303(d) for Ten Mile River.	NA. Recommendation based on oral testimony
17	South Fork Trinity River	Elevated temperatures impact coldwater fisheries.	1) Add temperature as a limiting factor under Section 303(d) for the South Fork Trinity River.	45
18	Usal Creek	Sedimentation, threat of sedimentation, impaired irrigation water quality, impaired domestic supply water quality, impaired spawning habitat, increased rate and depth of flooding due to sediment, property damage.	1) Determine if objectives are being met.	46
19	Van Duzen River	Elevated temperatures impact coldwater fisheries.	1) Defer further action until USEPA staff begins TMDL effort or supporting data are provided; or: 2) Add temperature as a limiting factor under Section 303(d) for the Van Duzen River.	6
20	Yager Creek	Current land management activities subject to California Department of Forestry actions for violation of Forest Practice Rules.	1) No action recommended.	6

* 1) Indicates preferred recommendation
2) Indicates alternate recommendation

Bruce Gwynne
November 10, 1997

California Regional Water Quality Control Board
North Coast Region

Resolution No. 97-132

Adopting the List of Waterbodies as Required
in Section 303(d) of the Clean Water Act

WHEREAS, Section 305(b) of the Federal Clean Water Act requires the State to prepare a biennial update of an assessment of the waters within the State; and

WHEREAS, Section 303(d) of the Federal Clean Water Act requires the State to provide an update of a list of the waters within the State for which existing limitations are not stringent enough to meet water quality standards applicable to such waters; and

WHEREAS, On December 7, 1995, the North Coast Regional Water Quality Control Board (Regional Water Board) adopted a revised Water Quality Assessment and 303(d) list; and

WHEREAS, The Regional Water Board has been directed to review and revise the Water Quality Assessment and 303(d) list for waters within the Region for inclusion in the 1998 California Water Quality Assessment and California 305(b) Report on Water Quality; and

WHEREAS, On September 25, 1997 in Eureka California, and October 23, 1997 in Santa Rosa, California, the Regional Water Board conducted an extended public hearing and carefully considered all testimony and comments, both oral and written, received regarding the 1998 Water Quality Assessment and 303(d) list for the North Coast Region.

THEREFORE, BE IT RESOLVED that the North Coast Regional Water Quality Control Board, in fulfillment of the requirements described in Sections 305(b) and 303(d) of the Clean Water Act, hereby adopts the revised 303(d) Priority List, as detailed in Attachment 1 of this resolution, for inclusion in the 1998 California Water Quality Assessment and California 305(b) Report on Water Quality.

<u>Certification</u>

I, Benjamin D. Kor, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, North Coast Region, on December 11, 1997.

____

Benjamin D. Kor
Executive Officer

(wcares1)

ATTACHMENT 1

North Coast Region Clean Water Act, Section 303(d) List of Waters Requiring the Development of Total Maximum Daily Load limits and implementation plans. (Additions to the 1996 303(d) list are indicated in bold print.)

WATERBODY	POLLUTANT
1. Laguna de Santa Rosa	Nutrients
2. Stemple Creek/ Estero de San Antonio	Nutrients
3. Garcia River	Sediment, **Temperature (for designated reaches)**
4. Americano Creek/Estero Americano	Nutrients
5. Tomki Creek	Sediment
6. Redwood Creek	Sediment
7. **Elk River**	**Sediment**
8. **Freshwater Creek**	**Sediment**
9. Noyo River	Sediment
10. Navarro River	Sediment, **Temperature**
11. Russian River	Sediment
12. Greenwood Creek	Sediment
13. Gualala River	Sediment
14. Big River	Sediment
15. Mattole River	Sediment
16. Klamath River	Nutrients, Temperature, **Dissolved Oxygen**
17. Scott River	Sediment, Temperature
18. Shasta River	Dissolved Oxygen, Temperature
19. Beaughton Creek	Unpermitted discharge of waste
20. South Fork Trinity River	Sediment, **Temperature**
21. Van Duzen River	Sediment
22. Eel River	Sediment, Temperature
23. **Ten Mile River**	**Sediment**
24. Trinity River	Sediment
25. Albion River	Sediment
26. Mad River	Sediment, Turbidity

(wcaatt1)

RRWPC

Russian River Watershed Protection Committee

Post Office Box 501
Guerneville, CA 95446
(707) 869-0410

Draft letter to EPA re: 303 (d) listing of the Laguna de Santa Rosa
August 6, 1998

Dear Ms. Marcus:

It came to our attention on Aug. 5th, in a meeting with Michael Lozeau, attorney for and executive director of Baykeeper, that the EPA is finalizing its current 303 (d) list in the next few days. In discussing the Laguna de Santa Rosa, we informed Michael that the North Coast Regional Board had casually delisted the Laguna at their Dec. 11, 1997 board meeting. Brenda Adelman of Russian River Watershed Protection Committee (RRWPC) and Dr. John Rosenblum, technical consultant, were present at that meeting in Ukiah and spoke in opposition to this action. They had been tracking this issue closely for years. Mr. Dave Smith of your office was present at the Dec.11th meeting and concurred with the delisting.

After the meeting Brenda and John were informed by Board staff (Bruce Gwynne) that the 303 (d) list was not meant for streams having established goals but only for those streams in the process of establishing tmdl goals. Michael informed us this week however that streams cannot be casually delisted without a formal process proving that tmdl goals had been met. No one is stating that Laguna tmdl goals have been met.

The North Coast Board noticed meetings on the Water Quality Assessment process for their Sept. 25, 1997 meeting in Eureka (Item #2), their October 23, 1997 meeting in Santa Rosa (Item #1) and their Dec. 11, 1997 meeting in Ukiah (Item # 6). RRWPC and John Rosenblum were in possession of the staff report showing the tmdl status of the Laguna in which there was no indication of delisting. The staff recommendation handed out before the final meeting was ambiguous. It called for deferrment of further action (this appears to mean that it would stay listed) until Regional Board staff can study dissolved oxygen but then it also called for listing the Laguna as impaired for low dissolved oxygen. Since that time staff has completed its study and has since reported that indeed, low dissolved oxygen is a serious problem in the Laguna de Santa Rosa. Furthermore, Attachment #1 with the Dec. 11th staff report indicates that the Laguna is to stay on the list.

What is of further concern to us is the Regional Board staff recommendation for the Basin Plan Triennial Review coming up on August 27, 1998, is an item calling for redefining the beneficial use in the Laguna from a year round cold water body to a seasonal cold water and warm water body. Further, Santa Rosa's new proposed NPDES permit calls for a change in temperature requirements for receiving waters that we believe is a downgrading of their former permit. We have historical evidence that warm water fish species were introduced, not native, that vast sedimentation is a rather recent occurance, and that ag practices, wastewater discharges and riparian removal are probably responsible for increased water temperature.

Not only is Laguna impairment **not** improved, it may be worse. According to Miles Ferris, director of Santa Rosa's Utility Department, Laguna sediments have aggraded about 700% in the last twenty years. It is believed that the development in Rohnert Park and Cotati may be responsible for this. Also, the Sonoma County Water Agency deserves some credit for the problem as they continue to operate the Laguna as a flood control channel, speeding urban waters downsteam. To add insult to injury, the City of Santa Rosa continues to base their wastewater discharge on Russian River flow rather than flow rates of the receiving waters (Laguna and tributaries) resulting in Laguna flows that can go as high as 70%.

The tmdl process for the Laguna as accomplished thus far, has not developed an actual nutrient budget, only estimates. Santa Rosa has continuously violated receiving water limits over the last seven years and the Board's response is to change their permit to accomodate their situation. We find this unacceptable.

We would appreciate your urgent attention to this matter. We want assurance that the Laguna de Santa Rosa will contine to be on the EPA's 303 (d) list of impaired water bodies.

Sincerely,

Brenda Adelman

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An association including a professional corporation
902 Stevenson Street Santa Rosa, California 95404
Phone 707-527-8811 Fax 707-527-5443

Paul S. Silver
Professional Corp

Jack Silver

August 6, 1998

Felicia Marcus, Regional Administrator
U.S.E.P.A., Region 9
75 Hawthorne Street
San Francisco, California 94105-3901

RE: 303 (d) Listing of the Laguna de Santa Rosa

Dear Ms. Marcus:

This letter is to address the North Coast Regional Board's recent recommendation to remove the Laguna de Santa Rosa from EPA's 303(d) list. Russian River Watershed Protection Committee (RRWPC) objects to this delisting and requests EPA not remove the Laguna from the list.

In a recent meeting with BayKeeper executive officer Michael Lozeau RRWPC became aware that the EPA is finalizing its current 303(d) list in the next few weeks. In discussing the Laguna de Santa Rosa, we informed Mr. Lozeau that the Region 1 Board had recently delisted the Laguna at their December 11, 1997, meeting. Brenda Adelman of RRWPC and Dr. John Rosenblum, technical consultant, were present at that meeting in Ukiah and spoke in opposition to this action.

After the meeting Ms. Adelman and Dr. Rosenblum were informed by Board staff Bruce Gwynne that the 303(d) list was not meant for streams having established goal's but only for those streams in TMDL process of establishing TMDL goals. Mr. Lozeau informed us this week however that streams cannot be delisted without a formal process providing that the TMDL goals had been met. It is an established fact that the Laguna TMDL goals have NOT been met. After hearing the description of the procedure that resulted in the delisting of the Laguna, Mr. Lozeau expressed some concern that the Board action may have violated substantive and procedural requirement of law.

The North Coast Board noticed meetings on the Water Quality Assessment process for their Sept. 25, 1997 meeting in Eureka (Item #2), their October 23, 1997 meeting in Santa Rosa (Item #1) and their December 11, 1997 meeting in Ukiah (Item # 6). RRWPC and John Rosenblum were in possession of the staff report showing the TMDL status of the Laguna in which there was no indication of delisting. The staff report handed out before the final meeting did not indicate staff was recommending delisting. This report only called for deferment of further action until Regional Board staff can study dissolved oxygen and for listing the Laguna as impaired for low dissolved oxygen (this appeals to mean that the Laguna would stay listed). Since that time staff has completed its study and has since reported that indeed low dissolved oxygen its a serious problem in the Laguna de Santa Rosa. Attachment #1 with the December 11, 1997 staff report indicates that the Laguna is to stay on the list (enclosed).

What is of further concern to us is the Regional Board staff recommendation for the Basin Plan Triennial Review coming up on August 27, 1998, is an item calling for redefining the beneficial use in the Laguna from a year round cold water body to a seasonal cold water and warm water body. In addition, Santa Rosa's new proposed NPDES permit calls for a relaxation of temperature requirements for receiving waters. Santa Rosa claims that the Laguna is naturally a mixed water body. However, it must be noted that warm water fish species were introduced in the Laguna, not native. Temperature increases due to the filling up of the Laguna with sediment is a recent occupance due mostly due to poor agricultural practices, wastewater discharges and the removal of native riparian vegetation.

Not only is Laguna impairment not improved, it has become worse. According to Miles Ferris, director of Santa Rosa's Utility Department, Laguna sediments have aggraded about 700% in the last twenty years.

The TMDL process for the Laguna as accomplished thus far, has not developed an actual nutrient budget, only estimates. Santa Rosa has continuously violated receiving water limits over the last seven years and the Board's response is to change their permit to accommodate their situation. We find this unacceptable.

We would appreciate your urgent attention to this matter. We want assurance that the Laguna de Santa Rosa will continue to be on the EPA's 303(d) list of impaired water bodies.

Sincerely,

Jack Silver
Attorney for RRWPC

CC: Brenda Adelman, RRWPC
Mike Lozeau, S.F. BayKeeper
Dave Smith, EPA - Region 9
Lee Michlin, RWQCB - Region 1

State of California
Regional Water Quality Control Board
North Coast Region

Peter Otis
August 14, 1997

EXECUTIVE OFFICER'S SUMMARY REPORT
8:30 a.m., August 28, 1997
Regional Water Quality Control Board
Hearing Room
5550 Skylane Boulevard, Suite A
Santa Rosa, California

ITEM: 1

SUBJECT: Update on the Waste Reduction Strategy for the Laguna de Santa Rosa

DISCUSSION

Background

The Laguna de Santa Rosa was placed on the Clean Water Act, Section 303(d) list of impaired waterbodies in 1992 and 1994 because of occurrences of high unionized ammonia and low dissolved oxygen. High unionized ammonia levels are the result of inputs of nitrogen in various forms. Low dissolved oxygen levels arise from inputs of organic matter, and algal growth using more oxygen than is produced in the system. Pursuant to the provisions of the Clean Water Act, the Regional Water Board prepared a Waste Reduction Strategy for the Laguna de Santa Rosa, dated March 1,1995, which set forth estimates for the pollutant sources of concern, as well as pollutant reduction goals. The 1995 Waste Reduction Strategy (WRS) identified and provided estimates of the nitrogen sources to the Laguna de Santa Rosa, and recognizing that it may not be feasible to immediately attain the desired levels of water quality in the Laguna de Santa Rosa, established numeric interim and final goals for nitrogen compounds as well as for unionized ammonia concentrations. For dissolved oxygen, the WRS set forth a final but not an interim goal. The U.S. Environmental Protection Agency approved the WRS as consistent with Section 303(d) of the Clean Water Act on May 4, 1995.

The dynamics of the hydrology of the Laguna de Santa Rosa are complex, and the WRS acknowledged the uncertainty of the estimates with respect to pollutant sources and loads. In order to gather field data to validate the assumptions, the WRS contains a monitoring program for the Laguna de Santa Rosa. The monitoring was intended to provide information regarding attainment of the goals, as well as the basis for reevaluating the goals at a future date if necessary. In October 1995, Regional Water Board staff prepared an Interim Water Quality Monitoring Report for the Laguna de Santa Rosa, which described the results of monitoring from January through June 1995. This report provides an update to the October 1995 report.

Ex 47

State of California
Regional Water Quality Control Board
North Coast Region

Peter Otis
August 14, 1997

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Ex 47

Laguna de Santa Rosa from wastewater. From the Self-Monitoring Reports and the measured flows at LTH, Regional Water Board staff calculated wastewater loading estimates at LTH. Following is a comparison of the WRS and Self-Monitoring nitrogen loading estimates for LTH.

Estimates of Nitrogen Loading from Wastewater, in pounds per year, at Trenton-Healdsburg Road

Season	WRS	Self-Monitoring Reports	
		1995-1996	1996-1997
Winter	244,932	443,045	375,094
Spring	22,059	32,297	5,588
Summer	0	0	0
Fall	18,148	0	6,128
Total	285,139	475,342	386,810

The estimates set forth in the WRS strategy are lower than the estimates calculated from the Self-Monitoring Reports. Staff tends to place more reliance in the results provided by the Self-Monitoring Reports, and proposes to use those values as a basis for comparison in the future. A reduction in nitrogen loading from wastewater can be expected to occur in the near future as a result of the Upgrade Project at the Subregional Wastewater Treatment Plant. The Upgrade Project includes the addition of two aeration basins with anoxic zones and a fifth secondary clarifier, designed to provide an increased level of ammonia nitrogen removal. This additional level of treatment is expected to go on line prior to the next discharge season.

Dairy Agriculture: Several Clean Water Act Section 319(h) grants for nonpoint source control have been implemented by the City of Santa Rosa and the Goldridge and Sotoyome-Santa Rosa Resource Conservation Districts in efforts to reduce inputs of waste to the Laguna de Santa Rosa from confined animal operations, primarily dairies. The results of these efforts, although not specifically quantified at this time, without a question contribute to the improvement of water quality in the Laguna de Santa Rosa over the long term.

Urban Runoff: Efforts have increased to control pollutants contained in urban runoff through the recent implementation of federally-mandated storm water regulations. In compliance with those regulations, the Regional Water Board adopted Resolution No. 97-3, an NPDES Permit and Waste Discharge Requirements for the City of Santa Rosa, the Sonoma County Water Agency and the County of Sonoma (Co-Permittees), in March 1997. Resolution No. 97-3 established a municipal storm water permit for the urban area surrounding the City of Santa Rosa, based on a storm water management program, which included steps to fulfill the waste reduction goal set forth in the WRS. Resolution No. 97-3 calls for the Co-Permittees to provide, on July 1, 1998 and each year thereafter, a summary of analytical results, and an evaluation of the effectiveness of their storm water control efforts in meeting the goals.

In addition, the Regional Water Board has issued approximately 250 industrial and 100 construction storm water permits throughout the Region. Each permitted site is required to

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February 22, 2000

Mr. Lee Michlin
Executive Officer
North Coast Regional Water Quality Control Board
5550 Skylane Blvd.
Santa Rosa, CA 95403

Dear Mr. Michlin,
I am forwarding to you a recently completed study of the role of phosphorus in pollution of the Laguna de Santa Rosa and the Russian River for consideration at the upcoming March 1 meeting at the State Board which will consider Santa Rosa's permit. This report was contracted by the City of Santa Rosa at the request of the Russian River Watershed Protection Committee and represents the first comprehensive analysis of extant data on phosphorus loading to the Laguna.

The Regional Board collected much of these data in its own phosphorus monitoring program, largely conducted by Mr. Peter Otis of your office. To date, however, no attempt to develop regulatory guidelines or TMDL's for phosphor compounds has been implemented by the Regional Board.

In this report you will see:

1. The Laguna de Santa Rosa contains concentrations of phosphate that rank it among the most heavily impacted waterways in the United States.

2. Algae blooms resulting in serious degradation of the Laguna are highly correlated with phosphate concentrations but not with nitrate concentrations.

3. Attempts to control eutrophication due to nutrient loading by focusing solely on nitrogen cannot be effective if phosphate is not controlled first.

4. The City of Santa Rosa releases large enough volumes of phosphate into the Laguna during surface effluent releases that increases in concentration can directly be tracked to their wastewater.

5. Data are insufficient to determine what other sources of phosphate load to the Laguna might be significant, even though geographical trends in the data point to Santa Rosa as a major source.

6. Phosphate from Santa Rosa is loaded during the winter high-flow period, however, a sufficient portion of that is deposited in the sediments so that it becomes available through resuspension processes that lead to heavy algae blooms in the Laguna in summer.

7. Excessive phosphate levels are widely known to change the structure of algal communities in freshwater, allowing nitrogen fixing species to predominate. These communities biologically load the environment with nitrogen from atmospheric sources, negating any infrastructure commitment to control of urban or agricultural nitrogen loading.

8. Data on land application of effluent demonstrate the effectiveness of soil filtration for removal of phosphate. This indicates that the Regional board should phase out surface discharges in favor of subsurface forms of releases to freshwater bodies under their control.

9. The phosphate signal from the Laguna de Santa Rosa is seen in the Russian River and is the most obvious source in the River. The level of resolution of river samples is 0.1 mg/L. Any further sampling in the river should be at least at the 0.01 mg/L level of resolution to determine the actual load to the river coming from the Laguna de Santa Rosa.

These are only a few of the highlights of the report. An extensive discussion of EPA work on the central role of phosphor compounds in freshwater eutrophication is included. We understand the historical focus on nitrogen in the Laguna due to its role as a direct toxin, especially in the ammonia form. The Laguna was heavily impacted by nitrogen from both urban and agricultural sources and gaining control of this load was a logical priority.

This load, however, has been substantially reduced. Loading of nitrogen due to phosphate mediated algal blooms has now achieved relative parity with direct releases and it is now appropriate to shift focus to phosphate loading and emphasize efforts to control phosphate load, while retaining and improving the existing nitrogen control programs.

Phosphor and nitrogen compounds interact in complex fashion and the dynamics of their specific loading differ in the natural environment. We would urge the Regional Board to develop the in-house expertise to understand these dynamics and implement a much more sophisticated nutrient budget program than has existed to date.

We also enclose the response to the report provided by Mr. Miles Ferris of the Santa Rosa Subregional System. As can be seen, he is largely in agreement with the conclusions of the report and has highlighted actions that the Subregional system is currently planning that could act to mitigate concerns over their specific phosphate load.

We request that the Regional Board directly address the concerns presented in our report, and explicitly hold Santa Rosa to programs that begin to mitigate effects of phosphate loading in the Laguna de Santa Rosa.

We further urge the Regional Board to consider all releasers of phosphate laden effluent to the freshwater systems under their control and to implement an active control program that will reduce eutrophication from such sources. This is especially true where effluents might be released to bodies of water that have low flow or low hydraulic turnover. This would include the Laguna, Mark West Creek below the confluence with the Laguna, Lake Sonoma, and any other freshwater body either acting currently as a recipient of reclaimed effluent or under study for such releases in the future.

Respectfully submitted by,

Dr. Daniel E. Wickham
Executive Vice President for Research and Development

dates DO	1	2	3	4	5A	5B	6A	6B	7	8	
11-5-96	3.6					13.5				13.2	10.5
11-12-96	4.3					10.4				14.0	10.2
11-19-96	4.4	4.7	3.5	5.0		8.6				14.5	9.6
11-26-96	3.2	6.4	4.8	3.8		12.0	10.4			13.0	8.2
12-3-96	7.1	9.6	9.4	9.2		14.0				13.2	12.0
12-10-96	7.4	5.2	5.9	6.4		10.2	10.2			9.8	9.0
12-17-96	6.4	7.3	5.9	6.0		9.0	9.8	8.7		10.7	8.4
12-24-96	8.2	8.0	6.3	6.0		11.4	6.6			11.2	8.8
12-31-96	6.8	6.6	5.4	7.6		9.8				7.4	9.4
1-7-97	9.7	8.6	5.9	4.8		11.7	10.3			10.4	9.6
1-14-97	7.1	9.2	7.8	7.4		12.1	9.7	5.2		10.7	9.6
1-21-97	8.1	8.4	6.8	6.8		11.6	10.8	10.8		11.4	10.6
1-28-97	8.2	8.2	6.5	5.3		10.9		6.4		11.1	8.5
2-4-97	8.2	7.6	6.5	6.5		10.6	9.0	9.8		12.0	9.2
2-11-97	8.2	8.6	9.1	8.8		12.6	10.2	9.2		11.0	10.7
2-18-97			8.0	8.4		15.0	10.1	10.4		10.3	10.5
2-25-97	9.8	10.2	12.0	7.3		13.4	9.9	11.2		10.6	10.2
3-4-97	5.6	8.8	12.0	9.8						8.5	15.0
3-11-97	11.1	9.3	10.7	9.2						10.4	10.3
3-18-97	6.0	10.6	8.4	6.6						10.6	10.1
3-25-97	5.4	3.6	9.8	14.8		12.9	6.5	9.4		9.5	9.5
4-1-97	9.2	7.2	9.2	10.2		13.6	8.6	8.6		9.8	10.2
4-8-97	9.9	6.0	8.9	8.4		10.5	8.8	9.0		8.8	10.0
4-15-97			9.8	11.7						8.4	9.3
4-22-97	2.9	2.1	4.5	6.0						8.7	9.6
4-29-97			6.8	8.4						8.2	8.0

date DO	1	2	3	4	5A	5B	6A	6B	7	8	
1-3-96	4.0	5.8	6.7	5.4		10.7		8.3		10.8	9.[illegible]
1-10-96	1.6	5.2	8.6	5.0		11.2		10.0		11.0	10.5
1-17-96	8.0	6.2	5.4	5.8		11.2		10.4		11.2	10.3
1-24-96	8.2	6.4	6.6	6.2		10.3		9.6		10.7	9.3
1-31-96	9.0	8.6	6.8	5.2		11.2		8.8		10.4	10.0
2-7-96	5.7	6.4	5.7	4.2							7.2
2-14-96	7.0	7.2	8.7	6.4		10.2	7.9				9.5
2-21-96	9.2	8.6	7.8	7.5		11.2	11.0				9.6
2-28-96	10.0	9.8	13.5	8.1		11.8	10.8				10.2
3-6-96	8.4	9.2	7.0	6.8		11.3	10.8	9.7		10.5	10.1
3-13-96	8.4	8.4	7.3	7.0		11.8	10.6	6.9		11.2	9.7
3-20-96	8.2	5.4	8.8	10.4		11.6	7.7			9.4	9.0
3-27-96	7.8	7.1	8.5	7.3		15.0	10.8			10.0	9.4
4-3-96	6.2	6.3	6.4	5.5		8.9	9.2			10.1	7.3
4-9-96			2.6	6.1		12.9	9.8			9.4	8.6
4-16-96			8.2	11.1		11.1	10.0			10.4	9.4
4-23-96			8.0	6.0		12.0	5.2			9.6	9.0
4-30-96			9.4	14.0		10.0	6.8			9.2	8.0
5-7-96			7.6	7.0		8.6	6.8			8.2	8.4
5-14-96			6.4	8.9						8.2	8.4
10-8-96	5.3					7.4				8.0	8.7
10-15-96	5.4					8.9				12.4	12.1
10-22-96	8.4					10.6				10.4	10.2
10-29-96	10.0					8.1				7.9	11.0

Date DO	1	2	3	4	5A	5B	6A	6B	7	8	
2-1-95			3.9	4.0		9.8			3.8	10.2	
2-8-95	9.2	7.8	6.4	6.0		11.6			8.0	11.4	10.4
2-15-95	6.8	7.1	6.8	4.9		8.8			5.8	8.2	7.8
2-22-95										10.3	9.7
3-1-95			10.6	7.0		15.5			5.2	8.4	8.8
3-8-95	7.8	6.2	7.8	6.2						9.0	9.5
3-15-95	8.4	8.6	7.8								8.8
3-22-95	8.6	9.0	8.2	8.1						10.3	9.6
3-29-95	7.8	8.8	8.3	8.1						10.8	10.3
4-4-95	6.6	5.0	12.4	11.3		12.5			8.4	10.2	10.5
4-12-95	6.9	7.1	5.0	5.8						10.8	10.0
4-19-95	7.3	8.0	8.8	7.3						9.0	9.2
4-26-95	7.6	8.4	9.0	12.8						9.6	9.4
5-3-95	4.7	8.7	8.0	3.3						9.2	[illegible]
5-10-95	7.4	9.8	7.5	7.4						10.1	9.3
Nov '95 — no river disposal											
12-6-95	6.4	6.4	8.1	6.2						6.9	10.2
12-13-95	5.5	6.9	5.2	5.1*						9.4	7.6
12-20-95	5.6	10.6	6.4	5.8		8.6		9.2		10.6	8.8
12-27-95	6.8	5.8	7.3	6.1		10.2		8.2		10.1	10.2

Date - PO	1	2	3	4	5A	5B	6A	6B	7	8	
3-2-94	5.6	9.2	10.0	9.5		14.0			8.2	9.8	9.[illegible]
3-9-94			10.2	7.8		11.8			6.8	10.3	9.4
3-16-94			12.8	9.1		11.3			8.0	10.1	9.2
3-23-94			10.5	9.9	11.6	16.5			8.0	10.0	10.7
3-30-94	16.5	5.5	9.4	14.4						9.8	9.8
4-6-94	11.0	9.2	9.2	14.4						16.6	8.9
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11-2-94										8.8	11.8
11-9-94			4.8	3.3						10.0	6.4
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11-30-94				3.8		11.4			8.4	11.4	10.2
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12-28-94	7.0	7.2	9.8	6.9						11.1	10.7
1-4-95	10.0	6.2	5.4	5.6		11.9			8.9	10.2	10.8
1-18-95	7.8	7.8	5.3	5.5	10.0				8.6	11.1	9.3
1-25-95			4.8	6.0	10.2				10.8	10.1	8.0

Date - DO	1	2	3	4	5A	5B	6A	6B	7	8	
4-6-93	5.5	4.5	5.2	5.4						6.1	5.6
4-14-93		4.8	5.2	6.0						8.4	9.0
4-21-93	4.7	4.0	4.8	4.5						4.8	4.6
4-28-93	5.0	4.5	4.8	6.0						5.4	5.0
5-5-93			8.1	8.7						11.0	8.8
5-12-93			8.5	9.0						7.5	9.3
10-14-93	5.6	4.7				4.0			6.5	7.4	9.0
11-3-93											
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11-17-93	9.6	9.2	6.1	13.9						11.2	11.9
11-24-93	10.6	8.7	8.6	13.5						9.6	11.2
12-1-93	5.4	5.5	5.8	3.8						11.4	7.8
12-8-93	6.4	6.3	6.9	4.1						4.3	3.7
12-15-93	5.8	5.6	4.7	4.3						9.0	7.2
12-22-93	6.9	6.2	5.5	6.0	11.4				4.7	10.7	9.8
12-29-93			7.5	10.2	13.8				7.4	11.2	10.0
1-5-94			10.1	8.7		18.8			8.3	13.4	12.6
1-12-94			8.0	6.9		7.6			9.2	11.8	10.5
1-19-94	8.8	8.2	7.6	7.4						10.6	8.6
1-26-94	7.4	8.8	5.6	5.0	7.70	12.0			8.3	11.6	10.2
2-2-94	8.2	6.6	7.8	6.5	12.0				5.6	11.4	10.2
2-9-94	6.0	6.8	4.0	4.7	11.4				4.2	10.9	6.9
2-16-94				4.0		13.2			8.8	10.8	10.4
2-23-94	10.2	11.2	8.2	7.0	13.5	14.0			7.0	13.0	11.0

Date - D.O.	1	2	3	4	5A	5B	6A	6B	7	8	9	Laguna Stony Pt
11-4-92			8.4		15.4				5.7	11.4	12.2	
11-12-92			5.2		7.7				7.7	7.0	10.8	
11-18-92			7.0		8.8				7.6	8.7	9.2	
11-24-92			8.5							8.4	10.7	
12-2-92		9.4	9.0	13.4						8.4	13.0	
12-9-92	7.5	8.5	8.0	7.4	10.4	6.4			8.8	10.8	10.4	
12-16-92		6.7	5.8	4.4	10.6	3.4			3.4	11.1	8.8	7.6
12-23-92		6.6	11.4	8.6	13.8				9.6	13.4	13.8	
12-30-92		9.3	7.8	6.7						11.6	10.8	
1-6-93	9.4	10.2	8.8	8.2	10.2				5.9	9.3	10.2	
1-13-93	11.8	11.4	11.5	11.8	11.6				11.0	11.4	11.4	
1-20-93	10.2	10.5	7.2	10.2	11.3				10.6	9.8	11.2	
1-27-93	9.2	8.3	6.8	6.2						10.3	10.6	
2-3-93	10.4	8.8	7.4	8.6						10.9	10.8	
2-10-93			4.8	5.2	11.2	8.3				10.2	9.6	
2-17-93	8.5	7.4	7.2	6.9	8.9	6.2			8.4	9.5	8.8	
2-24-93	8.0	7.6	6.7	6.0	9.1	9.3			5.3	9.1	7.4	
3-3-93	7.6	6.9	6.3		8.2	7.8			8.2	9.0	8.4	
3-10-93			7.4		12.2	8.6				9.3	8.4	
3-17-93			5.2		7.8					8.8	7.6	
3-24-93	7.3	7.9	6.4		8.8				7.0	9.1	8.3	
3-31-93	6.0	5.0	6.0		6.6				6.2	7.4	→	

RRWPC

Russian River Watershed Protection Committee

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Analysis of receiving water data from Santa Rosa Self Monitoring Reports
Jan.'93 to May, 1997.
Report of violations for temperature, dissolved oxygen, pH, and turbidity.

RRWPC has examined all of the self monitoring reports from Jan.,1993 to May, 1997, to ascertain receiving water violations. Over 95% of the violations occurred at three discharge sites, D Pond, Kelly Pond and Delta Pond, so we have limited our analysis to those three.

We wish to acknowledge Mr. Tuck Vath's analysis of violations from Dec.'95 to Nov.'97. For the most part we concur with his findings. We will note those that are different on our list with an asterick (**). We do not understand why he confined his data to only two years.

We list only the dates and locations of violations for simplicity's sake but we have all of the backup data for our allegations. We also believe that Regional Board staff should conduct an independent analysis of our findings in any case.

Temperature Violations:

D Pond:

1-27-93	5-3-95	4-1-97
12-15-93	5-10-95	
12-22-93	12-20-95	Total: 35
1-26-94	1-3-96	
3-2-94	1-17-96	
11-23-94	1-31-96	
12-2-94	2-7-96	
12-9-94	3-6-96	
12-21-94	12-3-96	
12-28-94	12-17-96	
1-18-95	12-24-96	
2-8-95	1-7-97	
2-15-95	1-14-97	
3-8-95	1-21-97	
3-29-95	2-4-97	
4-12-95	3-4-97	
4-26-95	3-18-97	

Delta Pond Temperature Violations:

1-27-93	2-15-95	4-9-96	3-1-95
2-17-93	4-4-95	4-23-96	
12-29-93	1-10-96	5-7-96**	Total: 31
1-13-94	2-14-96	12-17-96	
2-2-94	2-21-96 **	12-24-96	
2-16-94	3-6-96	1-7-97**	
3-9-94	3-13-96**	1-14-97	
11-23-94	3-20-96	2-11-97	
1-18-95	3-27-96	3-25-97**	
2-8-95	4-3-96	4-1-97	

Kelly Pond Temperature Violations:

12-9-92	1-5-94	1-18-95	5-10-95

2-2-93	1-19-94	2-1-95	We support Tuck's data for 1996 and 1997.
2-24-93	1-26-94	2-8-95	
3-10-93	2-23-94	2-15-95	
3-24-93	3-2-94	3-1-95	
4-14-93	3-9-94	3-29-95	
4-21-93	3-16-94	4-4-95	
4-28-93	3-30-94	4-12-95	
11-17-93	4-6-94	4-19-95	
12-15-93	12-7-94	4-26-95	

Dissolved Oxygen Violations:

D Pond:

4-28-93
12-15-93
3-8-95
12-27-95**

Delta Pond:

3-9-94	4-23-96
11-23-94	4-30-96
2-15-95	5-7-96**

Kelly Pond:

12-8-93	12-20-95	4-23-96**
2-2-94	1-24-96	
2-8-95	4-3-96	

pH Violations:

D Pond:

1-26-94	3-30-94
2-9-94	4-13-94

Delta Pond:

2-29-93	3-2-94	2-14-96
1-5-94	1-4-95	3-25-97
1-13-94	2-15-95	4-1-97**
2-2-94	3-1-95	

Kelly Pond:

1-26-94	4-13-94
2-9-94	3-11-97
3-9-94	

Turbidity Violations:

D Pond:

11-10-93	12-27-95**	1-14-97
11-24-93	3-27-96**	4-1-97
12-17-95**	12-17-96	

Delta Pond:

12-23-93	2-1-95	1-7-97**
1-13-94	3-1-95	1-14-97
3-2-94	4-4-95	1-21-97**
3-23-94	1-3-96**	1-28-97**
11-23-94	2-14-96	2-4-97
11-30-94	3-13-96**	2-11-97
12-7-94	3-20-96	2-25-97**
1-4-95	3-27-96	4-1-97
1-18-95	5-7-96**	4-8-97**
1-25-95	12-17-96	1-10-96

Kelly Pond:

11-9-94	2-7-96**
12-7-94	2-21-96**
12-28-94	12-10-96**
1-17-96**	1-28-97

Total receiving water violations prior to Nov., 1995: 106

Total violations we found that were not noted in staff's report: 24

Reporting Violations: Ponds

D Pond:
3-1-95: turbidity (turb.)
11-16-94: turb., temperature (temp.), dissolved oxygen (DO), pH

Kelly Pond:
11-16-94: D.O., Temp.

Delta Pond:
11-16-94: D.O., temp.
12-21-94: D.O., temp., turb., pH
12-3-96: D.O., temp.

Reporting Violations: upstream and downstream monitoring

D Pond Upstream:
2-3-93: temp.
2-10-93: temp., turb., D.O., pH
4-14-93: D.O.
12-29-93: temp., turb., D.O., pH
3-9-94: temp., turb., D.O., pH
11-15-94: temp., turb., D.O., pH
11-23-94: temp.
11-30-94: temp., D.O.
1-25-95: temp., D.O.
2-22-95: temp., turb., D.O., pH

D Pond Downstream:

2-10-93: temp., turb., D.O., pH
12-29-93: temp., turb., D.O., pH
3-9-94: temp., turb., D.O., pH
11-15-94: temp., turb., D.O., pH
11-23-94: temp.
11-30-94: temp., D.O.
1-25-95: temp., D.O.
2-22-95: temp., turb., D.O., pH

Kelly Pond Upstream:

11-15-94: temp., turb., D.O., pH
2-22-95: temp., turb., D.O., pH
11-30-94: D.O.

Kelly Pond Downstream:

3-3-93: temp., turb., D.O., pH
3-10-93: D.O.
3-17-93: D.O.
3-24-93: D.O.
3-31-93: D.O.
5-5-93: turb., pH
5-12-93: turb., pH
11-15-94: temp., turb., D.O., pH
2-22-95: temp., turb., D.O., pH
3-15-95: temp., turb., D.O., pH
12-6-95: temp.
12-13-95: temp.
12-20-95: temp.
12-27-95: temp.

