ANALYSES OF RECREATIONAL WATER QUALITY AS RELATED TO SEDIMENT RESUSPENSION

by

Jack David Doyle

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As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Jack David Doyle

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and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Stanley K. Brickler	Date 14 Feb 85
Charles P. Gerba	Date Feb. 14, 1985
Naomi G. Sinclair	Date 2/14/85
William J. Matter	Date 2-12-85

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Stanley K. Brickler	14 Feb 85
Dissertation Director	Date

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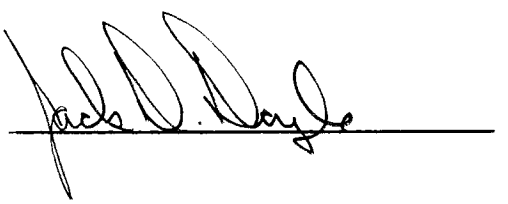
SIGNED: 

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ABSTRACT

Aquatic sediments, at a lake beach site in the Tonto National Forest, Arizona, were experimentally disrutped to quantitatively determine the impact of sediment resuspension on recreational water quality. Sediment resuspension was found to significantly degrade the quality of recreational waters. Mean sediment fecal coliform densities exceeded mean fecal coliform densities in overlying waters by 24.7 fold. When these sediments were experimentally disrupted, fecal coliform densities and turbidity levels in the water column increased by 1.4 to 2.8 and 1.1 to 5.4 fold, respectively. The impact of sediment resuspension on overlying waters was short-lived at the point of disruption. Increasing FC densities and turbidities generally peaked within 5 sec of resuspension and declined to pre-resuspension levels within 500 sec. The magnitude of the resuspension impact was most significantly influenced by water depth. The greatest risk to public health was found to be within the 0.3 m depth zone; that near-shoreline area most intensively used by young children for water play.

INTRODUCTION

Resuspension of aquatic sediments and associated enteric microorganisms is an important but often overlooked process that may greatly influence the quality of overlying recreational waters (16,20). Sediments have been identified as reservoirs of enteric indicator bacteria in the aquatic environment (5,6,20,74). Typically fecal coliform (FC) densities in sediments have been found to exceed those of the water by up to three orders of magnitude (5,6,32,46). Increased occurrences of enteric pathogens, as compared to overlying waters, have been associated with these elevated sediment FC densities (25,32,46,74). Sediments laden with enteric bacteria may, therefore, represent a potential health hazard to users of recreational waters; particularly when those sediments are resuspended.

Increased densities of FC organisms have been found in waters containing resuspended sediments (5,28). Resuspension of some contaminated sediments has been found to degrade waters beyond current recreational contact standards (5,6,29,71) and epidemiological evidence has suggested that there may be a relationship between microorganisms associated with suspended particles and gastrointestinal illness (14). The fact that swimming in

general increases the risk of waterborne gastrointestinal illness and infections of the skin, ears, eyes and throat has already been established (8,66,69).

A number of common processes which may resuspend sediments in recreational waters have been identified: including intensive water play (42,75,76); natural and boat-wake induced wave action (7,21,42,74); prop wash from power boats (21); hydroelectric water level regulation of lakes and streams (71); tributary stormflows (21,24); and dredging (29). Sediment resuspensions may be of particular public health significance within the near-shore zone, where waters are shallow ($\leq$ 1 m). Near-shore waters are intensively used for water play recreation, especially by children. Children are generally less cautious than adults regarding purposeful or accidental contact with or consumption of waters. These waters may have a higher frequency of degradation, as a result of resuspended microorganisms, than do deeper waters. The portion of the water column effected by resuspension processes is usually inversely proportional to water depth (54). Currents which may disperse resuspended materials are also often reduced in shore-line waters, as compared to off-shore locations. Examination of two hydroelectric reservoirs used for recreation in Arizona has shown near-shore sediments and waters ($\leq$ 0.7 m depth) to have higher and more variable

densities of FC than waters and sediments at greater depths (0.9 to 1.8 m)(44).

A number of workers have advised that bottom sediments and the role they play in recreational water quality should be carefully considered when assessing waters for recreational use (21,23,67). At least two general hypotheses regarding sediment assessment have been proffered. First, FC densities in sediments have been suggested as a more stable index of water quality than densities of FC in the water (56,74). This premise has been fairly widely regarded, but only rarely tested. FC densities in two reservoirs in Arizona were found to be equally variable in waters and sediments at recreational beaches (44). Data on the variability of these organisms in the sediments and waters of other water bodies in a variety of locations is not readily available in the literature.

Second, sediments represent a potential direct disease hazard, requiring attention when assessing the quality of recreational waters (21,23,72). FC and/or pathogen loading of sediments must be determined as well as the interactive processes between enteric microorganisms in the sediments and overlying waters during resuspension events. Data quantifying sediment hazards or resuspension impacts in overlying waters is again limited. Grimes (29)

found that hydraulic dredging in the Mississippi River significantly increased concentrations of FC, total coliforms, and fecal streptococci in waters downstream of the dredge site. Changes in overlying water bacterial distributions due to dredging in the Mississippi River represent a somewhat unique situation, particularly when compared to sediment disruptions that may occur at recreational beaches in lakes or small streams as a result of recreation activities, wave actions, and/or other processes. To date, no general or specific techniques have been developed for routinely assessing the impact sediment-associated enteric microorganisms might have on recreational water quality, although such assessment has been recommended (20,71). Because of the scarcity of quantitative information about the role sediment and sediment resuspension plays in recreational water quality, monitoring agencies have been unable to complete this type of assessment.

To eventually develop techniques which will allow routine assessment of bottom sediments and the hazard they represent to users of recreational waters, data quantifying the impact of sediment resuspension on overlying waters is needed. Accordingly, the study reported herein was undertaken to measure, in situ, the effects of experimentally induced sediment resuspensions on recreational water quality.

MATERIALS AND METHODS

Study Site

Butcher Jones (BJ) beach on Saguaro Lake, in central Arizona (Fig. 1) was selected as the site for this study. Because Saguaro Lake and its three companion reservoirs in the Salt River Chain of Lakes (SRC) are located within the arid, upper Sonoran desert and in close proximity to the Phoenix metropolitan area, they receive intensive recreational use; ca. tenth highest recreational use nationally (53). BJ beach has the highest recreational site use of designated swimming beaches in the SRC. Located within a large cove, BJ is a shallow-sloping, curvilinear beach protected from wind and boat-wake generated waves, originating on the main body of Saguaro Lake (Fig. 1).

Sampling Methodology

The specific purpose of the study was to quantify the microbial impact of experimental sediment resuspension on overlying waters. This required a four step sampling procedure: 1) before experimentally resuspending sediment, vertically stratified water samples were collected, to determine background FC densities; 2) the bottom sediments

Figure 1. Sampling design for experimentally induced sediment resuspension.

Note: Vertically stratified water samples were collected within the 0.3 and 0.9m depth zones on parallel trransects. Sediment samples were collected directly below the sampled water column at each of the four locations.

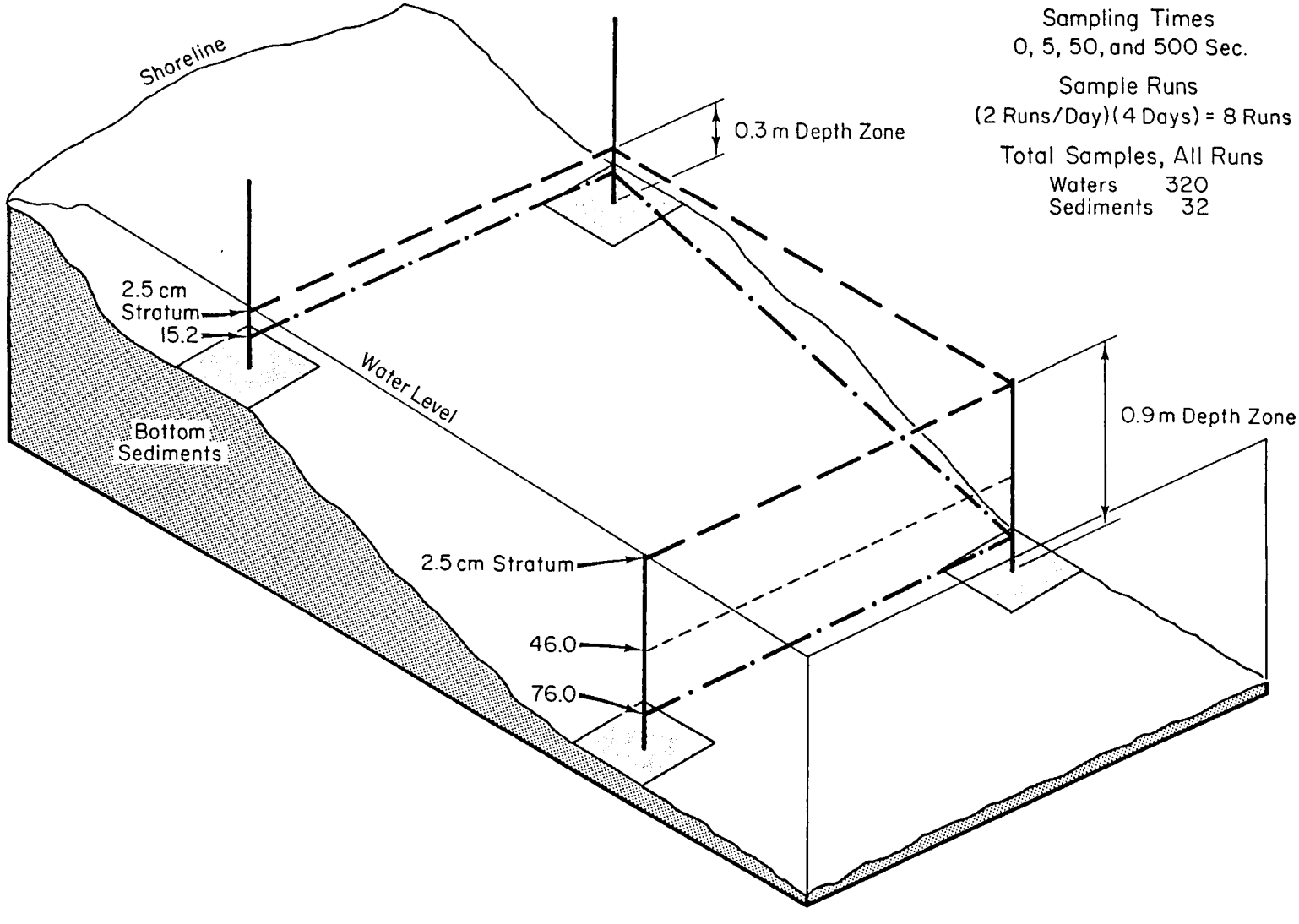


Figure 1. Sampling design for experimentally induced sediment resuspension.

