INFLUENCE OF GEOCHEMICAL PROCESSES ON NUTRIENT SPIRALING WITHIN THE RECIRCULATION ZONES OF THE COLORADO RIVER IN THE GRAND CANYON

ANNUAL REPORT: 31 January, 1995

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Cooperative Agreement: CA8000-8-0002

Project Name: Influence of Geochemical Processes on Nutrient Spiraling Within the Recirculation Zones of the Colorado River in the Grand Canyon

Principal Investigator: Dr. Roderic A. Parnell

Government Technical Representative: Dr. Peter Rowlands

Title of Work: BEACH GEOCHEMISTRY AND NUTRIENT SPIRALING: Annual report

Effective Date of Cooperative Agreement: 2-15-93

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Funded by: The U.S. Department of Interior Bureau of Reclamation Glen Canyon Environmental Studies

Sponsored by: The U.S. Department of Interior
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Cooperative Parks Studies Unit
Northern Arizona University, Campus Box 5614
Flagstaff, AZ 86011

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BEACH GEOCHEMISTRY AND NUTRIENT SPIRALING ANNUAL REPORT: 1995

A. MAJOR ACCOMPLISHMENTS

1. Overview of Project

The Bureau of Reclamation is the lead agency charged with preparing an Environmental Impact Statement on the impacts of Glen Canyon Dam operations on resources downstream in Glen and Grand Canyons. Implementation of Interim Flow criteria for Glen Canyon Dam during the EIS preparation period requires that sand bar conditions be monitored to assess how linkages between sediment resources and channel flow have been affected by this action. The present research is a monitoring study designed to determine the influence of fluctuating flows on biogeochemical reactions occurring within the recirculation deposits, specifically the reattachment bar. This project is being conducted through the National Park Service Cooperative Parks Studies Unit at Northern Arizona University in Flagstaff

2. Objectives

A. Describe and interpret the redox chemistry, especially with respect to nitrogen species, within the alluvial deposits of the recirculation zones.

B. Document the changes in water chemistry as waters flow through the alluvium.

C. Construct a geochemical model providing insight into the relationship between geochemical processes within the alluvial deposits and the biogeochemistry of the main stem.

3. Accomplishments

We have installed 61 wells across 4 reattachment deposits: -6.7L, 43.5L, 71.2L, and 194L. Well locations were determined using a grid with spacings based upon the length of the bar. Wells are clustered in pairs with a shallow well at approximately three meters depth and a deeper well at a depth of approximately six meters . During installation, well screens (1.5' of .001") were located in the coarsest units to avoid well screen clogging problems associated with fine-grained units. The three reattachment bars below Lee's Ferry have been sampled seasonally five times while the bar above the ferry has been sampled four times. When available, return channel surface samples and at least two eddy samples were taken when wells were sampled. We have had the opportunity to sample three bars at different river stage levels. Laboratory analyses of the all the samples is near completion and a representative data set is compiled along with field measurements in Appendix 1. Data is presented in parts per million unless otherwise noted.

We have also undertaken physical and chemical analysis of soil samples from all four beaches. These studies include grain size analysis and fractionated extractable phosphate. A representative data set appears in Appendix 2.

4. Conclusions

A. Ortho-phosphate concentrations decrease downstream from -6.7L (Figure 1).

B. Dissolved [T-PO_4] increase from RCC to river while extractable non-occluded P decrease along the same line (Figures 2 and 3).

C. Speciation of nitrogen and dissolved oxygen measurements reflect a changing redox environment with higher [NO_3-] and lower [NH_{4+}] moving from the RCC toward the river. The most abundant source of NH_{4+} is highly reduced RCC sediments (Figure 4, 5, and 6).

5. Interpretations

The return current channels along the reattachment bars in the Grand Canyon are distinctive environments, physically, chemically, and geologically. Other workers have demonstrated that the RCCs have the highest primary productivities and accumulations of organic matter of all bar environments. As the flows recede during fluctuating flows, RCCs are stranded from the main current, and left with standing water. Fine-grained clastic and organic material settle out in these backwaters as the stranded waters evaporate. For example, at mile 194, we observed a thick mat of vegetation buried under 12" of clayey silt brought in by the LCR winter floods of 1993. This infilling of the RCC with fine-grained clastics and organics is an effect of dam-regulated flows that leads to a dewatering of the RCC and the occurrence of emergent marsh-type vegetation. These changes in the RCC represent changes in the size and distribution of various nutrient (N,C,P) pools for the Colorado River. Nitrogen cycling, particularly denitrification, in riparian fens such as these has been the subject of much attention in areas where changing ecologies are of concern (Groffman, 1994). Our DO, Eh, and NH_4^+ data are evidence that the RCC sediments provide a reducing environment, presumably caused by the decomposition of buried organics such as the buried mat at 194. Reduced environments, coupled with the increased availability of carbon and ammonium point to an increased importance of denitrification in the nitrogen cycle. This would provide a nitrogen sink for the Colorado River and a large net loss of nitrogen to the atmosphere.

Cores of mid-beach and beach-face sediments are much coarser than those of the RCCs. Higher DO and Eh under the mid-bar demonstrate a more oxidized environment than that in the RCCs. Speciation of dissolved nitrogen reflects these changing conditions, with higher [NO_3^-] and lower [NH_4^+] moving from the RCCs toward the river. One form of N exists only at the expense of the other. The most abundant source of N appears to be river water NO_3^-, with decreasing concentrations moving away from the river.

Seasonal variations in N and P species concentrations are readily explained by differential biological uptake and decomposition release rates. Higher N and P uptake in the summer removes more N from beach ground waters, but increasing rates of microbial activity in the warmer weather provides more NH_4^+ to ground waters. N in river water, as NO_2^- and NO_3^-, also appears to fluctuate through the year . we hypothesize that these fluctuations are caused by seasonal changes in the rates of denitrification and ammonification occuring in the beaches, which would control the amount of N available tot hje surface waters and demonstratethe degree to which the beaches act as a N sink.

Non-occluded [T-PO_4] in sediments is the only measureable form of P in the bars. It decreases moving outward from the RCC and across the reattachment bar. Dissolved [T-PO_4] increases along the same line. The regular, diurnal fluctuations in river flow under the current river management system leach the labile phosphate from the sediments close to the river. The downstream decrease in dissolved [T-PO_4] occurs above mile 43. This decrease in available P can be explained in two ways. First, it could be taken up biologically by Cladophora, a green algae which exists in great numbers in Glen Canyon but not below. Secondly, we believe that there is a net loss of P as phosphorous occluded sediments settle out in the active RCCs.

Interim flows, mandated by The Grand Canyon Protection Act of 1992, require relatively low daily fluctuating and dampened seasonal fluctuations, which have resulted in less dramatic changes in hydraulic head within the beaches. Thus, the impact of flow fluctuations on beach ground water chemistry is restricted to a narrow reach of bar sediments within 50m of the river channel. The current range of flows prevents significant exchange of nutrients between the river and return current channel sediments, where most organic matter and nutrients are being sequestered.

B. PROBLEMS ENCOUNTERED

During reduction of the field measurements for nitrate and nitrite, we observed that regression curves for standards run on one trip (July 1994) were not satisfactory. In our subsequent discussion with Hach, our supplier, we were informed that the lot of reagents used for nitrate and nitrite analysis were bad, forcing us to question all our field nitrate and nitrite numbers from the July trip. We did collect samples for laboratory analysis of nitrate and nitrite. We will compare lab and field measurements of N-species for the April trip to determine if we can use lab values for N-species from our July trip.

We discovered large amounts of drift in our Eh measurements which we believe are due to poorly poised waters. Therefore, we added Winkler titrations to our field measurements in order to gain accurate knowledge of the oxidation states within the reattachment bars.

We have recently lost our GTR. This poses several problems, not the least of which involves communication. This project was originally funded for two years. We demonstrated that two years of sampling was necessary for statistical validity. After project startup, funds were taken back, causing a reduction in sample collection. Also, as stated in our original proposal, hydrologic data was needed to quantify flux of nutrients through the reattachment bars. These data were to be supplied to us. This has not happened. We provided our former GTR with a plan to obtain this hydrologic data, but funding was denied. We are concerned that without statistical validity and hydrologic information, our conclusions will be limited. As stated in the Draft EIS, the linkages between sediment and water need to be established. The biogeochemical reactions taking place in the reattachment bars are an important aspect of the fluvial ecosystem and need further study. Reaction paths of nutrients are dependent on two factors: water and oxygen. Fluctuating flows control the delivery of both. Any management alternative that is implemented will have profound effects on biogeochemical reactions (nutrient cycling) within the river corridor. Our ability to predict these effects will be limited by the situation described above.