Delta Pond Upstream:

4-21-93: D.O.
1-19-94: temp., turb., D.O., pH
3-16-94: turb., pH
11-23-94: temp.
11-30-94: temp.
12-21-94: temp., turb., D.O., pH
2-22-95: temp., turb., D.O., pH

Delta Pond Downstream:

3-10-93: temp., turb., D.O., pH
4-21-93: D.O.
1-19-94: temp., turb., D.O., pH
11-23-94: temp.
11-30-94: temp.
12-21-94: temp., turb., D.O., pH
2-22-95: temp., turb., D.O., pH

in the contact chamber (20-minute duration). Daily effluent coliform during this period was <2 MPN/100ml (Order 95-18, Section B.1 Effluent limitations).

- May 1995 – Excavation contractor broke a reclaimed water line, resulting in approximately 4,300 gallons of reclaimed water being discharged to the storm sewer. During the same time frame, the contractor broke the wall of an existing sewer manhole, resulting in the spill of approximately 200 gallons of raw sewage. Storm sewers were sandbagged and none of this sewage left the plant site.

None of these unit process incidents resulted in any discharge prohibition violations or exceedence of any effluent limitations. Based upon staff's judgement these should be classified as less than significant violations.

Less than significant: 6 violations

Receiving Water Violations

Receiving water limitations covering the period from April 1995 through March of 2000 are as follows:

Temperature

Date	Number of Violations	Severity
Nov 98 All Instantaneous Increases	1 1 3 1 1 1 4 2 3	Between 5°F and 7°F 5°F and 6°F 5°F and 9°F 5°F 7°F and 9°F 5°F and 10°F 5°F and 19°F 7°F and 9°F 5°F
Oct 98 All Instantaneous Increases	6	Temperature increases of between 2°F and 4°F above allowable limit
May 98	3	2 increase of 1°C 1 decrease of 1°C
April 98	4	1 increase of 2°C 2 decreases of 1°C 1 increase of 1°C
March 98	11	6 increases of 1°C 2 increases of 2°C 2 decreases of 2°C 1 decrease of 1°C
Feb 98	5	4 increases of 1°C 1 decrease of 1°C
Jan 98	4	4 increases of 1°C
Dec 97	9	Inc. 3°C (1), Inc 2°C (1) Inc. 1°C (4), Dec 1°C (3)
Nov 97	3	Inc 1°C (2), Dec 1°C (1)

Apr 97	4	Inc 1.5°C , 0.8°C Dec 0.9°C, 0.5°C
Mar 97	5	Inc. 0.5°C,1.9°C Dec 0.8°C (2), 1.5°C
Feb 97	6	Inc. 0.7°C, 0.5 C, 0.1°C Dec 0.5°C, 3.0°C, 1.3° C
Jan 97	6	Inc. 3.7°C, 0.5°C, 1.5°C, 0.2°C, 0.3°C Dec 1.0°C
Dec 96	6	Inc. 1.5°C, 1.0°C, 3.5°C, 0.5°C, 0.2°C, 2.5°C
Apr 96	7	Inc. 1.0°C, 1.2 C°(2) Dec. 1.0°C, 0.3°C, 2.0°C, 1.0°C
Mar 96	7	Inc. 1.8°C, 1.0°C (2), 0.2°C, 0.5°C, 2.0°C Dec. 2.0°C
Feb. 96	5	Inc. 0.5°C (2), 3.5°C, 1.0° C Dec 0.7°C
Jan. 96	7	Inc. 1.0°C, 2.0°C, 0.3°C (2) Dec 1.0°C, 0.1°C, 0.3°C
Dec. 95	3	Inc. 1.2°C, 0.3°C Dec. 0.2°C
May 95	2	Inc. 1.0°C, 2.0°C Dec 2.0°C, 1.5°C

There were a total of 122 temperature violations.

Based upon staff's judgement, all violations involving decreases in temperature should be considered less than significant since a cooling of ambient water conditions is expected to have minimal (and possibly beneficial) impacts on aquatic habitat. Temperature increases of less than 1.0°C (2°F) should be considered as less than significant, increases of between 1.0°C and 2°C (2-4°F) should be considered as moderate violations, and any increases over 2°C (over 4° F) should be considered as significant violations. Instantaneous temperature violations were calculated over a 24-hour period from the time of the first excursion (highest instantaneous temperature over a 24-hour period, timed from point of first excursion). This scenario yields the following receiving stream violations for temperature:

<u>Less than significant: 48 violations</u>
<u>Moderate: 52 violations</u>
<u>Significant: 22 violations</u>

<u>Dissolved Oxygen</u>

Date	**Number of Violations**	**Severity (Decrease in downstream DO Levels) (mg/l)**
Nov 98	8	0.2, 2.3, 2.5, 2.6, 3.0, 3.0, 2.2, 1.8
Oct 98	3	1.0,0.3,0.1
March 98	1	1.0
February 98	1	0.3
January 98	1	1.0
December 97	4	0.2, 0.8, 2.1, 1.3

December 96	1	0.3
April 96	3	0.9, 1.8, 0.2
Jan 96	1	0.4
December 95	2	0.1, 0.6

There were 25 dissolved oxygen receiving water violations. Based upon staff's judgement violations that resulted in downstream DO level reductions of less than 0.5 mg/l should be considered as less than significant, reductions between 0.5 and 1.5 mg/l be considered as moderate; decreases of greater than 1.5 mg/l be considered significant. This scenario yields the following violations:

Less than significant: 9 violations
Moderate: 7 violations
Significant 9 violations

pH

Date	Number of Violations	Severity
March 98	1	pH depressed 0.2 units below limit range
February 98	1	0.2 units below limit range
December 97	1	0.2 units below limit range
April 96	2	0.3 units below limit range 0.5 units below limit range
February 96	1	0.1 units below limit range

Based upon staff's judgement pH depressions of 0.2 units or less should be considered as a less than significant violation; pH depressions greater than 0.2 and less than 0.5 units be considered as a moderate violation; and depressions of 0.5 or more units be considered as significant.

Less than significant: 4 violations
Moderate: 1 violations
Significant: 1 violation

Turbidity

There were 27 violations for turbidity over the period studied, as shown below.

Date	Number of Violations	Downstream Turbidity Level (NTU)	Respective Severity (downstream % increase over upstream value plus 20%) (% increase)
December 99	1	9	450
March 99	1	48	11
February 98	1	54	3
December 97	5	42,45,8, 43, 45	68, 150, 167, 30, 105
April 97	2	14,11	27, 588
February 97	3	7,16,65	94,146,35
January 97	3	45, 70.8, 27	582, 65, 42
December 96	2	26.7, 15.4	191, 36
April 96	4	8.4, 25.1, 18.9, 8.7	546, 561, 28, 164

March 96	3	15.8, 9.8, 26.9	394, 180, 28
February 96	1	36.6	618
January 96	1	12.5	635

The severity of turbidity violations are suggested to be determined based on a matrix ranking that includes both percentage increase of downstream versus upstream turbidity levels, in conjunction with absolute NTU readings. When downstream turbidity readings are relatively low, regardless of relative increase in turbidity, the violation should be classified as less severe (less than significant to moderate). Higher downstream turbidities coupled with relatively higher percentage increases of downstream versus upstream turbidity readings should result in more severe violation classification (significant). The suggested matrix is as follows:

Downstream NTU Levels → Percentage Increase Over Allowable (upstream +20%) for Downstream Turbidity Levels (below)	**0 to 10**	**10-20**	**20-30**	**Over 30**
0-20%	Less than significant	Less than significant	Less than significant	Less than significant
20–50 %	Less than significant	Less than significant	Moderate	Moderate
50-80%	Less than significant	Moderate	Moderate	Significant
80-100%	Less than significant	Moderate	Significant	Significant
Over 100%	Moderate	Moderate	Significant	Significant

This matrix yields the following violations:

Less than significant: 5 violations
Moderate: 14 violations
Significant: 8 violations

Copper
Copper (December 95 to March 00) – There were no reported copper violations based on receiving stream hardness levels and no reported copper violations based on copper analysis with no hardness data. The City has recently begun to incorporate quantified hardness numbers into their calculations for receiving water copper concentrations, per permit requirements contained in Order 2000-2.

Equipment Malfunction and Reporting and Monitoring Incidents

Monitoring and reporting requirements state that samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity. All monitoring instruments and devices used by the permittee to fulfill the prescribed monitoring program shall be properly maintained and calibrated as necessary. The following equipment malfunctions and/or monitoring and reporting incidents have occurred over the period examined, resulting in a lack of data or in non-representative data:

- February 2000
  Data logger recorded air from 2/19-2/20

RRWPC

Russian River Watershed Protection Committee

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Presentation to North Coast Regional Board

Re: Basin Plan Triennial Review

August 27, 1998

Russian River Watershed Protection Committee wishes to make the following comments in regard to staff's Public Report of June 23, 1998. Items underlined are direct quotes from our comments on Santa Rosa's new NPDES permit.

Some general comments:

- RRWPC does not believe that the narrative standards are defined in such a way to allow for an evenhanded interpretation of their meaning. More expressive and definitive meanings need to be developed and integrated with objective numerical standards for all water quality perimeters. We support Santa Rosa's request on this item.
- There is a need for more specific definition of *receiving waters*. Explanation is necessary for interpretation allowing Santa Rosa to discharge at 40% to 70% of the *receiving* water (and occasionally higher) and then additionally *average* their discharge over a 30 day period. Since Santa Rosa has 17 discharge points, what analysis has been conducted for *each* receiving water to assure protection of beneficial uses?

  Furthermore, we wonder about meeting the coliform standard at the plant rather than the point of discharge. Where are locations of specific points of compliance for receiving water protection? Why are they not in the permit? Santa Rosa blames the birds and ducks for high coliform in the ponds, but what portion of the coliforms are from regrowth.

  Similarly, we believe that discrepancies in the Basin Plan and Santa Rosa's NPDES permit indicate that the ponds actually provide treatment and the discharge point where compliance is met, is ambiguous. We refer you to the following comments.

....unwillingness to determine whether Santa Rosa's ponds are *treatment ponds* or *receiving waters*. Different pH requirements for plant effluent and pond discharge appears to count on ponds for treatment although it is stated that ponds do not serve in a treatment capacity. In another example, Santa Rosa relies on ponds to settle out priority pollutants. Yet high coliform levels are discharged from ponds and no attempt is made to determine what portion is a result of regrowth. Clean water standards should be met at the plant discharge OR the pond discharge, not wherever it is convenient.

And....

Page 2 of the permit states that, *"These storage ponds* [all ponds in system] *are not a part of the treatment system."* The Basin Plan states that pH should be between 6.5 and 8.5 for the Laguna de Santa Rosa. (page 3-7.00) The NPDES permit (page 10) states that, *"The pH must not cause the pH of the receiving waters to be depressed below 6.5 nor raised above 8.5."* All of this is fine and good, but the plant effluent requirements in the proposed permit (page 9) state that the *pH should fall between 6.0 and 9.0.* This appears contrary to the Basin Plan requirement for discharge, ***so there must be an assumption that something happens in the ponds to bring the pH up or down to meet the regulation.*** This gives the appearance of a standard being altered to accommodate previous violations.

- Prior to discharging at 5% the Executive Officer is to request certain information (spelled out in the Basin Plan), which supposedly demonstrates a protection of beneficial uses. Yet none of the standards or uses are definitive and in effect the Executive Officer is given too much leeway in making his decision.

Prior to discharging over 1% of the Russian River flow as measured at the Hacienda gauge, Santa Rosa is required to report on several factors, none of which are specifically defined (page 9). Further, it is unclear if all factors listed must demonstrate the need for a higher discharge or if only some will do.

And further....

In many instances it is stated that Santa Rosa should demonstrate that their discharge will not cause harm to the beneficial uses, but no specific criteria are set to objectively determine if that goal is being met. Rather, it is left up to the judgment of the executive officer. While evidence provided to the executive officer may, as a whole, document Santa Rosa's need for the higher discharge, there is almost nothing in the required evidence that specifically analyzes impacts on beneficial uses nor even defines those beneficial uses to determine their condition before and after the discharge.

And....

....the proposed permit relies even further than the last on the subjective decisions of the executive officer. Loosely or non-defined perimeters for discharge decisions gives Mr. Michlin a broad spectrum of choices and narrows to the extreme the ability of citizen groups to challenge those decisions. In Section B3 of the permit for example, the executive officer is only required to *consider* the discharge situation and is not required to provide *proof* that beneficial uses are being protected, a violation of the Basin Plan.

Comments specific to issues in the Public Report:

ISSUE: Consider specific objectives for nutrients

We disagree with staff that this item should be continued but have a low priority. It is obvious that the Laguna de Santa Rosa, the Russian River and many other tributaries are dying from nutrient overload. Your own staff has proven that nutrients are a serious problem. It cannot be excused away with the statement that that is its natural state! Furthermore, phosphorus may also be a nutrient of concern. Dr. Dan Wickham is doing a study for the City of Santa Rosa on whether phosphorus is a limiting nutrient in the Laguna. It may be cause for great concern

ISSUE: Consider revisions to the water quality objectives for dissolved oxygen and temperature.

RRWPC supports staff's recommendation to carry this item into the next year although not for the same reasons as the City of Santa Rosa. Dissolved oxygen is a serious problem in the Laguna de Santa Rosa. We have discussed this extensively in our paper concerning Santa Rosa's permit and we copy here some of our comments on dissolved oxygen.

One year ago, Mr. Peter Otis of the Regional Board staff provided the Board with a report, *"Update on Waste Reduction Strategy"* in which statistics indicated that Santa Rosa was not meeting the winter goals of the strategy. The winter goal was 244,932 pounds per year and the city reached 443,045 in 1995-96 and 375,094 in 1996-97. Mr. Otis goes on to say, *"The estimates set forth in the WRS strategy are lower than the estimates calculated from the Self Monitoring Reports. Staff tends to place more reliance in the results provided by the Self Monitoring Reports, and proposes to use those values as a basis for comparison in the future."*

Not only is this statement inaccurate for winter loadings (the most profuse), but in effect it says that whatever Santa Rosa does is protective of the Laguna and meets the tmdl goal. This tends to totally ignore the evidence developed by Mr. Otis himself of serious dissolved oxygen problems in the Laguna at the present time. In other words, this is another example of adjusting regulations to fit what Santa Rosa wants to do.

We obviously have concerns about the status of the tmdl process in the Laguna. We are disturbed by previous Regional Board staff comments as well as Santa Rosa's to the effect that low dissolved oxygen and degraded conditions are a norm for the Laguna. We believe that goals should be developed to assure that minimum dissolved oxygen standards as currently listed in the Basin Plan are strictly adhered to. We support *increased* standards as possibly alluded to in the staff report but we do not support any lowering of standards. This is a very important issue from our perspective. (Please see discussion under the Issue of changing the Laguna designation from a COLD water body to a COLD AND WARM water body.)

ISSUE: Review the Action Plan for the City of Santa Rosa.

We strongly believe that the issue of Santa Rosa's exceptions to the 1% dilution requirement need to be reexamined for the following reasons.

- Since the 1994 Basin Plan revision, the salmon and steelhead species have been listed as endangered. We believe there are still elements of Santa Rosa's wastewater causing degradation to the waterway.
- Santa Rosa's long range plan will not be up and running for at least five years. They will continue to discharge at a high rate during that time.
- New development in the regions of the subregional partners is extensive. Inflow to the system is rapidly increasing even while conservation efforts are being increased. Russian River water flows (and therefore discharge opportunities) may be further limited due to global warming and other factors such as possible elimination of Eel River diversions.

Please see comments of RRWPC, Jack Silver, and John Rosenblum regarding renewal of Santa Rosa's permit. These comments are germane to this issue.

ISSUE: Develop a comprehensive action plan which would include point source measures and nonpoint source measures, for the Russian River.

We agree with staff's recommendation to extend this issue to the 1998 Triennial Review.

ISSUE: Amend Table 2-1, Beneficial Uses

#3: Include the WARM beneficial use designation for the Laguna de Santa Rosa.

RRWPC has many concerns about this change which we detailed in comments on Santa Rosa's new permit.

At the present time the Basin Plan lists the Laguna as a cold water body. Yet the proposed permit claims that protection of *indigenous* warm water fish provides justification for temperature change requirement and gives protection from anti backsliding arguments (A.25 revision). We do not believe this argument holds since most of the warm water fish currently inhabiting the Laguna and tributaries are non-native species and that for the most part, *man made* activities have altered the original balance and caused degraded conditions to occur.

Regional Board staff, in their *Public Report for the Triennial Review* (page 10: to be considered on Aug. 27, 1998) under amending beneficial uses, #3 states, *"Include the WARM beneficial use designation for the Laguna de Santa Rosa. The Laguna de Santa Rosa historically and presently supports a warmwater fishery. This beneficial use has been erroneously left out of this table."* The proposed permit does not acknowledge that the Basin Plan has not been changed yet! Furthermore, we do not believe that the cold water designation is incorrect.

A 1977 report entitled, *"Laguna de Santa Rosa Environmental Analysis and Management Plan,"* written by Sonoma State students under faculty guidance determined that warmer temperatures were primarily caused by riparian habitat removal.

All Laguna reports note that extensive loss of riparian canopy has created more warm water habitat, especially in the summer time. The Laguna Advisory Committee Report (Jan. 1988) states, (p. 23) *"According to the Department of Fish and Game, summer water in the stream was probably abundant and with the dense canopy of the surrounding trees, was cool and of high quality. Steelhead trout and coho salmon probably used the waters of the Laguna...as a summer nursery." (Cox, March, 1986)*

The Sonoma State Report (Laguna de Santa Rosa Environmental Analysis and Management Plan, 1977) states (p.40), *"Laguna several decades ago was a superior example of wetland wildlife habitat and even today has been identified as the second most important riparian marshland in the state."* Riparian removal was most extensive in areas channelized and dredged by agricultural and SCWA projects.

And in the Santa Rosa report (History, Land Uses, and Natural Resources of the Laguna de Santa Rosa, section on historical use) it states (p. 6-8) *"Study of 1941 aerial photographs....reveals that at least 500 acres of riparian forest...had been cleared before McBride's survey...by local farmers wishing to increase cultivated acreage along the boundaries of the Laguna floodplain."*

There have been so many significant manmade changes in the Laguna in the last forty years that it is hard to know its precise historically natural state. RRWPC believes that an *attainability analysis* should be made before any *beneficial use* designations are changed! For reasons given, the addition to A.25 fails as an anti-backsliding argument.

Santa Rosa's May 20, 1998, letter to Mr. Michlin includes a quote from the City's 1990 report on the Laguna, giving their version of the historical Laguna environment.

The Laguna is a low-gradient stream flowing through a region of high summer temperatures and mild winters. The present Laguna has a resident biota of warm water fish species, several of which have been introduced, as well as annual wild steelhead runs in two of its tributaries, Mark West Creek and Santa Rosa Creek. Before human settlement the Laguna probably had a more continuous riparian canopy, and its tributaries probably carried less sediment eroded from the watershed. The historic Laguna was therefore cooler than the present stream, but considering its low gradient and high summer temperatures, was never a cold-water stream.

What this paragraph fails to tell you, according to Table 7-5 in the same report, that 10 of the 18 species of fish found in the Laguna were *introduced*. (The fish listed are basically the same as those listed in Appendix C of the Laguna Advisory Committee Report in Jan.,1988. Four additional species were listed as *possibly* present in the latter report.) Those *introduced* included some of the most commonly found warm water species such as carp, catfish, and largemouth bass.

ISSUE: Consider revision to the water quality objective for toxicity

We support a change in existing Basin Plan language on this item. In general, we believe that it should be very much strengthened.

ISSUE: Amend Section IV. Implement action plans to include TMDL implementation strategies for 303(d) listed water bodies.

The Russian River listing for sediment should be included. Also we disagree that Laguna should be delisted for nutrients. We believe the estimated goals are not being met for dissolved oxygen and the implementation that goals will be lowered is unacceptable.

Another concern is Santa Rosa's contribution to nutrients in the Laguna. This is a huge topic that has been addressed separately through the tmdl process. Our attorney, Jack Silver has written a letter to the EPA about the delisting of the Laguna from EPA's 303(d) list. I will include a copy of the letter with these comments. We pose the question, why is there nothing in the permit about nutrient or dissolved oxygen goals in the wastestream?

Between Nov. 1992, May, 1997, RRWPC noted about 55 times when Santa Rosa's discharge may have caused a lowering of dissolved oxygen in the receiving water. Our concern is that nothing has been done about this by the Regional Board. What are the means of compliance for this very important issue and what standard does the Board utilize to determine when a violation has taken place?

The waste reduction strategy has been based on estimates rather than an actual nutrient budget. The focus has been on nitrogen but our consultant, Dan Wickham, believes that phosphorus may also play a leading role. He is in the process of researching the issue as a result of our legal settlement with the City of Santa Rosa. Depending on the outcome of his research, phosphorous may need to be addressed in the Laguna tmdl process. Can this be included in the permit process in some way?

One year ago, Mr. Peter Otis of the Regional Board staff provided the Board with a report, *"Update on Waste Reduction Strategy"* in which statistics indicated that Santa Rosa was not meeting the winter goals of the strategy. The winter goal was 244,932 pounds per year and the city reached 443,045 in 1995-96 and 375,094 in 1996-97. Mr. Otis goes on to say, *"The estimates set forth in the WRS strategy are lower than the estimates calculated from the Self Monitoring Reports. Staff tends to place more reliance in the results provided by the Self Monitoring Reports, and proposes to use those values as a basis for comparison in the future."*

Not only is this statement inaccurate for winter loadings (the most profuse), but in effect it says that whatever Santa Rosa does is protective of the Laguna and meets the tmdl goal. This tends to totally ignore the evidence developed by Mr. Otis himself of serious dissolved oxygen problems in the Laguna at the present time. In other words, this is another example of adjusting regulations to fit what Santa Rosa wants to do.

ISSUE: Review the seasonal waste discharge prohibitions in Section IV. Implementation Plans

RRWPC strongly disagrees with this issue. Up to now, in deference to summer recreational uses, the cessation of winter discharge on May 15th has been a sacred cow. If this Board insists on moving forward with consideration of this item, we ask that you also consider that discharges be stopped BEFORE May 15th when the river is flowing below 500 cfs. There is probably no change that will bring lower Russian River property and business owners out in force than this item.

ISSUE: Consideration of West Sonoma County wastewater issues

RRWPC has deep concerns about the direction the Sonoma County Water Agency is taking West County communities. Please see our comments on Russian River County Sanitation District's appeal of fine.

APPENDIX C

FISH OF THE LAGUNA DE SANTA ROSA[1]

Steelhead Trout	native	*Salmo gairderi*
Silver Salmon	native	*Oncorhynchus Kisutch*
~~Pink Salmon*~~		*Oncorhynchus gorbuscha*
Largemouth Bass	introduced	*Micropterus salmoides*
~~Smallmouth Bass*~~		*Micropterus dolomieu*
Bluegill	introduced	*Lepomis macrochirus*
Green Sunfish	introduced	*Lepomis cyanellus*
White Catfish	introduced	*Ictalurus catus*
Pacific Lamprey*	introduced	*Lampetra tridentata*
German Carp	introduced	*Cyprinus carpio*
Western Sucker	native	*Catostomus occidentalis*
Black Chub or Sacramento Blackfish	introduced	*Orthodon microlepidotus*
Sacramento Roach	native	*Hesperoleucus symmetrius*
~~Hitch*~~		*Lavinia exilicauda*
~~Hardhead*~~		*Mylopharodon conocephalus*
Sacremento Squaw Fish*	native	*Ptychocheilus grandis*
Mosquito Fish*	introduced	*Gambusia affinis*
Three Spine Stikleback*	~~nat~~ native	*Gasterosteus aculeatus*
Prickly Sculpin*	native	*Cottus asper*
California Roach*	native	*Lavinia symmetricus*
Tule Perch*	native	*Hysterocarpus traski pomo*

17

[1]This list supplements that presented in the publication *Laguna de Santa Rosa Environmental Analysis and Management*, Plan-1977. (The Blue Book)

*Species so marked are of possible occurence, with no recent verification by collecting. At least one species, the Tule Perch, can probably be listed as threatened. Data from Dr. Peter B. Moyles, Department of Wildlife and Fisheries Biology, University of California, Davis; 1987.

Table 7-5. Fish Species Collected by Gill Net and Seine in Laguna de Santa Rosa System, 1988 (from Technical Memorandum No. L1).

Family	Scientific Name	Common Name
Catostomidae	*Catostomus occidentalis*	Sacramento sucker
Centrarchidae	*Lepomis macrochirus**	Bluegill
	*Lepomis microlophus**	Redear sunfish
	*Lepomis cyanellus**	Green sunfish
	*Pomoxis annularis**	White crappie
	*Micropterus salmonides**	Largemouth bass
Cyprinidae	*Orthodon microlepidotus**	Sacramento blackfish
	*Cyprinus carpio**	Carp
	Hesperoleucus symmetricus	California roach
	Ptychocheilus grandis	Sacramento squawfish
Cottidae	*Cottus asper*	Prickly sculpin
Embiotocidae	*Hysterocarpus traski*	Tule perch
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback
Ictaluridae	*Ictalurus catus**	White catfish
	*Ictalurus melas**	Black bullhead
Petromyzontidae	*Lampetra* sp.	Lamprey
Poeciliidae	*Gambusia affinis**	Mosquitofish
Salmonidae	*Oncorhynchus mykiss*	Steelhead, rainbow trout

*Introduced species

The warm water assemblage found on the Laguna represents a "typical" assemblage for Northern California rivers. All of the warm water species found in the Laguna de Santa Rosa are known to occur in the Russian River drainage (McGinnis 1984), and may move in and out of the lower Laguna searching for food and reproduction sites. It should be noted that the three most abundant species caught in the 1988 survey (Sacramento blackfish, carp and green sunfish) are known to be tolerant of low oxygen levels, high temperatures, and to some extent high alkalinity -- water quality parameters similar to those in the lower Laguna. This flexibility would make them well-adapted to slack water areas with limited replenishing flows during the summer. These fish (all introduced species) are also fierce competitors for food and space in the aquatic ecosystem. If summer flows were to increase through the existing habitats, it would probably result in an expansion of the existing populations rather than a change in the fish assemblage.

California roach, prickly sculpin, threespine stickleback, and steelhead (rainbow) trout are known to inhabit cool freshwater streams in California (Moyle 1976). The habitat assemblages are similar to those found on undisturbed northern California streams of comparable size (J.L. Nielsen, unpublished data, 1989), with the exception of riffle abundance. Lateral scour pools, especially those formed around large organic debris and rootwads, are known to be preferred habitat for salmonid juveniles (Bisson *et al.* 1982). Backwater eddies associated with rootwads and secondary channels are used by juvenile salmon and trout as overwintering habitat (J.L. Nielsen, unpublished data). An increase in the abundance of riffles and backwater habitat in the Laguna would increase the potential for salmonid fish production.

Riffles are known to be important to freshwater stream fishes for three reasons: They are the site of significant production of food in the form of aquatic invertebrates; they are needs to be addressed as to what discharge scenarios exist during high water periods?

Issue: Nutrient contamination and tmdl's

Another concern is Santa Rosa's contribution to nutrients in the Laguna. This is a huge topic that has been addressed separately through the tmdl process. Our attorney, Jack Silver has written a letter to the EPA about the delisting of the Laguna from EPA's 303(d) list. I will include a copy of the letter with these comments. We pose the question, why is there nothing in the permit about nutrient or dissolved oxygen goals in the wastestream?

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Issue: Thirty day average is backsliding.

In order to be in compliance, Santa Rosa will be allowed to *average* their discharges over a 30 day period even though the permit also states that, *"When approved, as provided by Effluent Limitation B.3, the discharge of advanced treated wastewater shall not exceed five percent of the flow of the*

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January 28, 2000

Report to
Russian River Watershed Protection Committee
and
City of Santa Rosa

on

Phosphate Loading and Eutrophication in the Laguna de Santa Rosa

by

Dr. Daniel E. Wickham
and
Robert W. Rawson

Table of Contents

Phosphate Loading and Eutrophication in the Laguna de Santa Rosa

by
Dr. Daniel Wickham and Robert Rawson
IOS Corporation
January 28, 2000

Introduction

IOS Corporation was contracted by the Russian River Watershed Protection Committee in conjunction with the City of Santa Rosa to conduct a study of existing data on the release of phosphor compounds into the Laguna de Santa Rosa. The intent of this study was to determine whether phosphate pollution from Santa Rosa Subregional System reclaimed water was a significant factor in nutrient loads to the Laguna and Russian River.

Phosphate

Liminologists widely regard phosphate as the predominant limiting nutrient for plant production in freshwater ecosystems. While other nutrients combine with phosphate to fulfill the metabolic needs of plants, such as nitrogen, sulfur, iron, and various other mineral and organic compounds, phosphate is typically the compound that is in lowest availability in free form. Where all available phosphate has been consumed in the course of the production cycle, plant growth stops. This can occur even though all other nutrients, including nitrogen, remain abundant.

Phosphate is not the only compound that can function as a "limiting nutrient". Any of the other nutrients can equally be limiting if they are the least available component in solution. Typically nitrogen is the other compound of primary concern in studies of nutrient loading and, because nitrogen has other effects beyond its role as a nutrient, including nitrate toxicity to humans and ammonia toxicity to aquatic wildlife, nitrogen has typically received equal attention. Phosphate in usually encountered concentrations does not have toxicity effects beyond its nutrient role so is not considered a direct public health threat.

Eutrophication

Eutrophication is the process whereby nutrient loading into aquatic ecosystems stimulates the level of plant production in the water. Phosphorus is a key nutrient in this process. The reason eutrophication is a concern is that water bodies have balanced ecosystems that require various conditions in order to maintain a diverse plant and animal community. Virtually all food to support these ecosystems originates through photosynthesis by plants. Briefly, plant chlorophyll catalyzes the chemical combination of carbon, derived from carbon dioxide in the atmosphere, and water to create carbohydrates in the form of sugars, the basic metabolic building block. This process is driven by the energy of sunlight and requires the other nutrients such as nitrogen to form proteins and amino acids and phosphorus to form DNA, RNA, NADP, ATP and the other essential compounds necessary for complex life.

Photosynthesis generates one primary waste byproduct, oxygen. Virtually all of the oxygen in the modern atmosphere is produced through photosynthesis. Oxygen dynamics are complex in aquatic environments because water has a limited ability to hold oxygen in solution. Freshwater of typical ambient temperature can only hold in solution about 7-9 mg of oxygen per liter. Clear water that is free of plant life will be saturated with oxygen since it will diffuse in from the atmosphere and reach equilibrium. Plants add to the oxygen in water through its release as a byproduct of photosynthesis. However, in the dark, when photosynthesis is not occurring, plants metabolize and use oxygen in the same fashion that animals do.

During the course of a 24 hour cycle an individual plant will produce slightly more oxygen than it consumes as it increases in biomass. Over the course of a plants entire life cycle the total amount of oxygen released by the plant as it grows will eventually be consumed in its decay and no net oxygen production will occur. The exception to this is that some plant material escapes oxidation by sinking to the bottom of lakes or oceans where it forms petroleum or is stored as wood in forests for decades or centuries. The reason there is a residual of oxygen in the atmosphere today is because billions of tons of unoxidized plant material are bound in the form of long-lived wood product in forests and in the form of petroleum beneath the earth's surface.

Cycling of Oxygen

Eutrophication is a concern because, while aquatic plants can produce copious quantities of oxygen during photosynthesis, most of this oxygen escapes into the atmosphere due to water's inability to contain more than 7-9 mg/L over long periods. In heavy algae blooms one frequently finds readings as high as 20 mg/L oxygen concentration in water, but that is a transient phenomenon. Any excess over 7-9 mg/L will quickly escape. The more plants you have producing oxygen in the water during the day, the more plants you have consuming oxygen during the night. Since the bulk of the oxygen produced by dense phytoplankton populations during the day escapes, remaining oxygen in the water at night is often insufficient to meet plant respiratory needs. Aquatic plants end up competing for the oxygen with fish and invertebrate populations which are far more sensitive to oxygen deficits.

These processes are dynamic and must be balanced. Specific environments achieve these balances at different levels. There are many natural water bodies with high levels of plant productivity that contain animals communities capable of surviving in a low oxygen environment. Aquatic communities of value in Northern California, however, are typical of those in low nutrient water bodies. The species of fish most closely identified with the Russian River watershed, and of highest concern in our efforts to conserve our natural resources, are the salmonids, along with their associated fauna. These species evolved in waters with very low nutrient levels (oligotrophic as opposed to eutrophic). They can only survive where water is clear, relatively cool, and high in oxygen.

Laguna de Santa Rosa:
The Laguna de Santa Rosa is the southern drainage for the Santa Rosa plain into the Russian River. Much debate exists over the exact nature of the Laguna prior to settlement by people of European descent. The very fact that this system was home to salmonid populations and still contains upland salmonid habitat indisputably indicates that a large portion of it was oligotrophic in nature with low levels of plant nutrients.

The Laguna de Santa Rosa of today is highly eutrophic. Levels of plant nutrients are extremely high compared to other local water bodies. Turbidity during winter due to sediment loading is high while turbidity due to persistent algae blooms is high during the rest of the year. Oxygen levels in many portions of the Laguna are low during dark periods or in the deeper sections but range to as high as 20 mg/L in the sunshine, indicating excessive phytoplankton growth. Salmonids are virtually non-existent in the southern reaches of the Laguna and the current fish population is typical of eutrophic environments, carp and sucker being two examples. Deep channels no longer exist in much of the Laguna indicating that sedimentation in the watercourse has been substantial.

Dense algae blooms are common in much of the Laguna all summer indicating that nutrient levels persist at a high level. Multiple sources of these nutrients include urban development with increased runoff of sediment and petroleum hydrocarbons; nitrogen compounds from automobile and industrial air pollution; increased flow and erosion from channelization for flood control; cattle ranching with surface runoff of manure and sediment from pasture lands; urban lawn fertilization; farm fertilization for sod or vegetable production along the Laguna; septic tank and leach field loading from rural residences; and releases to the Laguna from the Santa Rosa Subregional Wastewater Treatment system which collects and treats waste from most of the human population in the Santa Rosa plain.

Past Management of Nutrient Loading
While the contributors to eutrophication of the Laguna are easily identified their quantitative roles are difficult to assess. Many isolated studies of nutrients in the Laguna and Russian River have been undertaken over the years. Unfortunately few have comprehensively addressed the total nutrient budget of the Laguna or included all the pertinent data necessary to understand nutrient cycling. This document, therefore, rests on a data collection that contains substantial voids.

Most attention to nutrients in the Laguna has been on nitrogen loading. The Subregional System has worked closely with the North Coast Regional Water Quality Control Board (NCRWQCB) to reduce the volume of nitrogen released to the Laguna through their wastewater discharges. They have also made substantial investment in infrastructure to minimize nitrogen loading from watershed dairies using reclaimed water for pasture irrigation. The Regional Water Quality Control Board is developing standards for Total Maximum Daily Loads (TMDL) of nitrogen in the Laguna that ultimately will encompass all identifiable sources of this nutrient in order to control its absolute volume.

Nitrogen, however, can never be completely controlled since it is available from numerous other sources, including natural ones. Nitrogen oxides are readily available from polluted air typical of an urbanized area such as the Santa Rosa Plain. Many species of photosynthetic bacteria and blue-green algae are nitrogen fixers capable of drawing nitrogen in molecular form from the atmosphere and incorporating it into plant tissue as they photosynthesize. The attempt to limit nitrogen in the Laguna, while a worthy goal for many reasons, is potentially fruitless if it is the sole nutrient being addressed.

Phosphate operates very differently in this dynamic because it is not available from the atmosphere in gaseous form. Typically it occurs in three forms; 1) dissolved as phosphate in water, 2) incorporated in biological compounds such as ATP or DNA which are primarily in particulate cellular form, or 3) adsorbed and chemically bound in soil or precipitated as mineral particles that settle to the sediments.

Dissolved phosphate, or orthophosphate, is the form in which it is most readily available as a nutrient for algae growth. When accompanied by various mineral particles phosphate can readily be adsorbed and removed from the water column. Wastewater that is discharged through subsurface infiltration in soils is readily cleansed of phosphate because it is easily adsorbed by the minerals in soil. This is not the case with nitrate and makes nitrate concentration an important consideration in assessing groundwater contamination by wastewater.