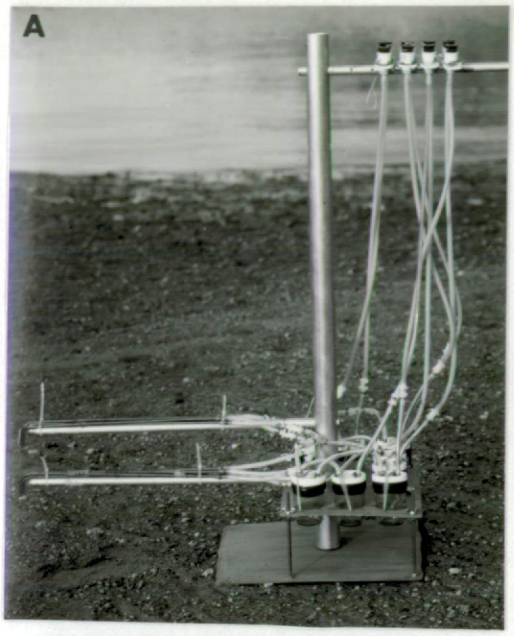
directly below the previously sampled water column were collected to determine the FC load; 3) sediments were disrupted within a ca. 2 m diameter circle centered at the base of the previously sampled water column; and 4) vertically stratified water samples were collected at 5, 50, and 500 sec intervals post-sediment resuspension. These sequential steps provided a means for determining the degree to which bottom sediment FC (BSFC) densities can influence water quality, through comparison of pre- and post-resuspension water samples.

Samples were collected daily between 6:00 and 8:00 am, from 24 to 27 May 1983. Early morning sampling on weekdays minimized the possibility of uncontrolled sediment disturbance due to public recreation. There were two experimental runs per day for four days. Two parallel sample transects were selected for each run (Fig. 1). Transects were located perpendicular to a 61 m baseline that paralleled the shoreline. Transect locations were chosen as random distances east and west of the baseline center, with the provision that they be at least 15 m apart to reduce any sampling error caused by sample collection on the adjacent transect.

Along each transect, water samples were collected at 2.5 and 15 cm below the surface at the 0.3 m depth zone and 2.5, 46, and 76 cm below the surface at the 0.9 m depth

zone (Fig. 1). Stratified samples at the 0.3 and 0.9 m depth zones were taken to determine the locational effects of sediment disruption in near-shore waters. Hydraulic head pressure was used to force water through autoclave sterile collection tubing into autoclave sterile 250 ml jars on the sampling device (Fig. 2). To prevent cross contamination, each collection jar had its own sterile air vent and water collection tube. A one-way valve was incorporated into the sampling tube to prevent back-flushing of the collected specimen. Four sample collection apparatuses were used for each experimental run, one each at the four locations on the two transects simultaneously (Fig. 1).

Pre-resuspension water samples and water and air temperatures were obtained prior to collection of sediment samples. Water temperatures were taken at the 15 cm stratum in the 0.3 m depth zone and at the 46 cm stratum in the 0.9 m depth zone. Air temperatures were taken at the baseline center position ca. 1.2 m above the ground and in the shade. Sediments were then collected in sterile glass jars from the upper 5 cm of sediment immediately below the sampled water column. Once these samples had been obtained, the sediments were resuspended at each sampling location with 20, 1.0 x 0.42 m push-pull strokes of an ethanol (70%) washed rake. Disruption of sediments



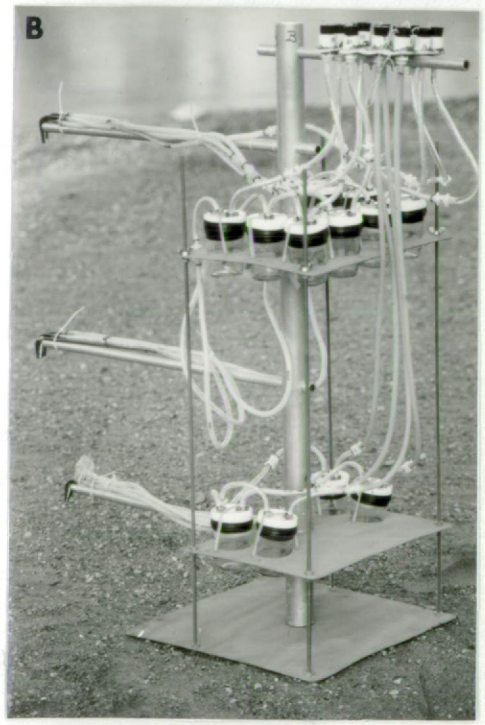


Figure 2. Collection apparatuses for vertically stratified water sampling within the 0.3 (A) and 0.9 m (B) depth zones.

occurred within a 2 m diameter circle centered at the base of the sampled water column.

Following sediment resuspension, water samples were taken at 5, 50, and 500 sec. These sampling times were selected on the basis of theoretical sedimentation rates for gravel, sand, silt, and clay. Theoretical sedimentation rates for these sediment types were calculated using the particle diameters of Marshall (52) and Stokes' sedimentation equations (11). The sampling times selected bracket the calculated periods required for complete settling of gravel and sand particles. Silt and clay fractions would remain in suspension following the 500 sec sample.

Between sample runs, used collection tubings and jars were replaced with autoclaved sterile tubings and jars, and rakes were re-washed with 70% ethanol. Immediately after collection, all samples were stored on ice for transport to the USDA Forest Service Rocky Mountain Forest and Range Experimental Station, Tempe, Arizona. A total of 352 samples were collected and analyzed, 320 from waters (64 per vertical water strata) and 32 from bottom sediments (16 per depth zone).

Sample Analyses

All samples were processed within 6 h. Water samples were analyzed for overlying water FC (OWFC) densities, using four filter volumes (100,70,30 and 10 ml) per sample, a single lot of m-FC medium (Difco Laboratories, Detroit, Mich.), and standard membrane filteration (MF) procedures for recreational waters (2). In addition to FC enumeration, the water samples were analyzed for turbidity (in nephlometric turbidity units or NTU), pH, and total dissolved solids (TDS) using an HF Instruments Model DRT15 turbidimeter, an Orion Model 407A Research Ionalyzer, and a Myron Deluxe DS Meter, respectively.

FC densities in bottom sediments were enumerated using the standard 5 tube most-probable-number fermentation tube test (2). Sediment samples were prepared for inoculation into fermentation tubes as per Doyle et al. (12). Sediments were thoroughly mixed in their sample container with an ethanol (70%) flamed, stainless steel spoon. Approximately, 100 ml (wet volume) of sediment was transferred to an autoclave sterile, 250 ml graduated cylinder, where it was compacted for 30 sec with a Sybron Thermolyne Maxi Mix (vortex mixer) to ensure precise volume measures. Sterile 0.1% poly-peptone (BBL Microbiology Systems, Cockeysville, MD.) was then added until the liquid supernatant was in equivolume to the compacted sediment, a

1:1 volume ratio. The cylinder was then sealed with M-Parafilm (American Can Company, Greenwich, CT.) and the contents mixed by inversion for 1 min. After settling for 4 min, samples were removed from mid-depth of the supernatant, and serially diluted in 0.1% poly-peptone to inoculate appropriate fermentation tubes with 1, 0.1, and 0.01 ml of original samples. Analyses then proceeded according to Standard Methods (2).

Once bottom sediment inoculums had been removed from the mixing-cylinder, the entire contents of the cylinder were rinsed with distilled water into pre-dried, tare weighed beakers for oven drying (110^{o}C for 24 h) and subsequent weight determination. Particle size composition of each sediment sample was then derived using the hydrometer method of Day (11). The total carbon per sediment sample was assessed by ignition at 550^{o}C for 16 h (3,39).

Data Analyses

The Statistical Package for the Social Sciences (SPSS) software (38,60) was used in conjunction with Dec-10 and Cyber 175 computers to analyze the data. To normalize variance in the dependent variables, data analyses were preceeded in all cases by logarithmic (base 10) transformation.

RESULTS

Bottom Sediments

Based on the analyses of 16 random samples from each of the two depth zones sampled, 0.3 and 0.9 m, BJ bottom sediments were found to have a mean composition of 50.1% gravel (particle diameter $\geq$ 2 mm), 47.6% sand (0.02-2 mm), 2.4% silt (2-20 um), and 0.4% clay (<2 um). These sediments were also found to have an average total carbon concentration of 0.09 mg carbon per gram sediment (Appendix A). Using the SPSS subprogram, Breakdown (a one-way analysis of variance employing the F-test) no significant difference ($P>0.05$) was found between either the sediment particle size compositions or the total carbon content for the 0.3 and 0.9 m depth zones. This indicated that the near-shore sediments at BJ were fairly homogeneous between the two depth zones sampled. Coarse sediments (> 90% sand and gravel) are typical of near-shore waters of southwestern U.S., desert reservoirs.

The FC load in these coarse sediments was measued per 100 ml wet compacted sediment and per gram oven-dry-weight (ODW) of the sediment sample (Appendix B). Comparison of these two methods of measurement helped to determine whether standardization of the data by either method would

reduce variation due to sampling. Montagna (56) has reported that standardization of the data by dry weight reduced sampling variance from a mud site, but not from a sand site. When BSFC densities per 100 ml wet compacted sediment and per gm ODW were compared using a one-way analysis of variance (Breakdown subprogram of SPSS), their logarithmic means were found to be significantly different ($P<0.01$). The eta-squared statistic computed in this analysis was, however, 0.9996. This indicated that almost 100% percent of the variance in the BSFC densities measured per gm ODW could be explained by the variance in BSFC densitites measured per 100 ml wet compacted sediment. Further, a linear relationship ($r^2 = 0.997$) was found between the two parameters, when they were compared using a test of linearity (Breakdown subprogram, SPSS). Therefore, while the logarithmic means of BSFC densities were different, as expected for different unit density measurements, variations in the data could be equitably accounted for by either system of measurement. These results confirmed those of Montagna (56) for coarse sediments. To be consistent with the measurement of FC in overlying waters, BSFC densities were standardized per 100 ml (wet compacted sediment) for the remainder of the study.

Based on logarithmic means, an average of 2.9×10^2 and 4.5×10^2 BSFC 100 ml^{-1} were detected in sediment

samples from the 0.3 and 0.9m depth zones, respectively (Appendix B). These mean BSFC densities both exceeded the 2.0×10^2 FC 100 ml^{-1} standard for primary contact in recreational waters (19). Comparison of the raw BSFC densities from the two depth zones, by the SPSS subprogram T-test, revealed no significant difference ($P>0.05$) between the two population densities. Further, no significant correlation could be found between BSFC densities and sediment total carbon or any specific sediment particle size fraction using the SPSS (60) subprograms Pearson Corr (Pearson Product-Moment Correlation analysis) and Nonpar Corr (Spearman Rank-Order Correlation analysis). These results indicated that FC distributions in BJ bottom sediments were not dependent on carbon content or sediment particle size and that FC were homogeneously distributed within the sampling area. The results also suggested that BSFC densities might have been of sufficient magnitude to influence overlying water quality, when resuspended. Prior to experimental sediment resuspension, the logarithmic mean FC densities in overlying waters were 10 and 20 FC 100 ml^{-1} for the 0.3 and 0.9 m depth zones, respectively. Logarithmic mean BSFC densities from these depth zones, were 36.2 and 22.5 fold greater, respectively, than those of the overlying waters.