Finally, our initial proposal stated that we were to be given a complete set of hydrologic data on flow paths and rates of groundwater in these beaches. This work was to be completed by other contractors. This information was never produced. Without this water flow information we are unable to create nutrient budgets for the beaches. For this reason, we are attempting to acquire some of this data in the context of our existing study. Initiating this additional objective has spread us very thin, forcing us to commit resources in areas we had not anticipated. In addition, because the hydrogeologic work is being conducted on a shoe-string budget, it will not be as detailed or conclusive as the other contractor's work was supposed to be.

C. FISCAL STATUS

Due to the budget shortfall for FY93, this project has been reduced in scope. All biological objectives have been suspended. In addition, the number of sampling trips has been reduced to five. In order to offset the reduction in sampling trips, we have submitted a pre-proposal to Dr. Patten, Department of Environmental Sciences, Arizona State University to sample extensively 194L before and during the experimental flood flow during the spring of 1995. Lastly, much of the laboratory analysis of samples collected this year will be put off until FY94.

1. Cooperative Agreement Amount: $116,014

2. Expenditures and Commitments to Date: $86,383.27

3. Estimated Funds Required to Complete Work: $29,630.73

4. Estimated Date of Completion of Work: 11-1-95

Final report, final management report,final oral report..........................1 June, 1995

D. ACTION REQUESTED OF NPS

1.Continued support of this project during the analysis and report preparation phases is requested of the NPS. In order to complete the added objectives we are pursuing(see Problems Encountered, above),we request a 7 month no cost extension of the contract, with a new termination data of Nov. 30, 1995.

E. FUTURE PLANS

1. The schedule has been modified as follows.

Table 1: Schedule for activities and deliverables.

Initiation	March 1, 1992 or on notification of funding
Quarterly report	April 1, 1993
Initial oral report to NPS	April 15, 1993
First sampling trip	April 17, 1993
Quarterly report	July 1, 1993
Second sampling trip	July 9, 1993
Quarterly report	October 1, 1993
Third sampling trip	October 10, 1993
Draft 1993 annual technical and administrative reports	December 1, 1993
Final 1993 annual and oral reports	January 15, 1994
Fourth sampling trip	January 5, 1994
Quarterly report	April 1, 1994
Quarterly report	July 1, 1994
Sampling trip to -6 mile	July 26, 1994
Quarterly report	October 1, 1994
Sampling trip to -6 mile	November,1994
Draft annual technical and administrative reports	December 1, 1994
Fifth sampling trip	January ,1994
Final 1994 annual and oral reports	January 30, 1995
Sampling trip to -6 mile	April,1995
Final sampling trip, hydrogeologic study and removal of all sampling wells	August ,1995
Final technical and annual report	November 30, 1995

Figure 1. Averages of all river orthophosphate values for all trips.

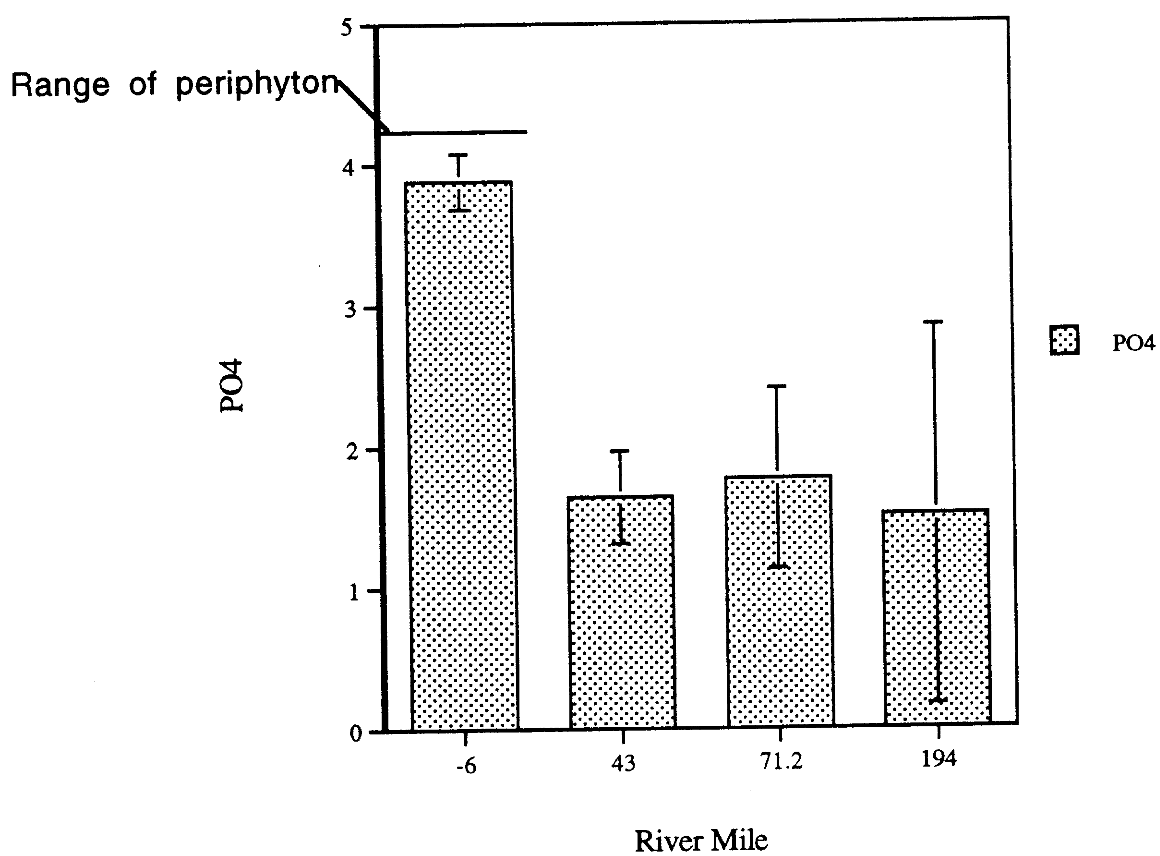


Figure 2. Dissolved [T-PO_4] trend for -6A, November 21, 1993

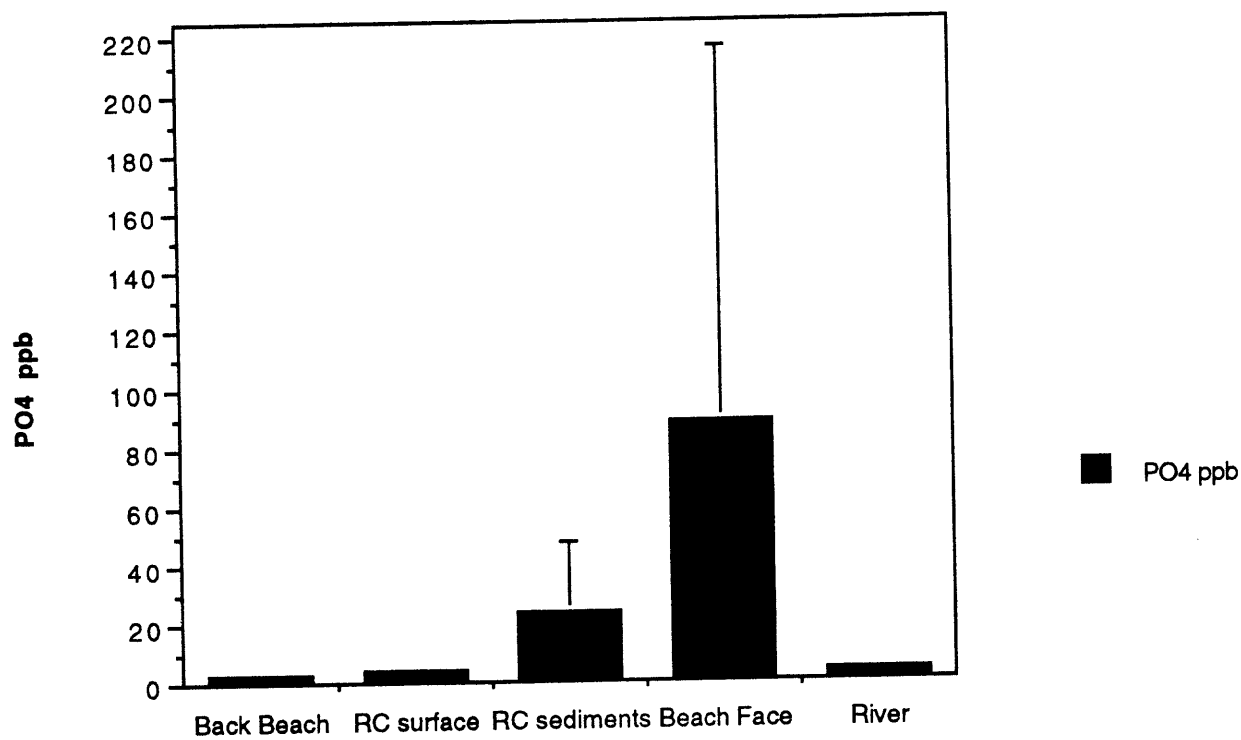


Figure 3. Non-occluded [T-PO_4] for surface sediments along line 30 (RCC to river) for November 21, 1993.