Surface releases of phosphate, especially orthophosphate, are readily available to planktonic and fixed plants in freshwater bodies. Similarly phosphates that precipitate into sediments are often recycled as wind mixes them back into suspension or when pH or redox conditions release them from their bound form back into solution. These processes make phosphorus in sediments re-available to stimulate phytoplankton growth.

The unique characteristics of phosphate that make it critical in controlling water pollution are fully addressed in EPA-R3-72-001 Ecological Research Series paper "Role of Phosphorus in Eutrophication". This paper unequivocally states "...of all nutrient elements known to be growth-controlling in lakes, only phosphorus is also controllable by man." (their underline). Their discussion is presented in the context of lake pollution but is equally applicable to the Laguna because for much of the year the Laguna exists as a series of pools that are equivalent to lakes in their dynamics. Their conclusions are presented in whole in italics to underscore the urgency with which they view this issue:

" Conclusions

1. It is affirmed that limiting phosphorus availability in lakes is the single, most important and necessary step to be taken now in eutrophication control.

2. The most effective way to do this is to reduce phosphorus inputs.

3. Because all inputs are additive, and therefore potentially significant, all should be considered for control.

4. Municipal sewage is the major point source. All such discharges to lakes and other susceptible waters should be treated to reduce phosphorus content to realistic target levels.

5. Phosphorus contributions to sewage should be reduced in every feasible way.

6. Nutrient budgets should be established for all major lakes to facilitate curtailing nutrient inputs from all significant diffuse and point sources.

7. Technology, where not at hand, must be developed to effectively curtail phosphorus inputs from all significant point and diffuse sources.

8. Where slow flushing impedes improvement from curtailed phosphorus inputs, accessory steps to inactivate, harvest, or otherwise retrieve nutrients from lakes must be considered."

We will return to these recommendations later in the discussion of phosphate dynamics in the Laguna de Santa Rosa and the need for the Regional Board and the Subregional System to seriously consider such dynamics.

<u>Phosphate Concentration in Santa Rosa Treated Effluent</u>

Phosphate concentrations in the effluent from the Santa Rosa Llano Road Treatment Plant have historically been relatively high. Santa Rosa expresses phosphate as mg/L of the element phosphor (or P). The average reading of phosphate concentration (measured as P) presented in the Subregional EIR prepared in 1996 equals 4.2 mg/L (Appendix 1). It should be noted that typical concentrations of phosphate (as P) in most natural water bodies are less than ranges from 0.005 - 0.1 mg/L (Wetzel, 1983).

To understand just how much phosphate this represents, at the above concentration the Santa Rosa treatment plant releases in 20 MGD of treated effluent approximately 700 lb. of elemental phosphor to the Laguna each day. This is the equivalent of 3,500 lb. of one of the most common commercial phosphate fertilizers, Calcium Phosphate $Ca_3(PO_4)_2$, every day. In the past the Santa Rosa Subregional system released 1,300 lb. P daily (California Water Resources Board, 1968) or the equivalent of over 2,300,000 pounds of this same commercial fertilizer per annum into the Laguna.

To put this in context Buhr, et al., WEF Operators Forumn (1999) discussed phosphate control by the Las Vegas, Nevada WWTP, which discharges 88 MGD of treated effluent. Las Vegas has been able to achieve average phosphorus releases of 0.16 mg/L, largely through operational modifications to a plant that is similar to the Santa

Rosa Llano Road Plant. Very little capital spending was necessary to achieve this goal. The Santa Rosa Plant would need to reduce phosphor loading from 700 to 27 lb./day in order to match the performance of the Las Vegas WWTP.

The Calif. Water Resources Board (1968) Report on the Russian River identified phosphate pollution as the primary cause of excessive phytoplankton blooms in the Russian River. As earlier mentioned phosphor releases by City of Santa Rosa into the Laguna at that time equaled approximately 1,300 lb./day. This quantity, when entering the river from Mark West Creek, resulted in a doubling of phosphate concentration in the River. The 700 lb load cited above indicates that Santa Rosa has been able to reduce phosphorus by about 30% since then. Nevertheless, at that level the load of phosphorus from Santa Rosa is still considerable, particularly when compared to that achieved in other parts of the country.

Closer analysis of the EIR data, however, show that throughout the 1990's Santa Rosa has steadily moved to reduce the phosphate concentration in its effluent. The four years covered by the EIR indicate the following average annual concentrations:

Year	Phosphor conc. (Mg/l)
1991	5.26
1992	5.13
1993	3.81
1994	2.54

Subsequent data over the period from 1995 through the early part of 1999 show that phosphate concentrations in Santa Rosa effluent reached their lowest levels in spring of 1999 (Appendix 2). This decrease did not persist, however. Data for December 1999 indicate that Phosphate concentration has returned to higher levels with a concentration of over 2 mg/L. The reduction in concentration in spring of 1999 occurred when flow volumes were high due to spring rains. The December 1999 increase in phosphate may have been due to reduced water flows during this dry period. This suggests that phosphate concentration in City effluent may be more a function of dilution than actual changes in daily load on a lb. basis. The system appears to have a great deal of room for improvement in reducing phosphorus load to the Laguna and one recommendation would be that phosphorus be monitored closely in the plant to work toward greater phosphate removal at the plant.

The most significant reduction in nutrient loading to the lower Russian River occurred in the early 1970's when the City of Santa Rosa discontinued direct summer stream discharge. Since then wastewater has been applied to the land through one of the states largest wastewater irrigation systems. Summer is the season in which phosphate pollution has the most significant effect since that is the season when river flows decline and phytoplankton blooms most heavily. Summer releases of phosphate into the Laguna, and concomitantly into the Russian River, have been dramatically reduced because instead of surface discharge direct to the Laguna, wastewater only reaches the Laguna through subsurface recharge. Data obtained from groundwater studies within the City's irrigation system show that phosphate in all forms is absent from groundwater when the treated effluent passes through soil before it reaches the Laguna (Appendix 3).

The concentration of orthophosphate as P taken from samples of ground water at Subregional irrigation fields only exceeded the 0.1 mg/l level of resolution in one sample of 21 readings. This was 0.4 mg/l at the Lakeville South site. It should be noted that this was not the case with nitrate. Nitrate concentration often exceeded the public health safe guideline of 10 mg/L in groundwater. Nitrate will be discussed in more detail later.

The phosphate reduction documented in the Santa Rosa irrigation system sampling is consistent with a large body of information being developed on the use of "Side Stream Infiltration" for release of wastewater to natural water bodies. Because of adsorption and filtration by soil, water can achieve a high level of purity before it resurfaces as stream flow if it is administered in carefully designed infiltration systems. This technology is most advanced in Germany at this time but is increasingly being used elsewhere. One local example is a 3.1 acre redwood forest under design by Lescure Engineers for AVG Winery in Graton. Effluent will be disposed through a raised infiltration field that will have water applied directly to redwood tree roots using subsurface Ecochamber emitters. Water will be transpired directly by the tree roots at far higher levels than is possible using pasture irrigation, and any excess flow will recharge the adjacent Atascadero Creek with highly purified subsurface flow. An advantage of such recharge at AVG is that it keeps the water within the aquifer from which it was drawn to the maximum extent possible.

The city of Santa Rosa has demonstrated the effectiveness of this type of subsurface irrigation at a demonstration Redwood forest at Sonoma State University using its reclaimed water. An expanded system with this form of infiltration could be used by Santa Rosa to irrigate riparian forest corridors along the Laguna. With such a system it would be possible to virtually eliminate phosphate from release into the open water environment. By introducing the infiltrate through the root system of a riparian forest another advantage would be dramatic reductions in nitrate as the nitrogen is absorbed by the trees at a far higher rate than competitive ecosystems. Lowrance(1992) showed that riparian forest removed as much as 300 lb. of nitrogen per acre per year compared to only about 15 lb. in pasture. As mentioned earlier, nitrate is not removed from percolate by Santa Rosa's pasture irrigation system to the extent that phosphate is. This is either an indication that water is being applied at levels beyond that necessary to meet the limited transpiration and nutrient uptake capacity of pasture or that cattle manure at the sites is contaminating the applied water. It would be important to determine which was the case in subsequent studies of nutrient loading to the Laguna.

<u>Phosphate Sampling in the Laguna de Santa Rosa</u>

The North Coast RWQCB has conducted recent studies of phosphate in the Laguna but it is not clear whether these studies will continue. A substantial record of phosphate measurements now exist from both the NCRWQCB and Santa Rosa Subregional system sampling programs. Unfortunately, there has been little coordination between the two sampling programs and efforts to pinpoint phosphorus sources to the Laguna have yet to be undertaken. One aspect of phosphate loading of highest concern in Water Quality Board studies has been recycling of loaded phosphates from the sediments. This will be discussed in detail later.

We have collated as much of the existing data as was readily available and are including it in tabular form (see Appendices 2, 4, and 5). The city of Santa Rosa expresses phosphate concentration in mg/L as phosphorus, while the Water Quality Control Board expresses it as mg/L as phosphate (PO4) although the laboratory analysis were conducted for concentration as P.

Analyses of these data have been organized according to the following parameters:

1. Geographic variation in concentration over the Laguna watercourse.
   General spatial variation.
   Point by point upstream/downstream comparisons at discharge points.

2. Phosphate recycling from sediments
3. Phosphate/nitrate interactions and phytoplankton density

Geographic Variation

The most southerly sampling in the Laguna starts upstream at the intersection of the Laguna with Stony Point Road. Moving downstream samples have been taken at Llano Road, Todd Road, Highway 12, Occidental Road, Upstream of the confluence with Santa Rosa Creek, Guerneville Road, and Trenton-Healdsburg Road. Samples also have been taken from Santa Rosa Creek at Delta Pond and at Willowside Road, Mark West Creek, and from the Russian River both upstream and downstream of the confluence with the Laguna. Other samples include upstream and downstream of discharge at Roseland Creek and upstream and downstream of discharge from Kelly Pond into Duer Creek.

The Santa Rosa Subregional system releases to the Laguna between the Llano Road sampling point and the Todd Road intersection. They also release from Delta Pond just upstream of the confluence of Santa Rosa Creek as well as minor releases from the treatment marsh system at the Llano Road plant and from Kelly Pond just upstream of the Occidental Road sampling point.

While incidental data on phosphate concentration exists at most of these station, the only stations with any extensive systematic sampling are Stony Point Road, Todd Road, Occidental Road and Guerneville Road. Data sets containing measures of Total Phosphate concentration taken by both the city of Santa Rosa and the NCRWQCB over the period of 1989-1992 for the board and 1991-1994 for the City are presented in the City of Santa Rosa 1996 EIR (Appendix 4 - Santa Rosa and Appendix 5 - Regional Board).

Table 1. Ranges and averages for the regularly sampled stations are presented as mg/L Total Phosphate as P:

	City of Santa Rosa		Regional Board	
Sample Station	Range	Avg.	Range	Avg.
Laguna at Stony Pt.	.33 - 1.2	0.64	.22 -1.4	0.61
Laguna at Todd Rd.	.6-4.1	1.54	.32 -6.2	2.45
Laguna at Occidental Rd.	1.2-2.6	1.74	.07 -3.3	2.15
Lag.upstream S.R.Creek	.18-2.98	1.36	.02 -3.5	1.77
S.R. Creek at Willowside	.05-.73	0.20	.01 -2.9	0.36
Mark West at Slusser	.06-1.5	0.47	.00 -.49	0.10

The two data sets are in general agreement showing that phosphate concentration is lowest at the Stony Point station, upstream of the central portion of the Laguna, and upstream of any release of treated Santa Rosa effluent. A substantial increase in concentration occurs in the stretch between Stony Point and Todd, an area that encompasses the major release point from Pond D, the City's major storage pond at the Llano Road WWTP. The Regional Board data indicate a higher phosphate load, however, the series encompass different time frames and can be expected to vary somewhat in detail. Occidental Road samples are high in phosphate and a slight reduction occurs by the time one gets to the Laguna station just upstream of the confluence with Santa Rosa Creek.

Phosphate concentration is the lowest in either Santa Rosa Creek or Mark West Creek, when measured upstream of the confluence with the Laguna.

More current data are available from both sources. The City of Santa Rosa has implemented an automated sampling program at several stations in the Laguna and these data are available from the City of Santa Rosa web-site. We present these data as Appendix 2. The regional board has also continued it's monitoring program and these data have been provided and are included as Appendix 6.

Upstream-Downstream Discharge Point Comparisons

The NPDES permit for Santa Rosa discharges contain general restrictions against increasing concentration of plant nutrients due to discharge of treated effluent. Phosphate concentration measurements from identified upstream and downstream locations near effluent discharge points taken at the same time are presented in Appendix 7 for comparison. These sampling points include:

(7A) Upstream - 36" Discharge from Pond D.
Downstream - Todd Rd., nearest point downstream from Pond D.

(7B) Upstream - Roseland Creek

	Downstream -	Roseland Creek
(7C)	Upstream -	Duer Creek at Kelly pond discharge.
	Downstream -	Duer Creek at Kelly pond discharge.
(7D)	Upstream -	Santa Rosa Creek at Delta Pond discharge.
	Downstream -	Santa Rosa Creek at Delta Pond discharge.

These data from indicate that phosphate concentrations from downstream sampling points are frequently elevated over upstream concentrations (Table 2).

Table 2. Frequency of increase in phosphate concentration from upstream to downstream reading, downstream to upstream reading, and avg. increase in phosphate concentration in those instances with a positive increase downstream of discharge points.

Discharge Location	% Upstream to Downstream Increase	%Downstream to Upstream Increase	Avg. Increase in mg/L Phos. Downstream
D - Pond	65.0	5.0	.27
Roseland Creek	100.0	0.0	.60
Duer creek/Kelly Pond	97.1	2.9	1.01
S.R. Creek/Delta Pond	100.0	0.0	.84

Similar increases in Nitrate loading are seen at these same stations (Table 3).

Table 3. Frequency of increase in nitrate concentration from upstream to downstream, downstream to upstream, and avg. increase in nitrate concentration in those instances with a positive increase downstream of discharge points.

Discharge Location	% Upstream to Downstream Increase	%Downstream to Upstream Increase	Avg. Increase in mg/L NO3. Downstream
D - Pond	90.0	10.0	1.26
Roseland Creek	100.0	0.0	2.86
Duer creek/Kelly Pond	90.0	10.0	2.50
S.R. Creek/Delta Pond	100.0	0.0	2.36

It is evident from the above Santa Rosa monitoring data that increases in nutrients due to effluent releases are common and that the increase in concentration is significant. In the instance of Phosphate it should be pointed out that EPA 841-F-95-002 Watershed Protection: Clean Lakes Case Study (1995) discusses a phosphate end-point of .03 mg/L as the point that separates an impacted from a non-impacted lake. By these criteria the levels in the Laguna are extraordinarily high and the documented increases tracked to Santa Rosa discharges are above this level by one to two orders of magnitude depending on the water body.

One other set of upstream/downstream comparisons exists in the Santa Rosa data. This is the comparison between samples taken at Wohler Bridge in the Russian River, upstream of the confluence with the combined Laguna and Mark West Creek flows entering through the terminus of Mark West Creek, with downstream measures taken at Mirabel. Table 4 shows that nutrient loading from the combined Mark West and Laguna flow often results in increased nutrient concentrations in the Russian River at this point.

Table 4. Frequency of increase in phosphate and nitrate concentration from upstream Wohler Bridge to downstream Mirabel readings (in Mg/L).

% Upstream to Downstream Increase		%Downstream to Upstream Increase		Avg. Increase Downstream	
PO4	NO3	PO4	NO3	PO4	NO3
30%	52%	0%	0%	.08	.12

Mark West Creek receives effluent from both the Windsor WWTP and SCWA Airport WWTP. Monitoring data from neither of these systems was available for inclusion in this study so it is not possible to distinguish the source of the elevated nutrients.

An earlier study of nutrient loading to the Russian River (California Water Resources Bull 143-4: 1968) also identified Mark West Creek as a source of nutrient loading to the Russian River.

Table 5. Concentration of NO3, organic nitrogen, and phosphate in mg/L measured at various stations on the Russian River on August 19, 1966.

Station	NO3	Organic N	PO4
North of Cloverdale	0.0	.10	.06
Healdsburg	0.0	.20	.10
Mark West Cr. at Trenton	0.3	2.40	.26
Guerneville	0.0	.30	.59
Duncans Mills	0.0	.30	.35

Unfortunately these data derive from a single days sample and must be considered in that light, however, the reports conclusions are quoted verbatim below.

"The Orthophosphate from the Mark West Creek system increase the concentration downstream of the confluence by more than 100%. This is the principle reason for excessive phytoplankton growth in the lower Russian River."

"Prospects are that phosphate concentrations in the lower Russian River will increase and as a consequence there will be more extensive growth of phytoplankton. The discharge from the City of Santa Rosa sewage treatment plant presently contains about 1,300 lb.. of orthophosphate per day. About 30% of this discharge, containing 390 lb.. of orthophosphate per day, reaches the Russian River during the critical summer period."

This report goes on to specify an objective of reducing phosphate concentration to .25 mg/L at Guerneville.

From the monitoring data obtained recently it is clear that phosphate loading to the Russian River via the Laguna/Mark West Creek system has reduced dramatically. Most significant to this reduction has been the substitution of summer surface discharge of effluent by the City of Santa Rosa for land application of effluent through one of the states most extensive pasture irrigation systems.

Still, however, the nutrient signal at the confluence to the Russian River persists. Unfortunately the level of resolution of the current sampling is insufficient to accurately measure nutrient loading. As mentioned earlier EPA considers .03 mg/L the endpoint for impacted vs. non-impacted water bodies. In 74% of the samples phosphate concentration at Wohler Bridge was reported simply as <.1 mg/L. There are 17 instances when upstream is <.1 mg/L and downstream was <.1 mg/L. Therefore even an impacted Russian River at .03 mg/L at Wohler could have concentration tripled to .09 mg/L downstream, highly impacted by EPA standards, without it being measured by the current sampling program.

Phosphate Recycling in the Laguna

The NCRWQCB has conducted an extensive analysis of phosphate in the Laguna over the past several years (Peter Otis, 1999, personnel communication). These studies have not yet led to a TMDL program with regard to phosphate in the Laguna but do provide a starting point for moving toward such a goal.

One of the most important aspects of this study has been the role of phosphorus recycling from the sediments in the Laguna. Measurements taken from the sediments in both the Occidental Pond immediately to the south of the Occidental Road Bridge and the Sebastopol Pond downstream from the Highway 12 Bridge show that the sediments in these ponds sequester very high levels of phosphates. Concentrations range from 311 mg/kg to 2564 mg/kg in these sediments. Recirculation of these sediments into the water column can release significant quantities of phosphate for plant growth stimulation (Appendix 8).

Such recirculation is quite complex, however, and is governed by a wide variety of physical and biological factors. One such factor is the aerobic state in the sediments. When conditions become anoxic, phosphorus can be released from the sediment into the water column as phosphoric acid. This is seen at the Sebastopol Pond where scouring of phosphate from the sediments has occurred during periods where indicators of anoxic conditions in the sediments, such as increased H_2S concentration are seen. During such periods phosphate concentration in the sediments has decreased.

The Sebastopol Pond portion of the Laguna is densely covered by riparian forest and a good deal of organic detritus in the form of leaf litter falls in that area. This contributes to both a high carbon load as well as nitrogen loading from species of trees such as alders which fix atmospheric nitrogen. At the same time this riparian cover prevents winds from mixing the upper and lower water column and stratification occurs leading to anoxic conditions in the bottom sediments. Phosphate concentrations in the sediments have reduced considerably from 1997 to 1999 in the Sebastopol Pond from an average of 1197 mg/kg in 1997 to 986 mg/kg in 1998 to 588 mg/kg in 1999. This coincides with a period during which concentrated apple sugars coming from leaks at a local apple processing plant may have increased BOD in that section of the Laguna thereby increasing the rate of sediment scouring.

At the same time the reduction from 1998 to 1999 coincides with an extensive bacterial bioremediation implemented to counter the apple waste using *Pseudomonas* bacteria (D.E.Wickham, personal data). Wetzel (1968) discusses the ability of bacteria to inhibit algal growth by out-competing them for phosphate. He comments that while algae have a slightly higher membrane affinity for phosphate, the bacteria are so much smaller that the surface area/volume ratio shifts the advantage in phosphate uptake and utilization to the bacteria.

Sediment concentrations in Occidental Road Pond have stayed relatively stable, fluctuating in a narrow range from 1305 mg/kg in 1997 to 1465 mg/kg in 1998 to 1337 mg/kg in 1999. Occidental Pond experiences regular mixing due to wind during the midday. This maintains higher oxygen levels at the sediment interface preventing substantial phosphor releases. Nonetheless, the concentration of phosphate in the water column as indicated by the water monitoring program are always high enough that algae blooms persist in the Occidental Pond all summer. These blooms do not appear to deplete the sediment reservoir so either recycling is highly contained in the pond or continued loading from upstream is occurring.

Stratification is more common in Sebastopol Pond since the riparian forest prevents mixing and carbon load is high. The sediment data suggest that some movement of phosphates may occur from Sebastopol Pond to Occidental Pond, at least in 1998. Average sediment phosphate concentration in June was 1182 mg/kg in Sebastopol Pond and 1216 mg/kg in Occidental Pond. By September Sebastopol Pond had decreased to 791 mg/kg while Occidental Road concentration increased to 1713 mg/kg.

The data between Highway 12 and Occidental Road encompass a short period and are difficult to consider representative of the entire Laguna. Nevertheless they indicate phenomena of scientific interest as well as possibly of practical value in designing phosphate remediation programs throughout the Laguna. Much more information on the dynamics between sediment and water column with regard to phosphate transfer is necessary to understand this phenomenon.

The above data show that sequestration in the sediments is a significant sink for phosphates in the Laguna. Most phosphate readings in the water column of the

Laguna, particularly from Santa Rosa monitoring, are taken during the winter when the city is discharging. Phytoplankton production is low during such periods so biological uptake resulting in depletion of nutrients in the water column is less significant. In the case of phosphates, winter declines in concentration over space or time are more likely due to sedimentation than biological uptake.

Most phosphate released by the City of Santa Rosa is in the form of orthophosphate (dissolved P). This is the form most readily taken up by phytoplankton, but since plant production is low during the release season it has been assumed that most of these releases pass through the Laguna and into the Russian River where they then flow to the ocean with the high winter flow.

This is an important assumption that has never been tested. We can attempt to address this issue by analyzing phosphate concentrations measured during the winter when algal production is at its lowest level. Reductions in phosphate concentration from upstream to downstream Laguna stations would likely result from sediment deposition rather than algal uptake at that time since algae production is low (Table 6)

Table 6. Average concentrations of total phosphate in the pertinent Laguna stations derived from the 1990-94 data in the 1996 EIR for the months of November through March, when river flows are highest, and algae production is lowest.

Station	Total Phosphate Concentration
Stony Point Road	0.43 mg/L
Todd Road	1.83 mg/L
Highway 12	1.63 mg/L
Occidental Road	1.71 mg/L
Upstream Santa Rosa Cr.	1.40 mg/L
River Road	1.03 mg/L

These data suggest some sequestering of phosphorus as it passes through the Laguna even though the change in concentration seems slight. The reduction at River Road might be explained by dilution from Santa Rosa Creek and Mark West Creek which both enter upstream of that station and typically have lower phosphate concentrations.

It is evident from the data that substantial phosphate loading occurs between Stony Point and Todd Road. The reduction as it passes downstream appears to be slight, indicating that a large portion does in fact pass out of the Laguna during the discharge season. However, the flows at this time are very high and the total load, which can be calculated from the concentration times daily flow, during this season suggest that very large quantities of phosphate are contained in this water. A reduction of 0.43 mg/L from Todd Road to upstream of Santa Rosa Creek in flows typical of the Laguna in most winters is equivalent to several hundreds of pounds of phosphates being sequestered in the sediments each day. This is consistent with the high concentration of phosphates seen in the few sediment samples taken to date in Occidental and Sebastopol Ponds.

In an attempt to address Phosphate deposition more closely we collated all data points in which were taken on the same day from the following stations:

Todd Road
Occidental Road
Upstream Confluence of Laguna and Santa Rosa Creek

These data are presented in Appendix 9. They provide a rough index of loss of phosphate from the water column as it passes through the Laguna. Samples downstream of Santa Rosa Creek were not included since lowered concentration of phosphate there could be from dilution from Santa Rosa Creek, known to have lower concentrations, and not necessarily from deposition.

The grand averages for the data set indicate that phosphate concentration decreases from 1.91 mg/L at Todd to 1.36 mg/L near Santa Rosa Creek indicating sequestration of approximately .55 mg/L of phosphor within that reach of the Laguna.

Selecting only the winter (Nov-Apr) samples results in average concentration of phosphor of 2.0 mg/L at Todd Road declining to 1.25 mg/L near Santa Rosa Creek, or sequestration of .75 mg/L within that stretch. This suggests that phosphates, even though released during the high flow season are not necessarily voided from the Laguna. To the extent that these phosphates are recycled in the summer, they represent a load to the Laguna and Russian River even though they are not being discharged in the summer.

Sediment Control

Sediment loading has been identified as a major pollutant in the Laguna system and the Russian River. In fact the Russian River has been included in the EPA list of impaired watersheds for sediment pollution for 10 years. Loads of fine clay in suspended sediments alters the physical structure river bottoms by sealing the bottom gravel. Salmonids require clean gravel as habitat for egg development. Debate exists over whether the Laguna was ever more than a migratory pathway for these fish as they traveled upstream to tributaries for breeding. Clogging of bottom sediments with clay, however, will prevent filtration of water flowing through the river. This natural filtration is an important component to maintenance water quality. To the extent it is prevented, natural water purification by the stream habitat is impaired.

This sediment loading has an important impact on phosphate dynamics in the Laguna through its role in transporting and depositing adsorbed phosphates. Where they are deposited in bottom sediments they can be recycled into the water column later during periods of low flow. As mentioned, phosphate released from the Santa Rosa Subregional Treatment System is primarily in dissolved form. While this is the form most readily taken by plants most of the Santa Rosa releases are during the period of minimal phytoplankton growth. The primary mode of phosphate sequestration at this time is through adsorption by clay particles. This will occur both in the Laguna after effluent is discharged, as well as when sediment particles are flushed into the storage ponds with river flow during storm flow equilization. Some of the phosphate sequestered by this particulate matter will settle to the sediments of the Laguna. Reductions of sediment loads to the Laguna would minimize the quantity of phosphates retained in the deposits of the Laguna basin. A vigorous program to reduce erosion in the Laguna watershed would be the most direct method to maintain a higher level of washout of dissolved phosphate from Santa Rosa surface releases if that method is retained as the primary form of discharge. This, however, increases loads to the Russian River so sediment control to reduce phosphate deposition in the Russian River watershed might also be necessary.

A much more direct and effective method to reduce phosphate deposition in the waters of the Laguna would be for Santa Rosa to eliminate surface discharge of its treated effluent. Subsurface discharge either through infiltration galleries, or through ecochamber type forests, similar to the demonstration Redwood forest at SSU, would virtually eliminate all phosphate load from the Santa Rosa system to the Laguna. Distribution through a riparian forest system would, as earlier mentioned, help control nitrate contamination of groundwater, currently seen in the pasture irrigation system. If this same system were utilized in summer the city could direct a substantial flow to subsurface recharge of both groundwater in the Laguna basin as well as to recharge of stream flow to substantial advantage to habitat values of the aquatic environment.

The addition of substantial riparian habitat in the form of subsurface ecochamber galleries would act to further reduce the flow of sediments into the water column. Leaf litter and root permeation in forest soils is the most effective method to increase soil permeability. This system represents the most powerful sediment trap available and would do as much as any engineered sediment trap in increasing clarity of Laguna waters.

<u>Phosphate and Nitrate Interactions and Phytoplankton in the Laguna</u>

The most important technique for investigating adverse impacts of phosphate loads to the Laguna is to analyze phosphate concentrations in association with other nutrients and with the concentration of algae. Excessive growth of phytoplankton is the problem caused by phosphate stimulation so it is the most important parameter to measure in studies of eutrophication.

The City of Santa Rosa undertook an extensive series of measurements at various stations in the Laguna from 1990 through 1994 as a part of their 1996 EIR. These data are presented in Appendix 4. We selected the following parameters: NO3, NH3, Total P, Dissolved P, Chlorophyll a, and Phaeophytin, which are presented in Table 7. They were chosen because they represent the critical variables in understanding phytoplankton dynamics in the Laguna. Unfortunately a critical gap exists in these data. It is a measure of Total Nitrogen, which would reflect the nitrogen bound in the plant cells. Total nitrogen is taken in many of the other data sets included in this study. It is unfortunate that in this series it was not measured since this is the one analysis where it is pertinent.

Table 7. Average values for nutrient concentration and plant photosynthetic pigments at stations along the Laguna. Nutrients are measured in mg/L while pigments are presented in ug/L concentrations

Station	NO3	NH3	Total P	Dissolved P	Chlorophyll A	Phaeophytin	Combined Pigments
L/Stony Pt.	1.65	.13	.63	.45	22.80	10.56	33.36
L/Todd	2.91	.65	1.56	1.30	48.66	65.76	114.42
L/Occ.Rd	2.40	.37	1.73	1.26	81.89	26.72	108.61
L/SR Crk.	1.18	.18	1.28	.92	47.40	49.98	97.38
L/River Rd.	1.32	.16	.60	.49	39.69	34.10	73.79
SR Ck/Wlsd.	1.35	.09	.21	.12	5.48	8.36	13.84
MkWestCk.	1.55	.14	.50	.19	15.00	5.94	20.94

This table demonstrates a 1:1 correlation between average phosphate concentration and average combined plant pigment (Spearman - Rank Order Correlation coefficient = 1.00). The correlation with nitrate is slightly positive but not significant (Spearman Rank Order Correlation Coefficient = .43) These data, however, must be interpreted with caution since samples were taken at intervals of from nearly one month to several months. Nutrient dynamics in nature are highly complex since a nutrient loading event will be followed at some lag by a phytoplankton bloom which will then deplete those nutrients with a concomitant die-off of the phytoplankton. A random sample may be taken at the onset, during or at the end of such an event so the relationship between a nutrient concentration and a concentration of plant material can vary accordingly.

A more comprehensive data set exists taken by the Regional Board. This includes Phytoplankton cell density (a more direct measure of phytoplankton abundance) and TKN, an important parameter missing from the Santa Rosa data. These are presented as Appendix 10.

Correlation analysis using these data (Table 8) indicate that, while phosphate cannot be considered a limiting nutrient since it is never totally depleted, it can still acts as the "controlling nutrient". There exists a very highly significant correlation ($p=.001$) between either ortho-phosphate concentration or total phosphate concentration and the measure of phytoplankton cell density. At the same time the correlation between nitrate and phytoplankton density is insignificant.

Table 8. Correlation coefficients between plant nutrient concentrations and phytoplankton cell densities in the Laguna Regional Board data (n=41).

Comparison	Correlation Coefficient	Significance
OrthoPO4 vs. Cell Density	.544	>.001
TotalPO4 vs. Cell Density	.500	>.001
Nitrate vs. Cell Density	.162	NS
Ammonia vs. Cell Density	.158	NS
TKN vs. Cell Density	.687	>.001

Several other interesting correlations can be seen in these data that indicate the study of nutrient dynamics is not only vital to developing control measures for improving water quality but also that much significant basic research potential exists for students of limnology in the Laguna.

The rationale presented by the 1996 City of Santa Rosa EIR for its focus on nitrogen as the limiting nutrient in the Laguna is based on studies done on Algal Growth Potential (AGP) in waters taken from the Laguna at various times. An aliquot of water from a particular station is isolated and held for 14 days. Algae production is monitored and nutrient uptake is measured to see which nutrients are depleted first. In samples where nutrients were stimulatory it was found that growth discontinued when nitrogen was depleted. Phosphorus in these samples never reduced to levels where its lack inhibited plant growth.

These results are to be expected in that field monitoring showed that phosphate was found at high levels, especially when the ratio of P to N was considered, at all times and at all Laguna Stations. These experiments represent a totally artificial condition since extraneous sources of nitrogen, readily available in the field, were not included. Peter Otis of the Regional Board (personal communication, 1999) discussed instances in the Laguna during which dense blooms of blue-green algae correlated with very high levels of ammonia, even though nitrate was lacking. His conclusion was that this represented atmospheric nitrogen that was fixed by these algae. Blue green algae blooms are common in the Laguna, and in fact are considered indicator species for nutrient conditions in which phosphate is abundant but nitrate is limited, typical of the Laguna. Blue-green algae are often noxious species with little food value and their prevalence in polluted environments is one of the main reasons that ecologists have worked to control phosphate pollution in freshwater environments.

In the field nitrogen cannot become strictly limiting when phosphate is abundant since new nitrogen is introduced by a variety of means at all times. What is typically achieved is a steady state in which nitrogen continues to enter the system sustaining continued algal growth even though measurable dissolved nitrate is virtually nil. This is because new nitrogenous material is immediately incorporated into plant tissue and never becomes nitrified. The City of Santa Rosa data presentation omitted TKN which would have measured this form of nitrogen. The high correlation of TKN with phytoplankton density in the Regional Board data reflects the above dynamic. Attempting to control algal blooms by limiting nitrogen releases from wastewater is doomed to failure if phosphate is not also reduced, as is emphatically stated by the EPA document on phosphate loading mentioned earlier.

EPA-R3-72-001 discusses in detail experiments in Lake Washington where sewage load was diverted from the lake. Phosphate concentration in the water column reduced by 72% and algae concentration reduced by 80%. Nitrate concentration decreased only by 20% and bore no relationship to algal production. This shows that extraneous sources of nitrogen continued to load the system even though sewage loading of nitrogen had diminished by the same proportion as phosphate.

The positive message of this study was that reductions of phosphate resulted in immediate and direct reductions of eutrophication even though nitrate concentration did not decline by the expected amount.

Wetzler (1968) presents an extensive discussion of the central role that phosphate plays in freshwater plant nutrient dynamics. He reviews the extensive experimental demonstrations showing improved water quality following reductions of phosphate loading. He provides a detailed discussion of the importance of nitrogen fixation by blue-green algae, pointing out that these algae need high concentrations of phosphate to drive the incorporation of fixed nitrogen into the system.

His discussion is indirectly confirmed in the Regional Board data by the very highly significant correlation between TKN and phytoplankton cell density ($r=.687$, $p<.001$). While correlation analysis must always be considered in light of known causal mechanisms the following is a reasonable scenario.

Phosphate, by increasing phytoplankton abundance increases incorporation of nitrate into cells, thereby reducing nitrate concentration, leading to a shift in community structure to nitrogen fixing algae which are not limited by nitrate. These algae need the high phosphate concentration to drive fixation of nitrogen, thus, the phosphate, in effect "causes" the nitrogen loading. The biological reality of this sequence makes control of water quality through reductions in wastewater nitrogen loading to the Laguna impossible without first controlling phosphate loading.

Studies on Reclamation of Stone Lake, Michigan (EPA-600/3-76-106; 1976) discusses a scenario that is almost exactly that of the above hypothesis for a similar situation in which phosphate is not "limiting" but is controlling. *"In the beginning of June it would appear that nitrogen was limiting in Stone Lake, yet, at the same time, a large algae bloom begins to develop. The anomaly is explained by the theory that nitrogen-deficient conditions provide a competitive advantage to nitrogen fixing blue green algae."* Their analysis showed that, in fact, as green algae consumed nitrogen Anabaena, a blue green took over. Anabaena secretes inhibitory substances. The Anabaena bloom was short-lived but introduced enough nitrogen to allow green algae to bloom again. This same study showed that elimination of phosphate loading allowed the stores in the sediment to be depleted over an approximate 6-8 year period.

Phosphate Control
A very powerful technology for reducing phosphate loading exists that is not only consonant with the increasing public interest in restoration of the riparian habitat of the Laguna, but also would harness this riparian zone for nitrate reduction as well. It is clear from the ground water analysis at Santa Rosa irrigation sites that nitrate occurs at very high levels. This may or may not be due to the reclaimed water, and in fact is likely related to manures at the dairy sites where the irrigation is occurring.

Studies of nitrogen uptake by riparian forests show that 70-90% removal rates occur in the first 10 meters of passage by water through the root zone (Lowrence, 1992). Assays for bacterial denitrification enzymes demonstrated that this reduction was not due to bacterial denitrification in the soils but rather to direct uptake by the riparian vegetation. The demonstration subsurface forest irrigation project put in place at a redwood grove at SSU by the City of Santa Rosa provides an experimental site for investigating nitrate and phosphate uptake by forest systems as a comparison to their pasture irrigation systems.