Overlying Waters

Experimental resuspension of bottom sediments did increase OWFC and turbidity levels above pre-resuspension values (Fig 3,4). These increases seemed to diminish over the time observed, 500 sec. To determine if these increases and subsequent decreases were significant relative to pre-resuspension measurements, the raw OWFC and turbidity data (64 samples per stratum; Appendix C) were analyzed with the SPSS subprogram T-test; a two-tailed T-test of the logarithmic mean differences between the raw data of the two variables being tested. This analysis was based either on the pooled-variance estimate or on the separate variance estimates, as determined by a two-tailed F-test of sample variances (60).

Turbidity was used as a physical indicator of the distribution of sediment resuspensions (36,41). With sediment resuspension, overlying water turbidity in the 2.5 and 15 cm strata of the 0.3 m depth zone increased significantly ($P<0.01$) 4.4 and 5.0 fold, respectively, and 1.6 and 2.9 fold in the 46 and 76 cm stratum of the 0.9 m depth zone, respectively (Fig.4). No significant increase ($P>0.05$) in turbidity was found for either the 2.5 or 46 cm strata of the 0.9 m depth zone. Based on these results experimental resuspension of the coarse BJ sediments was most extensive

Figure 3. Overlying water fecal coliform (OWFC) densities before and after sediment resuspension.

Note: Significant differences in OWFC densities, as indicated by 99% confidence intervals, were determined at alpha=0.01 unless otherwise indicated. Bottom sediemnt fecal coliform (BSFC) densities prior to resuspension are indicated for each depth zone.

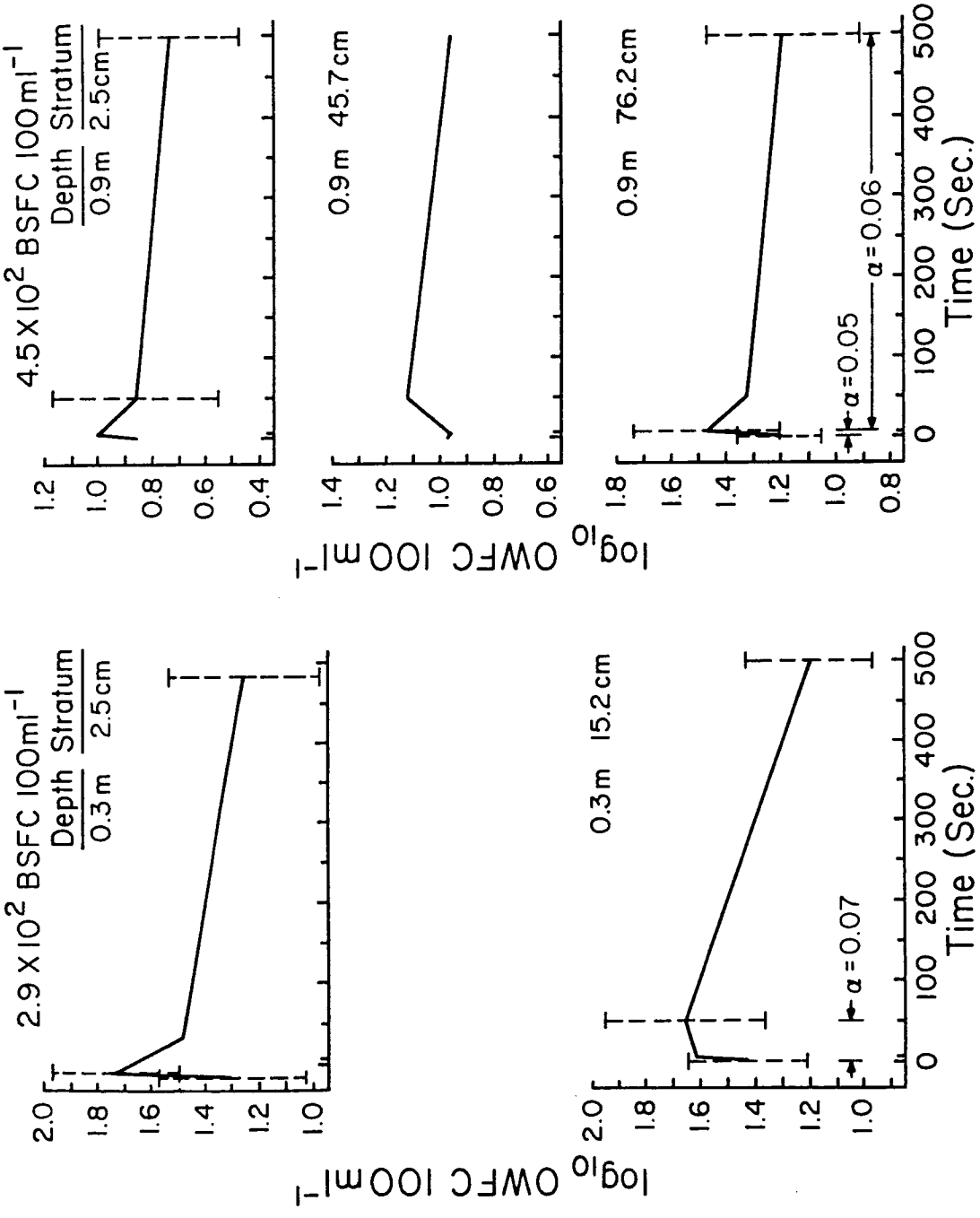


Figure 3. Overlying water fecal coliform densities.

Figure 4. Changes in turbidity resulting from sediment resuspension.

Note: Significant differences in turbidities, as indicated by 99% confidence intervals, were determined at alpha=0.01 unless otherwise indicated.

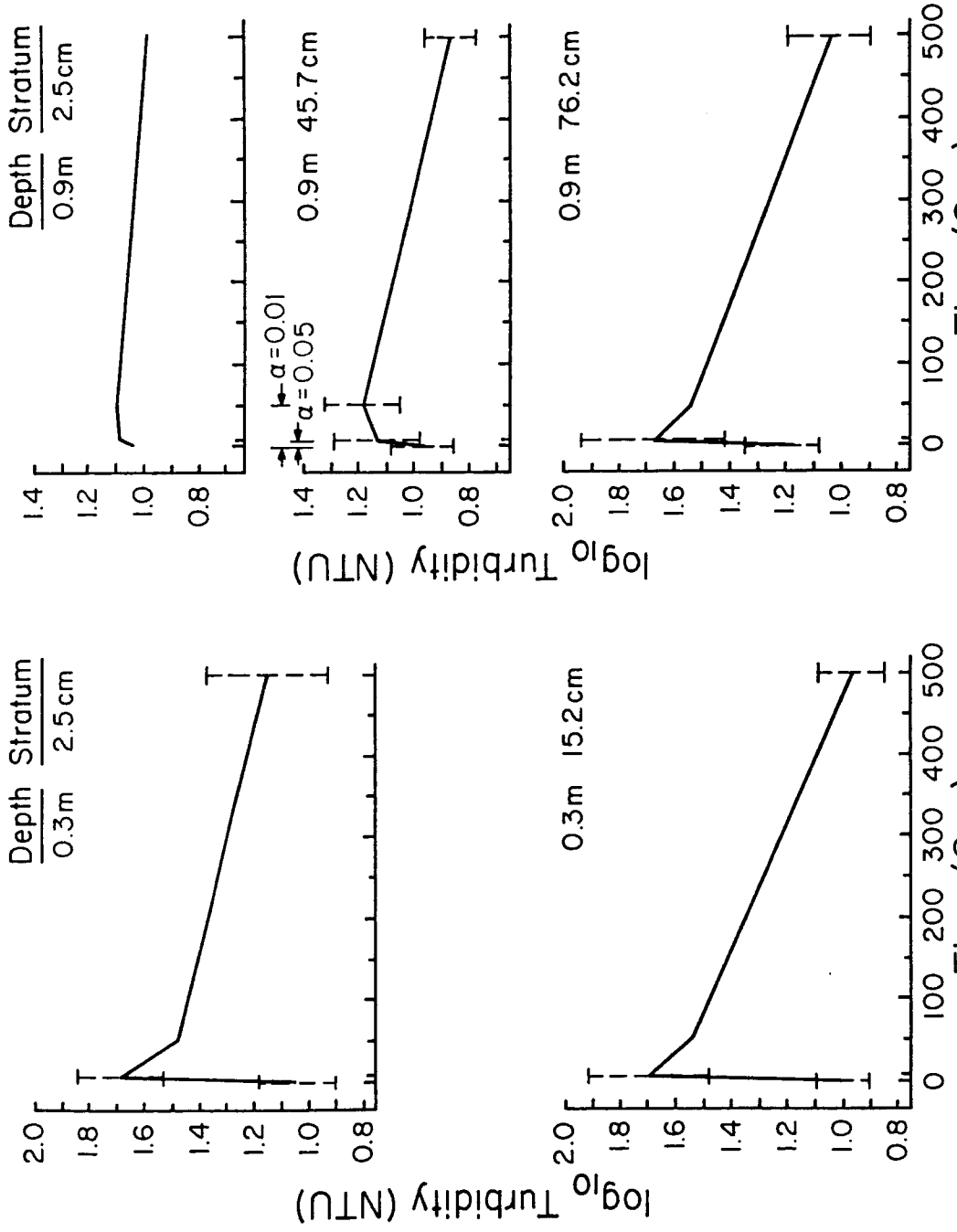


Figure 4. Changes in turbidity resulting from sediment resuspension.

in the 0.3 m depth zone; the area of principal use by small children for primary contact recreation.

In contrast to turbidity increases, significant increases in OWFC were detected only in the 2.5 and 15 cm strata (a 2.7 and 1.7 fold increase, respectively) of the 0.3m depth zone ($P<0.01$ and $P<0.07$, respectively) and in the 76 cm stratum (a 1.8 fold increase) of the 0.9m depth zone ($P<0.05$) (Fig. 3). Turbidity increases were almost double those of the OWFC densities. At no time during the post-resuspension period did OWFC densities exceed the 2.0×10^2 FC 100 ml^{-1} primary contact standard (19) for recreational waters.

Although the overall mean BSFC density exceeded that of the overlying waters by 24.7 fold, BSFC densities were either not high enough to severly impact recreational water quality when resuspended, or BSFC were not resuspended proportionately with the solid sediment material. Because the resuspension of BJ sediments did not increase OWFC levels beyond the primary contact limit (Fig. 3), the threshold concentration of BSFC capable of degrading overlying waters beyond the contact standard could not be determined for those sediments. Further, since no significant correlations ($P>0.05$) could be found between pre-resuspension BSFC densities and post-resuspension OWFC densities, a model predicting those OWFC densities

following sediment resuspension could not be formulated at this time, for BJ.