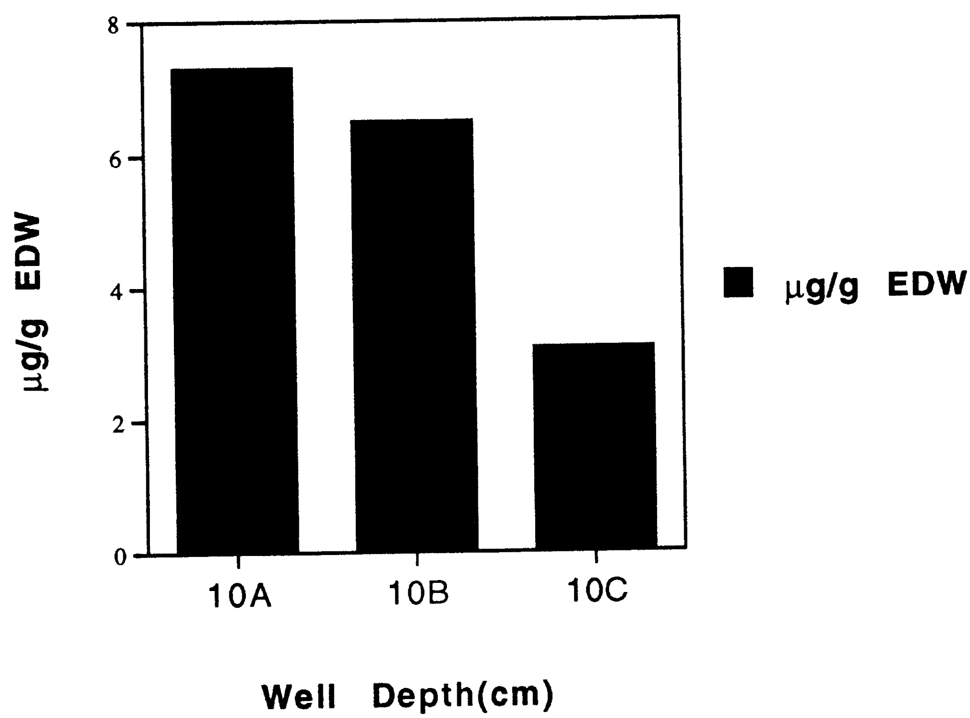


Figure 4. Nitrate distribution for -6A, November 21, 1993

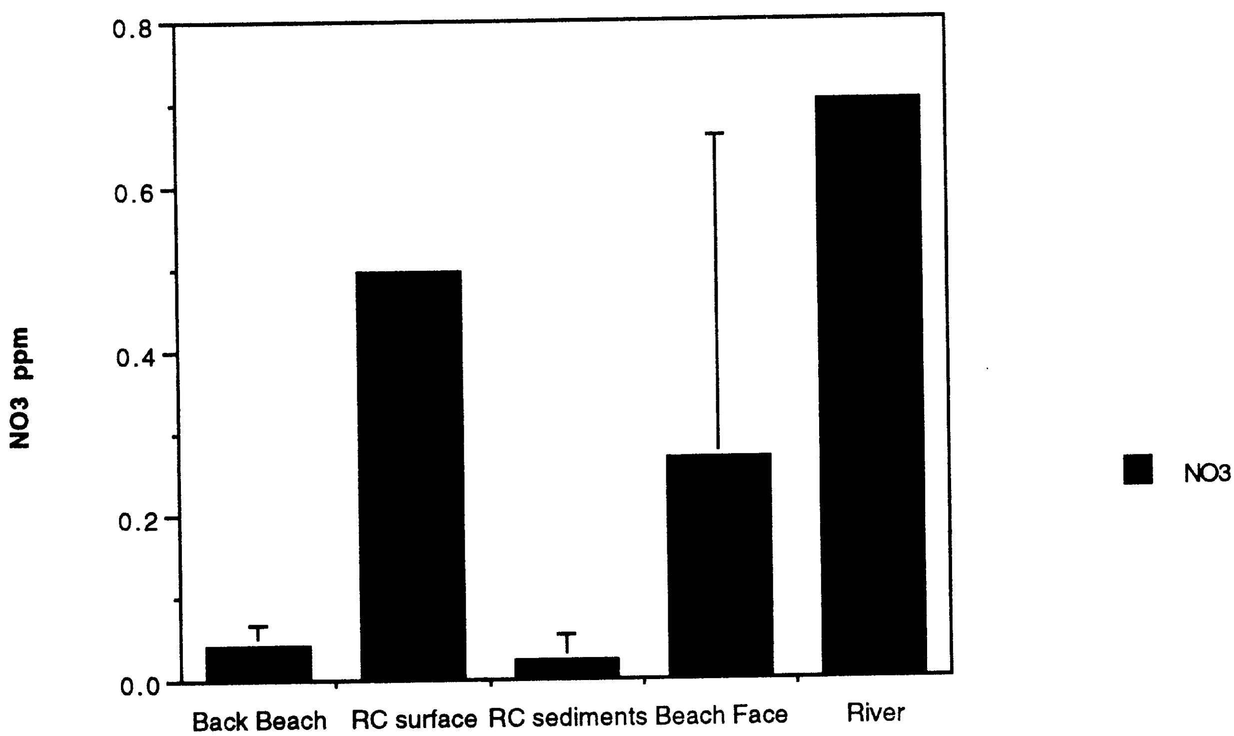


Figure 5. Ammonia distribution for -6A, November 20, 1993

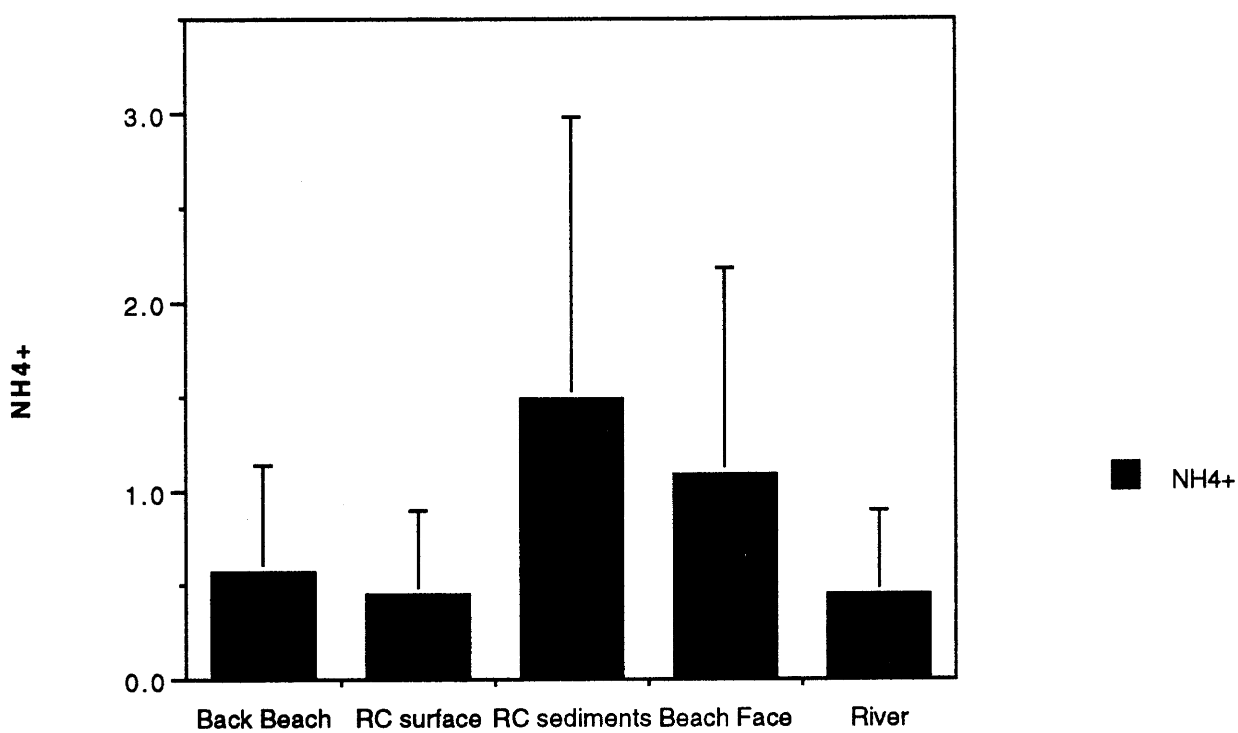
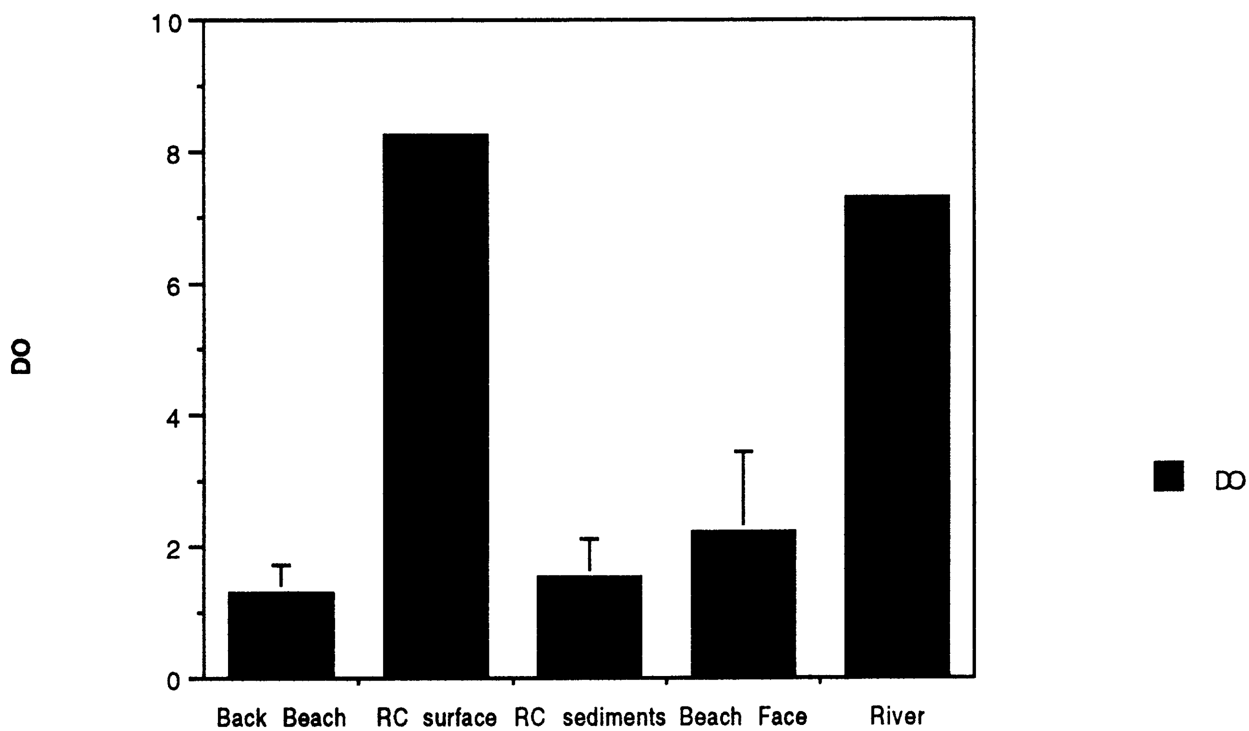