Uptake studies (EPA Manual for Land Application of Sewage Sludge, 1982) show that pasture irrigation removes approximately 15 lb/Nitrogen/acre/year as opposed to forest ecosystems that remove from 150-300 lb/Nitrogen/acre/year. The only way to control groundwater nitrate pollution in a sprinkler irrigation system like that of the Santa Rosa pasture system is to carefully control the application rate so that the maximum possible water is taken actively by grass transpiration and is not allowed to leach beyond the root zone. Levels of nitrate greater than 10 mg/L, as measured in association with the Santa Rosa irrigation system, may represent a technical violation of the City's permit. A more thorough study of this phenomenon is advisable to determine the cause of the elevated nitrate levels at irrigation sites.
With trees this limitation is not as critical since not only do trees consume much higher volumes of water and nitrogen, their root systems penetrate to much greater depths increasing the uptake opportunity.

The subsurface system at the Sonoma State demonstration plot illustrated that Santa Rosa could enjoy the added advantage of discharging reclaimed water in winter when their surface irrigation system was inactive. They were able to discharge through subsurface forest irrigation, in almost pure adobe clay soil, at rates ranging from a low of over 8,000 gpd/acre in February 1999 to a high of over 15,000 gpd/acre in August of 1999. This compares to a rate of only 5,000 gpd/acre in the driest months of the summer and zero irrigation during almost 5 months for surface pasture irrigation. The redwood demonstration project at SSU unequivocally demonstrates that Santa Rosa could irrigate with all of its reclaimed water year around in the Laguna and does not need to restrict it to the summer season. By so doing phosphate loading by the Subregional system to the Laguna could be virtually eliminated, and nitrate loading would also be significantly reduced.

Significance of Phosphate Readings

It is undeniable that Phosphate levels in the Laguna are high, both relative to typical unpolluted freshwater worldwide, and relative to other streams within the same watershed. The important questions are:

1. Do the high concentrations and daily load released with treated Santa Rosa wastewater contribute significantly to the elevated levels of phosphorus in the Laguna?
This question cannot be answered since the required nutrient budget, which would include phosphorus, has regrettably never been conducted in the Laguna. Phosphate, however is such an important nutrient that levels as low as .03 mg/l can be considered as bordering on eutrophic by the EPA. In the past Santa Rosa released an equivalent of 315 kg/day. This would increase pure water with no phosphate to the above .03 mg/l in a volume of over 10.5 billion gallons. Even now with the reduced loading of about 75 kg/day in 1999 Santa Rosa loading would increase the concentration of 2.5 billion gallons to a similar highly enriched level.

Clearly the 0.03 mg/L endpoint is unrealistic and can probably never be achieved. These standards are for standing lake water where phosphate control needs to be more stringent. The Laguna and Russian Rivers are flowing water so a good portion of loaded phosphate is not captured in the system. However, discussion has arisen of the possible use of Lake Sonoma as a receiver for treated effluent generated by the SCWA treatment system. **A severe cautionary warning should be expressed at this time by the Regional Board to any phosphate loading to Lake Sonoma given the extreme sensitivity of lake water to phosphate increases**.

There can be no doubt that Santa contributes to phosphate load, even though it is not clear just what the proportion of the total is. Increases in phosphate concentration can be seen at most discharge points so, no matter what other sources may be involved, Santa Rosa wastewater is a significant contributor to loads. A more thorough study of the Laguna and its tributaries would be necessary to determine the allocation of current loading. Such a study is well past due since virtually every significant watershed in the United States has or is conducting similar studies. The role of phosphate in freshwater eutrophication has been understood for decades.

2. What are the other significant contributors to phosphorus loading to the Laguna?
As mentioned no study has ever attempted to determine the significant phosphate contributions to the Laguna. Candidates include sediment releases resulting from logging, home and industrial construction and development, vineyard planting, cattle ranching, sod farms along the Laguna, household phosphate uses such as detergents and lawn fertilizers, industrial cleaning with TSP or other phosphate compounds, flood control with resultant channelization and destruction of bioretention zones which are necessary to infiltration and settling of phosphate upstream, septic tank releases during the rare times that they occur at the surface, poultry farming, and several other sources that could easily be identified and quantified if the Regional Board implemented a program to do so.

3. Do the excessive loads of phosphate in the Laguna stimulate the excessive algae blooms typical in the Laguna?

The excessive phosphates in the Laguna may not stimulate algae blooms so much as rendering it impossible to avoid excessive algae blooms. The constant presence of superabundant phosphate makes any other control efforts, such as nitrate reductions, futile. Algae blooms continue to clot the Laguna despite decades of work in eliminating nutrients other than phosphate and the high correlation between phosphate concentration and phytoplankton density suggests it is the primary "controlling nutrient". Test-tube studies showing nitrate as a "limiting" nutrient have no relevance to conditions in the Laguna. Alternative sources for nitrogen are readily available "*in situ*" so the Laguna has no limiting nutrient in the traditional sense. Phosphate, as the only nutrient actually controllable by humans, should supersede nitrogen as the control point of choice.

4. Do releases of phosphate from the Laguna into the Russian River stimulate algae blooms in the River?

Phosphate probably does act as a limiting nutrient in the Russian River since levels are relatively low and more typical of clear flowing salmonid habitats. Phosphate loading in the past was identified as the single most important nutrient leading to excessive algal production in the lower Russian River. Conditions have improved but the signal of the Laguna can be seen in many samples when levels at Wohler Bridge upstream of the confluence are compared to Mirabel downstream. A doubling of concentration is common, even though levels are now lower than in the past. It is at these low levels that stimulation can be most apparent since the starting condition is relatively pure water with high visibility. Very slight increases in algal concentration become evident and are much more obvious. Unfortunately, again the sampling program is spotty and not at a high enough level of resolution to draw firm conclusions. For instance there is no sampling being conducted in Mark West Creek at Wohler Road. This would measure contributions from the Laguna and from Windsor and Airport. The Regional Board should require these dischargers to institute a more thorough monitoring program for nutrients, particularly phosphorus, since it has been identified as the primary nutrient of concern in the past.

5. What actions can be taken by the Subregional system or the other releasers to the Laguna to reduce phosphate loading?

The Subregional system has already made impressive progress in reducing its loading. The city should be encouraged to continue this effort by the development of targets consistent with other municipalities in the U.S. Santa Rosa has virtually eliminated phosphate loading in the summer by going almost exclusively to land based discharge where phosphate can be filtered as water passes through soil. Winter loading could be similarly eliminated if surface discharge were substituted with streamside infiltration galleries so that water received the same type of soil purification that a conventional leach system provides. If such systems incorporated riparian forest systems they would act to significantly reduce nitrate loading at the same time.

A first step in control of phosphate loads from surface discharge into the Laguna would be to restrict release to periods of maximum flow in the Laguna. Regulating releases to flows in the Russian River makes it impossible to control the sedimentation of phosphate in the Laguna. It is the sequestration of phosphate in the sediment that appears to be the main problem with winter releases. Avoiding such sequestration would be beneficial to eventual scouring of excessive phosphate from the sediments. Other obvious releasers such as the various county and city operated WWTP releasing to the Russian River tributaries should be brought into a similar management plan for phosphate reduction.

Small communities within the watershed should be actively discouraged by the Regional Board from developing conventional aerobic centralized treatment systems that use winter discharges to the rivers as part of their overall management. Well engineered community septic-step and leach systems are the most economical technologies capable of eliminating phosphate loading since they are based on soil filtration, the most powerful method to reduce phosphate load. Again incorporation of forest habitat into leach systems is the most effective way to also recapture the nutrient value from nitrogen and control concentration in the leachate.

6. Will such actions, if they successfully reduce phosphate concentration, lead to improved water conditions in the Laguna?
Phosphate exists at such high levels in the Laguna that improvements will take some time. However, correlation between phosphate and phytoplankton density in the open Laguna environment is highly significant. This suggests that continued reductions of load will allow some improvement. Phosphate stores in the sediments represent a serious problem, however, experience in most watersheds in the U.S. that have undertaken phosphate load reductions show that recovery can occur over periods of years to a decade. It should be remembered that a decade is a very short time in these situations, and most of us alive have seen many problems resolved successfully even if they do take decades.

Recommendations
Recommendations for action on phosphate loading to the Laguna and Russian River watersheds are presented in association with the previously cited conclusions of EPA-R3-72-001 (their comments in italics):

1. *It is affirmed that limiting phosphorus availability in lakes is the single, most important and necessary step to be taken now in eutrophication control.*
The Laguna data, as incomplete as it is, suggests strongly that phosphate concentration is the controlling nutrient for algal growth and that reductions in nitrate loading, in isolation, do not necessarily improve conditions. The Laguna is still highly eutrophic even though the City has vigorously pursued a strategy to reduce both their own nitrate loading and that of the dairies associated with them in the Laguna watershed.

Recommendation: The City and Regional Board should acknowledge the need to study phosphate as well as nitrate as a nutrient in the Laguna and implement programs to do so.

2. *The most effective way to do this is to reduce phosphorus inputs.* The most interesting observation coming from this study is recognition of the marked reduction in phosphate loading to the Laguna from the City of Santa Rosa's treated effluent, both as a result of increased irrigation to land, and in actual reductions in phosphate concentration in the releases. The city is to be commended for this and encouraged to mount a serious continued effort to limit phosphate releases. A much more exhaustive effort to reduce phosphate loading to the Laguna, as well as to the Russian River, from all sources is long overdue.
Recommendation: The Regional Board should make phosphate reduction an immediate priority in all watersheds under its purview.

3. *Because all inputs are additive, and therefore potentially significant, all should be considered for control.* The existence of high background phosphate levels do not excuse the City, or any other releaser, from reducing its contribution. Again the City should be commended for taking initiative on its own in this regard.
Recommendation: The Regional Board should implement a program to identify all sources of phosphate in the Laguna watershed.

4. *Municipal sewage is the major point source and should be treated to reduce levels to realistic levels*. The City of Las Vegas has shown that manipulation of a system similar to Santa Rosa's plant can reduce phosphate levels by an order of magnitude from Santa Rosa's current levels.
Recommendation: Santa Rosa should develop a program of phosphate removal at the plant that is equivalent to those achieved by similar systems in the US or develop disposal alternatives that will reduce phosphate loading to the Laguna.

5. *Phosphorus contributions to sewage should be reduced in every feasible way*. It is not clear whether Santa Rosa has made any attempt to reduce headworks concentration of phosphorus. Several extensive programs in the eastern and central United States have resulted in dramatic reductions in sewage phosphate loading.
Recommendation: The Santa Rosa Subregional System should implement a program to reduce headworks loading of phosphate consistent with similar programs already in effect throughout the US. This should incorporate industrial waste pretreatment as well as community outreach and conservation programs.

6. *Nutrient budgets should be established for all major lakes to facilitate curtailing nutrient inputs from all significant diffuse and point sources*. To date phosphate, the single most important plant nutrient in freshwater environments, has only received cursory attention in any attempt to develop a nutrient budget for the Laguna. The Regional Board as regulator for Laguna water quality, and the City of Santa Rosa as the major releaser of wastewater to the Laguna should begin a much more directed and

intensive study of all nutrients in the Laguna with a view to remediating conditions to the maximum extent possible. Without significant reductions in phosphate loading to the Laguna from all sources the substantial residual phosphate remaining in the sediments will never clear. Sedimentation during the winter is still substantial and acts as a major sink for keeping precipitated phosphate from leaving the Laguna with winter flows. The assumption that by releasing phosphate when algal growth is at its seasonal low will allow it to pass out of the Laguna is totally untested and likely not to be true due to substantial physical deposition in winter and recycling of sedimentary phosphate in summer.

Recommendation: The Regional Board should establish a program with the long term goal of determining a nutrient budget for the Laguna and Russian River watersheds. Such a nutrient budget should incorporate phosphate concentration and load as a central parameter. This budget should include methods to assess the fate of nutrients as well as their loads and concentrations.

7. *Technology, where not at hand, must be developed to effectively curtail phosphorus inputs from all significant point and diffuse sources*. The most powerful technology for phosphate removal from wastewater discharges is soil filtration. The City has demonstrated this with its summer irrigation program. It is now time to address winter discharges and to seek infiltration systems that function year round. The city of Healdsburg and Cloverdale release through infiltration pits and phosphate loading to the upper Russian River appears to be significantly lower. All releasers to the Laguna and Russian River system should be encouraged to implement programs to study streamside infiltration, subsurface forest irrigation, and riparian restoration along these watersheds as alternatives to the current practice of surface discharge. Systems should be developed to allow incorporation and facility sharing with the various agricultural inputs along the Laguna to maximize the return on investment in terms of phosphate reduction. Communities such as Healdsburg which currently use infiltration should be discouraged from changing their discharge method unless it can be proven to equally effective in phosphate removal.

Recommendation: Santa Rosa, and all other municipalities discharging to the Laguna or in the Russian River watershed, should institute pilot projects incorporating known methods to reduce phosphate loads from their winter discharges. The goal of these projects should be identification of economic methods to eliminate phosphate loads. An effort should be made to insure that such projects involve biological technologies that are consistent with ongoing efforts to restore native upland and riparian habitats.

8. *Where slow flushing impedes improvement from curtailed phosphorus inputs, accessory steps to inactivate, harvest, or otherwise retrieve nutrients from lakes must be considered.* Measurements of sediment concentration in Sebastopol Pond suggest that natural phenomena exist that stimulate release of phosphate from sediments. Attempts to manipulate these phenomena could be studied for feasibility. The reductions seen in Sebastopol pond are coincidental with bacterial bioremediation programs implemented to counter excessive carbon loading from apple waste spills in that region. These same bioremediation efforts may have inadvertently resulted in biological phosphate scouring.

Recommendation: The Regional Board should encourage experimentation on techniques, both physical, chemical and biological, to reduce sediment phosphate stores or releases from those stores, as long as such techniques do not exacerbate other remediation goals.

Further recommendations specific to the Russian River watershed include:
1. Any attempt to implement "toilet to tap" projects involving release and storage of treated wastewater in Lake Sonoma from any source must incorporate stringent nutrient controls, especially with regard to phosphate.

2. All applications from any proposed treatment system or expansions from existing treatment systems that involve surface discharge to the Laguna or any watershed leading into the Russian River should incorporate strict standards for phosphate loading.

3. Communities within the watershed of the Russian River, not already connected to conventional sewage treatment plants, should be encouraged to develop localized soil-based systems such as septic-step, community leach or wastewater forest systems that allow elimination of phosphate loading and localized recharge of watersheds. Such communities should be connected to regionalized systems only if they have aggressive phosphate removal programs, and only where it can be proven that local systems cannot function.

Summary

Because studies of the role of phosphate in pollution of the Laguna de Santa Rosa have always been conducted as an afterthought subsidiary to an interest in nitrate loading, the data at hand only begins to resolve questions regarding phosphate's role. Sampling is sporadic and long-term sequences in which all relevant parameters were measured in coordinated fashion are rare.

We can see from the above analysis, however, that extant data strongly indicate phosphate is the controlling nutrient and that efforts to reduce phosphate concentration will have beneficial effects on water quality in the Laguna de Santa Rosa and the Russian River.

The City of Santa Rosa has effected a substantial reduction in its loading to the Laguna as it has increased the overall efficiency of its treatment system. That the City has been able to do so almost as a side effect indicates that a more directed effort, which would include a more comprehensive attempt to identify and reduce the loads from all phosphate releasers to the Laguna, could reap tremendous improvements in the condition of the waters of the Laguna and the Russian River with regard to phosphate. The overwhelming weight of decades of study and experience with eutrophication in freshwater environments, both in the US and worldwide, show that phosphate is central to nutrient budgets and to remediation efforts. Attempting to improve conditions in the

Laguna by continuing to ignore this central role is doomed to failure. Reconfiguring the substantial efforts, both private and public, to restore the Laguna to include control of phosphate as a central goal will magnify the effectiveness of all such efforts.

It should be recognized that over a century went into degrading the Laguna environment and it may take several years to remedy this. The sooner that interested parties design a comprehensive program, including a more thorough understanding of the limnological principles at work, the quicker the public will see improvements and the more likely they will support continued effort.

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Appendix 3. Santa Rosa Reclaimed Water Routine Constituents, mg/L except as noted. *after a constituent indicates that it was below the detection limit. The number shown is the detection limit. Bolded areas indicate months when plant not nitrifying.

	Ammonia (mg N/L)			TKN (mg/L	Nitrite (mg N/L)			Nitrate (mg N/L)			Phosphate (mg P/L)		
Date	Avg	Min	Max	compos.	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Jan-91	2.9	0.1	10.1		1.33	0.1	2.5	15.7	11.6	20	5.4	4.9	5.8
Feb-91	1.4	0.1	4.8		0.65	0.15	2	15.2	11.2	23	5.9	5.5	6.7
Mar-91	1.7	0.1	6.4		0.34	0.04	0.8	13.8	6.1	19.3	3.1	2.2	3.9
Apr-91	0.7	0.1	9		0.43	0.07	1.76	18.3	8	24.8	4.7	4.4	5
May-91	0.8	0.1	5.5		0.52	0.18	1.4	18.4	15.4	20.4	6.1	5	7.1
Jun-91	2.3	0.6	9		0.95	0.6	1.46	18.1	12	28.2	5.7	5.1	6.3
Jul-91	**17.9**	**2.1**	**29.6**		**0.79**	**0.02**	**1.86**	**3.9**	**1.1**	**12.4**	4.9	2.4	7.1
Aug-91	**17.7**	**11.4**	**25.7**		**1.98**	**0.08**	**5**	**0.7**	**0.3**	**1**	4.5	3	5.9
Sep-91	**10**	**0.1**	**25.9**		**2.6**	**0.16**	**7.3**	**6.3**	**0.8**	**16.6**	5.2	4.1	6.4
Oct-91	**5.8**	**0.1**	**16.5**		**0.57**	**0.05**	**1.7**	**15.7**	**8.7**	**20.3**	5.7	5.4	6.2
Nov-91	2.4	0.1	8.9		0.13	0.05	0.27	20.8	14.6	34	5.7	5.2	6.1
Dec-91	0.9	0.1	5.2		0.36	0.04	1.75	17.9	8.4	22.5	6.2	5.8	7
Jan-92	1.3	0.2	7.1		0.93	0.03	3.3	15.1	7.6	23.4	4.8	4.5	5.3
Feb-92	1.6	0.1	8.9		0.78	0.11	2.1	15.7	8.9	38	3.4	2.7	4.7
Mar-92	0.5	0.1	2.6		0.32	0.04	0.96	15.3	8.6	25.1	3.8	2.3	4.8
Apr-92	0.9	0.1	4.4		0.58	0.01	1.3	15.8	11.6	20.9	4.7	3.3	6.2
May-92	0.1	0.1	0.7		0.15	0.01	1.06	16.6	11.4	20.4	6	5.2	7.1
Jun-92	0.6	0.5 *	1.9		0.13	0.01 *	0.6	19	15.4	24.5	6	5.1	7.7
Jul-92	0.9	0.5 *	1.8					19.2	16.7	21.5	6	4.6	8.4
Aug-92	0.9	0.5 *	2.6		0.03	0.01 *	0.16	16.1	12.6	20.7	5.6	5.2	6.2
Sep-92	2.5	0.5 *	7.8		0.15	0.01 *	1.6	16.5	9.7	23.1	6.4	5.2	7.8
Oct-92	2.7	0.9	8.5		0.08	0.01 *	0.42	22.3	10.7	37.8	4.5	3.9	5.4
Nov-92	3.8	1.1	14.9		0.15	0.01 *	0.6	23.8	16.1	34.4	5.4	4.4	6.2
Dec-92	3.4	0.5 *	14.5		0.02	0.01 *	0.14	24.1	14.9	44.4	5	4.3	6.5
Jan-93	2.7	0.6	7.8		0.02	0.01 *	0.07	16.7	9.5	28.6	4.3	3.2	6
Feb-93	2.1	0.5	5.4		0.01 *	0.01 *	0.03	16.6	8.8	21.6	3.6	2.6	4.1
Mar-93	2.2	0.5	5.9		0.06	0.01	0.64	18.5	12.9	24.3	4.2	3.6	4.8
Apr-93	2.4	0.5	7.5		0.02	0.01	0.09	17.7	12.6	22.4	4.1	3.1	4.8
May-93	**16.1**	**0.5**	**37**		**0.42**	**0.01**	**1.1**	**9.6**	**5.4**	**21.9**	4.2	4	4.6
Jun-93	**24.6**	**11.8**	**40.3**		**0.64**	**0.31**	**0.9**	**7.7**	**3.7**	**14.6**	2.8	2.5	3.5
Jul-93	**18.4**	**6.3**	**37.4**		**0.7**	**0.31**	**1.28**	**6.4**	**0.4**	**14.9**	2.9	1.8	4.9
Aug-93	1.9	0.5 *	3.7		0.19	0.01 *	2.5	20.9	15.1	27.4	5.3	4.1	8.1
Sep-93	1.9	0.7	4.3		0.01 *	0.01 *	0.05	21	16.2	26.4	3.8	3.4	4.3
Oct-93	1.9	1	4.2		0.02	0.01 *	0.11	20.2	15.1	27.8	3.6	3	4
Oct-93													
Nov-93	3	1.1	6.3		0.03	0.01 *	0.26	13.6	8.9	16.9	3.6	2	4.1
Dec-93	2.6	0.5 *	7.6		0.04	0.01 *	0.2	14.9	9.6	19.9	3.3	2.4	4.2
Jan-94	3	0.5 *	9.7		0.04	0.01 *	0.16	15.6	11.9	18.5	3.4	2.6	3.6
Feb-94	2.3	0.5 *	4		0.02	0.01 *	0.05	16.2	9.6	28.5	2.7	2.1	3.3
Mar-94	2.5	0.9	8.1		0.03	0.01 *	0.12	22.4	13.4	36.1	3.6	3.3	3.8
Apr-94	2.5	0.9	4.9		0.02	0.02	0.03	22	16.5	32.4	3.6	3.4	3.9
May-94	1.6	0.6	7.7		0.03	0.01 *	0.18	19.3	13.8	28.2	3.4	3.2	3.8
Jun-94	**7.8**	**1**	**19.3**		**0.24**	**0.01 ***	**0.54**	**9.6**	**4.5**	**23.4**	1.1	0.1	2.7
Jul-94	2.8	1.8	5.1		0.05	0.01 *	0.55	15.2	10.4	25.9	2.8	2.3	3.8
Aug-94	2.3	0.5	3.4		0.02	0.01 *	0.06	16.3	12.8	23.2	3.4	2.8	3.8
Sep-94	2.3	1.8	4		0.01 *	0.01 *	0.01	23.9	17.6	50.5	3.3	3.3	3.4
Oct-94	2.3	1.9	3.2		0.013	0.01	0.03	21.8	17	23.7	4.6	2.7	7.2
Nov-94	2.5	0.2	3.2	3.5	0.01	0.1 *	0.12	17.9	14.7	25.9	3.3	1.6	7.2
Dec-94	2.1	1	7.2		0.01	0.01 *	0.18	17.4	13	20.3	2.3	2	3
Jan-95	2.2	0.1 *	8.6		0.01	0.01 *	0.06	14.7	9.5	22.3	1.5	1	2.5
Feb-95				69.5									
		avg							avg				
	2.0	when nitrifying						18.1	when nitrifying				
	4.1	overall						16.3	overall				

Month and Day	Sampling site or pond			NH3	NO3	TON	PO4	Flow or Discharge
Oct-98								
28	Delta Pond 36" effluent				11.6	-0.1	3.7	18.7
16	Kelly Pond				1.8	2.7	1	17
21	Kelly Pond				2.4	0.8	1.2	19.01
16	Upstream Kelly Pond/Duer Crk.			0.3	1.2	1.3	1	
21				-0.1	-0.4	-0.1	0.8	
[illegible]				-0.1	-0.4	-0.1	0.8	
[illegible]	Downstream Kelly Pond/Duer			-0.1	1.6	0.7	2	
[illegible]				-0.1	4.7	1.2	2	
[illegible]				0.2	5	0.5	3	
[illegible]	Upstream Santa Rosa Crk			-0.1	0.4	-0.1	0.1	
[illegible]	Downstream S.R. Creek			-0.1	2.2	-0.1	0.6	
22	Laguna @ Trenton Healdsburg			-0.1	-0.4	-0.1	0.3	
7	RR at Wohler Bridge			0.2	-0.4	-0.1	-0.1	
14				-0.1	-0.4	-0.1	-0.1	
21				-0.1	-0.4	-0.1	-0.1	
28				-0.1	-0.4	-0.1	-0.1	
7	RR at Mirabel			0.3	-0.4	0.3	-0.1	
14				-0.1	-0.4	0.3	-0.1	
21				-0.1	-0.4	-0.1	-0.1	
28				-0.1	0.3	-0.1	-0.1	
Nov-98								
13	D-Pond 36"				3.5	1	2.9	1.4
18					3.1	0.8	3	4.2
24					4.9	1.8	3.4	34.3
4	Kelly Pond				6.1	0.6	3.2	1.1
12					7.3	1.5	3.1	0.9
18					6.4	1.1	3.1	0.8
24					3.4	2.4	2.3	0.9
4	Delta Pond 24" pipe				11	1.1	3.4	3.4
12					10.9	1	3.2	10
18					8	2.3	3.3	6
24					6.5	2.1	2.5	20
4	Laguna Wetlands				7.2	0.8	2.8	1.4
12					9.4	1.3	2.5	1.4
18					8.2	1.7	3.3	0.7
24					6.3	1.8	2.8	1.7
4	100 yd upstream Llano Rd. Brdg.			0.6	5.5	1.4	1.7	17.45
12				0.5	8.6	0.6	1.7	18.43
18				0.6	4.1	1.5	2.2	21.15
24				-0.1	1	0.8	0.6	23.49
4	Upstream D-Pond Incline Pump			1	3.6	0.9	2	
12				0.3	2.2	0.5	1	
18				0.5	1.3	0.9	1.2	
24				-0.1	1.2	1.1	0.7	
13	Upstream D-pond 36" discharge			0.2	1.9	0.4	1.1	
18				0.5	1.8	2	1.8	
24				-0.1	0.9	1.4	0.7	
13	Upstream Colgan Crk. at Laguna			0.4	0.6	0.9	0.5	
18				0.7	0.7	0.8	0.4	
24				0.1	1.4	1.9	0.8	
13	Laguna at Todd Rd.			0.4	2.3	1.2	1.7	
18				0.8	2.6	1.3	2.2	
24				0.2	2.3	1.8	1.6	
4	Upstream S.R. Crk at Delta			0.4	-0.4	0.2	-0.1	
12				0.2	0.5	0.4	0.1	

18				0.3	-0.4	0.4	-0.1	
24				-0.1	1.7	1	0.2	
4	Downstream S.R. Crk at Delta			0.4	4.8	0.4	1.4	
12				0.4	8.1	1.4	1.6	
18				0.6	4.4	1.8	1.6	
24				-0.1	3.7	2	1.2	
4	Upstream Duer Ck. at Kelly			0.6	0.4	0.9	1.2	
12				0.2	0.5	0.8	0.8	
18				0.4	0.5	0.8	0.5	
24				-0.1	-0.4	1.8	3.1	
4	Downstream Duer cr. & Kelly			0.5	4.4	0.9	2.6	
12				0.3	5.9	1.1	2.8	
18				0.3	5.9	1.4	3	
24				-0.1	2.7	3.2	2.2	
4	Russian River at Wohler Brdg.			0.3	-0.4	0.5	-0.1	
12				-0.1	-0.5	-0.1	-0.1	
18				0.2	-0.4	0.4	-0.1	
24				-0.1	0.6	1.2	0.5	
4	Russian River at Mirabel			-0.1	-0.4	-0.1	-0.1	
12				-0.1	-0.5	-0.1	0.2	
18				-0.1	-0.4	0.5	-0.1	
24				-0.1	0.8	0.8	0.5	
Dec-98								
1	D-Pond at 36"Discharge			0.9	6.3	1.5	3.3	38.7
9				0.5	6.5	2.2	2.3	24
16				0.5	7.4	0.7	2.2	4.9
22				0.3	7.3	1.3	2.1	3
29				0.2	7.4	1.5	2.1	1.9
9	Brown Pond			0.3	5	2.1	1.8	18.4
16				0.6	4.8	1.8	2.4	2.4
1	Kelly Pond			0.4	3.8	1.6	2.1	1.2
9				0.2	4.9	1.7	2.1	0.9
16				0.4	5.2	0.6	1	NA
22				0.2	6.2	1	1.8	0.9
29				0.1	7.7	1.5	2.3	1
1	Laguna Wetlands			1.2	6.2	1.1	2	1.5
9				0.9	8.3	0.7	1.8	1.2
16				0.5	7.4	0.8	1.9	1.4
22				0.4	9.7	1.2	2.1	1.5
29				0.8	9.1	0.5	3.2	1.7
2	Delta at 48" Discharge			0.5	-0.4	0.1	1.6	32.7
9				0.2	-0.4	2.1	1.1	8.1
1	100 yd Upstream Llano Bridge			0.8	3.1	2.3	1	28.11
9				0.2	3.2	1.2	0.5	21.61
16				1	4	1.9	0.6	21.09
22				0.4	1.5	0.3	0.5	19.98
29				0.3	1.3	0.6	0.3	17.41
1	Upstream D-pond Incline pump			0.8	3.2	2.2	1.1	
9				0.2	4	1.8	0.8	
16				0.7	2.4	0.5	1	
22				0.4	5.4	1.1	1.3	
29				0.4	5.7	0.4	0.8	
1	Upstream D-Pond 36" Discharge			0.9	3.1	1.3	1.1	
9				0.3	2.3	1.4	0.8	
16				0.5	3.8	1.2	0.9	
22				0.4	4.5	0.1	1.1	
29				0.3	5.2	0.9	1.7	
1	Colgan Ck Upstream Laguna			2.2	1.9	2.7	1.7	

9				1.4	1.8	2	1.1	
16				2.2	1.9	1.3	0.8	
22				11.8	3.1	6.9	2.5	
29				11.9	2.5	5.9	1.6	
1	Laguna at Todd Rd.			0.9	4	1.5	1.9	
9				-0.1	5	1.6	1.6	
16				0.5	4.8	1	1.2	
22				1	4.2	0.6	1.2	
29				1.4	5	1.5	1.6	
9	Laguna at Hwy 12			0.4	3.6	1.6	1.6	
16				0.5	3.5	0.8	1.1	
9	Upstream Duer at Kelly			0.5	1.1	1.1	0.9	
16				-0.1	0.8	1.3	0.5	
22				0.5	0.9	0.2	0.3	
29				0.2	1.4	0.4	0.2	
1	Downstream Duer/Kelly			0.6	1.9	0.8	1.3	
9				0.2	3.4	2.3	1.7	
16				0.5	4	0.6	1.5	
22				0.3	5.5	0.8	1.7	
29				0.3	3.9	1	1.6	
2	Laguna at La Franchi			0.5	1.3	0.7	1.3	
9				0.3	2	1.8	1.1	
2	Laguna upstream at Delta			0.5	1.4	1.6	1.5	
9				0.8	3.2	1.5	1.4	
2	Downstream SR Crk at Delta			0.4	1.5	0.3	0.2	
9				-0.1	1.3	1.1	0.1	
9	Russian River at Wohler Brdg.			0.3	0.4	0.4	0.4	
16				0.2	0.5	0.8	-0.1	
22				0.5	0.5	0.1	-0.1	
29				0.3	0.5	0.5	-0.1	
9	Russian River at Mirabel			0.5	0.7	0.6	0.4	
16				0.3	0.9	0.7	0.3	
22				0.4	0.7	0.2	0.1	
29				0.3	0.6	0.1	-0.1	
Jan-99								
13	Brown Pond			0.4	7.8	1.4	2.8	6.6
20				1.3	7.1	1.9	3.1	8.3
27				1.2	6.8	1.6	3.2	4.3
13	D-Pond 36" Discharge			0.5	7.5	1.5	2.2	5
20				0.7	8.2	2.1	2.4	48.2
27				0.8	8.3	0.9	2.5	27
6	Kelly Pond			0.3	3.3	0.1	2.6	1.1
13				0.2	7.6	0.9	2.7	0.9
20				0.3	6.3	1.4	2.8	0.7
27				0.3	8.1	0.6	2.9	0.8
6	Laguna Wetlands			0.6	4.2	0.3	2.7	1.3
13				0.7	9.8	0.6	3.6	1.7
20				1.4	8.9	2.4	3.3	1.3
27				0.3	8.5	1.3	2.8	1.6
13	Delta Pond 48" Discharge			0.6	4	1.8	2.7	4.1
20				0.7	3.3	1.9	1.4	2.7
27				0.3	6.6	2.4	2.4	23
6	100 yd upstream Llano Bridge			0.1	1	1.1	0.3	
13				0.1	-0.4	0.1	0.3	18.75
20				0.9	1.8	3.4	1	38.2
27				0.9	2	0.5	0.7	22.49
13	Colgan Creek upstream			3.2	2.8	2.6	0.8	
20				2.4	1.6	3.7	1.6	

27		1.8	1.4	1.1	0.9	
6	Upstream D-Pond Incline Pump	0.3	0.4	2	1.2	
13		0.6	6.3	0.9	1.9	
20		1.1	2	0.3	1.1	
27		0.8	2.5	1	0.9	
13	Upstream D-Pond 36" Discharge	0.5	4.9	1.1	1.9	
20		0.9	1.8	2.4	1.2	
27	.	0.4	2.5	1.4	0.7	
13	Laguna at Todd Rd.	0.5	6	1.1	1.9	
20		1.1	3	3.4	1.5	
27		0.7	5	1	1.5	
13	Laguna at Hwy 12	0.4	5.3	1.4	1.9	
20		0.7	2	3	1.3	
27		0.3	4.4	0.1	1.4	
6	Upstream Duer Creek/Kelly	0.3	7.1	1.7	0.9	
13		0.2	0.7	1	0.4	
20		0.4	1	2	0.7	
27		0.3	0.9	0.4	0.4	
6	Downstream Duer Creek/Kelly	0.6	10.1	0.1	1.5	
13		0.4	6.3	0.8	2.2	
20		0.3	1.1	2.2	0.8	
27		0.2	4.6	0.3	2.1	
13	Laguna at La Franchi	0.2	1.6	1.4	1	
20		0.5	0.7	1.2	0.4	
27		0.6	2.1	0.1	1.1	
13	Upstream Laguna at Delta	0.5	1.8	1.4	0.7	
27		0.6	2.5	1.2	1.3	
13	Downstream S.R. Creek/Delta	0.2	-0.4	0.4	-0.1	
20		-0.1	1.2	1.8	0.3	
27		0.2	1.1	0.1	-0.1	
6	Russian River at Wohler	0.1	-0.4	0.1	-0.1	643
13		0.2	-0.4	0.1	-0.1	502
20		-0.1	0.4	-0.1	0.5	2847
27		0.2	0.4	0.2	-0.1	3341
6	Russian River at Mirabel	0.1	-0.4	0.3	-0.1	
13		0.1	-0.4	0.3	-0.1	
20		0.3	0.6	1	0.6	
27		0.3	0.9	0.1	0.3	
Feb-99						
12	Alpha Pond	2.8	5	1.3	1.9	24.8
17		4.1	4.7	1.5	1.3	20
3	D-Pond 36" Discharge	1.6	7.3	1.9	2.5	17.2
10		2.3	6	1.5	1.7	49.7
17		2.8	NA	0.4	1.2	26.8
3	Kelly Pond	0.2	6.7	1.5	2.6	1
10		0.4	4.8	0.2	1.6	0.9
18		0.8	3.5	1.7	1.1	0.9
3	Laguna Wetlands	1.6	NA	1.7	2	
10		1.6	2.2	1.2	0.9	
17		0.7	1.2	0.1	0.9	
3	100 yd Upstream Llano Bridge	0.3	2	1.7	0.5	21
10		0.4	1.3	3.3	0.5	41.35
17		0.2	0.7	2.5	0.9	52.13
3	Colgan Creek Upstream	2.5	2.7	2.9	1.4	
10		0.7	1.2	3.2	1.2	
17		0.8	0.8	1.1	1	
3	D-Pond Upstream Incline Pump	0.6	2.6	1.6	0.7	
10		0.6	1.3	1.7	0.6	