Within 500 sec of sediment disruption, the increases in both turbidities and OWFC densities had discernibly decreased (Fig. 3,4). Turbidities significantly decreased ($P<0.01$) an average of 3.8 fold at all sampling locations, except for the 2.5 cm stratum of the 0.9 m depth zone (Fig. 4). No significant change ($P>0.05$) was noted at that location. Comparison of turbidities prior to resuspension with those taken 500 sec post-resuspension revealed no significant differences ($P>0.05$) between the two sample populations, for all experimental locations. As measured by turbidity, the impact of sediment resuspension was then a short-lived phenomenon at the location of the resuspension event. Since no significant turbidity increase or decrease was noted in the 2.5 cm stratum of the 0.9 m depth zone, there was no evidence that turbidity at this location was affected by bottom sediment disruption.

The decrease in OWFC densities post-resuspension was more location dependent than that of turbidity. OWFC densities significantly decreased ($P<0.01$) an average of 2.9 fold in both strata of the 0.3 m depth zone. A significant decrease of 2.0 fold was observed in the 2.5 ($P<0.05$) and

76 cm ($P<0.06$) strata of the 0.9 m depth zone. No significant decrease ($P>0.05$) occurred in the 46 cm stratum of the 0.9 m depth zone (Fig. 3). Although no significant increase in OWFC densities was detected for the 2.5 cm stratum of the and 0.9 m depth zone, the significant decrease noted there indicated that the resuspension process itself may have altered the initial OWFC distribution. No significant differences ($P>0.05$) were found when OWFC densities measured before resuspension were compared with those taken 500 sec post-resuspension, except in the 15 cm stratum of the 0.3 m depth zone (Fig. 3). In this stratum, OWFC densities significantly decreased ($P<0.01$) an average 1.7 fold below the pre-resuspension value; again suggesting that the resuspension process may have redistributed the background bacterial populations of the overlying water while increasing its bacterial load. Since few differences could be detected between initial OWFC densities and those 500 sec post-resuspension, the impact of sediment resuspension, as also indicated by the turbidity data, was a short-term event at the point of resuspension (Fig. 3). Because no significant increase or decrease in OWFC densities were detected in the 46 cm stratum of the 0.9 m depth zone, this location appeared to be only minimally affected by sediment disruption.

The distribution of significant changes in OWFC was investigated by comparing the stratification of OWFC populations per depth zone and between depth zones, pre- and post-resuspension, using the SPSS program MANOVA (multiple analysis of variance) for analysis of covariance (38). This procedure uses regression analysis to detect and account for the variation in the dependent variable due to covariates (in this case BSFC). If insignificant, variation due to covariates was removed and differences in OWFC populations of each strata per and between depth zones were explored directly by MANOVA. Where variation in OWFC densities due to the covariate (BSFC) was significant, regression lines of the OWFC populations were compared for differences using the method of Neter (59). Simply, this method compares the overlap of regression confidence bands (alpha=0.01). The 0.3 and 0.9 m depth zones were examined independently, using these analyses. No stratification of OWFC populations was observed in either the 0.3 or 0.9 m depth zones pre- and post-resuspension, with the exception of the 0.9 m, 2.5 cm stratum. This location had a logarithmic mean density that was significantly less than those detected in the other strata. Comparison of OWFC populations between the two depth zones, by strata, indicated that the FC population densities of the 2.5 and 15 cm strata of the 0.3 m depth zone were similar to those of the

46 and 75 cm strata of the 0.9 m depth zones, both pre- and post-resuspension. Accordingly, with the methodologies employed, OWFC populations were found to be homogeneously distributed in the water column prior to and after sediment resuspension, except for those in the 2.5 cm stratum of 0.9 m depth zone. Changes in the OWFC densities induced by resuspension processes were then fairly homogenous changes, influenced in part by water depth.

The water quality effects of sediment resuspension have been characterized in this study by both turbidity and OWFC measurements. Because these measurements have generally given similar results (Fig. 3,4), the potential relationship between turbidities and OWFC densities was examined. Both Pearson Product Moment and Spearman Rank-Order correlation analyses were used for comparing these parameters. Comparisons were made for each location (64 samples of each parameter per sampling location; Appendix C) per time interval, pre- and post-resuspension. In general, a statistically significant ($P<0.01$) correlation was found between turbidities and OWFC densities; as turbidity increased OWFC densities increased. But, the correlation coefficients ($r=0.36$, Pearson's and $r=0.37$, Spearman's) for the respective tests were so low that the variance in OWFC densities could not be explained to any useful degree by the variance in turbidities. Accordingly, bottom sediment

resuspension affected both turbidity and OWFC densities in a similar manner, but turbidity could not be used to predict OWFC densities either before or after sediment disruption.

To determine if experimental sediment disruption appreciably affected overlying water parameters other than OWFC, pH and TDS concentrations were observed before and after bottom sediment resuspension. Before resuspension, overlying waters had 501 mg TDS l^{-1}, and a pH of 7.6. Using the SPSS T-test (60), no significant changes ($P>0.05$) were detected in pH or TDS post-resuspension. Using the correlation analyses previously described, relationships between OWFC, TDS, and pH were examined. No relationship was found ($P>0.05$) between OWFC and TDS or pH pre- and post-sediment disruption. TDS was found to be negatively correlated with turbidity, and pH was found to be positively correlated with turbidity. pH was found, also, to correlate with TDS. The correlation coefficients were, however, quite low. These results suggested that while turbidity might influence TDS concentrations and pH, and TDS concentration might influence pH, TDS and pH could not be indexed by turbidity and pH could not be indexed by TDS. While sediment resuspension did affect both OWFC densities and turbidities at the locations examined, results for TDS

and pH indicate that sediment resuspension did not appreciably change overlying water chemistry.

Sampling Environment

To more fully characterize the sampling environment, air and water temperatures and water levels were measured for each sample run (Appendix D). No significance differences ($P>0.01$) were found between sample runs for any of these parameters. When air and water temperatures were compared no differences were noted. Water temperatures were, however, found to vary by sampling location. Given that samples were collected at 6:00 am, the fact that no difference was found between air and water temperatures or that these temperatures did not change between sample runs was not unexpected. Variance in water temperatures by location was not surprising, since different water depth zones were being sampled. The lack of a change in temperatures and water level between runs reflected the stability of the early morning, sampling environment.

DISCUSSION

Bottom sediment resuspension has long been implicated as a mechanism that can contaminate recreational waters (6,7,24,29,74). In this study, mean BSFC densities, prior to resuspension, exceeded mean OWFC densities by 24.7 fold; suggesting that resuspension of BJ sediments would result in a detectable impact on overlying water quality. Experimental resuspension of BJ sediments, in situ, did increase FC and turbidity levels in various portions of the water column (Fig. 3,4). These increases were solely the result of the experimental resuspension process and not other human (7,21,75) or natural causes (42,57).

Resuspension Impacts

Within the constraints of this study, the impacts of sediment resuspension on OWFC densities and water turbidities were found to be time and location dependent. In terms of time, the impact of sediment resuspension on overlying waters consistently peaked within 5 sec. The influence of sediment disruption on the water column was, however, short lived. OWFC densities and water turbidities, at the point of resuspension, declined to pre-resuspension levels within 500 sec of sediment disruption.

Although the patterns linking resuspension impacts on bacterial water quality and location were more variable than those with time, they showed, in general, that resuspension effects were inversely proportional to water depth.

Time Effects

Statistically significant increases in OWFC densities and water turbidities generally occurred within 5 sec of sediment resuspension (Fig. 3,4). Exceptions included the increases in OWFC and turbidity in the 0.3 m zone, 15 cm stratum and 0.9 m zone, 76 cm stratum, respectively. Both of these increases peaked at 50 sec. Overall, the patterns of OWFC and turbidity increases showed that sediment resuspension had an almost immediate impact on recreational water quality. These impacts were, as noted above, of short duration (Fig. 3,4).

The rapid recovery of initial water quality may have occurred as the result of a combination of mechanisms acting in concert. Following sediment disruption, suspended bacteria and solids may have been absorped, flocculated, and ultimately settled out of the water column (27,64,80), and/or they may have drifted laterally away from each of the four sampling locations (Fig. 1). These redistribution mechanisms are all somewhat dependent on sediment particle size. At BJ, the sediments were found to be coarse (>90%

gravel and sand). Because bacterial adsorption to coarse sediments is markedly less than to silts and clays (50), the bulk of the bacterial population within the sand and gravels of BJ sediments was probably located in the interstitial spaces between particles. As suggested by Tunnicliff and Brickler (72), coarse sediments may act in a manner analogous to a water treatment sand filter, where bacteria trapped in interstitial spaces are readily released when the filter is back-flushed (37). In the case of natural sediments, the back-flushing phenomenon could take the form of tidal influxes (63,69) or sediment resuspension processes (7,21,24,74-76). Hence most sediment associated bacteria would be released directly into the water column by resuspension, rather than as a result of desorption from resuspended particulates. Of course, either free floating or sediment bound enteric microorganisms suspended in recreational waters may constitute a public health hazard (14).

Following the peak rise, OWFC and turbidities may have declined at the rates observed, in part, because rapid sedimentation of the coarse sediment particles. Once the disruptive process had ceased and currents were no longer available to propel particulates and bacteria upward through the water column, they would begin to settle under the influence of gravity at rates predicted by Stokes'

sedimentation equations (11). Based on these equations, the bulk of the coarse sediments was expected to settle within 405 sec; the time required for very fine sand to settle 0.9 m - the maximum depth sampled. Previous laboratory observations of BJ particle settling rates confirmed that sedimentation could account for the observed decline in turbidity, following sediment disruption (12). What percentages of this decline may be attributed, however, to sedimentation and/or lateral drift remains undetermined.

In contrast to coarse sediments, bacteria free in suspension could not settle at a rate fast enough to attribute their disappearance in the time observed due to sedimentation alone (11,12,40,63). Sedimentation of OWFC could have been significantly accelerated, however, if they were adsorped and/or flocculated by resuspended particulates onto or into aggregates of higher specific gravities (27,64,80). Since BJ sediments were predominantly coarse with low adsorption potentials (52,63), accelerated sedimentation probably accounted for only a small percentage of the reduction in OWFC densities observed. Lateral drift of OWFC was probably the major factor contributing to the rapid decline of FC densities following resuspension.

The rapid improvement in water quality following sediment disruption may have also been an artifact of the experimental design. Samples were taken at 6:00 am to

minimize experimental variation due to the recreating public. The four sampling locations were also widely spaced to prevent cross contamination during the four independent but simultaneous resuspension events (Fig. 1). During actual recreation use periods, however, sediment resuspensions from water play activities would not occur as independent events, but rather would constitute a pattern of continuous and widespread disturbances. The result would be a general rather than a point specific degradation of water quality. Accordingly, the rapid improvement of water quality observed in this study following individual sediment resuspensions may not be expected during recreation use periods. The data obtained do, however point to the potential mechanisms of bacterial redistribution due to water play induced resuspension events.