Figure 6. DO distribution for -6A, November 21, 1993



Appendix 1. Representative data set.

Beach: 43.2L
Date: April 20,1993
Notes:

Sample	T(C)	Sp. cond.	pH	[H+]	Eh	Alkalinity (meq/l)	[N-NO2]	[N-NO3]
RC surface	24.5	1385	8.28	5.25E-09	411.2	2.97	0.0	0.1
RC sediments	16.6	1140	7.4	4.31E-08	155.6	5.07	0.0	0.0
RC sd.	0.81	97	0.19	1.73E-08	30.752	1.85	0.01	0.05
Mid-beach	16.7	1055	7.6	2.56E-08	377.6	3.24	0.0	0.1
MB sd.	1.36	71	0.15	1.01E-08	45.984	0.61	0.01	0.07
Beach Face	16.6	1041	7.8	1.88E-08	387.4	4.35	0.0	0.1
BF sd.	0.86	65	0.26	1.10E-08	97.488	1.19	0.01	0.04
River	17.2	970	8.1	8.91E-09	420.5	3.30	0.0	0.4
River sd.	0.28	14	0.09	1.87E-09	32.527	0.43	0.00	0.00
1AS	17.2	1100	7.73	1.86E-08	131.5	3.28	0.00	0.00
1AD	15.0	1080	7.39	4.07E-08	120.5	4.26	0.00	0.00
1BS	14.3	990	7.73	1.86E-08	335.0	2.50	0.01	0.00
1BD	17.0	1020	7.75	1.78E-08	379.5	3.39	0.02	0.11
1CS	17.5	990	7.89	1.29E-08	380.5	3.77	0.01	0.10
1CD	18.0	940	7.89	1.29E-08	369.0	4.92	0.02	0.08
2AS	16.7	1300	7.15	7.08E-08	203.9	8.41	0.00	0.00
2AD	17.0	1210	7.29	5.13E-08	145.5	5.87	0.00	0.01
2BS	18.0	1160	7.35	4.47E-08	376.8	4.25	0.01	0.17
2BD	18.0	1120	7.67	2.14E-08	320.5	2.75	0.01	0.08
2CS	14.6	1280	7.55	2.82E-08	373.7	4.61	0.02	0.12
2CD	15.5	945	8.13	7.41E-09	409.8	6.30	0.01	0.07
3AS	16.5	1040	7.44	3.63E-08	154.5	3.92	0.00	0.07
3AD	17.0	1110	7.39	4.07E-08	177.5	4.66	0.02	0.11
3BS	16.5	990	7.54	2.88E-08	444.5	3.30	0.00	0.08
3BSS	;ample							
3BD	16.5	1050	7.65	2.24E-08	409.5	3.23	0.02	0.20
3CS	17.0	980	7.55	2.82E-08	406.8	3.40	0.01	0.15
3CD	17.0	1110	7.63	2.34E-08	384.8	3.10	0.02	0.14
RC	24.5	1385	8.28	5.25E-09	411.2	2.97	0.01	0.08
EVH	17.0	980	7.99	1.02E-08	443.5	2.99	0.01	0.37
EM	17.4	960	8.12	7.59E-09	397.5	3.60	0.01	0.37

Appendix 1. Representative data set.

Beach: 43.2L
Date: April 20,1993
Notes:

Sample	[K] ppm	[Na] ppm	[Ca] ppm	[Mg] ppm	[Cl] ppm	[SO4] ppm
	2.37	59.83	73.59	29.41	66.59	34.18
aways average	2.4	62.1	89.7	34.4	62.3	31.8
awas std. dev.	0.56	9.98	13.04	8.46	2.59	0.87
middles average	2.4	58.2	82.5	27.4	61.8	32.9
middles std. dev.	0.34	1.56	5.14	2.38	1.58	0.18
close average	2.3	58.9	81.1	27.6	61.7	31.1
close td. dev.	0.27	1.80	5.88	1.30	1.29	2.84
Avg. surface water	1.7	58.5	77.5	29.4	60.0	32.7
Std.dev.	0.38	1.68	0.14	0.59	0.64	0.09
1AS	2.3	59.0	80.4	32.6	60.9	32.7
1AD	2.2	58.8	75.8	33.2	61.1	31.9
1BS	1.9	61.1	81.8	28.6	59.8	32.9
1BD	2.7	56.9	79.3	28.6	60.4	32.6
1CS	1.9	58.3	75.6	26.0	57.6	30.7
1CD	2.3	56.0	67.6	23.8	60.1	25.7
2AS	2.1	57.3	108.5	40.3	67.4	30.7
2AD	3.6	82.4	103.1	47.9	61.6	31.1
2BS	2.5	57.5	92.4	30.6	64.1	33.0
2BD	2.7	57.1	83.2	26.9	62.5	33.0
2CS	2.1	61.7	104.9	36.4	70.0	35.4
2CD	2.6	61.3	81.3	27.3	61.1	29.5
3AS	2.3	56.9	84.5	24.7	60.3	32.9
3AD	2.1	58.1	86.1	28.0	62.6	31.5
3BS	2.3	57.8	78.7	25.5	61.6	32.9
3BSS	no sample					
3BD	2.0	58.5	79.6	24.1	62.5	33.0
3CS	2.6	57.8	80.2	26.7	61.1	32.9
3CD	2.6	58.3	77.0	25.1	60.6	32.7
RC	2.4	59.8	73.6	29.4	66.6	34.2
EVH	1.4	57.3	77.4	29.0	59.5	32.7
EM	2.0	59.6	77.6	29.8	60.4	32.8

INFLUENCE OF GEOCHEMICAL PROCESSES ON NUTRIENT SPIRALING WITHIN THE RECIRCULATION ZONES OF THE COLORADO RIVER IN THE GRAND CANYON

QUARTERLY REPORT, APRIL 1, 1995

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Flagstaff, AZ 86011

Cooperative Agreement: CA8000-8-0002

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BEACH GEOCHEMISTRY AND NUTRIENT
SPIRALING ANNUAL REPORT: 1993

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1. Overview of Project

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We have also undertaken physical and chemical analysis of soil samples from all four beaches. These studies include grain size analysis and fractionated extractable phosphate. A representative data set appears in Appendix 2.