17		0.6	0.8	1.1	0.8	
3	D-Pond Upstream 36" Discharge	0.3	2.4	2.1	0.7	
10		0.4	1.2	2.4	0.7	
17		0.6	0.7	1.5	0.8	
3	Laguna at Todd Rd.	1.4	4.4	0.9	1.4	
10		0.9	2.2	0.9	0.9	
17		NA	0.9	NA	NA	
12	Upstream Roseland Ck. at Llano	0.3	3.1	1.1	0.2	
17		0.1	1	2.1	0.6	
12	Downstream Roseland/Summer	2.1	4.5	1.3	1.6	
17		1.8	2.4	1.1	0.9	
3	Upstream Duer/Kelly	0.1	1	2.1	0.4	
10		-0.1	0.7	-0.1	0.4	
17		0.2	0.5	1.7	0.5	
3	Downstream Duer/Kelly	0.2	4.6	0.9	2	
10		0.4	1.7	0.2	0.9	
17		0.7	3.3	1.5	1.2	
3	Russian River at Wohler	-0.1	0.5	-0.1	-0.1	
10		-0.1	-0.4	0.3	0.3	
3	Russian River at Mirabel	-0.1	0.9	0.7	0.3	
10		0.3	0.6	0.7	0.4	
Mar-99						
3	Alpha Pond	2.1	5.7	4.4	0.8	19
10		5.4	4.3	1.5	0.5	15.9
17		1.5	6.5	0.6	0.9	5
24		1	7.5	1.3	1.1	4
3	D-Pond 36"Discharge	1.6	5.1	3.7	0.9	20.5
10		2.5	1.2	2	0.8	24
17		1.8	6.1	2.1	0.8	3
24		1	5.9	1.2	0.4	
3	Kelly Pond	-0.1	2.8	3.2	1.1	0.5
10		-0.1	3.7	1.1	1	0.6
17		-0.1	4.2	1.2	0.8	0.5
24		0.1	3.8	1.8	0.9	0.5
3	Laguna Wetlands	1.9	6.3	3.7	0.8	1.6
10		4.5	4	0.2	0.6	1.8
17		-0.1	6.7	2.4	0.8	1.6
24		0.9	7.6	1.3	0.9	1.6
3	Delta Pond 24" Discharge	0.8	2.3	4.4	1.5	2.5
10		-0.1	0.8	3.2	1.6	2
16		-0.1	0.8	2.5	1.8	0.5
3	100 Yd Upstream Llano Bridge	0.1	1.3	3.2	0.4	31.99
10		0.3	0.8	2.3	0.6	29.38
17		0.5	1	1.3	0.4	25.89
24		0.1	0.8	0.1	0.3	28.89
3	Colgan Creek Upstream	0.5	1.4	3.4	0.5	
10		0.5	1.3	2.6	0.9	
17		0.2	2.3	2.2	0.6	
24		2.9	1.6	10	1.5	
3	Upstream Roseland Ck. Llano	-0.1	1.3	4.1	0.3	
10		0.3	1.7	1.2	0.3	
17		-0.1	1.8	2.4	0.1	
24		0.8	1.3	-0.1	0.2	
3	Downstrm.Roseland Crk.Llano	1.2	4	4	0.6	
10		2.7	3.3	2.3	0.5	
17		0.3	5.1	2.3	0.7	
24		0.2	5.9	1.7	0.9	
3	Laguna Upstream Incline Pump	0.3	1.4	3	0.5	

10				0.5	1	0.8	0.6	
17				0.5	1.5	1.3	0.5	
24				-0.1	1.3	1	0.4	
3	Laguna Upstream 36" Discharge			0.3	1.4	3.3	0.6	
10				-0.1	1	2.4	0.6	
17				0.9	1.5	1.2	0.6	
24				0.4	1.3	0.4	0.4	
3	Laguna at Todd Road			0.5	2.1	3.2	0.6	
10				1	1.8	1.6	0.7	
17				0.9	1.9	2.6	0.6	
24				0.6	1.6	1.3	0.5	
3	Upstream Duer/Kelly			-0.1	0.4	3.1	0.4	
10				-0.1	0.4	1	0.4	
17				-0.1	0.5	1.1	0.3	
24				0.4	0.5	0.5	0.4	
3	Downstream Duer/Kelly			-0.1	1.6	3.3	0.8	
10				0.3	1.6	1.3	0.7	
17				0.2	3	1.1	0.7	
24				-0.1	2.2	4.3	0.7	
3	Upstream S.R. Ck /Delta			-0.1	0.9	2.2	0.1	
10				-0.1	0.7	0.8	0.1	
17				-0.1	0.5	0.2	-0.1	
3	Downstream SR Ck./Delta			-0.1	0.7	3	0.2	
10				-0.1	0.9	0.7	0.2	
17				-0.1	0.7	0.7	0.2	
3	Russian River at Wohler			-0.1	0.4	2.5	0.1	7,267
10				-0.1	0.4	1.2	0.2	8,529
17				0.2	0.4	0.4	-0.1	4,431
24				0.2	0.4	1.6	-0.1	2,623
3	Russian River at Mirabel			-0.1	0.6	2.1	0.2	
10				-0.1	0.7	0.7	0.2	
17				-0.1	0.5	0.6	-0.1	
24				-0.1	0.4	0.1	-0.1	
Apr-99								
7	D-Pond 36" Discharge			0.9	5.7	2.2	0.8	6.6
14				1.2	5.5	0.7	0.8	34.3
21				1.2	5.5	1.8	1	7
7	Kelly Pond			0.4	2.9	0.9	0.9	0.7
14				-0.1	2.7	1.4	1	0.6
21				-0.1	1.9	3.6	1.1	0.5
7	Laguna Wetlands			4.2	5.8	1.2	1.2	1.7
14				2.1	5.2	2.6	2.6	1.6
21				2	6.1	1	1	1.6
7	100 Yd upstream Llano Bridge			0.7	0.8	1	0.3	22.34
14				-0.1	0.9	0.9	0.4	25.63
21				0.2	0.6	1.6	0.3	20.91
7	Colgan Creek Upstream			0.9	2.1	1.5	0.4	
14				2.1	2	1.4	1	
21				0.3	2	1.3	0.2	
7	Laguna Upstream Incline Pump			1.1	1.5	1.1	0.4	
14				0.3	1.3	1.1	0.5	
21				0.5	1.7	1.1	0.5	
7	Laguna Upstream 36" Discharge			0.8	1.3	1	0.3	
14				-0.1	1.3	1.1	0.5	
21				2	1.4	0.4	0.6	
7	Laguna at Todd Road			0.7	2.5	1.3	0.5	
14				1	4	1	0.7	
21				0.4	3	1.7	0.6	

7	Upstream Duer/Kelly			0.6	-0.4	0.2	0.3	
14				-0.1	0.5	0.7	0.4	
21				-0.1	0.4	2.1	0.3	
7	Downstream Duer/Kelly			0.6	2.1	0.7	0.8	
14				-0.1	1.9	0.9	0.8	
21				0.2	1.5	2.6	1	
7	Russian River at Wohler			0.1	0.4	-0.1	-0.1	
14				0.1	-0.4	-0.1	-0.1	
21				-0.1	0.5	1.2	-0.1	
7	Russian River at Mirabel			0.3	0.5	-0.1	-0.1	
14				0.1	0.4	0.5	0.2	
21				-0.1	0.5	2.5	-0.1	
May-99								
5	Kelly Pond			0.2	1.5	1.2	1.7	0.3
11				-0.1	1.2	1.1	1.6	0.1
5	Laguna Wetlands			1.4	5.4	1	1.2	1.6
11				0.9	4.8	0.8	0.3	0.7
5	100 Yd upstream Llano Bridge			-0.1	-0.4	0.7	0.2	21.83
11				-0.1	-0.4	-0.1	0.2	19.9
5	Upstream D-pond Incline Pump			0.3	1.7	1	0.6	
11				0.1	1.8	1.1	0.3	
5	Upstream Duer/Kelly			-0.1	-0.4	-0.1	-0.1	
11				-0.1	-0.4	-0.1	0.5	
5	Downstream Duer/Kelly			0.2	1.2	0.9	1.6	
11				0.1	0.9	0.4	1.6	
5	Russian River at Wohler			0.2	-0.4	-0.1	-0.1	940
11				-0.1	-0.4	-0.1	-0.1	955
5	Russian River at Mirabel			-0.1	-0.4	-0.1	-0.1	
11				-0.1	-0.4	-0.1	-0.1	

SANTA ROSA LONG-TERM WASTEWATER PROJECT

Name	Sample Location	Total Dissolved Solids	Chemical Oxygen Demand	Fluoride	Chloride	Nitrite as Nitrogen	Nitrite as NO3	Nitrate as Nitrogen	Nitrate as NO3	Ortho-phosphorus as P	Ortho-phosphate as PO_4	Sulfate SO_4	Hardness as $CACO_3$	Hardness (grains/gallon)
d Area West of Sebastopol														
SBS	Sebastopol-South	NA	NA	<0.1	15.8	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	50.4	54	3.2
'SM	Sebastopol-Middle	260	<5	<0.1	9.71	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	8.84	140	8.3
	Average Value	260	<5	<0.1	12.8	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	30	97.0	5.8
ohnert Park														
PS	Rohnert Park-South	340	<5	<0.1	30	<0.1	<0.3	5.5	16.9	<0.1	<0.3	21	200	12.0
PS	Duplicate of MWRPS	340	<5	<0.1	30	<0.1	<0.3	5.4	24	<0.1	<0.3	21	200	12.0
	Ave of MWRPS & Dup	340	<5	<0.1	30	<0.1	<0.3	5.5	20.5	<0.1	<0.3	21	200	12
PM	Rohnert Park-North	250	<5	<0.1	14.6	<0.1	<0.3	1.2	<0.4	<0.1	<0.3	5.7	150	8.8
	Average Value	295	<5	<0.1	22.3	<0.1	<0.3	3.3	10.3	<0.1	<0.3	13	175	10.4
na Valley														
S	Adobe-South	**500**	<5	<0.1	64	<0.1	<0.3	2.5	5.7	<0.1	<0.3	45.5	360	21
P	North Petaluma	380	<5	<0.1	82	<0.1	<0.3	1	4.4	<0.1	<0.3	36	220	13.0
N	Adobe-North	350	<5	<0.1	53	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	10	190	11.0
	Average Value	410	<5	<0.1	66	<0.1	<0.3	1.2	3.4	<0.1	<0.3	31	257	15
e-Hillside, Tolay, Sears Point														
M	Lakeville-Middle	**830**	<5	<0.1	230	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	44	120	7
N	Lakeville-North	**980**	9	<0.1	**330**	<0.1	<0.3	**12**	50	<0.1	<0.3	8.4	740	43
	Lakeville-South	470	7	<0.1	110	<0.1	<0.3	8.2	36	0.4	1.2	48	200	12
	Average Value	**760**	6.2	<0.1	223.3	<0.1	<0.3	6.8	29	0.2	0.5	33	353	20.7
o Creek														
	Americano-Middle	410	<5	<0.1	55	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	74	230	13.0
	Duplicate of MWAM	410	<5	<0.1	45	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	55	250	15.0
	Ave of MWAM & Dup	410	<5	<0.1	50	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	65	240	14.0
	Americano-Lower	**500**	<5	<0.1	35	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	89	8	0.5
	Americano-Upper	300	16	<0.1	43	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	28	130	9.4
	Average Value	403	7.0	<0.1	43	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	61	126	8.0
Creek														
	Stemple-South	**930**	16	<0.1	220	<0.1	<0.3	**33.0**	**150**	<0.1	<0.3	57	490	29.0
	Stemple/Two Rock-Lower	**1,240**	12	<0.1	**280**	<0.1	<0.3	**71.8**	**359**	<0.1	<0.3	120	540	32.0
	Stemple/Huntley-Lower	**3,530**	<5	<0.1	100	<0.1	<0.3	<0.1	<0.4	<0.1	<0.3	27	24	1.4
J	Stemple/Two Rock-Upper	330	82	<0.1	16.4	<0.1	<0.3	<0.1	<0.4	<0.1	2.1	24.2	170	9.9
	Average Value	**1,508**	28	<0.1	154	<0.1	<0.3	**26.2**	**127**	<0.1	0.6	57	306	18.1
eclaimed Water		444	NA	0.22	NA	0.3	NA	**16.3**	NA	NA	4.3	NA	NA	NA
						1		10	45					
LC		500		4	250	1		10	45			250[1]		

ary MCL All concentrations reported in mg/L (milligrams per liter) NA = Not analyzed MCL = Maximum Contaminant Level Concentrations [illegible]

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
Laguna de Santa Rosa at Stony Point Road																
24-Oct-90	1010	12.9	830	6.4	7.8	12	20		650	0.015 *	0.025 *		0.39	0.21	12	9.6
14-Dec-90	915	5.5	449	8.2	6.7	8.4	50.6		430	0.43	0.2	1.3	0.43	0.4	13	12
3-Apr-91	1030	15	366	8.3	7.35	6.9	6.8		290	0.89	0.025 *		0.4	0.29	9.1	9
12-Apr-91	1045	15	500	9.5	7.7					0.33	0.14	1.9				
30-Apr-91	1215	19.7	720	8.7	7.5	8.9	4.8	28.8	460	0.045	0.025 *			0.25	9	8.8
3-Jun-91	1230	21.2	1280	10.2	7.8	12	32	2	830	0.015 *	0.025 *		0.67	0.56	12	11
27-Jun-91	1205	18	1400	8.8	7.9	17	50	0	920	0.042	0.22	0.0058	0.68	0.4	12	11
20-Aug-91	1400	21.8	1230	7.8	7.9	6.4	16	3	810	0.015 *	0.058	1.75	0.83	0.66	12	12
11-Dec-91	1400	9.1	435	10.9	6.7	4.8	15		380	0.087	0.025 *		0.4	0.31	10	8.6
25-Mar-92	1448	17	413	9.2	7.8				280	0.7	0.19	3.74	0.59	0.57	11	11
29-Apr-92	1600	21	958	9.5	8.3	11	80	0.0003*	530	0.06	0.06	4.72	0.42	0.24	7	6.2
3-Jun-92	855	19	1072	3.1	7.9	70	60	12	650				0.66		13	10
1-Jul-92	1030	20	507	2.5	7.2	8.3	74	39	320	0.18	0.4	2.5	0.74	0.58	19	17
8-Sep-92	1300	22	1515	8.4	8.3				870	0.015 *	0.08	6.71	0.71		44	52
28-Oct-92	1130	16.5	105	6.8	7.3	99	13	38	85	0.43	0.37	2.25	0.82	0.23	13	8.3
16-Dec-92	1455	8	542	7.6	8.6	17	4	ND	350	2.4	0.36	19.8	0.51		11	7.4
17-Mar-93	1520	15	197	6.5	7.7	73	18.7	ND	210	0.61	0.3	3.72	0.68	0.55	22	19
14-Apr-93	1540	16	247	6.7	8.1	3.4	2.75 *	2.75 *	520	1.2	0.25	8.00	0.28	0.17	24	16
12-May-93	1350	19	819	10.7	8.1	19			500	0.03	0.025 *		0.73	0.21	14	9.8
16-Jun-93	1620	30	1260	7.8	6.8	22.7	18.7	7.48	340	0.015 *	0.025 *		0.33	0.24	12	12
18-Aug-93	920	20	1257	2.2	9.4	25	42.6	5.37	680	0.02	0.025 *		0.54	0.33	17	13
19-Oct-93	1355	21	712	6.8	7.6	11.2	13	2.78	433	0.9	0.2	2.982	1.12	0.6	17	17
14-Dec-93		10	240	6.7	7.6	33	4.6	5.1	185	26.7	0.3		1.00	0.56	12.0	12.0
22-Mar-94	1455	16.5	809	17.0	8.2	6.5	32.0	0.2 *	506	0.7	0.05 *		0.5	0.2	8.8	8.1
25-Apr-94	1545	14.5	391	5.6	7.4	25.5	6.9	1.7	226	0.4	0.05 *		0.52	0.34	10.0	13.0
24-May-94	1610	24.0	795	8.4	8.3	9.0	18.7	8.41	226	0.4	0.05 *		0.95	0.72	7.4	7.5
23-Jun-94	1623	23.2	1317	6.1	8.2	11.5	18.0	2.9	823	1.1	0.05 *		1.2	1.2	15.0	14.0
25-Aug-94	1730	18.8	1223	5.2	8.7	3.5	2.4	6.4	763	1.8	0.05 *		0.7	0.7		
25-Oct-94	1610	15.5	933	9.6	6.5	4.9	3.2	11.0	518	2.0	0.05 *		0.5	0.5	84	11.0
Laguna de Santa Rosa at Todd Road																
24-Oct-90	1040	12.5	960	3	8.3	5	46.5		760	0.015 *	0.62	26.78	1.7	1.4	24	23
14-Dec-90	1035	9.6	650	10.2	7.1	17	22.1		540	7.2	0.56	1.26	4.1	3.8	12	10
3-Apr-91	1130	18	434	9.4	7.3	13	38.8	24.6	330	5.3	0.22	1.5	1.8	1.7	11	11
30-Apr-91	1300	18.5	650	2.5	7.2	8	15.5	23.2	430	1.4	2.2	12.3		3.3	12	11
3-Jun-91	1254	21.5	980	6.8	7.8	12	24	11	640	0.21	2.4	0.065	2.2	1.9	18	16
27-Jun-91	1230	18	1000	7.6	8.1	17	117	2	670	0.042	0.025 *		1.4	1.3	20	16
20-[illegible]-91	1428	21	970	8.6	8.3	17	235	1	640	0.015 *	0.025 *		2.7	1.6	27	[illegible]2

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
11-Dec-91	1425	7.7	343	8.4	7.5	3.1	91	597	320	0.015 *	0.025 *		0.71	0.56	12	10
25-Mar-92	1505	17	523	6.6	7.5				340	5.4	0.38	3.79	2.3	2.3	11	11
29-Apr-92	1535	21	750	8.4	8.9	12	35	16	440	5.2	0.1	25.3	1.9	1.6	7.7	6.6
3-Jun-92	911	19	1096	0.4	8.1	40	147	64	650				1.4		25	17
1-Jul-92	1000	20	521	2.3	7.4	30	114	45	320	0.07	0.54	5.34	1.2	0.86	17	16
8-Sep-92	1240	23	1089	13.1	9.2				650	0.015 *	0.08	35.12	1.8		24	20
28-Oct-92	1645	17	205	7.2	7.5	22.6	0	2	420	0.015 *	0.07	0.7	2	1.6	18	16
16-Dec-92	1430	10	583	6.7	7.1	11	17.4	4.1	390	9.7	2.5	5.2	2		10	8
17-Mar-93	1700	15	217	5.8	7.7	55	18	4.5	220	0.95	0.41	5.08	0.9	0.83	18	15
14-Apr-93	1520	16	579	4.8	7.4	16.7	3.15 *	3.15 *	390	6.2	1.4	9.17	1.9	1.7	26	17
12-May-93	1425	16	898	6.9	7.7	33			540	0.85	2.4	31.16	1	0.91	29	9.2
16-Jun-93	1740	27	878	11.2	8.4	20.2	120	48.1	290	0.21	0.11	14.43	1.1	0.63	21	18
18-Aug-93	848	22	1055	2.5	9.3	47	96.1	17.5	600	0.028	0.064	28.769	1.1	0.66	34	22
19-Oct-93	1331	17	504	2.3	7.1	16.6	12.5	1.25	206	0.9	1	3.6594	1.51	0.8	22	18
14-Dec-93		10.5	212	6.9	7.9	29	13.4	0.05 *	168	22.9	0.7		1.50	0.80	12.0	10.0
22-Mar-94	1645	12.5	880	9.3	8.3	17.5	0.1 *	292	486	1.6	2.4		1.4	0.5	16.0	12.0
25-Apr-94	1600	14.9	484	6.8	7.5	15.2	21.4	19.0	228	0.9	0.2		0.51	0.44	14.0	14.0
24-May-94	1700	22.8	594	6.6	8.3	28.0	46.4	7.21	228	0.4	0.05 *		0.58	0.32	10.0	9.8
23-Jun-94	1607	23.1	822	4.2	8.3	15.0	32.0	6.1	490	0.6	0.05 *		1.1	1.0	13.0	12.0
25-Aug-94	1800	21.0	732	4.8	8.3	24.0	43.0	212	618	1.6	0.05 *		0.6	0.5		
25-Oct-94	1545	14.0	636	3.1	7.1	7.5	7.6	47.0	428	2.0	0.05 *		1.2	1.0	59	17.0
Laguna de Santa Rosa at Highway 12																
24-Oct-90	1135	12	169	2	6.9	4	15.8									
14-Dec-90	1110	6	580	9.7	6.1	9.2	38.8									
3-Apr-91	1150	18	430	11.4	7.3	18	11.1	67.8								
30-Apr-91	1400	18.2	550	9.2	7.5	16	100.8	135.8	400	0.15	0.059	0.6		1.1	14	13
3-Jun-91	1320	20	680	5.8	7.5	53	64	56								
27-Jun-91	1248	18	590	7.5	7.5	21	36	14								
20-Aug-91	1500	22.7	342	6.4	7.7	22	0	60								
11-Dec-91	1450	9.7	441	11.8	7.3	6.4	101	823								
25-Mar-92	930	14	473	5	7.4				280	2.2	0.24	1.52	1.8	1.9	14	14
1-Jul-92	1100	19	986	7.4	7.5	50			590	1.6	0.21	2.42	1.9	1.8	17	16
8-Sep-92	1220	18	680	4.9	7.8											
28-Oct-92	1630	17	647	7.5	7.2	24.5	137	17								
14-Apr-93	1405	20	620	5.2	7.6	45.4	17.6	15.2								
12-May-93	1320	15	646	8.5	7.7	81										
16-Jun-93	1500	26.5	816	3.8	6.9	61.3	3.325 *	103								
18-Aug-93	1013	21	1274	2.1	9.3	16	46.3	12								

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
19-Oct-93	1256	17	421	4.2	7.1		18.2	11								
14-Dec-93		10.5	411	6.2	7.8											
22-Mar-94	1425	16.2	709	13.6	8.6		0.1 *	246								
25-Apr-94	1440	15.4	580	10.2	7.6	26.0	64.1	13.4								
24-May-94	1535	24.0	438	1.9	8.2	34.0	30.3	16								
23-Jun-94	1548	16.8	713	7.8	3.4		14.0	11.0								
25-Aug-94	1650	17.2	461	3.5	7.9		8.2	45.0								
25-Oct-94	1520	14.0	723	3.3	6.9	10.5	29.0	137								
Laguna de Santa Rosa at Occidental Road																
24-Oct-90	1250	18.9	790	16.8	9.2	70	564		570	0.015 *	0.088	32.47	1.8	1.2	38	16
14-Dec-90	1130	8.4	600	8.4	6.7	22	27.9		530	1.6	1.1	0.91	1.9	1.8	15	14
3-Apr-91	1215	18.2	418	9.4	7.2	7.9	6.4	52.3	330	4.4	0.025 *		1.8	1.6	13	12
11-Apr-91	1615	17.6	481	14.2	8.3											
30-Apr-91	1430	22	590	17.5	8.8	26	155.9	37.7	380	0.015 *	0.025 *			1.3	15	11
3-Jun-91	1346	25	700	9.8	7.9	32	43	13	430	0.015 *	0.025 *		2.1	1.7	12	10
27-Jun-91	1305	21.5	730	11.4	8	29	85	0	440	0.051	0.071	0.003	1.3	1.2	12	11
20-Aug-91	1530	27	940	10.2	8.7	29	43	6	550	0.015 *	0.14	31.53	2.2	1.6	14	4.3
11-Dec-91	1520	9.6	415	6.2	7.5	22	66	303	390	0.015 *	0.063	0.36	1.3	1.2	15	13
25-Mar-92	1410	16	417	5.3	7.4				260	2.4	0.32	2.36	2.1	1.4	15	13
29-Apr-92	1500	20		5.6	7.8	30	67	36	370	0.015 *	0.1	2.44	1.8	1.1	15	13
3-Jun-92	955	24	738	3	7.6	85	84	31	460				1.6		14	14
1-Jul-92	910	20.5	802	4.8	7.6	45	100	0.0005*	490	0.015 *	0.14	2.25	1.3	0.86	12	11
8-Sep-92	1155	27	1150	8.8	8.3				720	0.015 *	0.025 *		2.3		23	22
28-Oct-92	1412	17.5	646	7.9	7.7	28.5	107	3	410	0.42	0.41	0.67	1.4	0.84	12	11
16-Dec-92	1310	10	554	4.4	6.8	12.4	5.4	25	360	8	2	2.15	2.6		13	11
17-Mar-93	1430	15	455	7.8	7.5	45	21.4	4.8	320	2.2	0.73	6.44	1.6	1	17	14
14-Apr-93	1250	15	623	6	8.2	14.5	94.4	3.15 *	330	3.2	0.13	0.13	1.3	1.2	22	20
12-May-93	1140	23	546	9	7.7	51			420	2	0.2	4.36	1.2	1	13	11
16-Jun-93	1337	24	585	3.7	7.3	77.6	33.4	27.4	140	0.05	0.26	2.50	1.3	1.2	14	16
18-Aug-93	1745	28	696	8.4	7.6	50	67.6	24.5	390	0.023	0.13	3.1569	1.8	1.4	37	17
19-Oct-93	1145	18	430	1.3	7	14.4	2.14	2.72	266	1.1	0.5	1.5689	1.95	1	20	17
14-Dec-93		10.5	403	4.7	7.7	47	13.4	0.05 *	239	36.6	1.2		2.30	1.40	13.0	13.0
22-Mar-94	1310	15.2	689	9.8	8.0	38.0	61.8	0.2 *	356	1.6	0.2		1.3	0.8	13.0	9.9
25-Apr-94	1335	14.2	603	13.5	8.6	39.0	105	12.0	326	0.5	0.05 *		1.6	1.09	7.5	13.0
24-May-94	1440	27.0	480	13.1	8.8	32.0	41.4	2.54	326	0.4	0.05 *		1.89	1.54	9.6	12.0
23-Jun-94	1512	31.1	566	7.9	8.3	22.5	15.0	6.7	347	0.4	0.2		1.9	1.8	10.0	10.0
25-Aug-94																
25- -94																

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
Laguna de Santa Rosa Upstream of Santa Rosa Creek																
24-Oct-90	1340	17	177	4.3	7.4	42	11.9		190	0.45	0.39	3.09	0.64	0.36	5.7	3.4
14-Dec-90	1228	7	520	9.2	6.9	22	15.7		470	1.6	0.98	1.44	2.2	0.91	19	13
3-Apr-91	1430	18.6	299	4.45	6.9	18	7.3		250	1.6	0.11	0.3	1.6	1.5	15	14
30-Apr-91	1455	19	550	10.8	7.7	35	24.6	268.5	370	0.11	0.025 *			1.1	15	11
3-Jun-91	1435	23.2	472	8.3	7.5	29	46	33	330	0.25	0.088	0.0014	1.1	1.1	8.2	7.2
27-Jun-91	1348	20	230	6.5	7.5	53	14	56	210	0.18	0.31	0.0038	1.2	1.1	5.8	4.5
20-Aug-91	1610	24.5	219	11.8	8.8	30	32	43	190	0.077	0.073	18.4	1.5	1.7	5.2	14
11-Dec-91	1600	9	360	8	7.6	9.7	262	303	350	0.19	0.14	0.95	1.2	0.88	14	12
25-Mar-92	1330	16	463	4.6	7.3				280	3.5	0.2	1.17	1.6	1.6	13	12
29-Apr-92	1355	21	560	2.6	7.1	38	98	9	360	0.06	0.17	0.91	1.2	1.2	15	13
3-Jun-92	1030	21	511	2.7	7.1	130	134	25	570				2.6		19	16
1-Jul-92	845	19.5	398	4.6	7.3	3.5	13	0.0005*	250	0.18	0.07	0.53	0.18	0.16	7.9	8
8-Sep-92	1100	20	299	6.1	7.7				220	0.015 *	0.025 *		2		10	10
28-Oct-92	1320	16.5	592	4.8	7.3	36.5	54	0	380	0.28	0.4	2.4	1.2	0.72	12	11
16-Dec-92	1140	9	380	3.4	6.7	30	5.4	0.3	290	3.9	0.92	0.73	1.9		19	16
17-Mar-93	1300	15	189	7.4	7.9	59	26.7	ND	190	0.46	0.1	1.95	0.33	0.21	11	11
14-Apr-93	1141	15	434	9.6	8.1	23.4	86.6	2.55 *	310	1.3	0.025 *		1.2	0.85	22	18
12-May-93	1045	16	589	5.7	7.4	67			400	0.66	0.025 *		1.3	1.1	20	14
16-Jun-93	1156	24	622	3.6	6.9	51.5	160	12.7	150	0.2	0.14	0.54	1.6	1.5	20	20
18-Aug-93	1405	26	464	7.6	7.3	31	94.3	12.8	280	0.016	0.025 *		0.63	0.44	16	13
19-Oct-93	1039	18	464	0.07	7	9	2	1.07	261	0.4	0.025 *		2.98	0.9	25	18
14-Dec-93		10	146	9.7	7.6	59	10.7	0.05 *	116	12.1	0.1		0.48	0.19	8.7	8.2
22-Mar-94	1125	13.5	621	7.9	6.8	32.0	8.9	50.9	330	1.1	0.05 *		1.2	0.7	17.0	10.0
25-Apr-94	1245	14.2	193	8.3	7.7	11.4	3.7	1.9	48	1.0	0.05 *		0.23	0.12	7.2	ND
24-May-94	1338	20.0	469	2.0	7.7	37.0	51.6	15.7	48	0.5	0.1		2.46	1.96	9.9	11.0
23-Jun-94	1410	23.9	419	7.2	7.8	23.0	61.0	0.2 *	337	0.3	0.05 *		1.4	1.3	7.7	8.3
25-Aug-94	1510	22.5	259	8.2	8.2	35.5	48.0	173	219	0.7	0.05 *		2.2	1.8		
25-Oct-94	1325	14.8	475	7.2	6.8	22.9	0.1 *	66.0	281	1.6	0.1		0.7	0.5	46	8.8
Laguna de Santa Rosa at River Road																
24-Oct-90	1430	16.5	443	7.2	7.7	6.1	3.8		350	0.047	0.025 *		0.27	0.22	7	6.2
14-Dec-90	1330	7	394	10.2	7	5.5	11.4		380	1	0.47	0.69	0.81	0.75	16	9.2
3-Apr-91	1510	17.5	279	7.6	7.15	18	4		220	1.3	0.1	0.5	0.91	0.8	9.9	9.2
11-Apr-91	1520	15.5	392	10.2	7.4					2.9	0.057	0.4				
30-Apr-91	1545	20	474	8.6	7.7	17.5	37.1	29.1	320	0.22	0.09	1.8		0.61	7.9	6.3
3-Jun-91	1505	22.5	520	6.4	7.5	28	11	29	350	0.066	0.14	0.0021	0.61	0.43	4.6	4.9
27-Jun-91	1413	20	550	4.2	7.5	28	11	12	350	0.1	0.17	0.0021	0.58	0.4	3.9	4.1
20-Aug-91	1638	22	590	6.2	7.9	13	13	7	370	0.015 *	0.11	3.51	0.5	0.36	4.8	4.6

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
11-Dec-91	1645	10	380	10.4	7.6	3.5	22		360	2.9	0.099	0.73	1.3	1.1	7.8	7.3
25-Mar-92	1103	14	428	5.4	7.6				260	2.3	0.06	1.6	1	0.93	8.7	8.2
29-Apr-92	1015	20	512	4.9	7.5	20	368	284	320	0.1	0.13	1.61	0.84	0.57	6.7	5
3-Jun-92	1100	21	570	3.5	7.5	55	20	6	350				0.65		6.6	5.6
1-Jul-92	750	17.5	356	5.6	7.5	19	27	0.0005*	230	0.28	0.15	1.55	0.4	0.29	11	11
8-Sep-92	1025	19	683	6.8	8				410	0.015 *	0.025 *		0.57		12	5.6
28-Oct-92	1125	16	576	7.8	7.7	11.4	21	9								
16-Dec-92	935	8	361	5.5	6.9	27	4	1.6								
17-Mar-93	1150	14	162	6.4	7.5	53	16	14.2								
14-Apr-93	1015	13	446	8.8	8.3	12.4	40.6	2.9 *								
12-May-93	938	16	520	6.3	7.8	40										
16-Jun-93	1028	22.5	738	3.4	7.4	30.9	4.45	8.01								
18-Aug-93	1118	22.5	604	2.8	7.5	26	12.8	0.29 *								
19-Oct-93	905	17	432	1.7	6.9		4	3.16								
14-Dec-93		9	169	9.3	7.4		8.0	0.1							11.0	9.9
22-Mar-94	1020	13.8	531	8.1	8.2		0.1 *	13.1								
25-Apr-94	1210	13.9	367	7.4	7.5	20.5	32.0	2.0	174	0.6	0.05 *		0.53	0.35	8.9	12.0
24-May-94	1305	19.0	494	5.2	8.1	15.0	17.2	2.76	174	0.8	0.05 *		0.79	0.62	7.0	6.9
23-Jun-94	1305	17.2	451	5.0	7.4	1.8	1.0	3.4	346	2.0	0.3		0.2	0.2	3.7	3.5
25-Aug-94	1410	17.5	832	7.4	7.3	2.0	0.5	1.7	566	8.7	0.2		0.4	0.4		
25-Oct-94	1250	13.0	541	4.4	6.7	0.8	0.6	4.1	360	1.7	0.3		0.2	0.2	51	3.3
Laguna de Santa Rosa at Trenton-Healdsburg Road																
24-Oct-90	1500	18.3	460	9.5	8.1	7.3	3.3									
14-Dec-90	1358	7	392	10.5	6.9	4.7	6.7									
3-Apr-91	1520	17.8	280	7.7	7.1	16	3.3									
30-Apr-91	1555	22	460	9.4	7.8	9.7	70.4	27.2	320	0.2	0.095	2:7		0.58	8	7.1
3-Jun-91	1518	22.5	520	7.6	7.7	17	21	23								
27-Jun-91	1423	20	520	7.6	7.5	15	16	10								
20-Aug-91	1700	22	580	7.8	7.9	12	8	1								
11-Dec-91	1655	9	375	10.5	7.5	3.1	25									
25-Mar-92	1122	14	420	6.9	7.6											
29-Apr-92	1030	20.5	510	6.2	7.6	18	4	9	310	0.14	0.11	1.77	0.8	0.57	6.8	4.9
3-Jun-92							20	10								
25-Apr-94	1150	14.0	336	8.2	7.7	29.5	11.0	2.8								
24-May-94	1225	19.0	484	6.3	8.2	18.0	18.2	2.03								
23-Jun-94	1225	21.8	599	6.2	8.0		1.0	9.0								
25-Aug-94	1345	19.2	652	5.8	7.8		0.3	1.8								
25-[illegible] 94	1000	13.0	603	7.8	6.7	2.8	1.2	-								

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
Santa Rosa Creek at Willowside Road																
24-Oct-90	1305	17.2	540	11	8.4	1.5	1.6		380	0.035	0.025 *		0.1	0.092	5.2	4.3
14-Dec-90	1157	7.5	325	11.2	7.5	1.8	6.7		320	0.29	0.025 *		0.14	0.14	5	4.7
3-Apr-91	1330	19	328	13.4	8.4	3.2	3.9		230	1	0.099	8.4	0.062	0.033	3.5	4.3
11-Apr-91	1555	17	377	16.9												
30-Apr-91	1515	19.5	495	9.5	8.1	2	7.7		310	0.35	0.056	2.5		0.11	4.5	4.4
3-Jun-91	1412	23.5	600	10.4	8.2	1.4	2	3	370	0.015 *	0.058	0.0044	0.14	0.14	2.8	3
27-Jun-91	1335	21	600	13	8.2	2.4	16	0	370	0.042	0.048	0.003	0.11	0.11	2.6	2.7
20-Aug-91	1550	26	660	12.5	8.8	1.3	3	0	380	0.015 *	0.057	14.7	0.13	0.096	4	3.6
11-Dec-91	1618	8.5	348	12.4	7.5	0.5	4		340	0.14	0.054	0.28	0.14	0.12	3.3	3.1
25-Mar-92	1307	16	425	14.6	8.7				250	0.66	1.4	180.6	0.47	0.34	9.1	6.4
29-Apr-92	1440	20	1561	12.2	8.5	2.2	10	34	330	0.04	0.025 *		0.13	0.04	3.4	2.8
3-Jun-92	1015	20	615	3.6	7.8	3.2	3	4	370				0.21		4.4	4
1-Jul-92	830	19	416	5.5	7.1	4.9	20	0.0005*	250	0.26	0.11	0.51	0.18	0.16	8.5	8.9
8-Sep-92	1130	23	692	9.3	8				410	0.015 *	0.025 *		0.13		3.5	4
28-Oct-92	1350	17	606	8.5	8.2	1	0	2	370	0.09	0.025 *		0.14	0.14	5.9	3.6
16-Dec-92	1106	8	391	10.6	7.7	7.6	5.2	ND	270	1.9	0.16	1.16	0.2		8.5	4.9
17-Mar-93	1330	15	350	7.8	7.4	52	18.7	ND	250	0.41	0.11	0.69	0.5	0.27	12	12
14-Apr-93	1214	13	559	11	8.6	1.2	2.8 *	2.8 *	270	0.3	0.025 *		0.07	0.03	25	21
12-May-93	1110	15	590	13.5	8.5	1.1			310	0.015 *	0.025 *		0.05	0.02	5.9	5.6
16-Jun-93	1243	26	770	9.4	8.3	2	1.48	1.11	200	0.015 *	0.025 *		0.23	0.08	6.1	6.4
18-Aug-93	1428	27	621	7.1	6.9	2.6			340	0.012	0.025 *		0.16	0.063	6.6	6.1
19-Oct-93	1115	17	562	7.75	7.8	4.3	10.1	1.82	319	1.4	0.025 *		0.73	<0.1	7.4	6.6
14-Dec-93		10.5	212	11.6	7.8	54	2.7	4.8	155	18.9	0.1		0.43	0.18		
22-Mar-94	1240	15.1	233	16.5	8.1	7.6	0.1 *	94.0	305	1.2	0.05 *		0.05 *	0.05 *	3.8	3.7
25-Apr-94	1305	15.0	281	11.3	7.8	9.2	4.3	2.8	98	0.9	0.05 *		0.27	0.19	11.0	10.0
24-May-94	1412	26.5	554	10.8	8.9	2.3	1.1	1.17	98	0.4	0.7		0.08	0.08	4.7	4.9
23-Jun-94	1438	29.0	611	12.3	8.5	1.8	2.1	0.2 *	361	0.3	0.05 *		0.1	0.1	4.2	5.0
25-Aug-94	1600	26.0	643	11.2	8.5	1.4	0.5	2.3	412	1.1	0.05 *		0.4	0.4		
25-Oct-94	1350	16.5	392	12.1	6.8	1.1	0.6	0.4	376	1.9	0.05 *		0.2	0.1	64	2.8
Mark West Creek at Slusser Road																
1-Jul-92	730	18.5	339	4.5	7.5	14	33	0.0005*	220	0.33	0.16	1.78	0.3	0.26	11	10
8-Sep-92	1000	19	680	3.3	7.8				400	0.015 *	0.07	1.6	0.61		5.1	5
28-Oct-92	1225	16	564	7	7.6	9.6	12	7	350	0.25	0.1	0.12	0.71	0.66	9	8.7
16-Dec-92	911	8	352	5	7.6	27	6.7	ND	300	3.5	0.61	3.53	1.5		14	10
17-Mar-93	1110	13	159	6.3	7.5	72	16	4.5	170	0.6	0.14	0.95	0.44	0.28	11	11
14-Apr-93	1048	13	286	9.4	8	2	2.9 *	2.9 *	210	0.15	0.025 *		0.14	0.09	13	13
12-May-93	953	12	337	10	7.7	1.1			250	0.07	0.025 *		0.06	0.12	3.8	2

Appendix 2. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data And Nutrients, 1990-1994. *indicates below the detection limit; number shown is one-half the detection limit. ND = undetectable, detection, limit not available.