Water Depth

The inverse relationship that was found between water depth and sediment resuspension impact confirms observations and speculations by earlier workers that such a relationship exists (20,25,54). More specifically, Matson, Hornor, and Buck (54) have suggested that the impact of sediment disruption may vary with water depth, as a function of the force of the disruptive process and the volume of water available to dilute resuspended materials.

In this study, experimental sediment disruption significantly increased OWFC densities and turbidities in both strata of the 0.3 m depth zone, and in the 76 cm stratum of 0.9 m depth zone (Fig. 3,4). No significant increase in either OWFC densities or turbidity was found in the 2.5 cm stratum of the 0.9 m depth zone, and only a significant increase in turbidity was found in the 46 cm stratum of 0.9 m depth zone (Fig. 3,4). A uniform disruptive force was used in both depth zones, and no significant difference was detected between mean BSFC densities in the two zones prior to disruption. Therefore, the differences in resuspension impact, in the two zones, could only be attributed to depth. Apparently, the disruptive process used had insufficient energy to propel resuspended materials into the upper most strata of the 0.9m depth zone and/or the water volume in this deeper zone effectively diluted any OWFC or turbidity increases below detectable levels. The procedure used to disrupt sediments caused a peak turbidity more than six times that of the pre-disturbance level in the 0.3 m depth zone and an average 2.5 fold turbidity increase in the 0.9 m zone (Fig. 4). The peak resuspension turbidity was ca. 50 NTU in the entire 0.3 m zone and in the lower stratum of the 0.9 m zone. These turbidity levels were in excess of that obtainable by one

person vigorously shuffling his feet in the BJ sediments (unpublished data). This suggested that the single point resuspension technique used was an effective means of resuspending the coarse BJ sediments. For finer sediments with specific gravities much lower than those of the BJ sediments, the resuspension technique used in this study probably would have lofted material higher in the 0.9 m zone, creating increased turbidity and microorganism impairment of overlying waters. Increased deterioration of water quality in the deeper depth zone might also be anticipated during recreation use periods. As noted previously, recreation causes widespread and continuous sediment disruption which may produce currents sufficient to carry sediments and microorganisms into the higher strata of the 0.9 m waters.

Although this study did not directly examine recreation induced sediment resuspensions, the results do have important implications for the relationship between recreational water quality and water depth. Both OWFC and turbidity measurements indicated that sediment resuspension had its greatest impact within the first 0.3 m above the bottom regardless of overall water depth. This partition of water not only interfaces with the source of both turbidity and FC increases, the sediment, but also limits the water volume available for dilution (20,25). Increased

water depth provides both volume and area for the interaction of diluting mechanisms (54,80). This suggests that primary contact recreation in limnetic waters would represent less of a hazard, than in shallow, near-shore ($\leq$0.9 m) waters. Not only does relatively little sediment resuspension occur in waters $>$ 0.9 m, but also these waters, in general, have lower FC densities than near-shore waters (7,44).

In near-shore waters, where overall water depth may not exceed 0.3 m, injection of sediment associated microorganisms into the surface stratum has the most serious consequences for water contact recreation. Surface stratum water is that portion of the water column most likely to be introduced into the oral-pharyngeal and/or nasal cavity and potentially swallowed or inhaled during water play. The greatest danger of water ingestion or inhalation probably occurs with activities involving complete submergence of the body or possibly splashing type of play. An important part of the water contact process is the post-emergence period when a water film streams down the skin surface providing an opportunity for entrance into the mouth, respiratory tract, ears, and eyes. Afflictions of the ears, eyes, mouth, nose, throat, and skin are among the most common of the water contact transmitted diseases (52,78). Gastrointestinal ailments are more significant in terms of

health impacts and, at times, life threatening diseases (18).

At special risk during water contact recreation are young children, who often engage in prolonged water play, have frequent facial contact with the water, and are not as cautious as older children and adults about swallowing water. The shoreline and near-shore waters are the primary aquatic play areas of young children. The waters of this same aquatic zone have been shown herein to be the most severely impacted by sediment resuspension. Near-shore waters probably also experience more frequent and extensive sediment resuspension than do deeper waters, because of the high density recreation use that occurs there; the relatively intensive force exerted by the action of numerous human feet on sediments in shallow waters; and the forceful action of surface waves on sediments in the shoreline and near shoreline areas. Although elevated OWFC densities resulting from sediment resuspension were found to decline quickly in this study, work on other fresh and marine waters has shown the bacteria can accumulate in the surface boundary layer (4,13,31,43).

Bottom Sediments

While water depth was found to be an important factor influencing the distribution of resuspension

impacts, the concentration of bacteria found in the undistributed sediments was probably the most significant factor influencing the overall magnitude of resuspension impacts. Experimental sediment resuspension increased OWFC densities up to 2.7 fold of the pre-resuspension background level. Elevation of OWFC densities was not, however, sufficient to exceed at any post-resuspension time observed, the primary contact standard of 2.0×10^2 FC 100 ml^{-1} (19). Sediment associated enteric microorganisms are usually confined to a relatively thin portion of the upper layer of the sediments (1,81). Consequently, BSFC densities may be high, but the total volume of contaminated material could be very low relative to the overlying water volume. Sediment resuspension could then result in a significant dilution of BSFC densities. Accordingly, BSFC densities would have to be quite large in relation to the volume of water available for dilution to result in dramatic changes in OWFC densities.

Previous work at BJ has shown that BSFC densities there have reached mean levels at least four times greater than those found in this study (44). Given these more elevated BSFC densities and the standardized disruptive process used in the present study, sediment resuspension would have undoubtedly caused a more severe water quality impact than reported here. Presumably, as BSFC densities

increased to a sufficiently high level, sediment resuspension by a standardized disruption technique would result in OWFC densities consistently exceeding some specified level, e.g., the primary contact standard. This threshold BSFC density would be expected to vary among water bodies, depending on factors such as sediment particle composition, organic matter concentration, and depth. Data collected in this study did not provide sufficient basis to determine a critical BSFC density threshold for BJ beach. Higher BSFC densities than those found in this study are necessary to explore the possibility of determining such values. Threshold values based on the study approach presented here would not have direct application for recreation induced resuspensions, but would establish a reference point from which probable recreation induced resuspension could be estimated.

The relatively low BSFC densities found at BJ in May 1983, in contrast to those detected in July and August 1982 (44), may be in part the result of low sediment organic carbon concentrations and/or seasonal variations in coliform densities. The near-shore (littoral) sediments sampled at BJ contained an average of only 0.09 mg total carbon per gram of sediment. Total carbon concentration was used as a qualitative indicator of sediment organic

content. Accordingly, these results indicated that organic matter concentrations in BJ sediments were quite low.

The significance of sediment organic carbon concentrations to this study lies in the potential influence organics may have on FC densities and distributions in sediments. Nutrient concentrations in sediments, which may support microbial persistence and/or reproduction, are proportional to the organic matter load. The organic load of sediments may be related to the available adsorptive surface area of the sediments (55,77). Associated with increased surface area is a possibility of nutrient concentration due to enhanced electrostatic and/or hydrophobic interactions between fine particles and organic matter (51,70). Using fine glass beads, Heukelekian and Heller (35) have shown that nutrient concentrations increase proportionally to available surface area. The organic matter - nutrient complex associated with sediments is thought to be an important factor supporting persistence and/or reproduction of both pathogenic and non-pathogenic enteric bacteria located there (33,47,65). The coarse nature of BJ sediments and the low carbon concentrations found there indicate that the nutrient reserves available to enteric bacteria may be proportionately low.

The overall mean BSFC density during the study period was 3.7×10^2 FC $100ml^{-1}$; a level 4.32 times lower

than that (1.6×10^3 FC $100ml^{-1}$) reported for the same site the previous summer (44). While no correlation was found between total sediment carbon and BSFC in this study, organic carbon may have been a factor supporting the higher BSFC concentrations detected in 1982; late June through August. This time interval may have been characterized by sediments richer in carbon than that found in late May, 1983; because the seasonal cycle of aquatic and terrestrial biomass production may have been more advanced. Tunnicliff and Brickler (72), in a study of stream sediments in Grand Canyon National Park, Arizona, found a dramatic summer seasonal increase in BSFC, with a peak in August-September.

The scarcity of organic matter in BJ sediments was probably related to a low level of organic input to the aquatic system and the coarse composition of bottom sediments (>90% gravel and sand). Because of the arid southwestern U.S. climate, percipitation over and surface runoff from watersheds draining into BJ beach is highly ephemeral (58). During the summers of 1982 and 1983, no surface runoff events occurred at BJ beach. In the absence of hydraulic flushing of the watershed, organic matter inputs at BJ beach must result from direct deposition by humans and wildlife, autochtohonous matter (plankton decay), and wind related deposition (e.g., leaves). This is in contrast to freshwater lakes located in moist climates

wherein high concentrations of organic carbon are maintained in part by continuous allochtohonous inputs from flowing streams (78).

Once organic matter is input to or produced in Saguaro Lake waters at BJ, the coarse composition of the bottom sediment may impede concentration and retention of organics. Organic carbon content in sediments and sediment particle size have been found to vary inversely in at least two other beach studies (30,49). This association presumably reflects the inverse relationship that exists between particle diameter and the particle surface area that is available to adsorb organic matter (55,77). The coarse BJ sediments probably do not provide much surface area to either concentrate or retain that organic matter that is present in Saguaro Lake waters.

Measuring Resuspension Impacts

A FC detection method of fairly high precision was required in this study to quantify changes in water quality induced by sediment resuspension. FC densities were determined in this study by standard MF procedures (2). While turbidity may reduce the absolute accuracy of this technique (34,48,61), the precision of the MF technique has been shown to be high for sediment elutriates (29). High precision is essential if variations in OWFC densities are

to be attributed to sediment resuspension phenomenon rather than experimental error.

Because turbidity can decrease the accuracy of MF analysis, it might also diminish the precision of the technique. The levels of turbidity can, however, vary with the type of particulates present (23,36,41). Therefore, the acceptable turbidity levels for MF analyses are often based on the experience of the microbiologist (22). Goyal and Adams (26) have used the MF technique for enumeration of fecal indicator bacteria from the presumably more turbid "bottom-hinge" of the Atlantic Ocean. Because BJ sediments were quite coarse, the turbidity resulting from resuspension of those sediments was much less than that expected to result from the resuspension of much finer sediments (11,52). To reduce the affects turbidity may have had on FC enumeration, MF analyses were done on four decreasing volumes of each water sample (22). The precision of FC recovery between sample volumes was found to be good (unpublished data), and there was no evidence of colony spreading due to capillary flow around embedded particles.

The MF technique has also been shown to be more precise than the most-probable-number method, which is really no more accurate than the MF technique (9). In comparing the most-probable-number and MF technique, as applied to water samples from BJ, Kramer (44) found no

significant difference ($P>0.05$) between FC densities determined by the two methods. He also found that FC densities determined by the two methods were highly correlated ($r=0.83$). Due to its quantitative precision, ease of use, capability of examining large water volumes, and accuracy comparable to the most-probable-number technique, MF analysis was the method of choice for enumerating FC in this study.