Pneumatic slug tests were conducted at all beaches within the study. Synoptic water levels were taken at varying river stage. These two hydrogeologic parameters are being utilized to characterize flow between the reattachment bars and the river

4. Interpretations

The return current channels along the reattachment bars in the Grand Canyon are distinctive environments, physically, chemically, and geologically. Other workers (Stevens et. al., 1993) have demonstrated that the RCCs have the highest primary productivities and accumulations of organic of all bar environments. As the flows recede during fluctuating flows, RCCs are stranded from the main current, and left with standing water. Fine-grained clastic and organic material settle out in these backwaters as the stranded waters evaporate. This infilling of the RCC with fine-grains and organics is a an effect of dam regulated flows that leads to a dewatering of the RCC and the occurrence of emergent marsh-type vegetation. We observed a thick mat of vegetation buried under 12" of clayey silt brought in by the LCR winter floods of 1993. These changes in the RCC represent changes in the size and distribution of various nutrient (N,C,P) pools for the Colorado River. Nitrogen cycling, particularly denitrification, in riparian fens such as these has been the subject of much attention in areas where changing ecologies are of concern (Groffman, 1994). DO, Eh, and NH_{4+} data are evidence that the RCC sediments provide a reducing environment, presumably caused by the decomposition of buried organics such as the buried mat at 194. Reduced environments, coupled with the increased availability of carbon and ammonium point to an increased importance of denitrification in the nitrogen cycle. This would provide a nitrogen sink for the Colorado River and a net loss of nitrogen.

Cores of mid-beach and beach face sediments are much coarser than those of the RCCs. Higher DO and Eh under the mid-bar demonstrate a more oxidized environment than that in the RCCs. Speciation of dissolved nitrogen reflects these changing conditions, with higher [NO_3^-]

and lower [NH_4^+] moving from the RCCs toward the river. One form of N exists only at the expense of the other. The most abundant source of N appears to be river water NO_{3-}, with decreasing concentrations moving away from the river.

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Non-occluded [T-PO_4] in sediments decreases moving outward from the RCC and across the reattachment bar. Dissolved [T-PO_4] increase along the same line. The regular, diurnal fluctuations in river flow under the current river management system leach the labile phosphate from the sediments close to the river. The downstream decrease in PO4 occurs before mile 43. This can be explained in two ways. First, biological uptake by Cladophora, a green algae which exists in great numbers in Glen Canyon but not below. Secondly, loss from fine grain sedimentation in the RCCs.

Interim flows, mandated by The Grand Canyon Protection Act of 1992, require relatively low daily fluctuating and dampened seasonal fluctuations, which have resulted in less dramatic changes in hydraulic head within the beaches. Previous Grand Canyon researchers have reported that hydraulic gradients under the RCC responded minimally to fluctuating flows. This has been described as the "hinge effect". Preliminary evaluation of our synoptic water level measurements indicate that there is equal or greater head reponse to changing river stage under the RCC. Head data results will need further evaluation. Hydraulic conductivities loosely correlate with grain size distribution for the reattachment bars.

5. Conclusions

A. Ortho-phosphate concentrations decrease downstream from -6.7L (Figure 1).

B. Dissolved [T-PO_4] increase from RCC to river while extractable non-occluded P decrease along the same line (Figure 2 and 3).

C. Speciation of nitrogen and dissolved oxygen measurements reflect a changing redox environment with higher [NO_3^-] and lower [NH_{4+}] moving from the RCC toward the river. The most abundant source of NH_{4+} is highly reduced RCC sediments (Figure 4,5 and 6).

D. Preliminary results of the slug tests indicate a spacial heterogeneity in hydraulic conductivity. The synoptic water levels indicate a stage dependent gradient within the reattachment bars (Figure 7).

B. PROBLEMS ENCOUNTERED

During reduction of the field measurements for nitrate and nitrite, we observed that regression curves for standards run on one trip (July 1994) were not satisfactory. In our subsequent discussion with Hach, our supplier, we were informed that the lot of reagents used for nitrate and nitrite analysis were bad, forcing us to question all our field nitrate and nitrite numbers from the July trip. We did collect samples for laboratory analysis of nitrate and nitrite. We will compare lab and field measurements of N-species for the April trip to determine if we can use lab values for N-species from our July trip.

We discovered large amounts of drift in our Eh measurements which we believe are due to poorly poised waters. Therefore, we added Winkler titrations to our field measurements in order to gain accurate knowledge of the oxidation states within the reattachment bars.

Last year we lost our GTR. This poses several problems, not the least of which is communicative. This project was originally funded for two years. We demonstrated that two years of sampling was necessary for statistical validity. After project startup, funds were taken back, causing a reduction in sample collection. Also, as stated in our original proposal, hydrologic data was needed to quantify flux of nutrients through the reattachment bars. These data were to be supplied to us. This has not happened. We provided our former GTR with a plan to obtain this hydrologic data, but funding was denied. We are concerned that without statistical validity and hydrologic information, our conclusions will be limited. As stated in the Draft EIS, the linkages between sediment and water need to be established. The biogeochemical reactions taking place in the reattachment bars are an important aspect of the fluvial ecosystem and need further study. Reaction paths of nutrients are dependent on two factors: water and oxygen. Fluctuating flows control the delivery of both. Any management alternative that is implemented will have profound effects on biogeochemical reactions (nutrient cycling) within the river corridor. Our ability to predict these effects will be limited by the situation described above.

The confusion at the time of start up over finances was corrected in the late spring by a budget modification and adjustment of scope submitted in late spring of 1995. this document also moved the ending date to June 30, 1995. Somehow this was not recognized by the university administration. To correct this we have submitted a request for a no cost extension.

C. FISCAL STATUS

Due to the budget shortfall for FY93, this project has been reduced in scope. All biological objectives have been suspended. In addition, the number of sampling trips has been reduced to five. In order to offset the reduction in sampling trips, we have submitted a pre-proposal to Dr. Patten, Department of Environmental Sciences, Arizona State University to sample extensively 194L before and during the experimental flood flow during the spring of 1995. Lastly, much of the laboratory analysis of samples collected this year will be put off until FY94.

1. Cooperative Agreement Amount:$116,014

2. Expenditures and Commitments to Date: $88.442.44

3. Estimated Funds Required to Complete Work: $27,571.56

4. Estimated Date of Completion of Work: 9-30-95

Final report, final management report,final oral report..........................September 30, 1995

D. ACTION REQUESTED OF NPS

1.Continued support of this project during the analysis and report preparation phases is requested of the NPS.

E. FUTURE PLANS

1. The schedule has been modified as follows.

Table 1: Schedule for activities and deliverables.

Initiation	March 1, 1992 or on notification of funding
Quarterly report	April 1, 1993
Initial oral report to NPS	April 15, 1993
First sampling trip	April 17, 1993
Quarterly report	July 1, 1993
Second sampling trip	July 9, 1993
Quarterly report	October 1, 1993
Third sampling trip	October 10, 1993
Draft 1993 annual technical and administrative reports	December 1, 1993
Final 1993 annual and oral reports	January 15, 1994
Fourth sampling trip	January 5, 1994
Quarterly report	April 1, 1994
Quarterly report	July 1, 1994
Sampling trip to -6 mile	July 26, 1994
Quarterly report	October 1, 1994
Sampling trip to -6 mile	November,1994
Draft annual technical and administrative reports	December 1, 1994
Fifth sampling trip	January ,1994
Final 1994 annual and oral reports	January 30, 1995
Quarterly Report	July 1, 1995
Final technical and annual report	September 30, 1995

Figure 1. Averages of all river orthophosphate values for all trips.