Date	Time	Temp °C	Cond umho	DO ppm	pH	Turbid. FTU	Chl a µg/L	Phaeo µg/L	TDS mg/L	NO3-N mg/L	total NH3-N mg/L	un-ion NH3-N ug/L	Tot P mg/L	Diss P mg/L	TOC mg/L	DOC mg/L
16-Jun-93	1045	19.2	540	6.9	7.5	0.4	1.48	0.37 *	81	0.015 *	0.18	2.08	0.22	0.05	4.5	4.5
18-Aug-93	1310	20.5	514	5.6	6.8	0.1	0.135 *	1.12	290	1.6	0.025 *		0.17	0.13	4.5	7.6
19-Oct-93	950	16	342	6.6	7.3	0.4	77.6	1.2	224	0.4	0.025 *		0.23	0.05 *	6	5.1
14-Dec-93		9	111	12.5	7.7	56	0.05 *	11.2	136	8.1	0.05 *		0.57	0.16	11.0	9.4
22-Mar-94	1040	11.4	326	13.0	7.0	0.9	0.1 *	31.1	114	0.6	0.05 *		0.7	0.05 *	3.0	2.7

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
Laguna de Santa Rosa at Stony Point Road															
17-Oct-89	1445	17.3	10.0	8.0	1115	650		0.070	0.001	0.025	0.93	0.36	0.43	9.3	9.6
14-Nov-89	1315	16.5	13.2	8.5	1247	720		0.030	0.008	0.070	0.80	0.18	0.23	8.3	8.7
22-Jan-90	1250	9.6		7.5	670			1.400	0.140	0.560	1.50	0.54	0.60		
26-Jan-90	1031	8.6		7.7	787			1.300	0.230	0.080	1.50	0.46	0.40		
31-Jan-90	1225	9.5		7.7	665			0.940	0.220	0.250	1.70	0.36	0.36		
2-Feb-90	1509	10.1		7.3	378			1.600	0.590	0.640	2.50	0.92	0.76		
7-Feb-90	1225	8.3		7.4	454			0.690	0.090	0.180	1.20	0.50	0.57		
14-Feb-90	1252	9.4		8.1	794			1.400	0.320	1.400	2.50	0.79	0.91		
20-Feb-90	1139	7.1		7.0	372			0.700	0.077	0.580	1.30	0.64	0.66		
21-Feb-90	1110	9.3		7.0	414			0.650	0.058	0.220	1.10	0.45	0.58		
28-Feb-90	1409	15.1		7.9	723			0.580	0.220	0.080	1.00	0.43	0.58		
6-Mar-90	1429	14.8		7.4	410			0.600	0.100	2.400	4.30	1.30	1.60		
14-Mar-90	931	12.7		7.9	534			0.430	0.040	0.240	0.81	0.39	0.38		
23-Mar-90	1050	18.6		7.8	908			0.150	0.074	0.060	1.70	0.49	0.54		
4-Apr-90	1318	22.0		8.1	1175			0.100	0.007	0.380	0.60	0.48	0.50		
10-Apr-90	1217	20.8		8.1	1211			0.620	0.007	0.120	0.90	0.06	0.64		
18-Apr-90	1302	20		7.6	1154			0.100	0.010	0.025	1.80	0.99	1.10		
25-Apr-90	1420	26.3			1091			0.050	0.001	0.060	1.20	0.64	0.91		
1-May-90	1345	22.4		8.0	1108			0.110	0.001	0.120	1.10	0.10	1.20		
9-May-90	1120	19.3		7.8	1164			0.120	0.001	0.025	0.90	1.20	1.40		
16-May-90	1224	21.9		8.2	2020			0.070	0.001	0.025	1.00	1.40	1.40		
24-May-90	1400	25.3	10.6		405	260	17.00	0.140	0.044	0.025	0.24	0.86	0.90	17.7	12.2
5-Jun-90	1315	27.3	10.2	8.2	774	430	7.00	0.050	0.025	0.030	1.10	0.56	0.57	11.9	12.6
12-Jun-90	1320	28	10.5		1055	620	10.00	0.050	0.001	0.030	1.00	0.73	0.83	11.1	9.6
19-Jun-90	1220	28	9.7	8.1	1157	630	8.30	0.030	0.001	0.030	1.20	1.10	1.70	8.5	8.6
4-Dec-90	1015							0.130	0.048	0.025	0.10	0.20	0.26	14.0	11.0
6-Dec-90	0930							0.120	0.043	0.025	0.30	0.17	0.22	13.0	12.0
11-Dec-90	0940							1.200	0.320	0.590	1.20	0.52	0.69	18.0	15.0
13-Dec-90	0925							0.800	0.230	0.100	0.20	0.51	0.59	11.0	13.0
18-Dec-90	1012							4.800	0.230	0.160	0.81	0.69	0.79	15.0	10.0
20-Dec-90	0920							0.860	0.092	0.110	0.29	0.15	0.44	9.6	8.1
27-Dec-90	0920							0.300	0.040	0.025	0.24	0.25	0.26	10.0	6.8
3-Jan-91	0925							0.290	0.025	0.025	0.05	0.23	0.23	11.0	6.1
10-Jan-91	1005	7.7	8.6	7.9	622			0.410	0.240	0.025	0.15	0.30	0.34	8.9	9.2
15-Jan-91	0930	11.2	8.2	7.9	645			0.080	0.020	0.025	0.15	0.28	0.34	9.3	8.8
23-Jan-91	0940							0.040	0.001	0.025	0.12	0.25	0.28	8.4	8.9
30-Jan-91	0955							0.040	0.001	0.025	0.05	0.18	0.23	9.0	11.0
2-Feb-91	1540	12.8		8.0	155			2.200	0.200	0.350	0.38	0.38	0.46		
8-Feb-91	1100	11.8	4.2	7.3	425			1.400	0.360	0.920	1.10	1.20	1.20	17.0	18.0
12-Apr-91	1050	14.8	10.0	8.2	521			0.370	0.034	0.025	1.00	0.16	0.27		
17-Apr-91	1320	18.4	10.0		610			0.410	0.070	0.025	0.80	0.16	0.22		
7-Jun-91	1330	24.8	9.8	8.2	1438			0.020	0.001	0.025	1.00	0.38	0.54		

Appendix 3-1. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data and Nutrients, 1989-1992 (RWQCB data).

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
29-Jan-92	1050	9.9	8.5	8.0	802					0.100	1.10		0.38		
Laguna de Santa Rosa at Llano Road															
29-Jan-92	1155	9.6	5.0	7.7	930					7.900	14.00		0.82		
14-Feb-92	1100	11.2	7.0	7.5	360					5.000	8.81	0.00	1.40		
Laguna de Santa Rosa at Todd Road															
14-Nov-89	1345	14.4	4.4	7.4	484	320		0.550	0.076	0.830	2.30	0.80	0.91	11.8	10.8
22-Jan-90	1220	12.0		7.1	731			6.200	0.880	9.400	9.50	2.10	2.10		
26-Jan-90	1008	10.8		7.2	757			5.500	0.980	10.000	11.00	3.40	1.90		
31-Jan-90	1130	10.4		7.2	810			3.300	0.700	8.500	9.70	0.32	1.70		
2-Feb-90	1450	10.6		7.0	340			2.200	0.410	2.000	5.30	1.20	0.72		
7-Feb-90	1133	12.4		6.9	689			3.700	0.890	12.000	13.00	2.00	2.00		
14-Feb-90	1203	10.2		7.2	758			5.200	0.970	10.000	11.00	3.00	3.20		
20-Feb-90	1113	11.9		6.8	552			2.500	1.300	6.800	8.50	2.50	2.70		
21-Feb-90	1126	11.7		7.1	740			5.600	1.000	11.000	11.00	3.20	3.20		
28-Feb-90	1226	15.8		6.7	820			2.700	4.300	14.000	12.00	3.10	3.20		
6-Mar-90	1155	15.1		6.7	527			2.000	1.300	7.800	7.90	2.80	2.90		
14-Mar-90	958	15.4		6.5	751			5.600	2.600	13.000	12.00	3.10	3.30		
23-Mar-90	1024	17.7		6.7	892			7.400	3.000	15.000	19.00	4.80	5.60		
4-Apr-90	1241	19.0		6.8	876			5.300	2.000	9.600	13.00	3.80	4.10		
10-Apr-90	1155	16.7		7.2	990			0.670	0.470	11.000	17.00	3.50	3.70		
18-Apr-90	1142	17.6		7.0	1080			0.270	0.330	5.600	7.30	2.60	3.00		
25-Apr-90	1316	19.8			1148			0.250	0.500	4.500	6.90	1.60	2.00		
1-May-90	1326	20.3		7.8	1221			0.200	0.120	2.600	3.20	2.20	2.60		
9-May-90	1100	18.3		7.7	1442			0.170	0.020	12.000	16.00	4.80	6.20		
16-May-90	1155	20.5		8.2	2120			0.240	0.670	9.000	15.00	5.10	5.80		
24-May-90	1220	17.9	5.1	0.0	469	280	22.00	0.160	0.061	0.170	0.38	0.77	0.80	14.1	7.8
5-Jun-90	1220	21.7	6.1	7.2	608	380	10.00	0.200	0.340	2.000	4.80	1.20	1.10	17.8	16.0
12-Jun-90	1230	23.6	9.5		637	410	10.00	0.080	0.001	0.025	2.70	1.00	1.10	18.7	15.5
19-Jun-90	1125	23.5	8.5	7.7	685	380	9.80	0.070	0.001	0.025	2.50	0.85	0.87	17.1	21.6
4-Dec-90	0930							0.220	0.070	0.025	0.50	0.46	0.52	17.0	14.0
6-Dec-90	0900							6.200	0.290	0.660	1.00	4.00	2.60	15.0	13.0
11-Dec-90	0900							8.900	0.330	0.590	1.00	4.20	4.60	17.0	11.0
13-Dec-90	0855							6.300	0.220	0.360	0.60	2.90	3.40	10.0	13.0
18-Dec-90	0945							6.300	0.310	0.390	0.65	2.50	2.50	11.0	8.7
20-Dec-90	0855							10.000	0.400	0.420	1.20	3.70	3.70	9.9	7.3
27-Dec-90	0855							9.600	0.470	0.400	1.10	3.80	3.90	11.0	8.9
3-Jan-91	0910							10.000	0.400	0.270	0.71	3.80	3.70	12.0	10.0
10-Jan-91	920	7.1	6.9	7.6	543			0.810	0.140	0.210	0.46	0.66	0.73	10.0	11.0
15-Jan-91	0905	11.6	9.2	7.7	726			0.080	0.020	0.025	0.30	0.46	0.51	12.0	18.0
23-Jan-91	0920							0.060	0.001	0.025	0.30	0.48	0.54	11.0	10.0
30-Jan-91	0905							0.060	0.001	0.025	0.05	0.40	0.49	10.0	11.0
2-Feb-91	1430	11.8		7.8	294			1.600	0.400	0.320	0.22	0.39	0.65		
8-Feb-91	0950	10.9		7.3	422			1.600	0.400	0.960	1.10	1.30	1.30	17.0	19.0

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
10-Apr-91	1445	15.6	6.2	7.7	666			1.100	0.360	1.400	2.00	1.30	1.20		
17-Apr-91	1230	15	5.6		571			0.360	0.200	0.025	2.40	0.86	0.93		
29-Jan-92	1130	11.2	8.8	7.4	779			0.000		2.200	4.60	0.00	4.50		
Laguna de Santa Rosa at Highway 12															
29-Jan-92	1210	8.7	5.2	7.5	1452					3.500	5.90		2.10		
14-Feb-92	1220	11.2	7.0	7.5	360					4.200	9.30		5.50		
Laguna de Santa Rosa at Occidental Road															
27-Sep-89	1140	19.5	9.2	7.3	504	350		0.570	0.070	0.100	4.30	1.10	0.53	18.0	17.0
14-Nov-89	1230	15.7	9.6	7.8	371	220		0.430	0.016	0.025	3.20	0.71	1.10	9.6	9.4
22-Jan-90	1150	9.7		7.0	647			5.600	0.310	5.200	5.60	1.90	1.90		
26-Jan-90	940	9.1		7.1	671			6.500	0.200	5.000	6.00	2.00	1.60		
31-Jan-90	1054	10.3		7.1	696			5.600	0.480	4.400	4.60	1.70	1.90		
2-Feb-90	1421	11.6		7.1	649			3.100	0.360	2.500	4.00	1.20	1.40		
7-Feb-90	1103	10.4		6.9	515			3.400	0.260	1.800	4.60	1.30	1.60		
14-Feb-90	1131	10.1		7.0	680			4.900	0.490	5.600	6.30	1.90	2.00		
20-Feb-90	1030	9.9		7.1	416			3.000	0.200	0.025	2.20	1.70	2.10		
21-Feb-90	1208	10.3		6.9	463			3.100	0.180	2.600	4.80	1.60	1.60		
28-Feb-90	1154	13.7		7.0	700			4.700	0.590	4.900	5.90	3.20	3.40		
6-Mar-90	1118	15.5		6.8	410			2.200	0.220	2.800	3.90	1.50	1.80		
14-Mar-90	1031	12.3		7.0	613			3.300	0.440	3.400	3.50	1.80	2.10		
23-Mar-90	956	16.6		7.1	749			3.800	0.720	4.200	8.50	2.70	3.00		
4-Apr-90	1216	18.8		7.0	771			10.000	1.500	2.900	61.00	3.00	3.10		
10-Apr-90	1127	18.0		7.8	751			7.600	1.030	2.500	4.20	2.50	2.60		
18-Apr-90	1115	19.5		8.5	711			4.700	0.710	0.530	3.80	2.20	2.70		
25-Apr-90	1251	21.1			682			1.900	0.480	0.060	1.30	1.90	2.60		
1-May-90	1304	20.4		8.2	692			0.750	0.280	0.230	2.10	2.70	2.90		
9-May-90	1041	19.9		7.9	704			0.110	0.014	0.100	1.10	3.20	3.40		
16-May-90	1140	21.5		8.3	1019			0.080	0.048	0.150	3.70	2.20	3.00		
24-May-90	1120	19.5	11.1		693	410	27.00	0.340	0.120	0.680	0.90	2.60	2.70	24.3	12.6
5-Jun-90	1145	23.2	19.2	8.4	363	300	16.00	0.110	0.076	0.030	3.00	1.80	1.60	19.1	17.3
12-Jun-90	1200	25.7	13.2		409	300	44.00	0.080	0.001	0.030	1.40	1.80	1.90	17.8	15.0
19-Jun-90	1040	25.9	12.2	8.7	446	290	28.00	0.090	0.001	0.030	2.50	2.30	2.60	17.5	16.4
4-Dec-90	1100							0.005	0.001	0.025	0.50	0.07	0.33	18.0	15.0
6-Dec-90	1000							0.005	0.001	0.025	0.30	0.09	0.27	24.0	19.0
11-Dec-90	1025							1.500	0.078	1.400	2.00	1.50	1.50	14.0	16.0
13-Dec-90	1000							2.400	0.082	0.910	1.40	1.50	1.80	12.0	16.0
18-Dec-90	1043							6.000	0.330	0.490	1.40	2.60	3.30	14.0	11.0
20-Dec-90	0950							7.300	0.460	0.550	1.40	2.40	2.90	14.0	20.0
27-Dec-90	0956							8.100	0.350	1.100	1.60	2.90	2.80	13.0	11.0
3-Jan-91	1000							9.700	0.390	0.140	0.68	3.30	3.40	16.0	12.0
10-Jan-91	1040	7.9	8.7	7.6	860			8.300	0.270	0.390	0.59	2.80	3.00	12.0	12.0
15-Jan-91	1010	10.6	6.4	7.7	921			6.300	0.320	1.900	2.70	2.60	2.70	16.0	14.0
23-Jan-91	1015							6.300	0.430	1.600	1.80	2.60	2.80	15.0	13.0

Appendix 3-1. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data and Nutrients, 1989-1992 (RWQCB data).

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
30-Jan-91	1100							5.500	0.230	0.470	0.56	2.30	2.50	25.0	12.0
2-Feb-91	1615	11.0		7.8	760			4.200	0.160	0.170	0.25	2.10	2.20		
8-Feb-91	1150	12.3	6.5	7.3	400			1.400	0.320	0.420	0.63	1.50	1.60		
10-Apr-91	1415	17.2	14.0	8.3	575			3.900	0.140	0.025	0.99	1.80	1.90		
17-Apr-91	1215	17.6	13.8		524			1.800	0.200	0.900	2.10	1.40	1.20		
29-Jan-92	1310	10	7.1	7.3	770					0.270	2.10		3.00		
Laguna de Santa Rosa upstream of confluence with Santa Rosa Creek															
30-Aug-89	0915	18.6	2.7	7.2	234	160		0.800	0.007	0.500	0.90	0.31	0.02	2.0	2.6
18-Oct-89	1000	16.4	10.4	7.0	413	270		0.740	0.027	0.490	1.20	0.81	1.00	13.0	11.0
14-Nov-89	1120	14.8	7.4	7.1	353	210		0.400	0.022	0.025	1.60	0.52	0.73	8.8	9.1
22-Jan-90	1110	9.4		6.8	525			2.800	0.180	3.400	4.40	1.80	1.60		
26-Jan-90	910	8.8		6.9	610			3.400	0.150	4.000	4.40	1.60	1.40		
31-Jan-90	1054	9.40		7.0	652			4.700	0.330	3.200	3.30	0.31	1.20		
2-Feb-90	1353	12.2		6.9	539			2.400	0.430	2.600	3.30	1.20	0.70		
7-Feb-90	1027	9.30		6.6	399			1.400	0.190	2.000	3.40	1.10	1.30		
14-Feb-90	1047	8.60		7.0	599			2.700	0.340	4.400	5.60	1.50	1.60		
21-Feb-90	1422	12.6		6.6	309			1.700	0.080	0.030	0.88	1.14	1.30		
28-Feb-90	1110	12.7		6.9	641			3.900	0.460	2.800	2.90	0.95	1.50		
6-Mar-90	1030	13.7		6.8	521			2.900	0.410	3.600	3.50	1.70	1.80		
14-Mar-90	1149	12.3		6.9	599			3.300	0.420	3.600	4.10	1.70	1.90		
23-Mar-90	918	15.6		7.0	701			3.200	0.430	6.600	6.60	2.10	2.60		
10-Apr-90	1032	16.1		7.3	696			4.300	0.590	0.460	3.10	1.70	2.00		
18-Apr-90	0957	17.3		7.0	560			2.900	0.310	0.025	3.50	1.60	2.00		
25-Apr-90	1220	20.0			622			1.200	0.150	0.140	1.90	1.30	2.20		
1-May-90	1049	19.5			624			0.450	0.170	0.100	2.80	2.30	2.70		
9-May-90	955	18.6		7.5	470			0.150	0.020	0.003	2.70	2.40	2.50		
16-May-90	1010	19.6		7.2	625			0.590	1.000	0.250	1.30	1.80	2.20		
24-May-90	1100	17.2	8.0		564		13.00	0.350	0.104	0.700	0.80	2.20	2.30	12.2	12.2
5-Jun-90	1045	20.7	1.2	7.0	334	240	10.00	0.180	0.003	0.030	3.10	2.30	2.20	20.9	17.3
12-Jun-90	1050	22.1	16.6		419	300	29.00	0.290	0.051	0.030	2.80	2.20	2.50	17.3	13.2
19-Jun-90	1005	22	6.3	7.2	374	180	28.00	0.140	0.033	0.160	2.30	1.60	1.60	10.0	9.7
4-Dec-90	1220							1.200	0.050	0.440	0.20	0.20	0.26	3.2	1.9
6-Dec-90	1030							1.300	0.034	0.120	0.20	0.19	0.26	5.3	3.7
11-Dec-90	1100							0.560	0.056	0.290	0.40	0.45	0.51	8.7	10.0
13-Dec-90	1035							2.300	0.100	0.850	1.50	1.20	1.40	14.0	14.0
18-Dec-90	1136							6.100	0.320	0.320	1.60	2.20	2.30	14.0	11.0
20-Dec-90	1025							6.100	0.410	0.380	1.10	2.00	2.70	12.0	11.0
27-Dec-90	1030							8.000	0.330	0.800	1.40	2.70	2.70	12.0	11.0
3-Jan-91	1035							9.800	0.380	0.130	0.52	3.20	3.20	14.0	9.4
10-Jan-91	1105	7.6	8.8	7.6	803			8.400	0.350	0.320	0.64	2.40	2.50	12.0	12.0
15-Jan-91	1040	11.0	7.4	7.6	866			6.500	0.350	1.500	1.60	2.30	2.60		
23-Jan-91	1050							5.700	0.450	1.100	1.50	2.10	2.50	12.0	13.0
30-Jan-91	1215							7.200	0.240	0.180	0.23	2.00	2.20	11.0	19.0

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
8-Feb-91	1225	12.3	4.2	7.4	434			1.100	0.450	0.450	0.75	1.50	1.60	16.0	13.0
10-Apr-91	1345	16	8.1	7.7	546			2.500	0.130	0.120	0.98	1.60	1.60		
17-Apr-91	1143	16.0	7.6		485			1.400	0.160	0.100	1.80	1.20	1.40		
31-May-91	1210	22.2	9.8	7.7	510			0.220	0.100	0.025	2.80	0.98	0.72		
7-Jun-91	1520	24.1	9.4	8.0	502			0.050	0.001	0.025	1.80	0.87	1.10		
17-Jun-91	0920	19.1		6.8	290			0.110	0.040	0.025	1.10	2.00	2.00		
29-Jan-92	1530	10.9	8.2	7.4	715					0.330	1.60		3.50		
Laguna de Santa Rosa at River Road															
5-Jun-90	1245	23.2	10.2	7.6	554	230	8.00	0.100	0.001	0.030	1.80	1.20	1.20	13.6	14.2
12-Jun-90	1255	23.4	8.0		668	280	37.00	0.130	0.030	0.030	1.00	0.48	0.53	6.7	6.2
19-Jun-90	1155	23.4	6.8	7.6	861	280	34.00	0.050	0.044	0.030	0.70	0.36	0.44	4.0	3.7
Santa Rosa Creek at Melita Road															
30-Aug-89	1215	17.1	4.1	8.1	486	430		0.500	0.006	0.050	0.05	0.06	0.01	1.7	1.7
17-Oct-89	1310	16.2	12.5	8.1	495	300		0.240	0.001	0.300	0.28	0.07	0.06	2.6	2.2
14-Nov-89	1500	13.0	14.5	8.4	496	280		0.030	0.120	0.050	0.05	0.05	0.04	2.2	1.9
2-Feb-91	1245							0.810	0.001	0.025	0.13	0.11	0.33	14.0	
30-Jan-92	0920	7.2	8.8	8.3	452					0.055	0.40		0.03		
Santa Rosa Creek at Willowside Road															
30-Aug-89	1000	19.2	7.6	7.9	635	360		0.040	0.003	0.050	0.10	0.09	0.06	2.8	3.9
16-Sep-89	1215	17.2		7.8	346			0.890	0.050	0.440	5.80	0.16	0.84	24.0	24.0
16-Sep-89	950	18.5		7.9	648			0.050	0.002	0.250	1.20	0.10	0.11	5.5	4.6
27-Sep-89	1030	19.8	8.1	7.6	584	400		0.050	0.002	0.025	0.58	0.10	0.09	4.0	1.3
18-Oct-89	1040	16.7	10.1	8.1	618	360		0.040	0.003	0.120	0.30	0.10	0.06	2.4	3.2
14-Nov-89	1200	14.2	11.2	8.4	570	340		0.040	0.003	0.025	0.05	0.04	0.07	2.4	2.5
22-Jan-90	1040	7.9		7.8	446			1.600	0.022	0.025	0.42	0.10	0.12		
26-Jan-90	835	8.7		7.6	490			0.800	0.020	0.070	0.27	0.08	0.09		
29-Jan-90	2100			8.4	494			0.830	0.014	0.025	0.29	0.06	0.08		
30-Jan-90	1020			7.8	432			0.890	0.060	0.025	0.29	0.10	0.14		
30-Jan-90	1430			8.3	393			0.740	0.052	0.025	0.17	0.11	0.18		
31-Jan-90	945	9.0		7.6	407			0.860	0.030	0.025	0.58	0.06	0.10		
2-Feb-90	1325	11.6		7.9	355			0.840	0.060	0.025	0.70	0.16	0.14		
7-Feb-90	950	7.6		7.5	360			0.930	0.020	0.030	0.48	0.10	0.09		
14-Feb-90	1012	6.8		7.9	480			0.550	0.016	0.025	0.05	0.04	0.05		
20-Feb-90	1018	8.2		7.7	319			0.910	0.022	0.260	0.69	0.12	0.17		
21-Feb-90	1347	13.1		7.9	352			0.970	0.022	0.025	0.55	0.16	0.17		
28-Feb-90	1025	12.4		7.6	445			0.630	0.020	0.025	0.29	0.05	0.01		
6-Mar-90	944	12.5		7.4	211			0.790	0.030	0.260	0.87	0.21	0.20		
14-Mar-90	1206	11.6		6.9	599			0.260	0.010	0.160	0.24	0.06	0.06		
23-Mar-90	840	15.1		7.8	490			0.070	0.020	0.160	0.53	0.08	0.11		
4-Apr-90								0.640	0.040	0.150	7.20	0.06	0.08		
10-Apr-90								0.350	0.041	0.025	0.30	0.70	0.08		
18-Apr-90	1018	17		7.8	552			0.280	0.020	0.570	1.20	0.05	0.08		
25-Apr-90	1157	21.6			500			0.070	0.012	0.130	0.40	0.16	0.21		

Appendix 3-1. Laguna de Santa Rosa and Tributaries: Physical-Chemical Data and Nutrients, 1989-1992 (RWQCB data).

Date	Time	Temp C	DO mg/L	pH	Cond umho/cm	TFR mg/L	TURB NTU	NO3 mg/L	NO2 mg/L	NH3 mg/L	TKN mg/L	Ortho PO4 mg/L	Total PO4 mg/L	TOC mg/L	DOC mg/L
1-May-90	1118	19.1			559			0.015	0.001	0.070	0.30	0.06	0.07		
9-May-90	1010	18.7		7.6	470			0.040	0.001	0.025	0.30	0.08	0.10		
16-May-90	1105	20.0		8.0	866			0.050	0.001	0.025	0.70	0.08	0.20		
24-May-90	1020	17.6	9.6		336		4.00	0.540	0.033	0.025	0.11	0.11	0.13	5.6	6.3
5-Jun-90	1115	21.0	12.0	8.0	476	290	2.00	0.170	0.015	0.030	0.60	0.01	0.04	3.9	4.6
12-Jun-90	1130	21.8	7.0		532	320	1.20	0.010	0.001	0.030	0.40	0.05	0.02	3.1	3.0
19-Jun-90	0925	21.0	6.7	8.0	564	290	3.00	0.030	0.001	0.030	0.30	0.08	0.11	2.9	2.9
4-Dec-90	1200							0.005	0.001	0.025	0.05	0.05	0.05	2.9	3.0
6-Dec-90	1100							0.005	0.001	0.025	0.05	0.04	0.05	3.7	4.7
11-Dec-90	1050							0.660	0.230	0.170	0.30	0.11	0.26	9.6	12.0
13-Dec-90	1020							0.170	0.013	0.025	0.05	0.08	0.09	7.1	8.0
18-Dec-90	1116							1.100	0.041	0.025	0.33	0.31	0.31	5.9	5.5
20-Dec-90	1015							0.250	0.010	0.025	0.16	0.08	0.10	3.9	4.4
27-Dec-90	1015							0.250	0.015	0.025	0.05	0.05	0.06	3.3	2.4
3-Jan-91	1020							7.200	0.280	0.520	0.69	2.70	2.80	7.1	4.7
10-Jan-91	1055	8.0	10.8	8.0	556			6.700	0.220	0.460	0.60	2.00	2.00	6.5	5.9
15-Jan-91	1025	10.2	11.0	8.3	663			6.600	0.190	0.680	0.88	2.00	2.10		
23-Jan-91	1035							0.005	0.001	0.025	0.05	0.03	0.05	3.2	3.4
30-Jan-91	1115							0.440	0.030	0.025	0.05	0.16	0.19	3.2	3.8
2-Feb-91	1710	13.1		7.0	161			2.000	0.110	0.100	0.10	0.25	0.40	6.3	
2-Feb-91	0830	14.6		7.8	171			1.500	0.100	0.025	0.15	0.38	0.74	18.0	
2-Feb-91	1030							1.600	0.090	0.200	0.16	0.19	0.35	11.0	
8-Feb-91	1210	11.4	10.8	7.8	644			8.800	0.250	0.460	0.68	2.80	2.90	7.4	5.9
10-Apr-91	1325	15.5	12.4	7.9	558			7.500	0.150	0.290	0.69	1.70	0.69		
17-Apr-91	1130	15.3	12.4		461			7.500	0.180	0.100	0.70	1.70	1.70		
31-May-91	1155	21.1	10.0	8.3	598			0.040	0.011	0.025	1.40	0.06	0.07		
7-Jun-91	1500	24.6	9.2	8.3	615			0.050	0.001	0.025	0.42	0.08	0.09		
17-Jun-91	0850	18.7		7.5	634			0.005	0.001	0.160	1.60	0.06	0.07		
30-Jan-92	0820	10.4	8.3	7.9	489					0.310	0.83		0.15		
14-Feb-92	1030	11.3	9.8	7.7	255					0.170	1.30		0.28		
Mark West Creek at Slusser Road															
30-Aug-89	0840	16.3	3.0	6.6	575	330		1.400	0.012	0.100	0.20	0.08	0.01	1.7	2.4
17-Oct-89	0930	12.1	9.0	6.7	355	230		0.060	0.001	0.025	0.24	0.07	0.07	4.1	3.8
14-Nov-89	1030	10.8	10.1	7.5	363	230		0.005	0.003	0.025	0.10	0.10	0.10	2.8	1.1
10-Apr-91	1215	13.3	9.4	7.9	213			0.240	0.006	0.025	0.15	0.04	0.05		
17-Apr-91	1112	13.1	11.6	8.2	231			0.130	0.001	0.025	0.20	0.02	0.06		
30-May-91	1520							0.040	0.001	0.025	0.21	0.07	0.07		
18-Jun-91								0.000	0.001	0.025	0.70	0.08	0.00		
30-Jan-92	1055	8.8	11.2	8.0	319					0.025	0.35		0.05		
14-Feb-92	1300	10.8	10.4	7.7	131					0.060	1.40		0.49		

STATION	DATE	AMMONIA NITROGEN	NITRATE	TKN	ORGANIC NITROGEN	TOTAL PHOS	NPRATIO
LSP	07/23/1997	0.025	0.0531			0.234	
LOR	07/23/1997	0.025	0.025			1.79	
LGR	07/23/1997	0.0695	0.025			0.15	
LTH	07/23/1997	0.025	0.0965			0.224	
SRCWS	07/23/1997						
LSP	08/05/1997	0.025	0.025	1.060	1.035	0.349	3.18
LGR	08/05/1997	0.025	0.025	1.130	1.105	0.22	5.36
LTH	08/05/1997	0.025	0.025	0.798	0.773	0.294	2.88
SRCWS	08/05/1997						
LSP	08/21/1997	0.025	0.0927			0.665	
LOR	08/21/1997	0.025	0.095			0.832	
LGR	08/21/1997	0.025	0.396			0.307	
LTH	08/21/1997	0.025	0.432			0.216	
SRCWS	08/21/1997						
LSP	09/02/1997	0.025	0.0536	0.893	0.868	0.626	1.55
LOR	09/02/1997	0.025	0.0593	5.900	5.875	1.37	4.37
LGR	09/02/1997	0.025	0.0654	1.370	1.345	0.462	3.16
LTH	09/02/1997	0.025	0.0953	1.020	0.995	0.652	1.75
SRCWS	09/02/1997						
LSP	09/17/1997	3.24	0.025			0.523	
LOR	09/17/1997	0.105	0.025			0.847	
LGR	09/17/1997	1.3	0.025			0.493	
LTH	09/17/1997	0.117	0.0761			0.211	
SRCWS	09/17/1997						
LSP	10/01/1997	0.156	0.025	0.564	0.408	0.366	1.68
LOR	10/01/1997	0.84	0.025	2.510	1.670	0.739	3.46
LGR	10/01/1997	0.182	0.025	0.610	0.428	0.262	2.52
LTH	10/01/1997	0.135	0.0561	0.362	0.227	0.342	1.30
SRCWS	10/01/1997						
LSP	10/15/1997	0.119	0.025			0.27	
LOR	10/15/1997	0.6	0.108			0.612	
LGR	10/15/1997	0.275	0.025			0.494	
LTH	10/15/1997	0.269	0.0526			0.359	
SRCWS	10/15/1997						
LSP	10/28/1997	0.919	0.025	0.640		0.186	3.71
LOR	10/28/1997	0.528	0.025	2.400	1.872	0.525	4.67
LGR	10/28/1997	0.534	0.025	1.050	0.516	0.252	4.37
LTH	10/28/1997	0.678	0.0615	0.834	0.156	0.259	3.55
SRCWS	10/28/1997						
LSP	11/10/1997	1.28	0.523	0.709		0.248	5.07
LOR	11/10/1997	1.13	0.025	1.720	0.590	0.611	2.90
LGR	11/10/1997	0.55	0.602	1.020	0.470	0.331	4.98
LTH	11/10/1997	0.587	0.0907	0.400		0.25	2.06
SRCWS	11/10/1997	1.29	0.496	0.969		0.309	4.82
LSP	11/24/1997	1.05	0.508			0.751	
LOR	11/24/1997	0.025	2.7			1.49	
LTH	11/24/1997	0.786	0.66			0.87	
SRCWS	11/24/1997	0.178	0.9			0.112	
LSP	12/10/1997	0.025	2.84			0.554	
LOR	12/10/1997	0.338	3.02			1.13	
LTH	12/10/1997	0.174	2.11			0.993	
SRCWS	12/10/1997	0.025	1.48			0.106	
LSP	12/23/1997	0.025	2.25	0.386	0.361	0.404	6.59
LOR	12/23/1997	0.025	2.32	0.793	0.768	0.874	3.59
LTH	12/23/1997	0.025	1.79	0.652	0.627	0.559	4.41
SRCWS	12/23/1997	0.025	1.46	0.100	0.075	0.0814	19.47
LSP	01/07/1998	0.792	1.26			0.656	
LOR	01/07/1998	0.0893	1.58			0.852	
LTH	01/07/1998	0.025	1.34			0.43	
SRCWS	01/07/1998	0.025	0.871			0.16	
LSP	01/21/1998	0.385	1.82	0.749	0.364	0.487	5.33