Because of its close association with OWFC densities, turbidity might be an easily assayed indicator of bacterial densities resulting from sediment resuspension. Bacterial association with suspended matter and turbidity is well documented (15,62,79). Elevations in FC and coliform densities have been closely linked to increased turbidities resulting from stormflows, river dredging, and tidal influxes (15,17,29,72). As shown in this study and in those of others (12,17,72), bacterial numbers generally increase as turbidity increases. In regards to the degree of correlation between FC and turbidity, there is, however, a fair amount of disparity in the literature. Grimes (29) and Saylor (68), both found FC highly correlated ($r\geq0.94$) with turbidity. In contrast, Oliver (61), Tunnicliff and Brickler (72), and this study showed a low significant correlation ($r\leq0.54$) between turbidity and FC densities, and Goyal et al. (25) found no

relationship between bacterial densities and turbidity at all.

The findings of Feachem (17) suggest that the relationship between FC numbers and turbidity may be affected by the physical masking of FC by suspended solids and competitive microorganisms (34,61). Masking would be particularly important where the suspended load was large; as with the resuspension of fine silts and clays. Where sediments are coarse as at BJ, the relationship between FC numbers and turbidity may be more influenced by environmental dilution. Turbidity dissipates rather quickly with coarse sediments (11,12,52). Since bacteria do not adsorp to coarse sediments as readily as they do to silts and clays (50), the majority of suspended bacteria may be free floating. Free floating bacteria, based on Stokes' sedimentation equations (52), would remain suspended much longer than coarse suspended solids, resulting in little relationship between bacteria and turbidity. Until further studies of these mechanisms are completed, the use of turbidity as an indicator of bacterial concentration is not warranted.

Although turbidity cannot be used at present to index FC concentrations, it might be useful as a model for studying the effects of environmental influences (e.g., currents) on the dispersal and/or transport of bacteria

following a resuspension event. As shown in this study and others, increases in FC parallel increases in turbidity (15,17,29,72). While the statistical significance of this relationship is uncertain for all environmental conditions, the dispersal and/or transport of free floating or sediment associated bacteria, following sediment disruption, should mirror that of suspended solids of similar size ranges. Grimes (29) and Thornton, Nix, and Bragg (73) measured turbidity and FC densities to follow the downstream effects of dredging and stormflow, respectively. Grimes (29) found a reduction in both bacterial numbers and turbidity downstream of the dredge effluent outlet. Thornton, Nix, and Bragg (73) found a reduction in coliform densities as the stormflow plume proceeded through a reservoir. These results suggest that turbidity may serve as a model for following the dispersal of bottom sediment bacteria transposed by sediment resuspension.

Conclusion

The results reported herein clearly demonstrate that the resuspension of bottom sediments into shallow nearshore waters has important implications for public health. The most significant factor influencing the impact of sediment resuspension on overlying waters was water depth. The greatest risk to public health at BJ was found to be within

the 0.3 m depth zone. Assuming that these findings hold direct implications for other beaches may not, however, be valid due to local sediment composition, topographical, and meterological differences (57). Studies similar to this one at beaches of differing sediment compositions and morphologies are needed, if the water quality affects of sediment disruption on near-shore recreational waters are to be fully understood and appreciated. Since higher bacterial numbers have been found in fine sediments than in coarse sediments (10,30), and since fine sediments remain in suspension longer than coarse sediments (11,52), the presence of these sediments may also increase the public health risk. Therefore, the resuspension of bacteria associated with fine silts and clays instead of coarse sands and gravels, particularly in quiet shallow coves, should be examined.

Previous work in the SRC has shown that beach morphology can be a factor influencing bacterial distributions in both sediments and overlying waters. At a steeply sloping linear (exposed) beach, with a sediment composition similar to BJ, BSFC and OWFC population distributions were distinctly different than those observed at BJ beach (44). These differences may be due solely to beach slope and shore line configuration. In contrast to shallow sloped protected beaches, like BJ, steep exposed beaches may

provide more opportunities for rapid environmental dilution of resuspended bacteria through increased current and wave actions; lessing the public health hazard due to sediment resuspension. The greatest impact of sediment resuspension would probably still occur, however, within the shallow near-shore waters, where decreased water volume can concentrate resuspension impacts. Consequently, water depth, as demonstrated by this study, would still be the most important factor influencing the impact of sediment resuspension on overlying water quality. Therefore, this study represents the basis for future investigations into the the nature of sediment-water interactions (due to sediment resuspension) and their impact on recreational water quality.

Although heterotrophic bacteria were not sampled in this study, the data presented suggest sediment disruption would also cause significant changes in population distributions of these bacteria within sediments and overlying waters. Krumbein (45) has shown that the densities and species composition of bottom sediments can be influenced by tidal currents and artificially caused changes of the benthic environment, e.g., boat-wake induced resuspension. Therefore, the techniques devised in this study might also be applied to examine the affects of sediment disruption on heterotrophic bacterial distributions, in situ.

APPENDIX A

BOTTOM SEDIMENT PARTICLE SIZES AND TOTAL CARBON CONTENT

RUN	TRANSECT	DEPTH (m)	%GRAVEL	%SAND	%SILT	%CLAY	TOTAL CARBON(mg/g)
1	LEFT	0.9	49.9	47.7	4.8	0.0	0.11
1	LEFT	0.3	30.2	69.8	0.0	0.0	0.07
1	RIGHT	0.9	46.1	53.3	0.6	0.0	0.12
1	RIGHT	0.3	33.8	63.0	3.2	0.0	0.32
2	LEFT	0.9	55.6	42.2	2.0	0.3	0.11
2	LEFT	0.3	44.9	52.5	2.3	0.4	0.14
2	RIGHT	0.9	55.0	41.7	2.8	0.3	0.07
2	RIGHT	0.3	55.1	42.7	2.2	0.0	0.09
3	LEFT	0.9	59.9	39.0	0.8	0.3	0.09
3	LEFT	0.3	45.7	51.7	2.2	0.3	0.12
3	RIGHT	0.9	62.4	36.7	0.5	0.4	0.06
3	RIGHT	0.3	63.9	34.4	1.5	0.2	0.03
4	LEFT	0.9	42.9	53.6	3.2	0.3	0.41
4	LEFT	0.3	24.1	74.0	1.9	0.0	0.06
4	RIGHT	0.9	59.7	38.8	1.5	0.0	0.05
4	RIGHT	0.3	38.1	55.5	6.0	0.4	0.08
5	LEFT	0.9	98.0	0.8	1.2	0.0	0.07
5	LEFT	0.3	35.2	61.6	3.2	0.0	0.11
5	RIGHT	0.9	42.0	52.3	5.7	0.0	0.08
5	RIGHT	0.3	34.8	57.2	8.0	0.0	0.08
6	LEFT	0.9	44.5	51.5	3.7	0.3	0.07
6	LEFT	0.3	30.0	65.8	4.2	0.0	0.07
6	RIGHT	0.9	58.7	38.3	2.7	0.2	0.01
6	RIGHT	0.3	53.0	41.9	4.8	0.3	0.07
7	LEFT	0.9	70.4	28.9	0.7	0.0	0.05
7	LEFT	0.3	63.5	35.6	0.9	0.0	0.09
7	RIGHT	0.9	20.3	75.8	3.9	0.0	0.07
7	RIGHT	0.3	42.9	53.0	4.1	0.0	0.10
8	LEFT	0.9	51.7	0.0	4.7	0.0	0.08
8	LEFT	0.3	59.7	38.8	1.5	0.0	0.07
8	RIGHT	0.9	69.8	29.4	0.8	0.0	0.07
8	RIGHT	0.3	33.4	61.8	4.8	0.0	0.10

APPENDIX B

BOTTOM SEDIMENT FECAL COLIFORM DENSITIES BY SAMPLING LOCATION

RUN	TRANSECT	DEPTH (M)	BSFC/100ML	BSFC/GM ODW*
1	LEFT	0.9	648.1	3.9
1	LEFT	0.3	105.8	0.7
1	RIGHT	0.9	220.0	1.2
1	RIGHT	0.3	759.6	4.5
2	LEFT	0.9	1274.5	7.8
2	LEFT	0.3	718.2	4.6
2	RIGHT	0.9	120.4	0.7
2	RIGHT	0.3	323.5	1.8
3	LEFT	0.9	1300.0	7.5
3	LEFT	0.3	80.0	0.5
3	RIGHT	0.9	490.0	2.7
3	RIGHT	0.3	490.0	2.5
4	LEFT	0.9	790.0	4.7
4	LEFT	0.3	20.0	0.1
4	RIGHT	0.9	480.4	2.8
4	RIGHT	0.3	660.4	3.8
5	LEFT	0.9	224.5	1.5
5	LEFT	0.3	122.6	0.7
5	RIGHT	0.9	330.0	1.9
5	RIGHT	0.3	330.0	1.9
6	LEFT	0.9	673.1	3.9
6	LEFT	0.3	130.0	0.9
6	RIGHT	0.9	490.0	2.9
6	RIGHT	0.3	750.4	4.4
7	LEFT	0.9	330.0	2.0
7	LEFT	0.3	1300.0	7.9
7	RIGHT	0.9	790.0	4.4
7	RIGHT	0.3	170.0	1.0
8	LEFT	0.9	170.0	1.0
8	LEFT	0.3	110.0	0.7
8	RIGHT	0.9	490.0	2.8
8	RIGHT	0.3	3500.0	0.32

* ODW = OVEN DRY WEIGHT

APPENDIX C

OVERLYING WATER FECAL COLIFORM DENSITIES, TOTAL DISSOLVED SOLIDS, PH, AND TURBIDITY BY TIME AND SAMPLING LOCATION

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
1	0	LEFT	0.9	0.025	14.4	460	7.9	14.0
1	0	LEFT	0.9	0.460	11.0	460	8.0	6.6
1	0	LEFT	0.9	0.760	49.5	450	8.1	8.1
1	0	LEFT	0.3	0.025	122.8	470	7.9	22.0
1	0	LEFT	0.3	0.150	97.0	460	8.0	17.0
1	0	RIGHT	0.9	0.025	5.8			31.0
1	0	RIGHT	0.9	0.460	10.0			13.0
1	0	RIGHT	0.9	0.760	14.1			14.0
1	0	RIGHT	0.3	0.025	25.4			12.0
1	0	RIGHT	0.3	0.150	33.8			5.5
2	0	LEFT	0.9	0.025	13.4			18.0
2	0	LEFT	0.9	0.460	3.7			7.2
2	0	LEFT	0.9	0.760	15.8			17.0
2	0	LEFT	0.3	0.025	14.5			5.5
2	0	LEFT	0.3	0.150	36.7			14.0
2	0	RIGHT	0.9	0.025	5.0			9.0
2	0	RIGHT	0.9	0.460	5.7			15.0
2	0	RIGHT	0.9	0.760	10.4			20.0
2	0	RIGHT	0.3	0.025	82.9			17.0
2	0	RIGHT	0.3	0.150	49.4			12.0
3	0	LEFT	0.9	0.025	53.5			13.0
3	0	LEFT	0.9	0.460	157.7			7.2
3	0	LEFT	0.9	0.760	40.2			16.0
3	0	LEFT	0.3	0.025	22.9			26.0
3	0	LEFT	0.3	0.150	45.1			6.6
3	0	RIGHT	0.9	0.025	16.8			19.0
3	0	RIGHT	0.9	0.460	12.0			14.0
3	0	RIGHT	0.9	0.760	21.1			14.0
3	0	RIGHT	0.3	0.025	23.4			20.0
3	0	RIGHT	0.3	0.150	54.0			9.5
4	0	LEFT	0.9	0.025	5.3			14.0
4	0	LEFT	0.9	0.460	7.5			4.7
4	0	LEFT	0.9	0.760	24.9			60.0
4	0	LEFT	0.3	0.025	31.0			9.2
4	0	LEFT	0.3	0.150	36.4			8.4
4	0	RIGHT	0.9	0.025	11.3	460	8.0	10.0
4	0	RIGHT	0.9	0.460	16.7	470	8.1	13.0
4	0	RIGHT	0.9	0.760	28.6	460	8.1	26.0