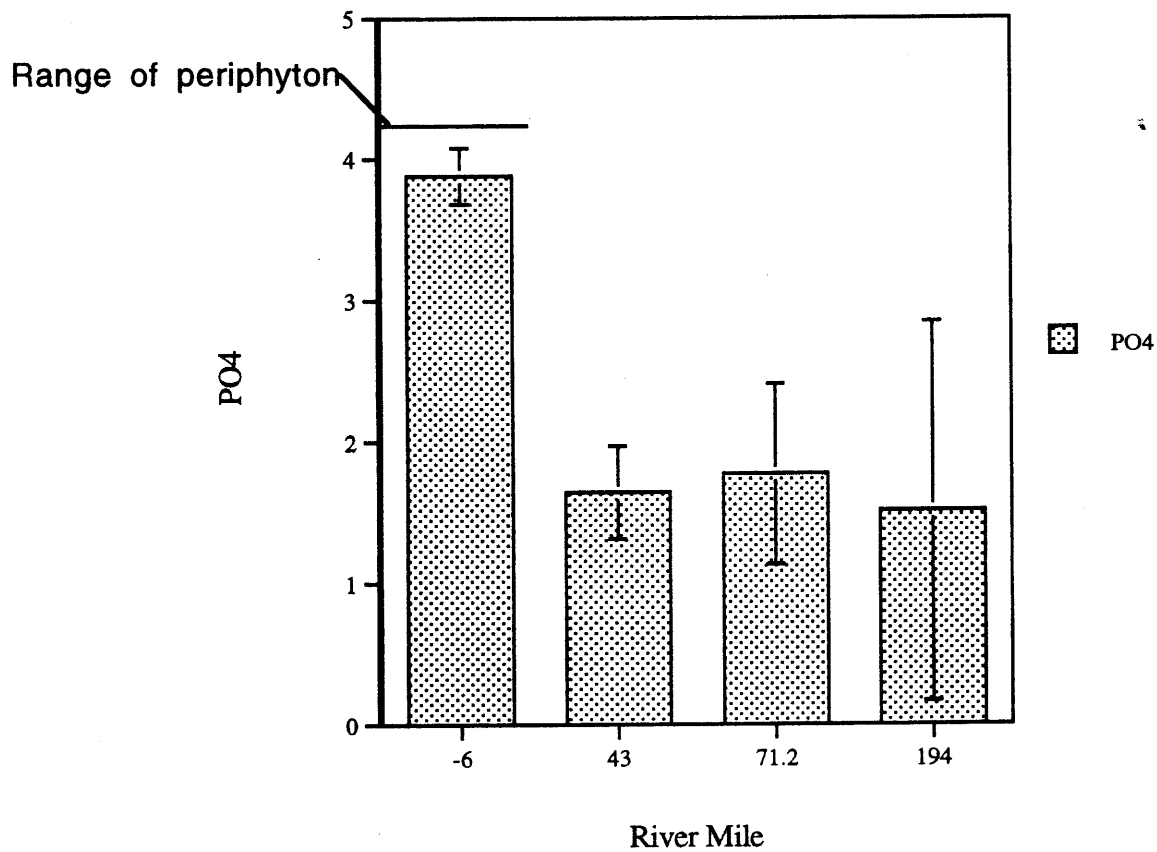


Figure 2. Dissolved [T-PO_4] trend for -6A, November 21, 1993

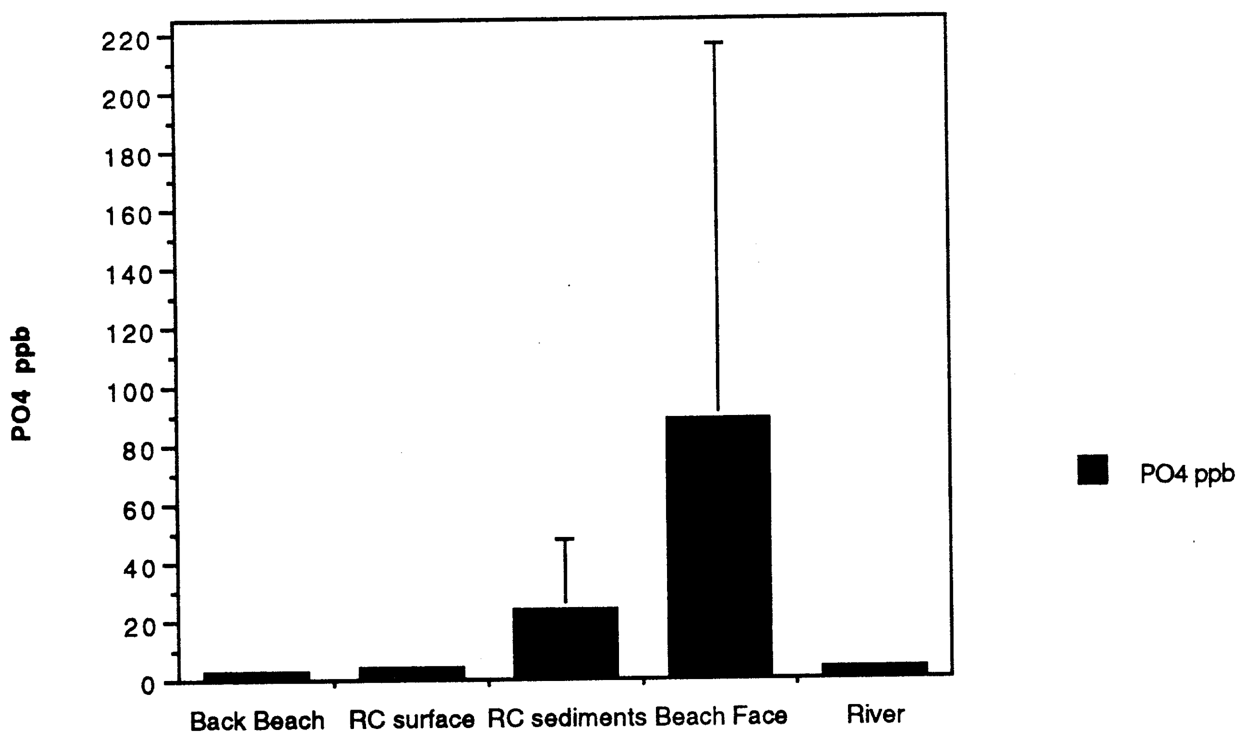


Figure 3. Non-occluded [T-PO_4] for surface sediments along line 30 (RCC to river) for November 21, 1993.