STATION	DATE	AMMONIA NITROGEN	NITRATE	TKN	ORGANIC NITROGEN	TOTAL PHOS	NPRATIO
LOR	01/21/1998	0.496	2.74	1.020	0.524	0.872	4.34
LTH	01/21/1998	0.354	1.18	0.835	0.481	0.614	3.32
SRCWS	01/21/1998	0.025	1.08	0.100	0.075	0.0932	12.93
LSP	02/03/1998	0.227	0.025			0.679	
LOR	02/03/1998	0.233	0.11			0.927	
SRCWS	02/03/1998	0.113	0.198			0.603	
LTH	02/03/1998	0.0723	0.256			0.456	
LSP	02/18/1998	0.165	0.949	1.040	0.875	0.518	3.94
LOR	02/18/1998	0.544	1.03	1.790	1.246	0.976	2.97
LTH	02/18/1998	0.238	1.45	0.990	0.752	0.573	4.37
SRCWS	02/18/1998	0.025	0.616	0.360	0.335	0.135	7.41
LSP	03/04/1998	0.0833	1.95			0.232	
LOR	03/04/1998	0.206	5.22			0.911	
LTH	03/04/1998	0.263	2.14			0.506	
SRCWS	03/04/1998	0.025	0.85			0.025	
LSP	03/18/1998	0.025	0.609	0.679	0.654	0.113	11.62
LOR	03/18/1998	0.025	2.55	1.360	1.335	0.894	4.45
LTH	03/18/1998	0.0509	1.53	0.993	0.942	0.32	7.96
SRCWS	03/18/1998	0.025	0.555	0.374	0.349	0.025	38.16
LSP	04/01/1998	0.446	0.476			0.428	
LOR	04/01/1998	0.106	3.98			1	
LTH	04/01/1998	0.239	0.426			0.259	
SRCWS	04/01/1998	0.025	0.311			0.0702	
LSP	04/13/1998	0.424	0.519	1.980	1.556	0.556	4.66
LOR	04/13/1998	0.329	2.93	1.650	1.321	0.863	5.41
LTH	04/13/1998	0.229	0.422	0.734	0.505	0.142	8.32
SRCWS	04/13/1998	0.133	0.376	0.712	0.579	0.0976	11.70
LSP	04/30/1998	0.202	0.568			0.297	
LOR	04/30/1998	0.15	3.05			1.07	
LTH	04/30/1998	0.0686	0.373			0.571	
SRCWS	04/30/1998	0.025	0.355			0.05	
LSP	05/11/1998	0.0854	0.624	0.423	0.338	0.216	5.15
LOR	05/11/1998	0.025	1.84	0.992	0.967	0.817	3.60
LTH	05/11/1998	0.0531	0.335	0.538	0.485	0.318	2.92
SRCWS	05/11/1998	0.025	0.476	0.231	0.206	0.05	14.64
LSP	05/28/1998	0.112	0.453			0.208	
LOR	05/28/1998	0.296	0.124			0.668	
LTH	05/28/1998	0.0574	0.24			0.184	
SRCWS	05/28/1998	0.109	0.434			0.182	
LSP	06/09/1998	0.0944	0.421	0.499	0.405	0.17	5.56
LOR	06/09/1998	0.0667	0.0748	0.943	0.876	1.03	1.01
LTH	06/09/1998	0.025	0.059	0.489	0.464	0.294	1.95
SRCWS	06/09/1998	0.025	0.0705	0.353	0.328	0.025	17.94
LSP	06/25/1998	0.28	0.41			0.22	
LOR	06/25/1998	0.18	0.025			0.73	
LGR	06/25/1998	0.05	0.025			0.025	
LTH	06/25/1998	0.06	0.025			0.34	
SRCWS	06/25/1998						
LSP	07/09/1998	0.1	0.05	0.500	0.400	0.46	1.30
LOR	07/09/1998	0.1	0.05	3.100	3.000	2	1.60
LGR	07/09/1998	0.1	0.05	1.500	1.400	0.46	3.48
LTH	07/09/1998	0.1	0.05	1.500	1.400	0.47	3.40
SRCWS	07/09/1998						
LSP	07/24/1998	0.633	0.025			0.518	
LOR	07/24/1998	0.127	0.025			0.651	
LGR	07/24/1998	0.186	0.025			0.218	
LTH	07/24/1998	0.352	0.153			0.343	
SRCWS	07/24/1998						
LSP	08/04/1998	0.124	0.025			0.381	
LOR	08/04/1998	0.025	0.025			0.478	
LGR	08/04/1998	0.134	0.025			0.264	

STATION	DATE	AMMONIA NITROGEN	NITRATE	TKN	ORGANIC NITROGEN	TOTAL PHOS	NPRATIO
LTH	08/04/1998	0.165	0.132			0.341	
SRCWS	08/04/1998						
LSP	08/19/1998	0.025	0.025			1.06	
LOR	08/19/1998	0.025	0.025			0.888	
LGR	08/19/1998	0.119	0.025			0.461	
LTH	08/19/1998	0.225	0.17			0.914	
SRCWS	08/19/1998						
LSP	09/04/1998	0.05	0.025	0.512	0.462	0.668	0.84
LOR	09/04/1998	0.025	0.025	0.953	0.928	1.66	0.60
LGR	09/04/1998	0.025	0.079	0.449	0.424	0.351	1.58
LTH	09/04/1998	0.025	0.116	0.489	0.464	0.626	1.01
SRCWS	09/04/1998						
LSP	09/14/1998	0.025	0.025			0.29	
LOR	09/14/1998	0.16	0.025			1.15	
LGR	09/14/1998	0.0605	0.025			0.181	
LTH	09/14/1998	0.0878	0.141			0.301	
SRCWS	09/14/1998						
LSP	09/29/1998	0.072	0.025	0.754	0.682	0.257	3.13
LOR	09/29/1998	1.95	0.122	2.310	0.360	0.951	2.58
LGR	09/29/1998	0.0854	0.066	0.505	0.420	0.19	3.14
LTH	09/29/1998	0.103	0.14	0.460	0.357	0.387	1.61
SRCWS	09/29/1998						
LSP	10/14/1998	0.025	0.025			0.189	
LOR	10/14/1998	0.549	0.447			0.755	
LGR	10/14/1998	0.025	0.129			0.23	
LTH	10/14/1998	0.0683	0.161			0.327	
SRCWS	10/14/1998						
LSP	10/29/1998	0.025	0.317	1.030	1.005	0.608	2.26
LOR	10/29/1998	0.208	0.788	1.190	0.982	0.795	2.57
LGR	10/29/1998	0.254	2.28	1.040	0.786	0.988	3.45
LTH	10/29/1998	0.153	1.18	0.860	0.707	0.606	3.48
SRCWS	10/29/1998						
LSP	11/12/1998	0.102	0.372			0.384	
LOR	11/12/1998	0.206	1.41			0.206	
LGR	11/12/1998	0.245	3.19			1.33	
LTH	11/12/1998	0.124	2.62			0.803	
SRCWS	11/12/1998						
LSP	11/25/1998	0.28	1.35	0.873	0.593	0.533	4.38
LOR	11/25/1998	0.235	1.31	1.020	0.785	1.18	2.05
LTH	11/25/1998	0.215	1.59	0.499	0.284	0.422	5.11
SRCWS	11/25/1998	0.025	1.49	0.336	0.311	0.0841	22.01
LSP	12/03/1998	0.672	2.92			0.847	
LOR	12/03/1998	0.526	2.97			1.63	
LTH	12/03/1998	0.233	1.24			0.776	
SRCWS	12/03/1998	0.0557	1.07			0.227	
LSP	12/15/1998	1.08	2.83	2.270	1.190	0.466	11.13
LOR	12/15/1998	0.565	4.46	1.520	0.955	1.23	4.88
LTH	12/15/1998	0.159	1.7	0.546	0.387	0.663	3.43
SRCWS	12/15/1998	0.025	1.14	0.337	0.312	0.1	15.02
LSP	12/30/1998	0.0593	0.964			0.196	
LOR	12/30/1998	0.36	2.93			0.815	
LTH	12/30/1998	0.12	0.47			0.167	
SRCWS	12/30/1998	0.025	0.47			0.025	
LSP	01/14/1999	0.025	0.145	0.782	0.757	0.111	8.58
LOR	01/14/1999	0.215	3.06	0.972	0.757	1.06	3.83
LTH	01/14/1999	0.192	1.53	0.815	0.623	0.859	2.76
SRCWS	01/14/1999	0.025	0.104	0.214	0.189	0.025	13.72
LSP	01/27/1999	0.23	1.15			0.383	
LOR	01/27/1999	0.173	4.69			1.46	
LTH	01/27/1999	0.213	1.74			0.8	
SRCWS	01/27/1999	0.025	0.933			0.084	

STATION	DATE	AMMONIA NITROGEN	NITRATE	TKN	ORGANIC NITROGEN	TOTAL PHOS	NPRATIO
LSP	02/12/1999	0.191	2.07	0.480	0.289	0.243	10.60
LOR	02/12/1999	0.34	2.63	0.917	0.577	0.792	4.60
LTH	02/12/1999	0.138	0.859	0.655	0.517	0.457	3.48
SRCWS	02/12/1999	0.025	0.983	0.010		0.071	14.34
LSP	02/25/1999	0.125	0.611			0.518	
LOR	02/25/1999	0.29	1.5			0.858	
LTH	02/25/1999	0.128	0.509			0.391	
SRCWS	02/25/1999	0.025	0.427			0.223	
LSP	03/11/1999	0.025	1.25	0.580	0.555	0.297	6.25
LOR	03/11/1999	0.218	2.04	1.290	1.074	0.674	5.03
LTH	03/11/1999	0.102	1.18	0.950	0.848	0.351	6.07
SRCWS	03/11/1999	0.025	0.601	0.100	0.075	0.066	11.00
LSP	03/23/1999	0.0691	0.927			0.231	
LOR	03/23/1999	0.0881	2.3			0.617	
LTH	03/23/1999	0.0518	0.495			0.174	
SRCWS	03/23/1999	0.025	0.415			0.112	
LSP	04/05/1999	0.181	1.04	0.506	0.325	0.123	12.77
LOR	04/05/1999	0.025	1.63	0.683	0.658	0.431	5.42
LTH	04/05/1999	0.104	0.575	0.625	0.521	0.28	4.38
SRCWS	04/05/1999	0.025	0.524	0.283	0.258	0.105	7.92
LSP	04/22/1999	0.159	0.552			0.12	
LOR	04/22/1999	0.235	1.97			0.897	
LTH	04/22/1999	0.0519	0.347			0.272	
SRCWS	04/22/1999	0.025	0.025			0.025	
LSP	05/05/1999	0.161	0.414	0.470	0.309	2.98	0.31
LOR	05/05/1999	0.025	0.576	0.510	0.485	0.566	1.96
LTH	05/05/1999	0.025	0.098	0.430	0.405	0.253	2.19
SRCWS	05/05/1999	0.025	0.223	0.810	0.785	0.025	42.32
LSP	05/20/1999	0.141	0.159			0.205	
LOR	05/20/1999	0.0527	0.063			0.694	
LTH	05/20/1999	0.107	0.153			0.237	
SRCWS	05/20/1999	0.0741	0.188			0.025	
LSP	06/03/1999		0.088	0.930		0.143	
LOR	06/03/1999	0.14	0.057	0.820		0.599	
LGR	06/03/1999		0.056	0.490		0.025	
LTH	06/03/1999		0.141	0.390		0.23	
SRCWS	06/03/1999	.					
LSP	06/17/1999	0.025	0.025			0.508	
LOR	06/17/1999	0.025	0.025			0.926	
LGR	06/17/1999	0.025	0.025			0.298	
LTH	06/17/1999	0.0616	0.076			0.327	
SRCWS	06/17/1999						
LSP	06/29/1999	0.025	0.025	0.662	0.637	0.626	1.14
LOR	06/29/1999	0.025	0.093	0.541	0.516	0.274	2.41
LGR	06/29/1999	0.0892	0.153	0.410	0.321	0.27	2.18
LTH	06/29/1999	0.0956	0.141	0.567	0.471	0.371	1.98
SRCWS	06/29/1999						
LSP	07/14/1999	0.025	0.0899			0.71	
LOR	07/14/1999	0.025	0.118			0.623	
LGR	07/14/1999	0.025	0.0863			0.144	
LTH	07/14/1999	0.0672	0.183			0.263	
SRCWS	07/14/1999						
LSP	07/27/1999	0.025	0.132	0.570	0.545	0.553	1.31
LOR	07/27/1999	0.025	0.166	1.270	1.245	0.64	2.28
LGR	07/27/1999	0.111	0.05	0.250	0.139	0.209	1.56
LTH	07/27/1999	0.025	0.221	0.250	0.225	0.278	1.78
SRCWS	07/27/1999						
LSP	08/12/1999		0.025			0.514	
LOR	08/12/1999		0.025			0.429	
LGR	08/12/1999		0.098			0.2	
LTH	08/12/1999		0.147			0.248	

STATION	DATE	AMMONIA NITROGEN	NITRATE	TKN	ORGANIC NITROGEN	TOTAL PHOS	NPRATIO
SRCWS	08/12/1999						
LSP	08/24/1999	0.025	0.025	0.548	0.523	0.629	0.95
LOR	08/24/1999	0.025	0.025	0.646	0.621	0.495	1.41
LGR	08/24/1999	0.025	0.025	0.250	0.225	0.201	1.49
LTH	08/24/1999	0.025	0.025	0.025	0.000	0.265	0.28
SRCWS	08/24/1999						
LSP	09/09/1999	0.025	0.025			0.461	
LOR	09/09/1999	0.025	0.025			0.476	
LGR	09/09/1999	0.025	0.025			0.186	
LTH	09/09/1999	0.025	0.025			0.223	
SRCWS	09/09/1999						
LSP	09/21/1999						
LOR	09/21/1999						
LGR	09/21/1999						
LTH	09/21/1999						
SRCWS	09/21/1999						

In 65% of the samples downstream at Todd
upstream at the 36" discharge pipe.
In 5% the reverse occurred.

Day	Sampling site or pond	NH3	NO3	TON	PO4	Discharge	Upstream 36"Discharg	Downstream Todd Rd	
Nov-98-13	Upstream Incline Pump	0.3	2.2	0.5	1	1.4	1.1	1.7	0.6
18		0.5	1.3	0.9	1.2	4.2	1.8	2.2	0.4
24		-0.1	1.2	1.1	0.7	34.3	0.7	1.6	0.9
13	Upstream D-pond 36" discharge	0.2	1.9	0.4	1.1		1.1	1.9	0.8
18		0.5	1.8	2	1.8		0.8	1.6	0.8
24		-0.1	0.9	1.4	0.7		0.9	1.2	0.3
13	Laguna at Todd Rd.	0.4	2.3	1.2	1.7		1.1	1.2	0.1
18		0.8	2.6	1.3	2.2		1.7	1.6	-0.1
24		0.2	2.3	1.8	1.6		1.9	1.9	0
Dec-98-1	Upstream D-pond Incline pump	0.8	3.2	2.2	1.1	38.7	1.2	1.2	0
9		0.2	4	1.8	0.8	24	0.7	0.7	0
16		0.7	2.4	0.5	1	4.9	0.7	1.4	0.7
22		0.4	5.4	1.1	1.3	3	0.7	0.9	0.2
29		0.4	5.7	0.4	0.8	1.9	0.6	0.6	0
1	Upstream D-Pond 36" Discharge	0.9	3.1	1.3	1.1		0.6	0.7	0.1
9		0.3	2.3	1.4	0.8		0.6	0.6	0
16		0.5	3.8	1.2	0.9		0.4	0.5	0.1
22		0.4	4.5	0.1	1.1		0.3	0.5	0.2
29		0.3	5.2	0.9	1.7		0.5	0.7	0.2
1	Laguna at Todd Rd.	0.9	4	1.5	1.9		0.6	0.6	0
9		-0.1	5	1.6	1.6			Avg. Diff.	0.265
16		0.5	4.8	1	1.2				
22		1	4.2	0.6	1.2				
29		1.4	5	1.5	1.6				
Jan-99-06	Upstream D-Pond Incline Pump	0.3	0.4	2	1.2				
13		0.6	6.3	0.9	1.9	5			
20		1.1	2	0.3	1.1	48.2			
27		0.8	2.5	1	0.9	27			
13	Upstream D-Pond 36" Discharge	0.5	4.9	1.1	1.9				
20		0.9	1.8	2.4	1.2				
27		0.4	2.5	1.4	0.7				
13	Laguna at Todd Rd.	0.5	6	1.1	1.9				
20		1.1	3	3.4	1.2				
27		0.7	5	1	0.7				
Feb-99-03	D-Pond Upstream Incline Pump	0.6	2.6	1.6	0.7	17.2			
10		0.6	1.3	1.7	0.6	49.7			
3	D-Pond Upstream 36" Discharge	0.3	2.4	2.1	0.7				
10		0.4	1.2	2.4	0.7				
3	Laguna at Todd Rd.	1.4	4.4	0.9	1.4				
10		0.9	2.2	0.9	0.9				
Mar-99-03	Laguna Upstream Incline Pump	0.3	1.4	3	0.5	20.5			
10		0.5	1	0.8	0.6	24			
17		0.5	1.5	1.3	0.5	3			
24		-0.1	1.3	1	0.4				
3	Laguna Upstream 36" Discharge	0.3	1.4	3.3	0.6				
10		-0.1	1	2.4	0.6				
17		0.9	1.5	1.2	0.6				
24		0.4	1.3	0.4	0.4				
3	Laguna at Todd Road	0.5	2.1	3.2	0.6				
10		1	1.8	1.6	0.7				
17		0.9	1.9	2.6	0.6				
24		0.6	1.6	1.3	0.5				
Apr-99-07	Laguna Upstream Incline Pump	1.1	1.5	1.1	0.4	6.6			
14		0.3	1.3	1.1	0.5	34.3			
21		0.5	1.7	1.1	0.5	7			
7	Laguna Upstream 36" Discharge	0.8	1.3	1	0.3				
14		-0.1	1.3	1.1	0.5				
21		2	1.4	0.4	0.6				
7	Laguna at Todd Road	0.7	2.5	1.3	0.5				
14		1	4	1	0.7				
21		0.4	3	1.7	0.6				

In 97% of the samples downstream exceeded Upstrea

Comparison of downstream and upstream samples on same day

Day	Sampling site or pond	NH3	NO3	TON	PO4	Discharge	Upstream	Downstream	Diff
Oct-98-16	Upstream Kelly Pond/Duer Crk.	0.3	1.2	1.3	1	17	1	2	1
21		-0.1	-0.4	-0.1	0.8	19.01	0.8	2	1.2
28		-0.1	-0.4	-0.1	0.8		0.8	3	2.2
16	Downstream Kelly Pond/Duer	-0.1	1.6	0.7	2		1.2	2.6	1.4
21		-0.1	4.7	1.2	2		0.8	2.8	2
28		0.2	5	0.5	3		0.5	3	2.5
Nov-98-04	Upstream Duer Ck. at Kelly	0.6	0.4	0.9	1.2	1.1	3.1	2.2	-0.9
12		0.2	0.5	0.8	0.8	0.9	0.9	1.7	0.8
18		0.4	0.5	0.8	0.5	0.8	0.5	1.5	1
24		-0.1	-0.4	1.8	3.1	0.9	0.3	1.7	1.4
4	Downstream Duer cr. & Kelly	0.5	4.4	0.9	2.6		0.2	1.6	1.4
12		0.3	5.9	1.1	2.8		0.9	1.5	0.6
18		0.3	5.9	1.4	3		0.4	2.2	1.8
24		-0.1	2.7	3.2	2.2		0.7	0.8	0.1
Dec-98-09	Upstream Duer at Kelly	0.5	1.1	1.1	0.9	1.2	0.4	2.1	1.7
16		-0.1	0.8	1.3	0.5	0.9	0.4	2	1.6
22		0.5	0.9	0.2	0.3	NA	0.4	0.9	0.5
29		0.2	1.4	0.4	0.2	0.9	0.5	1.2	0.7
1	Downstream Duer/Kelly	0.6	1.9	0.8	1.3	1	0.4	0.8	0.4
9		0.2	3.4	2.3	1.7		0.4	0.7	0.3
16		0.5	4	0.6	1.5		0.3	0.7	0.4
22		0.3	5.5	0.8	1.7		0.4	0.7	0.3
29		0.3	3.9	1	1.6		0.3	0.8	0.5
Jan-99-06	Upstream Duer Creek/Kelly	0.3	7.1	1.7	0.9	1.1	0.4	0.8	0.4
13		0.2	0.7	1	0.4	0.9	0.3	1	0.7
20		0.4	1	2	0.7	0.7	-0.1	1.6	1.7
27		0.3	0.9	0.4	0.4	0.8	0.5	1.6	1.1
6	Downstream Duer Creek/Kelly	0.6	10.1	0.1	1.5		0.6	1.8	1.2
13		0.4	6.3	0.8	2.2		0.8	2.1	1.3
20		0.3	1.1	2.2	0.8			Avg.diff.	1.010345
27		0.2	4.6	0.3	2.1				
Feb-99-03	Upstream Duer/Kelly	0.1	1	2.1	0.4	1			
10		-0.1	0.7	-0.1	0.4	0.9			
17		0.2	0.5	1.7	0.5	0.9			
3	Downstream Duer/Kelly	0.2	4.6	0.9	2				
10		0.4	1.7	0.2	0.9				
17		0.7	3.3	1.5	1.2				
Mar-99-03	Upstream Duer/Kelly	-0.1	0.4	3.1	0.4	0.5			
10		-0.1	0.4	1	0.4	0.6			
17		-0.1	0.5	1.1	0.3	0.5			
24		0.4	0.5	0.5	0.4	0.5			
3	Downstream Duer/Kelly	-0.1	1.6	3.3	0.8				
10		0.3	1.6	1.3	0.7				
17		0.2	3	1.1	0.7				
24		-0.1	2.2	4.3	0.7				
Apr-99-07	Upstream Duer/Kelly	0.6	-0.4	0.2	0.3	0.7			
14		-0.1	0.5	0.7	0.4	0.6			
21		-0.1	0.4	2.1	0.3	0.5			
7	Downstream Duer/Kelly	0.6	2.1	0.7	0.8				
14		-0.1	1.9	0.9	0.8				
21		0.2	1.5	2.6	1				
May-99-05	Upstream Duer/Kelly	-0.1	-0.4	-0.1	-0.1	0.3			
11		-0.1	-0.4	-0.1	0.5	0.1			
5	Downstream Duer/Kelly	0.2	1.2	0.9	1.6				
11		0.1	0.9	0.4	1.6				
Nov-99-10	Upstream Duer/Kelly	-0.1	-0.4	-0.1	0.6				
17		0.5	-0.4	1.5	0.8				
10	Downstream Duer/Kelly	-0.1	1.5	-0.1	1.8				
17		-0.1	1.4	2	2.1				

In 100% of the samples downstream exceeded upstream.

Comparison of daily samples

Day	Sampling site or pond	NH3	NO3	TON	PO4	Upstream	Downstream	
Oct-98-28	Upstream Santa Rosa Crk.	-0.1	0.4	-0.1	0.1	0.1	0.6	0.5
28	Downstream S.R. Creek	-0.1	2.2	-0.1	0.6	-0.1	1.4	1.5
Nov-98-04	Upstream S.R. Crk at Delta	0.4	-0.4	0.2	-0.1	0.1	1.6	1.5
12		0.2	0.5	0.4	0.1	-0.1	1.6	1.7
18		0.3	-0.4	0.4	-0.1	0.2	1.2	1
24		-0.1	1.7	1	0.2	0.1	0.2	0.1
4	Downstream S.R. Crk at Delta	0.4	4.8	0.4	1.4	0.1	0.2	0.1
12		0.4	8.1	1.4	1.6	-0.1	0.2	0.3
18		0.6	4.4	1.8	1.6		Avg. Diff.	0.8375
24		-0.1	3.7	2	1.2			
Mar-99-03	Upstream S.R. Ck./Delta	-0.1	0.9	2.2	0.1			
10		-0.1	0.7	0.8	0.1			
17		-0.1	0.5	0.2	-0.1			
3	Downstream SR Ck./Delta	-0.1	0.7	3	0.2			
10		-0.1	0.9	0.7	0.2			
17		-0.1	0.7	0.7	0.2			

In 100% of the samples Downstream exceeded Upstream

Day	Sampling site or pond	NH3	NO3	TON	PO4	Comparison Upstream	Downstream	
Feb-99-12	Upstream Roseland Ck. at Llano	0.3	3.1	1.1	0.2	0.2	1.6	1.4
17		0.1	1	2.1	0.6	0.6	0.9	0.3
12	Downstream Roseland/Summer	2.1	4.5	1.3	1.6	0.3	0.6	0.3
17		1.8	2.4	1.1	0.9	0.3	0.5	0.2
Mar-99-03	Upstream Roseland Ck. Llano	-0.1	1.3	4.1	0.3	0.1	0.7	0.6
10		0.3	1.7	1.2	0.3	0.2	0.9	0.7
17		-0.1	1.8	2.4	0.1	0.3	1	0.7
24		0.8	1.3	-0.1	0.2		Avg. Diff	0.6
3	Downstrm Roseland Crk.Llano	1.2	4	4	0.6			
10		2.7	3.3	2.3	0.5			
17		0.3	5.1	2.3	0.7			
24		0.2	5.9	1.7	0.9			
Dec-99-01	Upstream Roseland Creek	-0.1	0.7	0.9	0.3			
1	Downstream Roseland Creek	0.5	2.2	1.2	1			

In 30% of the samples Mirabel was higher in PO4 than Wohler. In no instances did t

Comparison of Wohler and Mirabel on days when both sampled.

Day	Sampling site or pond	NH3	NO3	TON	PO4	Wohler	Mirabel	Mirabel excess
Oct-98-07	RR at Wohler Bridge	0.2	-0.4	-0.1	-0.1	-0.1	-0.1	0
7	RR at Mirabel	0.3	-0.4	0.3	-0.1	-0.1	-0.1	0
14		-0.1	-0.4	-0.1	-0.1	-0.1	-0.1	0
14		-0.1	-0.4	0.3	-0.1	-0.1	-0.1	0
21		-0.1	-0.4	-0.1	-0.1	-0.1	-0.1	0
21		-0.1	-0.4	-0.1	-0.1	-0.1	0.2	0.3
28		-0.1	-0.4	-0.1	-0.1	-0.1	-0.1	0
28		-0.1	0.3	-0.1	-0.1	0.5	0.5	0
Nov-98-04	Russian River at Wohler Brdg.	0.3	-0.4	0.5	-0.1	0.4	0.4	0
4	Russian River at Mirabel	-0.1	-0.4	-0.1	-0.1	-0.1	0.3	0.4
12		-0.1	-0.5	-0.1	-0.1	-0.1	0.1	0.2
12		-0.1	-0.5	-0.1	0.2	-0.1	-0.1	0
18		0.2	-0.4	0.4	-0.1	-0.1	-0.1	0
18		-0.1	-0.4	0.5	-0.1	-0.1	-0.1	0
24		-0.1	0.6	1.2	0.5	0.5	0.6	0.1
24		-0.1	0.8	0.8	0.5	-0.1	0.3	0.4
Dec-98-09	Russian River at Wohler Brdg.	0.3	0.4	0.4	0.4	-0.1	0.3	0.4
16		0.2	0.5	0.8	-0.1	0.3	0.4	0.1
22		0.5	0.5	0.1	-0.1	0.1	0.2	0.1
29		0.3	0.5	0.5	-0.1	0.2	0.2	0
9	Russian River at Mirabel	0.5	0.7	0.6	0.4	-0.1	-0.1	0
16		0.3	0.9	0.7	0.3	-0.1	-0.1	0
22		0.4	0.7	0.2	0.1	-0.1	-0.1	0
29		0.3	0.6	0.1	-0.1	-0.1	0.2	0.3
Jan-99-06	Russian River at Wohler	0.1	-0.4	0.1	-0.1	-0.1	-0.1	0
13		0.2	-0.4	0.1	-0.1	-0.1	-0.1	0
20		-0.1	0.4	-0.1	0.5	-0.1	-0.1	0
27		0.2	0.4	0.2	-0.1	-0.1	-0.1	0
6	Russian River at Mirabel	0.1	-0.4	0.3	-0.1	-0.1	-0.1	0
13		0.1	-0.4	0.3	-0.1	0.2	0.2	0
20		0.3	0.6	1	0.6		Avg. diff	0.07666667
27		0.3	0.9	0.1	0.3			
Feb-99-03	Russian River at Wohler	-0.1	0.5	-0.1	-0.1			
10		-0.1	-0.4	0.3	0.3			
3	Russian River at Mirabel	-0.1	0.9	0.7	0.3			
10		0.3	0.6	0.7	0.4			
Mar-99-03	Russian River at Wohler	-0.1	0.4	2.5	0.1			
10		-0.1	0.4	1.2	0.2			
17		0.2	0.4	0.4	-0.1			
24		0.2	0.4	1.6	-0.1			
3	Russian River at Mirabel	-0.1	0.6	2.1	0.2			
10		-0.1	0.7	0.7	0.2			
17		-0.1	0.5	0.6	-0.1			
24		-0.1	0.4	0.1	-0.1			
Apr-99-07	Russian River at Wohler	0.1	0.4	-0.1	-0.1			
14		0.1	-0.4	-0.1	-0.1			
21		-0.1	0.5	1.2	-0.1			
7	Russian River at Mirabel	0.3	0.5	-0.1	-0.1			
14		0.1	0.4	0.5	0.2			
21		-0.1	0.5	2.5	-0.1			
May-99-05	Russian River at Wohler	0.2	-0.4	-0.1	-0.1			
11		-0.1	-0.4	-0.1	-0.1			
5	Russian River at Mirabel	-0.1	-0.4	-0.1	-0.1			
11		-0.1	-0.4	-0.1	-0.1			
Nov-99-03	Russian River at Wohler	-0.1	-0.4		-0.1			
10		-0.1	0.4	-0.1	-0.1			
17		-0.1	-0.4	-0.1	-0.1			
3	Russian River at Mirabel	-0.1	-0.4					
10		-0.1	0.5	-0.1	-0.1			
17		-0.1	-0.4	-0.1	-0.1			
Dec-99-01	Russian River at Wohler	0.1	0.5	0.3	0.2			
1	Russian River at Mirabel	-0.1	0.5	0.3	0.2			

Laguna S	diment Phosphate Concentration		(mg/kg)				
Stations - Occidental Pond (LOR) and Sebastopol Pond (SEB)							
	Date	Ortho-Phosphate	Total Phosphate	Nitrate	Ammonia	Sulfide	Avg. T Phos.
LOR 1	Oct 1/97	ND	1331.00	0.50	654.90	N/S	
LOR 2	Oct 1/97	ND	1215.00	0.50	647.89	N/S	
LOR 3	Oct 1/97	ND	1369.00	0.50	641.38	N/S	1305.00
SEB 1	Oct 1/97	ND	1326.00	0.50	1186.00	N/S	
SEB 2	Oct 1/97	ND	1198.00	0.50	1083.00	N/S	
SEB 3	Oct 1/97	ND	1068.00	0.50	1063.00	N/S	1197.00
LOR 1	Jun 1/98	61.00	1662.00	0.50	5.00	N/S	
LOR 2	Jun 1/98	12.83	891.00	4.53	81.78	N/S	
LOR 3	Jun 1/98	15.69	1095.00	3.91	5.00	N/S	1216.00
SEB 1	Jun 1/98	10.30	1448.00	0.50	5.00	N/S	
SEB 2	Jun 1/98	18.40	1268.00	0.50	5.00	N/S	
SEB 3	Jun 1/98	24.30	830.00	2.70	5.00	N/S	1182.00
LOR 1	Sep 1/98	1.90	2122.00	0.50	69.30	594.00	
LOR 2	Sep 1/98	1.79	611.00	0.50	5.00	1192.00	
LOR 3	Sep 1/98	2.00	2407.00	0.50	100.29	923.00	1710.00
SEB 1	Sep 1/98	ND	731.00	0.50	349.00	2088.00	
SEB 2	Sep 1/98	0.50	938.00	0.50	933.00	3057.00	
SEB 3	Sep 1/98	ND	703.00	0.50	676.00	2072.00	791.00
LOR 1	Jun 1/99	5.28	1050.00	0.50	6.12	1082.00	
LOR 2	Jun 1/99	2.72	2564.00	0.50	22.13	1245.00	
LOR 3	Jun 1/99	4.24	724.00	0.50	19.93	1685.00	1466.00
SEB 1	Jun 1/99	ND	315.00	11.40	90.98	3137.00	
SEB 2	Jun 1/99	ND	649.00	9.70	215.64	3379.00	
SEB 3	Jun 1/99	ND	799.00	0.50	72.55	2941.00	588.00