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDIDTY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
4	0	RIGHT	0.3	0.025	32.1	460	7.8	6.5
4	0	RIGHT	0.3	0.150	34.3	470	8.0	10.0
5	0	LEFT	0.9	0.025	1.4			5.2
5	0	LEFT	0.9	0.460	8.5			5.4
5	0	LEFT	0.9	0.760	22.7			14.0
5	0	LEFT	0.3	0.025	30.9			7.3
5	0	LEFT	0.3	0.150	29.1			12.0
5	0	RIGHT	0.9	0.025	13.0	460	7.9	8.5
5	0	RIGHT	0.9	0.460	16.0	480	8.1	14.0
5	0	RIGHT	0.9	0.760	8.5	400	7.9	14.0
5	0	RIGHT	0.3	0.025	28.2	470	8.1	5.8
5	0	RIGHT	0.3	0.150	30.1	470	8.1	6.9
6	0	LEFT	0.9	0.025	11.1			21.0
6	0	LEFT	0.9	0.460	13.1			6.8
6	0	LEFT	0.9	0.760	14.0			10.0
6	0	LEFT	0.3	0.025	3.1			12.0
6	0	LEFT	0.3	0.150	18.8			15.0
6	0	RIGHT	0.9	0.025	6.5			5.4
6	0	RIGHT	0.9	0.460	14.7			12.0
6	0	RIGHT	0.9	0.760	12.7			24.0
6	0	RIGHT	0.3	0.025	40.2			12.0
6	0	RIGHT	0.3	0.150	29.3			7.9
7	0	LEFT	0.9	0.025	2.9			6.2
7	0	LEFT	0.9	0.460	3.1			9.0
7	0	LEFT	0.9	0.760	11.2			17.0
7	0	LEFT	0.3	0.025	9.8			6.8
7	0	LEFT	0.3	0.150	11.4			9.6
7	0	RIGHT	0.9	0.025	0.9			6.5
7	0	RIGHT	0.9	0.460	4.7			6.6
7	0	RIGHT	0.9	0.760	8.7			8.5
7	0	RIGHT	0.3	0.025	9.5			13.0
7	0	RIGHT	0.3	0.150	22.8			8.5
8	0	LEFT	0.9	0.025	5.4	470	8.1	13.0
8	0	LEFT	0.9	0.460	8.6	480	8.1	15.0
8	0	LEFT	0.9	0.760	8.7	480	8.1	19.0
8	0	LEFT	0.3	0.025	7.9	480	8.1	7.8
8	0	LEFT	0.3	0.150	3.8	470	8.1	8.1
8	0	RIGHT	0.9	0.025	6.4			14.0

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
8	0	RIGHT	0.9	0.460	2.4			11.0
8	0	RIGHT	0.9	0.760	10.1			17.0
8	0	RIGHT	0.3	0.025	4.5			15.0
8	0	RIGHT	0.3	0.150	8.4			17.0
1	5	LEFT	0.9	0.025	12.6	460	8.1	16.0
1	5	LEFT	0.9	0.460	11.8	460	8.1	4.8
1	5	LEFT	0.9	0.760	28.1	470	8.1	14.0
1	5	LEFT	0.3	0.250	48.5	450	8.0	54.0
1	5	LEFT	0.3	0.150	58.3	470	8.1	13.0
1	5	RIGHT	0.9	0.025	6.3			11.0
1	5	RIGHT	0.9	0.460	10.8			11.0
1	5	RIGHT	0.9	0.760	19.8			40.0
1	5	RIGHT	0.3	0.025	44.3			21.0
1	5	RIGHT	0.3	0.150	9.2			13.0
2	5	LEFT	0.9	0.025	5.0			21.0
2	5	LEFT	0.9	0.460	18.7			22.0
2	5	LEFT	0.9	0.760	41.4			130.0
2	5	LEFT	0.3	0.025	46.3			32.0
2	5	LEFT	0.3	0.150	153.4			42.0
2	5	RIGHT	0.9	0.025	7.0			24.0
2	5	RIGHT	0.9	0.460	0.9			14.0
2	5	RIGHT	0.9	0.760	10.0			49.0
2	5	RIGHT	0.3	0.025	152.5			34.0
2	5	RIGHT	0.3	0.150	71.3			46.0
3	5	LEFT	0.9	0.025	51.5			13.0
3	5	LEFT	0.9	0.460	39.3			7.2
3	5	LEFT	0.9	0.760	49.4			41.0
3	5	LEFT	0.3	0.025	52.7			36.0
3	5	LEFT	0.3	0.150	92.6			45.0
3	5	RIGHT	0.9	0.025	12.0			15.0
3	5	RIGHT	0.9	0.460	14.3			18.0
3	5	RIGHT	0.9	0.760	29.5			44.0
3	5	RIGHT	0.3	0.025	318.8			110.0
3	5	RIGHT	0.3	0.150	385.7			112.0
4	5	LEFT	0.9	0.025	8.3			14.0
4	5	LEFT	0.9	0.460	3.3			18.0

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDIDTY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
4	5	LEFT	0.9	0.760	19.8			54.0
4	5	LEFT	0.3	0.025	28.2			56.0
4	5	LEFT	0.3	0.150	23.2			90.0
4	5	RIGHT	0.9	0.025	12.4	460	8.1	8.5
4	5	RIGHT	0.9	0.460	0.0			0.0
4	5	RIGHT	0.9	0.760	26.3	460	8.0	25.0
4	5	RIGHT	0.3	0.025	54.4	480	7.9	50.0
4	5	RIGHT	0.3	0.150	40.3	470	7.9	100.0
5	5	LEFT	0.9	0.025	23.1			5.0
5	5	LEFT	0.9	0.460	20.1			18.0
5	5	LEFT	0.9	0.760	49.4			18.0
5	5	LEFT	0.3	0.025	40.5			42.0
5	5	LEFT	0.3	0.150	39.5			42.0
5	5	RIGHT	0.9	0.025	10.0	460	8.1	18.0
5	5	RIGHT	0.9	0.460	7.4	470	8.1	6.2
5	5	RIGHT	0.9	0.760	99.3	460	8.0	64.0
5	5	RIGHT	0.3	0.025	41.6	470	8.1	17.0
5	5	RIGHT	0.3	0.150	24.6	470	8.1	16.0
6	5	LEFT	0.9	0.025	11.1			20.0
6	5	LEFT	0.9	0.460	131.6			40.0
6	5	LEFT	0.9	0.760	346.6			460.0
6	5	LEFT	0.3	0.025	19.3			64.0
6	5	LEFT	0.3	0.150	18.0			100.0
6	5	RIGHT	0.9	0.025	4.7			6.6
6	5	RIGHT	0.9	0.460	6.9			19.0
6	5	RIGHT	0.9	0.760	20.0			92.0
6	5	RIGHT	0.3	0.025	116.7			46.0
6	5	RIGHT	0.3	0.150	38.2			42.0
7	5	LEFT	0.9	0.025	9.5			15.0
7	5	LEFT	0.9	0.460	2.9			11.0
7	5	LEFT	0.9	0.760	21.5			152.0
7	5	LEFT	0.3	0.025	15.7			36.0
7	5	LEFT	0.3	0.150	21.8			41.0
7	5	RIGHT	0.9	0.025	16.3			7.6
7	5	RIGHT	0.9	0.460	22.2			14.0
7	5	RIGHT	0.9	0.760	6.8			18.0
7	5	RIGHT	0.3	0.150	39.7			92.0
8	5	LEFT	0.9	0.025	4.9	470	8.2	13.0

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
8	5	LEFT	0.9	0.460	0.9	480	8.2	14.0
8	5	LEFT	0.9	0.760	11.8	480	8.1	42.0
8	5	LEFT	0.3	0.025	16.6	470	8.1	72.0
8	5	LEFT	0.3	0.150	18.8	430	8.1	52.0
8	5	RIGHT	0.9	0.025	2.9			9.2
8	5	RIGHT	0.9	0.460	8.5			15.0
8	5	RIGHT	0.9	0.760	44.8			17.0
8	5	RIGHT	0.3	0.025	150.0			130.0
8	5	RIGHT	0.3	0.150	35.3			170.0
1	50	LEFT	0.9	0.025	5.3	460	8.0	10.0
1	50	LEFT	0.9	0.460	15.1	460	7.8	15.0
1	50	LEFT	0.9	0.760	67.2	460	8.1	32.0
1	50	LEFT	0.3	0.025	24.9	450	8.1	16.0
1	50	LEFT	0.3	0.150	130.2	460	8.1	27.0
1	50	RIGHT	0.9	0.025	9.5			21.0
1	50	RIGHT	0.9	0.460	6.9			16.0
1	50	RIGHT	0.9	0.760	9.3			18.0
1	50	RIGHT	0.3	0.025	19.5			29.0
1	50	RIGHT	0.3	0.150	34.6			15.0
2	50	LEFT	0.9	0.025	13.3			27.0
2	50	LEFT	0.9	0.460	26.1			30.0
2	50	LEFT	0.9	0.760	21.1			28.0
2	50	LEFT	0.3	0.025	34.8			34.0
2	50	LEFT	0.3	0.150	284.4			40.0
2	50	RIGHT	0.9	0.025	2.0			13.0
2	50	RIGHT	0.9	0.460	7.3			4.4
2	50	RIGHT	0.9	0.760	8.0			32.0
2	50	RIGHT	0.3	0.025	41.5			33.0
2	50	RIGHT	0.3	0.150	46.4			32.0
3	50	LEFT	0.9	0.025	30.3			19.0
3	50	LEFT	0.9	0.460	50.6			32.0
3	50	LEFT	0.9	0.760	50.5			44.0
3	50	LEFT	0.3	0.025	43.8			23.0
3	50	LEFT	0.3	0.150	55.2			38.0
3	50	RIGHT	0.9	0.025	12.5			6.5
3	50	RIGHT	0.9	0.460	24.1			11.0
3	50	RIGHT	0.9	0.760	63.0			16.0
3	50	RIGHT	0.3	0.025	219.1			66.0