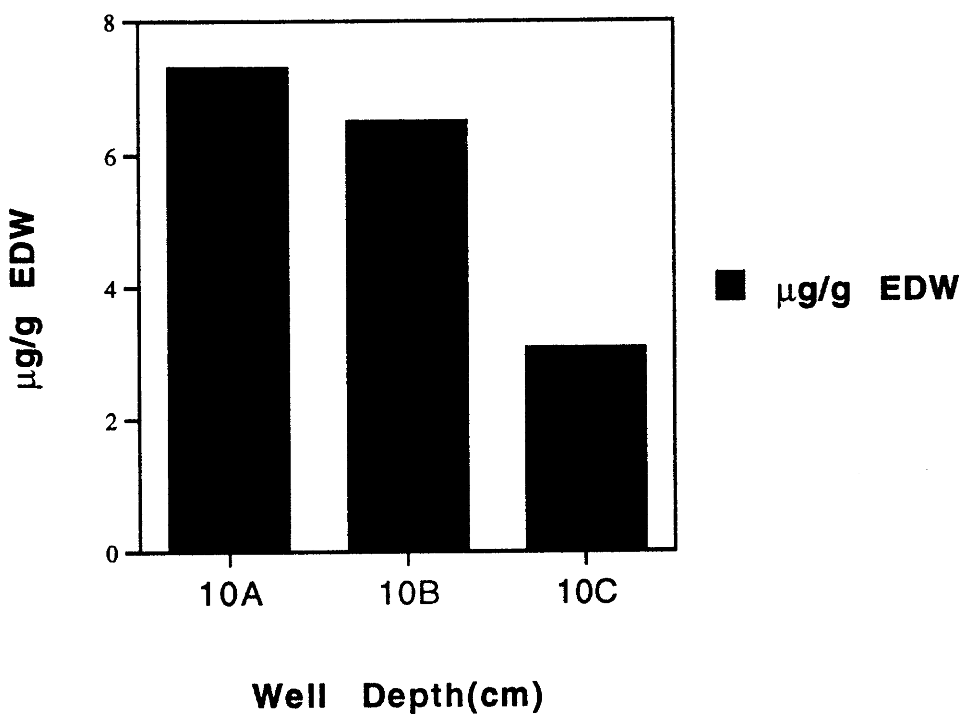


Figure 4. Nitrate distribution for -6A, November 21, 1993

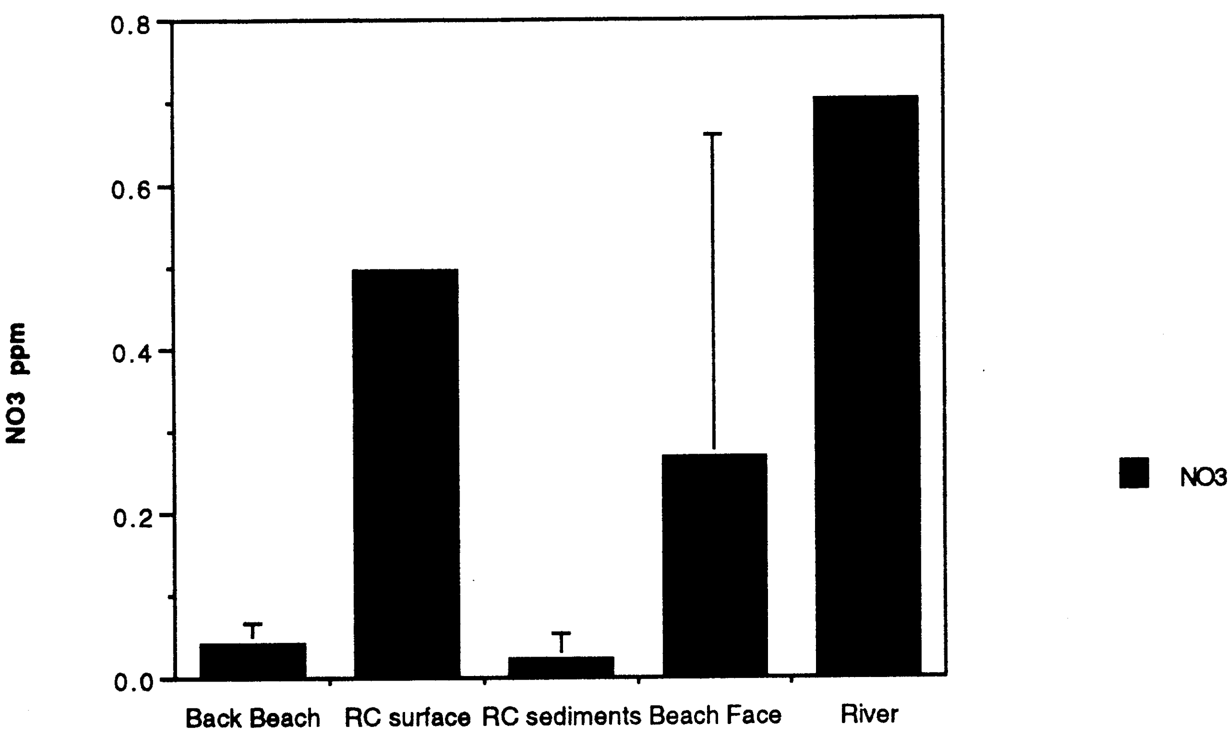


Figure 5. Ammonia distribution for -6A, November 20, 1993

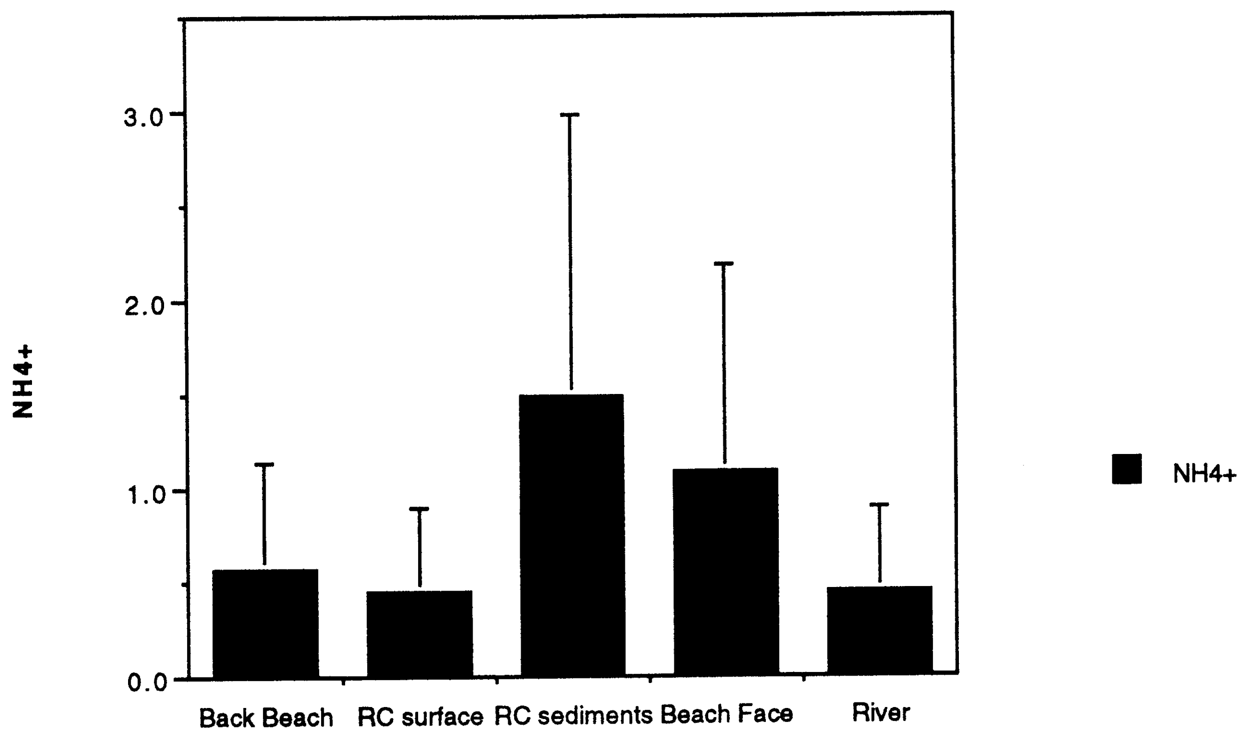


Figure 6. DO distribution for -6A, November 21, 1993

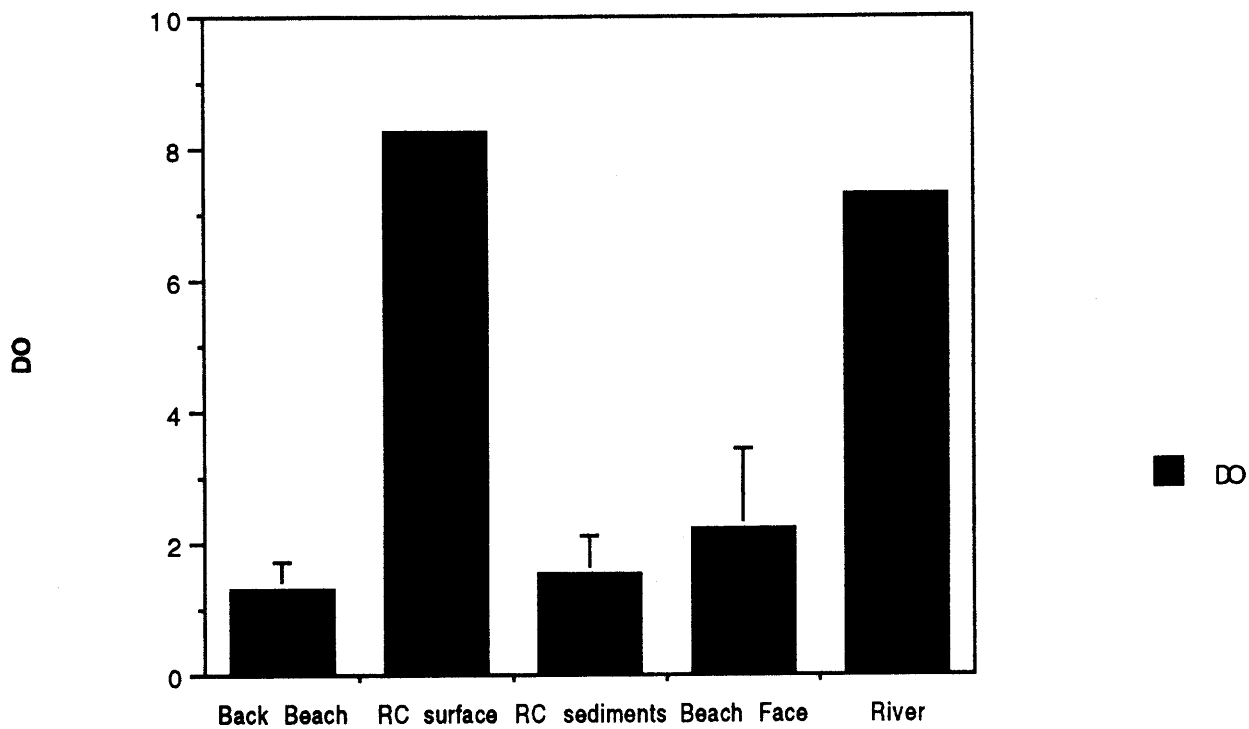
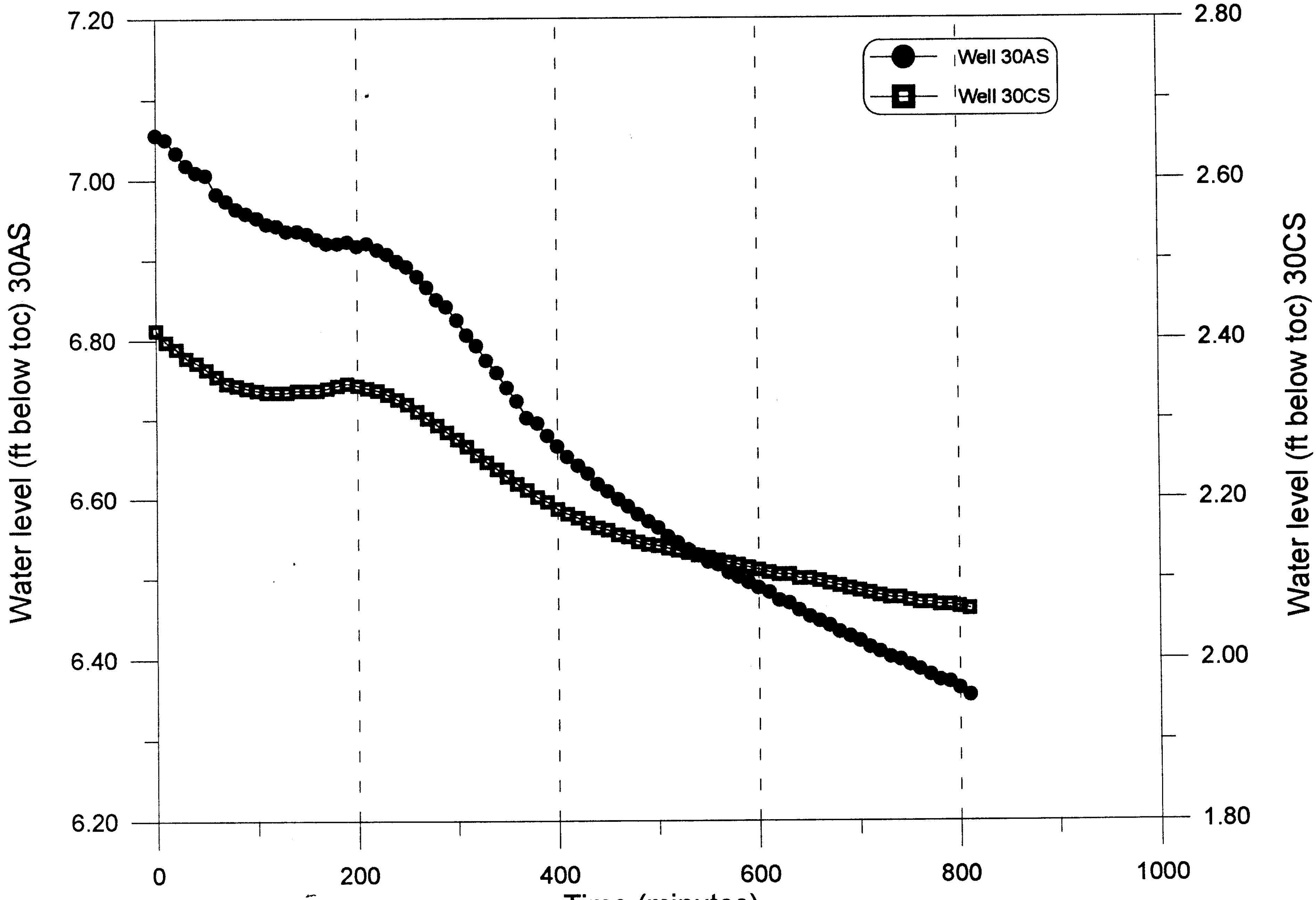