Samples where Todd, Occidental and Laguna upstream SR Creek all are sampled.										
		Todd	Occidental	SR Creek			Todd	Occidental	SR Creek	
Date	Nov14/89	0.8	0.71	0.52	0.28	Nov14/89	0.8	0.71	0.52	0.28
	Jan 26/90	3.4	2	1.6	1.8	Jan 26/90	3.4	2	1.6	1.8
	Jan31/90	0.32	1.7	0.31	0.01	Jan31/90	0.32	1.7	0.31	0.01
	Feb2/90	1.2	1.2	1.2	0	Feb2/90	1.2	1.2	1.2	0
	Feb7/90	2	1.3	1.1	0.9	Feb7/90	2	1.3	1.1	0.9
	Feb14/90	3	1.9	1.5	1.5	Feb14/90	3	1.9	1.5	1.5
	Feb21/90	3.2	1.6	1.14	2.06	Feb21/90	3.2	1.6	1.14	2.06
	Feb28/90	3.1	3.2	0.95	2.15	Feb28/90	3.1	3.2	0.95	2.15
	Mar6/90	2.8	1.5	1.7	1.1	Mar6/90	2.8	1.5	1.7	1.1
	Mar14/90	3.1	1.8	1.7	1.4	Mar14/90	3.1	1.8	1.7	1.4
	Mar23/90	4.8	2.7	2.1	2.7	Mar23/90	4.8	2.7	2.1	2.7
	Apr10/90	3.5	2.5	1.7	1.8	Apr10/90	3.5	2.5	1.7	1.8
	Apr18/90	2.6	2.2	1.6	1	Apr18/90	2.6	2.2	1.6	1
	Apr25/90	1.6	1.9	1.3	0.3	Apr25/90	1.6	1.9	1.3	0.3
	May1/90	2.2	2.7	2.3	-0.1	Oct24/90	1.4	1.2	0.36	1.04
	May9/90	4.8	3.2	2.4	2.4	Dec4/90	0.46	0.07	0.2	0.26
	May16/90	5.1	2.2	1.8	3.3	Dec6/90	4	0.09	0.19	3.81
	May24/90	0.77	2.6	2.2	-1.43	Dec11/90	4.2	1.5	0.45	3.75
	Jun5/90	1.2	1.8	2.3	-1.1	Dec13/90	2.9	1.5	1.2	1.7
	Jun12/90	1	1.8	2.2	-1.2	Dec14/90	3.8	1.8	0.91	2.89
	Oct24/90	1.4	1.2	0.36	1.04	Dec18/90	2.5	2.6	2.2	0.3
	Dec4/90	0.46	0.07	0.2	0.26	Dec20/90	3.7	2.4	2	1.7
	Dec6/90	4	0.09	0.19	3.81	Jan3/91	3.8	3.3	3.2	0.6
	Dec11/90	4.2	1.5	0.45	3.75	Jan10/91	0.66	2.8	2.4	-1.74
	Dec13/90	2.9	1.5	1.2	1.7	Jan15/91	0.46	2.6	2.3	-1.84
	Dec14/90	3.8	1.8	0.91	2.89	Jan25/91	0.48	2.6	2.1	-1.62
	Dec18/90	2.5	2.6	2.2	0.3	Jan30/91	0.4	2.3	2	-1.6
	Dec20/90	3.7	2.4	2	1.7	Mar/10/91	1.3	1.8	1.6	-0.3
	Jan3/91	3.8	3.3	3.2	0.6	Mar17/91	0.86	1.4	1.2	-0.34
	Jan10/91	0.66	2.8	2.4	-1.74	Apr3,91	1.7	1.6	1.5	0.2
	Jan15/91	0.46	2.6	2.3	-1.84	Dec11,91	0.56	1.4	0.88	-0.32
	Jan25/91	0.48	2.6	2.1	-1.62	Mar25/92	2.3	1.1	1.6	0.7
	Jan30/91	0.4	2.3	2	-1.6	Mar17,93	0.83	1.2	0.21	0.62
	Mar/10/91	1.3	1.8	1.6	-0.3	Apr14/93	1.7	1	0.85	0.85
	Mar17/91	0.86	1.4	1.2	-0.34	Oct19/93	0.8	1.4	0.9	-0.1
	Apr3,91	1.7	1.6	1.5	0.2	Dec14/93	0.8	0.8	0.19	0.61
	Jun3,91	1.9	1.2	1.1	0.8	Mar22/94	0.5	1.09	0.7	-0.2
	Jun27,91	1.3	1.6	1.1	0.2	Apr23/94	0.44	1.54	0.12	0.32
	Aug20/91	1.6	1.2	1.7	-0.1		Avg.	Avg.	Avg.	Avg.
	Dec11,91	0.56	1.4	0.88	-0.32		1.999211	1.718421	1.254737	0.744474
	Mar25/92	2.3	1.1	1.6	0.7					Sum
	Mar17,93	0.83	1.2	0.21	0.62					28.29
	Apr14/93	1.7	1	0.85	0.85					
	May12/93	0.91	1.2	1.1	-0.19					
	Jun16/93	0.63	1.4	1.5	-0.87					
	Aug18/93	0.66	1	0.44	0.22					
	Oct19/93	0.8	1.4	0.9	-0.1					
	Dec14/93	0.8	0.8	0.19	0.61					
	Mar22/94	0.5	1.09	0.7	-0.2					
	Apr23/94	0.44	1.54	0.12	0.32					
	May24/94	0.32	1.8	1.96	-1.64					
	Dec27/95	1.4	1.3	0.2	1.2					
		Avg.	Avg.	Avg.	Avg.					
		1.9112	1.7518	1.3572	0.572692					
					Sum					
					29.78					

Phytoplankton and Chlorophyll Data (RWQCB Data)

Station	Date	Phyto Density mil cells/L	%DIA	%GRN	%BG	%DINO	Ortho PO4	Total PO4	NO3	NH3	TKN	Turbidity
Laguna at	10/17/89	0.3500	89	1	1	9	0.36	0.43	0.07	0.025	0.93	
Stony Pt.	11/14/89	0.1070	82	2	0	16	0.18	0.23	0.03	0.07	0.8	
	05/24/90	0.2500	45	0	55	0	0.86	0.9	0.14	0.025	0.24	17
	06/05/90	0.3400	96	3	0	0	0.56	0.57	0.05	0.03	1.1	7
	06/12/90	0.0022	100	0	0	0	0.73	0.83	0.05	0.03	1	10
	06/19/90	0.0730	94	6	0	0	1.1	1.7	0.03	0.03	1.2	8.3
Laguna at	11/14/89	0.3130	26	70	0	4	0.8	0.91	0.55	0.83	2.3	
Todd Rd.	05/24/90	0.4000	100	0	0	0	0.77	0.8	0.16	0.17	0.38	22
	06/05/90	0.7800	63	35	0	0	1.2	1.1	0.2	2	4.8	10
	06/12/90	0.1500	94	6	0	0	1	1.1	0.08	0.025	2.7	10
	06/19/90	0.8000	97	3	0	0	0.85	0.87	0.07	0.025	2.5	9.8
Laguna at	09/27/89	2.4000	31	0	0	68	1.1	0.53	0.57	0.1	4.3	
Occidental	11/14/89	1.5500	1	4	0	95	0.71	1.1	0.43	0.025	3.2	
Rd.	05/24/90	0.8900	52	48	0	0	2.6	2.7	0.34	0.68	0.9	27
	06/05/90	0.1000	25	46	29	0	1.8	1.6	0.11	0.03	3	16
	06/12/90	0.4500	14	16	70	0	1.8	1.9	0.08	0.03	1.4	44
	06/19/90	1.4000	7	54	39	0	2.3	2.6	0.09	0.03	2.5	28
Laguna	08/30/89	0.0087	100	0	0	0	0.31	0.02	0.8	0.5	0.9	
Upstream	10/18/89	0.2600	77	1	1	21	0.81	1	0.74	0.49	1.2	
Santa Ros	11/14/89	0.9450	2	3	1	95	0.52	0.73	0.4	0.025	1.6	
Creek	05/24/90	0.9700	64	36	0	0	2.2	2.3	0.35	0.7	0.8	13
	06/05/90	0.4600	22	69	9	0	2.3	2.2	0.18	0.03	3.1	10
	06/12/90	0.8600	47	22	31	0	2.2	2.5	0.29	0.03	2.8	29
	06/19/90	0.8700	35	22	43	0	1.6	1.6	0.14	0.16	2.3	28
Laguna at	06/05/90	0.4400	40	42	18	0	1.2	1.2	0.1	0.03	1.8	8
River Rd.	06/12/90	0.1300	70	13	17	0	0.48	0.53	0.13	0.03	1	37
	06/19/90	0.4000	60	19	21	0	0.36	0.44	0.05	0.03	0.7	34
S.R.Creek	08/30/89	0.0039	99	0	1	0	0.06	0.01	0.5	0.05	0.05	
at Melita	10/17/89	0.0710	99	0	0	1	0.07	0.06	0.24	0.3	0.28	
	11/14/89	0.0024	100	0	0	0	0.05	0.04	0.03	0.05	0.05	
S.R. Creek	08/30/89	0.0310	99	1	0	0	0.09	0.06	0.04	0.05	0.1	
at	09/27/89	0.1000	94	1	1	4	0.1	0.09	0.05	0.025	0.58	
Willowside	10/18/89	0.0100	97	1	1	1	0.1	0.06	0.04	0.12	0.3	
Rd.	11/14/89	0.0340	95	3	1	1	0.04	0.07	0.04	0.025	0.05	
	05/24/90	0.2100	100	0	0	0	0.11	0.13	0.54	0.025	0.11	4
	06/05/90	0.1100	100	0	0	0	0.01	0.04	0.17	0.03	0.6	2
	06/12/90	0.0044	0	50	50	0	0.05	0.02	0.01	0.03	0.4	1.2
	06/19/90	0.0180	100	0	0	0	0.08	0.11	0.03	0.03	0.3	3
Mark West	08/30/89	0.0037	99	0	0	1	0.08	0.01	1.4	0.1	0.2	
at Slusser	10/17/89	0.0088	96	1	1	2	0.07	0.07	0.06	0.025	0.24	
	11/14/89	0.0043	54	16	16	30	0.1	0.1	0.005	0.025	0.1	
				0.544437	Ortho PO4 vs Phyto density							
Correlation coefficients				0.500451	Total PO4 vs. Phyto density							
				0.162426	NO3 vs Phyto density							
				0.686792	TKN vs. Phyto density							
				0.157609	NH3 vs. Phyto density							
				0.400542	Phyto density vs. Turbidity							

Excreted Drugs: Something Looks Fishy

Doctors recommend drinking plenty of water to replenish lost fluids and wash away wastes. Just where do the excreted wastes go? At least a few, including hormones and heart drugs, end up in streams—and eventually someone else's drinking water, a new study finds.

Though the amounts detected in water from a Louisiana tap were small—just a few parts per trillion (ppt)—they can be biologically active, another study finds. At these concentrations, one of the hormones measured and another found in birth control pills alter the apparent gender of fish and, possibly, their fertility.

In a suite of yet more studies, collaborating state, federal, and university scientists report finding male carp and walleyes in Minnesota that were producing "sky-high" quantities of vitellogenin, an egg-yolk protein normally made only by females. Such feminization might explain the suspected inability of some adult male fish to make sperm. The researchers had caught the walleyes in the effluent of a sewage-treatment plant—a type of facility that others have shown can release estrogenic pollutants (SN: 3/21/98, p. 187).

Researchers reported all these findings last week in Minneapolis at a meeting sponsored by the National Ground Water Association.

Glen R. Boyd, a civil engineer at Tulane University in New Orleans, described a preliminary survey this spring of the anticholesterol drug clofibric acid, the pain reliever naproxen, and the hormone estrone in local waters. His team's sampling turned up the drugs at three sites along the Mississippi River, at four sites around Lake Pontchartrain, and in Tulane's tap water.

Though the drugs weren't always detectable, assays revealed a minimum of 10 ppt of each at least once at every site. Estrone in tap water, for instance, averaged 35 ppt, with a high of 80 ppt.

Environment Canada detected similar pollutants in its 1998 nationwide survey of sewage-treatment effluent. At some sites, estrone reached 400 ppt and the hormone ethinylestradiol from birth control pills reached 14 ppt, notes Chris D. Metcalfe of Trent University in Peterborough, Ontario. He's now exposed eggs of a laboratory fish, the Japanese medaka (*Oryzias latipes*), for 100 days to concentrations typical of the survey.

At exposures of 0.1 ppt ethinylestradiol or 10 ppt estrone, some males became intersex, exhibiting both male and female reproductive tissues. Exposures to 1,000 ppt of either of these estrogens transformed all males into females. The findings are slated to appear in ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY.

Though not a North American fish, the medaka models the reproductive responses of native fish well, Metcalfe says. In fact, his fieldwork around the Great Lakes has uncovered signs of intersex white perch. That's worrisome, he observes, since intersex fish "usually aren't interested in sex—in spawning."

Moreover, in early March, Ira Adelman of the University of Minnesota in St. Paul caught male walleyes in local waters. He was able to extract sperm from all of them except those swimming in a channel that received effluent from a sewage-treatment plant.

The channel's unusual warmth may have triggered these males to release their sperm early, he said. However, he noted, it's also possible that those estrogenic pollutants that fostered males to produce egg-yolk protein also "arrested the fish in an early state of sexual development." His team is now looking for testicular abnormalities in the fish.

Local carp, which normally spawn later, made sperm. But Adelman reported preliminary data indicating that sperm from males in the sewage-treatment-plant channel show somewhat slowed motility.

None of the new data are strong enough to indict pharmaceutical pollution for harming wildlife, much less people, notes Leroy C. Folmar of the Environmental Protection Agency in Gulf Breeze, Fla. However, he adds, the studies by Metcalfe and Adelman hint that estrogens in water may be capable of inducing "functional sterility" in exposed fish.

Christian G. Daughton of the EPA's National Exposure Research Laboratory in Las Vegas says that Boyd's tap water data will be "disturbing" if they're confirmed. "If [drugs] are in drinking water now," he warns, "you can be guaranteed they've been there as long as the drugs have been in use." —*J. Raloff*

Satellite links may don quantum cloaks

Today's most powerful methods for protecting secret communications may not remain secure tomorrow. That's because they rely on the difficulty of gnarly calculations that may someday succumb to faster computers, scientists say. However, secrecy based on the inviolable laws of nature—if such protection proves technically feasible—will keep spies completely in the dark.

Researchers now present the first experimental evidence that laws of quantum mechanics could shield signals all the way from the ground to satellites in low orbits. This potential channel for totally secure communications may appeal to military and government agencies, banks, and other security-conscious organizations, says William T. Buttler of Los Alamos (N.M.) National Laboratory.

In the June 12 PHYSICAL REVIEW LETTERS, he and his colleagues describe their recent implementation of quantum-key distribution, a step in the transmission of secure communications.

"This is a convincing demonstration," comments William P. Risk of the IBM Almaden Research Center in San Jose, Calif. The Los Alamos researchers "understand the difficult technical challenges associated with Earth-to-satellite quantum-key distribution and have devised practical ways of overcoming them."

On a New Mexico mesa in daylight, the scientists tested whether they could transmit a code cloaked in quantum secrecy. They sent it from a red-light laser to a telescope 1.6 kilometers away.

To take advantage of quantum protection, they dimmed their laser pulses to less than one photon on average—so that many pulses are blanks—and polarized the pulses to represent binary 1s or 0s. Because photons are indivisible, an eavesdropper siphoning data would cause a noticeable intensity drop at the receiver. Other aspects of quantum mechanics prevent spies from surreptitiously measuring polarizations or copying them onto other photons (SN: 2/10/96, p. 90).

In open-air transmissions of laser beams, atmospheric turbulence typically causes trouble by wiggling and distorting the light. The pulses in the Los Alamos experiment passed through even more turbulence from laser to telescope than they would between a laser on a mountaintop and a satellite, Buttler says. That's because small eddies, common near the ground but not higher up, disrupt laser beams most strongly.

Despite all that air, the telescope successfully received a randomly generated string of bits, called a key, that serves as a shared guide for encoding and decoding messages. Although the key arrived more slowly than data on a cheap Internet phone-line connection, "even this rate is useful. What makes it so is the security of the bits," says coauthor Richard J. Hughes of Los Alamos. —*P. Weiss*

More Waters Test Positive for Drugs

Over the past decade, European chemists have been documenting widespread pharmaceutical contamination of their lakes, streams, and groundwater. In San Francisco this week, U.S. and Canadian scientists offered preliminary confirmation that traces of drugs, excreted by people and livestock, similarly pollute American waters.

They presented their findings at the first major American symposium on pharmaceuticals in water, held as part of the American Chemical Society's spring national meeting.

Water pollution by drugs "is a newly emerging issue," observes Christian G. Daughton, a symposium co-organizer and chief of environmental chemistry at the Environmental Protection Agency's National Exposure Research Laboratory in Las Vegas. By offering a U.S. venue for the meeting—and participation by many European leaders in this field (SN: 3/21/98, p.187)—he hoped to awaken domestic interest and catalyze research on the topic, he says.

Ironically, Daughton notes, EPA scientists examining the sludge from a U.S. sewage-treatment plant 20 years ago found that the incoming sewage contained excreted aspirin, caffeine, and nicotine. Daughton says that the findings were written off as a curiosity and all but forgotten.

At about the same time, recalls Herman Bouwer of the U.S. Agricultural Research Service in Phoenix, the cholesterol-lowering drug clofibric acid turned up in a groundwater reservoir being tapped to meet the Phoenix community's thirst. The drug had entered with treated sewage, which the city had been using to replenish the aquifer.

"At the time," Bouwer recalls, "we didn't pay attention to the finding." It should have been a wake-up call, he now argues, because if clofibric acid could pass through a sewage-treatment plant and percolate through soil unscathed, so could a host of other drugs.

And they do, new studies show.

Chris Metcalfe of Trent University in Peterborough, Ontario, reports finding a broad mix of drugs, including anticancer agents, psychiatric drugs, and anti-inflammatory compounds. "Levels of prescription drugs that we have leaving sewage-treatment plants in Canada are sometimes higher than what's being seen in Germany," he says.

He explains that many North American cities employ more rudimentary sewage treatment than those in Germany. Daughton observes also that some 1 million U.S. homes send their essentially untreated sewage directly into the environment.

Keith Weller/USDA-ARS

Scientist examines hog manure. Livestock wastes are often laced with drugs that can taint rivers and groundwater.

Two years ago, the symposium's other co-organizer, Thomas A. Ternes, documented unexpectedly high concentrations of drugs—many measured in parts per billion (ppb)—both in raw sewage and in water leaving treatment plants in Germany. The chemist, who is at the Institute for Water Research and Water Technology in Wiesbaden, Germany, now finds that these drugs enter groundwater.

Sewage effluent can amount to at least half the water in many of Germany's smaller rivers, he notes. Groundwater fed by streams carrying relatively undiluted effluent can be tainted with 1 ppb carbamazepine, an anticonvulsive drug. Ternes has also detected similar amounts of the anti-inflammatory drug diclofenac and up to 2.4 ppb of iodine-based drugs used to improve contrast in X rays.

Because people discard their excess drugs, the town dump can also be a source of pharmaceutical pollution. Under one landfill, Ternes found groundwater tainted with 12 ppb clofibric acid and 1 ppb phenazone, an analgesic.

The latter medication also turned up in groundwater—but at far higher concentrations—under a leaking dump in Zagreb, Croatia, notes Marijan Ahel of the Rudjer Boskovic Institute in Zagreb. Some of his water samples had the drug at as much as 50 times the concentration detected by Ternes.

In the United States, federal scientists recently began probing another source of drug pollution—large feedlots for livestock. An estimated 40 percent of the antibiotics produced in the United States is fed to livestock as growth enhancers. Geochemist Mike Meyer of the U.S. Geological Survey in Raleigh, N.C., and his colleagues have begun looking for antibiotics in hog-waste lagoons.

Three drugs frequently show up, one in concentrations approaching 1 part per million. The same three antibiotics, which are also prescribed for people, often appear in local waters—though usually only at one-tenth to one-hundredth the concentrations in the lagoons, Meyer notes. "So, it appears we're getting transport of these antibiotics into surface and groundwaters," he told SCIENCE NEWS.

His colleagues at the Centers for Disease Control and Prevention in Atlanta have begun sampling bacteria from the tainted waters to investigate their responses to the antibiotics present, Meyer says. Their findings could begin to resolve a long-standing question: What is the contribution, if any, of livestock to potentially dangerous reservoirs of bacteria (SN: 6/5/99, p. 356) resistant to common antibiotics?

Traces of drugs are sometimes making it all the way into tap water. Thomas Heberer of the Technical University of Berlin reported finding traces of at least three pharmaceuticals in samples from his home tap. The concentrations, however, were near the limits of detection, a few parts per trillion. Moreover, he found that running this water through an activated-carbon filter removes all vestiges of the drugs.

Ternes' studies confirm that two disinfection agents—activated carbon and ozone—which are used in many European drinking-water plants, generally remove any traces of drugs. It's because these relatively costly technologies aren't employed for treating sewage, he notes, that a large share of the drugs flushed down toilets can reach open waters.

To date, the symposium's scientists noted, few if any toxicological studies have evaluated risks posed by chronic exposure to trace concentrations of drugs. Most of the participants suspect, however, that the biggest risks face aquatic life—which may be bathed from cradle to grave in a solution of drugs of increasing concentration and potency.

David Epel of Stanford University's Hopkins Marine Station in Pacific Grove, Calif., expressed special concern about new drugs called efflux-pump inhibitors. Designed to keep microbes from ejecting the antibiotics intended to slay them (SN: 2/12/00, p. 110), efflux-pump inhibitors also impede the cellular pumps that nearly all animals use to get rid of toxicants, he says. If pump-inhibiting drugs enter the aquatic environment, Epel worries that they might render wildlife vulnerable to concentrations of pollution that had previously been innocuous. — *J. Raloff*

Medicines, chemicals taint water

Sac'to Bee 3-28-00

Contaminants pass through sewage plants

By Chris Bowman
Bee Staff Writer

SAN FRANCISCO – Scientists are finding urban America's rivers and ground water spiked with a dilute cocktail of pain relievers, caffeine, antibiotics, birth control pills and perfumes apparently passing from humans through sewage treatment plants.

INSIDE

- Antibiotics, drugs and hormones found in water supply. **Page A12**

While barely detectable, the contaminants are numerous and widespread. And they are raising new environmental and health concerns. Synthetic and naturally produced human sex hormones appear to be changing the reproductive organs in fish downstream from the outfalls of treated waste water.

The risks to human and ecological health are largely unknown because the steady infusion of medicine-chest chemicals into rivers and aquifers tapped for drinking water is not monitored or regulated. And little data exists for gauging their potential toxicity.

But growing numbers of researchers in the United States, Scandinavia and western Europe are finding the question worthy of further investigation. The latest findings received considerable attention Monday for the first time when they were presented at the American Chemical Society's annual meeting in San Francisco.

The special session on the issue broke conventional thinking by

Please see WATER, back page, A12

Water: Chemotherapy drugs retain most of their potency

Continued from page A1

shifting the spotlight on polluters from manufacturers and farmers to individual consumers.

"The fact that these chemicals get into the environment should show that every individual, whatever they do, affects the environment one way or the other," said Christian Daughton, a researcher with the U.S. Environmental Protection Agency, who led the special session.

In one of latest discoveries presented Monday, a German chemist said he found high concentrations of chemical fragrances used in perfumes, shampoos and detergents and sun-blocking compounds from sunscreen lotions accumulating in the flesh of carp, perch, eels and other fish down river from sewage treatment plants in Berlin. Thomas Heberer, of Technical University of Berlin, said the compounds are long-lived in water and easily penetrate the cells of aquatic organisms.

In the United States, a team of chemists with the U.S. Geological Survey is leading the search for drugs and personal care products that are flushed down toilets and rinsed down drains to sewage treatments plants that are not designed to filter out these contaminants. Most sewage plants, constructed years before scientists could detect the minute contaminants, were built primarily to disinfect and screen out solid waste.

The USGS group expected to pick up only a few medicinal compounds when it began last summer. Instead, the researchers found a veritable pharmacy of low-level contaminants downstream from sewage treatment plants and livestock yards.

"We're discovering that there are a whole suite of compounds – 25, 50, 100 – all at low levels, but we don't know what the combined effects of those are," said Donald Wilkison, a USGS scientist who is sampling streams in the Kansas City area.

One of the highest-volume contaminants turning up in streams is caffeine, "the Starbucks effect," as leading USGS researcher Edward Furlong put it. Others include codeine, antacids, cholesterol-lowering agents, antidepressants and Premarin, an estrogen replacement taken by more than 8 million women each year to treat symptoms of menopause and osteoporosis.

Less common, but more potent, are chemotherapy agents administered to cancer patients ending up downstream from some hospitals.

The USGS plans another round of testing this year at the same 100 sites in 24 states, including California. The results will provide the first national assessment on the occurrence of drugs, sex hormones and other unexplored contaminants in streams.

The search for pharmaceuticals and personal care products in the environment is a mark of how far researchers have come in isolating chemical culprits in the stew of water pollutants.

"In the early years we looked for the really toxic actors that have immediate effects like death or cancer," said Furlong, a chemist with the USGS National Water Quality Laboratory in Denver. "Now we are starting to look more at compounds whose effects are more subtle and whose effects are less easily identified."

The body's ability to break down medicine varies widely by individual and by drug. Chemotherapy drugs, for example, retain nearly all their potency as they leave the body. Female hormones, on the other hand, enter the sewage system inert but are reactivated through chemical reactions during sewage treatment.

Sewage plants remove most but not all drugs and household chemicals from the waste water. Some persist miles downstream of the outfall pipes.

Antibiotics and hormones from animal feed lots also end up in waterways by spreading manure and sewage sludge on land. USGS scientists reported a wide variety of antibiotics in and downstream from hog waste lagoons in North Carolina, Iowa and Missouri.

Public health officials are concerned that the release of antibacterial drugs in the environment will build resistance in disease-causing bacteria. The new class of contaminants has emerged during the past seven years as a result of advancements in pollution detection technology.

European scientists were the first to report the phenomenon. In 1992, Heberer and Hans-Jurgen Stan of the Technical University in Berlin stumbled upon a cholesterol-lowering drug called clofibric acid while looking for pesticides in ground water. They soon discovered that the drug was in tap water throughout Berlin.

Recent research in Britain suggests that estrogen, the female sex hormone, is mostly to blame for deforming reproductive systems in fish. Throughout England, scientists have found female egg protein in blood plasma samples of male trout living below sewage treatment plants.

In 1996, U.S. researchers found that effluent from the sewage treatment plant in Minneapolis and Las Vegas causing the same effect in carp living downstream. Again, estrogen in waste water was the prime suspect.

"It would be news to most people that birth control pills are implicated in feminizing fish as well the industrial chemicals and pesticides that get all the press," said USGS researcher Larry Barber, a pioneer in the unglamorous study of sewage waters as sources of environmental contamination. Pesticides and industrial chemicals that imitate natural hormones, however, have not been ruled out.

Arid regions in the Intermountain West and Southern California are especially vulnerable to waste water contaminants, scientists said. Many streams run almost entirely on sewage effluent during the dry season. And many cities depend on waste water to replenish aquifers tapped for drinking water.

Barber recently traced an agent called EDTA used in shampoo and food products from a sewage treatment plant in Los Angeles County to well water tapped by residents in Pico Rivera and Whittier. The compound is non-toxic, but Barber said, "it means synthetic compounds are making it into your drinking water."

Stream contaminants

A sample of some of the contaminants the U.S. Geological Survey is finding in the nation's water supply:

Veterinary and human antibiotics
- Chlortetracycline
- Oxytetracycline
- Tetracycline

Human prescription and non-prescription drugs
- Metformin (anti-diabetic agent)
- Cimetidine (antacid)
- Rantidine (antacid)
- Fluoxetine (anti-depressant)
- Ibuprofen (anti-inflammatory)
- Caffeine (stimulant)
- Dehydronifedipine (anti-anginal)
- Amoxicillin (antibiotic)
- Acetominophen (anti-pyretic)

Sex and steroidal hormones
- 17b-estradiol
- Testosterone
- Progesterone
- Cholesterol
- Equilenin

- Complete list on the Internet at http://toxics.usgs.gov/regional/contaminants.html

Source: U.S. Geological Survey

Bee graphic

SPECIAL REPORT

Pharmaceuticals and Personal Care Products in the Environment: Agents of Subtle Change?

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During the last three decades, the impact of chemical pollution has focused almost exclusively on the conventional "priority" pollutants, especially those acutely toxic/carcinogenic pesticides and industrial intermediates displaying persistence in the environment. This spectrum of chemicals, however, is only one piece of the larger puzzle in "holistic" risk assessment. Another diverse group of bioactive chemicals receiving comparatively little attention as potential environmental pollutants includes the pharmaceuticals and active ingredients in personal care products (in this review collectively termed PPCPs), both human and veterinary, including not just prescription drugs and biologics, but also diagnostic agents, "nutraceuticals," fragrances, sun-screen agents, and numerous others. These compounds and their bioactive metabolites can be continually introduced to the aquatic environment as complex mixtures via a number of routes but primarily by both untreated and treated sewage. Aquatic pollution is particularly troublesome because aquatic organisms are captive to continual life-cycle, multigenerational exposure. The possibility for continual but undetectable or unnoticed effects on aquatic organisms is particularly worrisome because effects could accumulate so slowly that major change goes undetected until the cumulative level of these effects finally cascades to irreversible change—change that would otherwise be attributed to natural adaptation or ecologic succession. As opposed to the conventional, persistent priority pollutants, PPCPs need not be persistent if they are continually introduced to surface waters, even at low parts-per-trillion/parts-per-billion concentrations (ng-µg/L). Even though some PPCPs are extremely persistent and introduced to the environment in very high quantities and perhaps have already gained ubiquity worldwide, others could act as if they were persistent, simply because their continual infusion into the aquatic environment serves to sustain perpetual life-cycle exposures for aquatic organisms. This review attempts to synthesize the literature on environmental origin, distribution/occurrence, and effects and to catalyze a more focused discussion in the environmental science community. *Key words*: aquatic, drugs, ecologic health, ecologic risk assessment, emerging risk, pharmaceuticals, pollution, sewage. — *Environ Health Perspect* 107(suppl 6):907–938 (1999).
http://ehpnet1.niehs.nih.gov/docs/1999/suppl-6/907-938daughton/abstract.html

Summary

Risks associated with previously unknown, unrecognized, unanticipated, or unsuspected chemical pollutants in the environment have long been a major concern of environmental scientists. The importance of identifying such emerging risks is reflected in one of the top five goals of the Strategic Plan 2000 for the U.S. Environmental Protection Agency's (U.S. EPA) Office of Research and Development. Early identification and investigation of potential environmental pollution issues before they worsen are critical for protecting ecologic and human health. It is also important to rule out issues that could be of concern but prove otherwise, so that limited resources can be redirected. Ecosystem change is effected by human activities primarily via three routes: habitat fragmentation, alteration of community structure (e.g., via nonindigenous species), and chemical pollution. The scope of the former two is highly delineated and obvious compared with the latter. During the last three decades, the impact of chemical pollution has focused almost exclusively on the conventional "priority" pollutants. This group of chemicals, however, is only one piece of the larger puzzle.

One large class of chemicals receiving comparatively little attention comprises the pharmaceuticals and active ingredients in personal care products (PPCPs), which are used in large amounts throughout the world; quantities of many are on par with agrochemicals. Escalating introduction to the marketplace of new pharmaceuticals is adding exponentially to the already large array of chemical classes, each with distinct modes of biochemical action, many of which are poorly understood. In contrast to agrochemicals, most of these products are disposed or discharged into the environment on a continual basis via domestic/industrial sewage systems and wet-weather runoff. The bioactive ingredients are first subjected to metabolism by the dosed user; the excreted metabolites and unaltered parent compounds can then be subjected to further transformations in sewage treatment facilities. The literature shows, however, that many of these compounds survive biodegradation, eventually being discharged into receiving waters; metabolic conjugates can even be converted back to their free parent forms. Many of these PPCPs and their metabolites are ubiquitous and display persistence in, and bioconcentration from, surface waters on par with those of the widely recognized organochlorine pollutants. Additionally, by way of continual infusion into the aquatic environment, those PPCPs that might have low persistence can display the same exposure potential as truly persistent pollutants since their transformation/removal rates can be compensated by their replacement rates.

Although certain biochemical actions of many drugs in humans have been elucidated, these actions are not necessarily always the ones responsible for the purported physiologic target effects. Sometimes the known pathways of action may have nothing to do with the actual desired effect, as the actual mechanism remains totally unknown. Understanding of the complex biochemical signaling pathways is currently too limited to design drugs that act only via targeted routes, and even then, if their activity can be limited to a single type of receptor, the tissue distribution of the receptor may not be fully known. Unpredicted and unknown side effects are often the norm. The possible actions and biochemical ramifications on nontarget aquatic biota are even less understood; many are totally unknown. The few that are known to elicit subtle but dramatic effects on aquatic life at very low concentrations, however, may point to an ill-defined vulnerability in aquatic ecosystems. A major concern is not necessarily acute effects to

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nontarget species (effects amenable to monitoring once they are understood), but rather the manifestation of perhaps imperceptible effects that can accumulate over time to ultimately yield truly profound changes—those whose causes would be obscured by time and that would not be distinguishable from natural events. The specter of subtle, cumulative effects could reduce the usefulness of current toxicity-directed screening methods in testing waste effluents for toxicologic end points due to PPCPs. Subtle effects, from low concentrations of bioactive PPCPs, whose continual expression over long periods of time in certain nontarget populations, could lead to cumulative, insidious, adverse impacts that would otherwise be attributed to natural change/adaptation or ecologic succession—any "signal" would be lost among the noise. Current comprehensive environmental risk assessments and epidemiologic studies do not factor in exposures/body burdens from PPCPs and therefore may be flawed by over simplicity.

It is useful to note that the data reported and evaluated in this review reflect the diverse and uneven nature of the PPCP literature published for source/origin, occurrence, distribution, transport, transformation, ecologic exposure and effects, risk assessment, and test strategies. The comprehensiveness of the published literature in each of these areas and across the broad spectrum of PPCP classes is very unequal. This review therefore does not present an exhaustive and rounded view of this emerging topic but rather summarizes most of the significant papers in an integrated, comprehensive manner, and thereby elucidates many of the questions that still need to be addressed by the environmental science community. This review aims to catalyze a discussion on the potential importance of PPCPs in the environment and presents recommendations for focusing further research (Table 1).

Introduction

For the purposes of this discussion, pharmaceutical (and veterinary and illicit) drugs (and the ingredients in cosmetics, food supplements, and other personal care products), together with their respective metabolites and transformation products, will collectively be referred to as pharmaceuticals and personal care products. PPCPs are continually infused into the environment via sewage treatment facilities and wet weather runoff. In many instances, untreated sewage is discharged into receiving waters (e.g., flood overload events, domestic "straight-piping," or sewage waters lacking municipal treatment). In the United States alone, possibly more than a million homes do not have sewage systems but instead rely on direct discharge of raw sewage into streams by straight-piping or by outhouses not connected to leach fields (*1*). A number of Canadian cities are reported to discharge 3.25 billion liters per day (over 1 trillion liters per year) of essentially untreated sewage into surface waters and the ocean (*2*). Raw/treated sewage is also disposed of from some locales in the deep ocean where it may possibly remix with upper waters.

We hope that this overview of PPCPs in the environment will *a*) catalyze a concerted effort among environmental chemists and ecotoxicologists to survey sewage treatment effluents, surface waters/groundwaters, and potable water for the presence of PPCPs and their bioactive transformation products and to determine their origins; *b*) elucidate the spectrum of possible physiologic effects of PPCPs on nontarget species, especially those that are aquatic; and *c*) promote discussion of whether this is an environmental issue deserving further investigation. We believe that a scientific debate on this topic is warranted given the evidence that has been accumulating over the last two decades on the occurrence of various pharmaceuticals in sewage effluent and in both surface waters and groundwaters. The big unknown is whether the combined low concentrations from each of the numerous PPCPs and their transformation products have any significance with respect to ecologic function, while recognizing that immediate effects could escape detection if they are subtle and that long-term cumulative consequences could be insidious. Another question is whether the pharmaceuticals remaining in water used for domestic purposes poses long-term risks for human health after lifetime ingestion via potable waters multiple times a day of very low, subtherapeutic doses of numerous pharmaceuticals; this issue, however, is not addressed in this review.

The hypothesis is further complicated by the fact that while the concentration of individual drugs in the aquatic environment could be low (sub-parts per billion or sub-nanomolar, often referred to as micropollutants), the presence of numerous drugs sharing a specific mode of action could lead to significant effects through additive exposures. It is also significant that drugs, unlike pesticides, have not been subjected to the same scrutiny regarding possible adverse environmental effects. They have therefore enjoyed several decades of unrestricted discharge to the environment, mainly via sewage treatment works. This is surprising especially since certain pharmaceuticals are designed to modulate endocrine and immune systems and cellular signal transduction and as such (as opposed to pesticides and other industrial chemicals already undergoing scrutiny as endocrine disruptors) have obvious potential as endocrine disruptors in the environment. Exposure to PPCPs in the environment, especially for aquatic organisms, may differ from that of pesticides and other industrial chemicals in one significant respect—exposures may be of a more chronic nature because PPCPs are constantly infused into the environment wherever humans live or visit, whereas pesticide fluxes are more sporadic and have greater spatial heterogeneity. It is quite apparent that little information exists from which to construct comprehensive risk assessments for the vast majority of PPCPs having the potential to enter the environment.

Although little is known of the occurrence and effects of pharmaceuticals in the environment, more data exist for antibiotics than for any other therapeutic class. This is a result of their extensive use in both human therapy and animal husbandry, their more easily detected effects end points (e.g., via microbial and immunoassays), and their greater chances of introduction into the environment, not just by sewage treatment plants, but also by run-off and groundwater contamination, especially from confined animal feeding operations (CAFOs). The literature on antibiotics is much more developed because of the obvious issues of direct effects on native microbiota (and consequent alteration of microbial community structure) and development of resistance in potential human pathogens. Because of the considerably larger literature on antibiotics, this review only touches on the issue; for the same reason, this discussion only touches on steroidal drugs (those purposefully designed to modulate endocrine systems).

For the purposes of this document, pharmaceuticals will refer to nonbiologic drugs (i.e., those that do not comprise proteinaceous or nucleotide material). The number of biologics approved by the U.S. Food and Drug Administration (FDA) is growing, and their fate in the environment is unknown. This overview covers only a subset of the commercially available classes of pharmaceuticals and active ingredients in personal care products. The subset of classes discussed in this review comprises the primary classes for which the limited data on environmental occurrence and effects on nontarget species can be found, in a highly fragmented, disjointed, and disparate literature.

Pharmaceutical drugs are chemicals used for diagnosis, treatment (cure/mitigation), alteration, or prevention of disease, health condition, or structure/function of the human body. The definition is extended to veterinary pharmaceuticals and can also be applied to illicit (recreational) drugs. It also must be noted that the active ingredient in a drug may or may not be the actual formulated parent compound. For example, prodrugs such as the esters of clofibric acid, a metabolite of certain lipid regulators, are converted from pharmacologically inactive parent