Figure 7. Water level vs. time - Colorado River, Beach at -6



Appendix 1. Representative data set.

Beach: 43.2L
Date: April 20,1993
Notes:

Sample	T(C)	Sp. cond.	pH	[H+]	Eh	Alkalinity (meq/l)	[N-NO2]	[N-NO3]
RC surface	24.5	1385	8.28	5.25E-09	411.2	2.97	0.0	0.1
RC sediments	16.6	1140	7.4	4.31E-08	155.6	5.07	0.0	0.0
RC sd.	0.81	97	0.19	1.73E-08	30.752	1.85	0.01	0.05
Mid-beach	16.7	1055	7.6	2.56E-08	377.6	3.24	0.0	0.1
MB sd.	1.36	71	0.15	1.01E-08	45.984	0.61	0.01	0.07
Beach Face	16.6	1041	7.8	1.88E-08	387.4	4.35	0.0	0.1
BF sd.	0.86	65	0.26	1.10E-08	97.488	1.19	0.01	0.04
River	17.2	970	8.1	8.91E-09	420.5	3.30	0.0	0.4
River sd.	0.28	14	0.09	1.87E-09	32.527	0.43	0.00	0.00
1AS	17.2	1100	7.73	1.86E-08	131.5	3.28	0.00	0.00
1AD	15.0	1080	7.39	4.07E-08	120.5	4.26	0.00	0.00
1BS	14.3	990	7.73	1.86E-08	335.0	2.50	0.01	0.00
1BD	17.0	1020	7.75	1.78E-08	379.5	3.39	0.02	0.11
1CS	17.5	990	7.89	1.29E-08	380.5	3.77	0.01	0.10
1CD	18.0	940	7.89	1.29E-08	369.0	4.92	0.02	0.08
2AS	16.7	1300	7.15	7.08E-08	203.9	8.41	0.00	0.00
2AD	17.0	1210	7.29	5.13E-08	145.5	5.87	0.00	0.01
2BS	18.0	1160	7.35	4.47E-08	376.8	4.25	0.01	0.17
2BD	18.0	1120	7.67	2.14E-08	320.5	2.75	0.01	0.08
2CS	14.6	1280	7.55	2.82E-08	373.7	4.61	0.02	0.12
2CD	15.5	945	8.13	7.41E-09	409.8	6.30	0.01	0.07
3AS	16.5	1040	7.44	3.63E-08	154.5	3.92	0.00	0.07
3AD	17.0	1110	7.39	4.07E-08	177.5	4.66	0.02	0.11
3BS	16.5	990	7.54	2.88E-08	444.5	3.30	0.00	0.08
3BSS	;ample							
3BD	16.5	1050	7.65	2.24E-08	409.5	3.23	0.02	0.20
3CS	17.0	980	7.55	2.82E-08	406.8	3.40	0.01	0.15
3CD	17.0	1110	7.63	2.34E-08	384.8	3.10	0.02	0.14
RC	24.5	1385	8.28	5.25E-09	411.2	2.97	0.01	0.08
EVH	17.0	980	7.99	1.02E-08	443.5	2.99	0.01	0.37
EM	17.4	960	8.12	7.59E-09	397.5	3.60	0.01	0.37

Appendix 1. Representative data set.

Beach: 43.2L
Date: April 20,1993
Notes:

Sample	**[K] ppm**	**[Na] ppm**	**[Ca] ppm**	**[Mg] ppm**	**[Cl] ppm**	**[SO4] ppm**
	2.37	59.83	73.59	29.41	66.59	34.18
aways average	2.4	62.1	89.7	34.4	62.3	31.8
awas std. dev.	0.56	9.98	13.04	8.46	2.59	0.87
middles average	2.4	58.2	82.5	27.4	61.8	32.9
middles std. dev.	0.34	1.56	5.14	2.38	1.58	0.18
close average	2.3	58.9	81.1	27.6	61.7	31.1
close td. dev.	0.27	1.80	5.88	1.30	1.29	2.84
Avg. surface water	1.7	58.5	77.5	29.4	60.0	32.7
Std.dev.	0.38	1.68	0.14	0.59	0.64	0.09
1AS	2.3	59.0	80.4	32.6	60.9	32.7
1AD	2.2	58.8	75.8	33.2	61.1	31.9
1BS	1.9	61.1	81.8	28.6	59.8	32.9
1BD	2.7	56.9	79.3	28.6	60.4	32.6
1CS	1.9	58.3	75.6	26.0	57.6	30.7
1CD	2.3	56.0	67.6	23.8	60.1	25.7
2AS	2.1	57.3	108.5	40.3	67.4	30.7
2AD	3.6	82.4	103.1	47.9	61.6	31.1
2BS	2.5	57.5	92.4	30.6	64.1	33.0
2BD	2.7	57.1	83.2	26.9	62.5	33.0
2CS	2.1	61.7	104.9	36.4	70.0	35.4
2CD	2.6	61.3	81.3	27.3	61.1	29.5
3AS	2.3	56.9	84.5	24.7	60.3	32.9
3AD	2.1	58.1	86.1	28.0	62.6	31.5
3BS	2.3	57.8	78.7	25.5	61.6	32.9
3BSS	no sample					
3BD	2.0	58.5	79.6	24.1	62.5	33.0
3CS	2.6	57.8	80.2	26.7	61.1	32.9
3CD	2.6	58.3	77.0	25.1	60.6	32.7
RC	2.4	59.8	73.6	29.4	66.6	34.2
EVH	1.4	57.3	77.4	29.0	59.5	32.7
EM	2.0	59.6	77.6	29.8	60.4	32.8