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
3	50	RIGHT	0.3	0.150	319.8			7.8
4	50	LEFT	0.9	0.250	10.3			17.0
4	50	LEFT	0.9	0.460	7.5			14.0
4	50	LEFT	0.9	0.760	13.2			79.0
4	50	LEFT	0.3	0.025	80.0			39.0
4	50	LEFT	0.3	0.150	18.3			64.0
4	50	RIGHT	0.9	0.025	4.2	460	8.1	5.6
4	50	RIGHT	0.9	0.460	14.9	470	8.1	12.0
4	50	RIGHT	0.9	0.760	33.0	450	8.1	18.0
4	50	RIGHT	0.3	0.025	70.0	460	7.8	49.0
4	50	RIGHT	0.3	0.150	43.1	460	7.9	72.0
5	50	LEFT	0.9	0.025	161.5			26.0
5	50	LEFT	0.9	0.460	13.8			20.0
5	50	LEFT	0.9	0.760	52.2			62.0
5	50	LEFT	0.3	0.025	22.5			7.2
5	50	LEFT	0.3	0.150	37.4			30.0
5	50	RIGHT	0.9	0.025	4.5	470	8.1	16.0
5	50	RIGHT	0.9	0.460	112.2	460	8.1	13.0
5	50	RIGHT	0.9	0.760	9.5	470	8.0	32.0
5	50	RIGHT	0.3	0.025	60.3	480	8.0	38.0
5	50	RIGHT	0.3	0.150	111.1	470	8.1	34.0
6	50	LEFT	0.9	0.025	11.4			15.0
6	50	LEFT	0.9	0.460	32.6			19.0
6	50	LEFT	0.9	0.760	189.0			90.0
6	50	LEFT	0.3	0.025	16.6			52.0
6	50	LEFT	0.3	0.150	20.6			60.0
6	50	RIGHT	0.9	0.025	4.7			5.4
6	50	RIGHT	0.9	0.460	8.5			19.0
6	50	RIGHT	0.9	0.760	10.4			44.0
6	50	RIGHT	0.3	0.025	43.7			13.0
6	50	RIGHT	0.3	0.150	39.7			16.0
7	50	LEFT	0.9	0.025	3.8			6.0
7	50	LEFT	0.9	0.460	6.2			21.0
7	50	LEFT	0.9	0.760	15.4			84.0
7	50	LEFT	0.3	0.025	11.4			18.0
7	50	LEFT	0.3	0.150	34.6			32.0
7	50	RIGHT	0.9	0.025	2.9			26.0
7	50	RIGHT	0.9	0.460	7.1			9.1

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
7	50	RIGHT	0.9	0.760	15.1			26.0
7	50	RIGHT	0.3	0.025	14.4			30.0
7	50	RIGHT	0.3	0.150	25.8			40.0
8	50	LEFT	0.9	0.025	1.4	480	8.2	8.1
8	50	LEFT	0.9	0.460	3.1	460	8.0	24.0
8	50	LEFT	0.9	0.076	5.4	480	8.1	24.0
8	50	LEFT	0.3	0.025	6.9	480	8.1	40.0
8	50	LEFT	0.3	0.150	4.5	460	8.1	64.0
8	50	RIGHT	0.9	0.025	7.0			13.0
8	50	RIGHT	0.9	0.460	6.0			12.0
8	50	RIGHT	0.9	0.760	8.3			24.0
8	50	RIGHT	0.3	0.025	11.9			58.0
8	50	RIGHT	0.3	0.150	28.7			64.0
1	500	LEFT	0.9	0.025	9.0	450	8.1	8.1
1	500	LEFT	0.9	0.460	8.8	450	7.9	10.0
1	500	LEFT	0.9	0.760	17.9	460	8.0	8.2
1	500	LEFT	0.3	0.025	35.8	470	7.9	13.0
1	500	LEFT	0.3	0.150	23.2	460	8.1	18.0
1	500	RIGHT	0.9	0.025	9.5			12.0
1	500	RIGHT	0.9	0.460	8.5			7.0
1	500	RIGHT	0.9	0.760	13.5			6.5
1	500	RIGHT	0.3	0.025	34.2			25.0
1	500	RIGHT	0.3	0.150	20.3			9.8
2	500	LEFT	0.9	0.025	4.0			6.0
2	500	LEFT	0.9	0.460	4.0			13.0
2	500	LEFT	0.9	0.760	13.4			17.0
2	500	LEFT	0.3	0.025	26.0			12.0
2	500	LEFT	0.3	0.150	41.0			13.0
2	500	RIGHT	0.9	0.025	7.5			7.5
2	500	RIGHT	0.9	0.460	6.4			7.9
2	500	RIGHT	0.9	0.760	6.0			10.0
2	500	RIGHT	0.3	0.025	14.0			24.0
2	500	RIGHT	0.3	0.150	12.7			12.0
3	500	LEFT	0.9	0.025	43.7			24.0
3	500	LEFT	0.9	0.460	36.5			7.2
3	500	LEFT	0.9	0.760	38.0			13.0
3	500	LEFT	0.3	0.025	32.9			52.0
3	500	LEFT	0.3	0.150	25.0			5.3

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS* (mg/l)	pH	TURB* (NTU)
3	500	RIGHT	0.9	0.025	15.4			4.6
3	500	RIGHT	0.9	0.460	235.7			7.9
3	500	RIGHT	0.9	0.760	28.0			10.0
3	500	RIGHT	0.3	0.025	17.5			10.0
3	500	RIGHT	0.3	0.150	33.7			5.4
4	500	LEFT	0.9	0.025	2.0			7.2
4	500	LEFT	0.9	0.460	7.8			5.5
4	500	LEFT	0.9	0.760	5.3			12.0
4	500	LEFT	0.3	0.025	3.7			5.8
4	500	LEFT	0.3	0.150	7.8			9.4
4	500	RIGHT	0.9	0.025	3.0	470	8.1	73.0
4	500	RIGHT	0.9	0.460	4.3	460	8.0	7.2
4	500	RIGHT	0.9	0.760	13.4	460	8.0	10.0
4	500	RIGHT	0.3	0.025	33.7	460	7.9	18.0
4	500	RIGHT	0.3	0.150	39.7	470	7.9	19.0
5	500	LEFT	0.9	0.025	2.4			4.4
5	500	LEFT	0.9	0.460	27.1			14.0
5	500	LEFT	0.9	0.760	87.5			17.0
5	500	LEFT	0.3	0.025	41.4			13.0
5	500	LEFT	0.3	0.150	21.3			8.2
5	500	RIGHT	0.9	0.250	4.3	470	8.0	4.9
5	500	RIGHT	0.9	0.460	11.2	460	8.1	6.4
5	500	RIGHT	0.9	0.760	55.4	470	8.1	5.5
5	500	RIGHT	0.3	0.025	38.9	480	8.0	6.1
5	500	RIGHT	0.3	0.150	69.6	470	8.0	11.0
6	500	LEFT	0.9	0.025	2.4			13.0
6	500	LEFT	0.9	0.460	5.4			5.6
6	500	LEFT	0.9	0.760	76.6			19.0
6	500	LEFT	0.3	0.025	2.9			6.0
6	500	LEFT	0.3	0.150	7.1			5.5
6	500	RIGHT	0.9	0.025	9.9			4.2
6	500	RIGHT	0.9	0.460	4.5			4.3
6	500	RIGHT	0.9	0.760	13.1			46.0
6	500	RIGHT	0.3	0.025	7.8			90.0
6	500	RIGHT	0.3	0.150	16.5			5.9
7	500	LEFT	0.9	0.025	10.0			5.4
7	500	LEFT	0.9	0.460	5.4			8.2
7	500	LEFT	0.9	0.760	9.4			6.1

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDITY

RUN	TIME	TRS*	DEPTH (m)	STRATA (m)	OWFC/100ML	TDS (mg/l)	pH	TURB* (NTU)
7	500	LEFT	0.3	0.025	7.9			9.0
7	500	LEFT	0.3	0.150	9.6			19.0
7	500	RIGHT	0.9	0.025	4.3			24.0
7	500	RIGHT	0.9	0.460	5.4			5.7
7	500	RIGHT	0.9	0.760	8.1			6.2
7	500	RIGHT	0.3	0.025	6.4			6.1
7	500	RIGHT	0.3	0.150	11.4			6.8
8	500	LEFT	0.9	0.025	0.9	450	8.0	21.0
8	500	LEFT	0.9	0.460	4.0	480	8.1	13.0
8	500	LEFT	0.9	0.760	3.1	470	8.0	8.2
8	500	LEFT	0.3	0.025	111.2	470	8.1	14.0
8	500	LEFT	0.3	0.150	3.1	470	8.2	8.0
8	500	RIGHT	0.9	0.025	7.1			12.0
8	500	RIGHT	0.9	0.460	4.0			5.4
8	500	RIGHT	0.9	0.760	7.2			13.0
8	500	RIGHT	0.3	0.025	15.8			18.0
8	500	RIGHT	0.3	0.150	5.2			6.6

TRS* = TRANSECT
TDS* = TOTAL DISSOLVED SOLIDS
TURB* = TURBIDIDTY

APPENDIX D

WATER LEVEL AND TEMPERATURE
BY
RUN

RUN	TIME	TRANSECT	VERTICAL WATER LEVEL(ft)	HORIZONTAL WATER LEVEL(ft)	AIR TEMP* (^{0}C)	WATER TEMP* (^{0}C)
1	0	LEFT	995.91	132.7	22	20
1	0	LEFT	995.91	132.7	22	18
1	0	RIGHT	995.91	132.7	22	21
1	0	RIGHT	995.91	132.7	22	20
2	0	LEFT	995.71	128.1	29	20
2	0	LEFT	995.71	128.1	29	15
2	0	RIGHT	995.71	128.1	29	21
2	0	RIGHT	995.71	128.1	29	20
3	0	LEFT	995.69	130.2	16	19
3	0	LEFT	995.69	130.2	16	19
3	0	RIGHT	995.69	130.2	16	21
3	0	RIGHT	995.69	130.2	16	19
4	0	LEFT	995.55	140.9	21	19
4	0	LEFT	995.55	140.9	21	19
4	0	RIGHT	995.55	140.9	21	22
4	0	RIGHT	995.55	140.9	21	20
5	0	LEFT	996.10	147.8	17	21
5	0	LEFT	996.10	147.8	17	20
5	0	RIGHT	996.10	147.8	17	20
5	0	RIGHT	996.10	147.8	17	20
6	0	LEFT	995.97	143.5	22	20
6	0	LEFT	995.97	143.5	22	19
6	0	RIGHT	995.97	143.5	22	22
6	0	RIGHT	995.97	143.5	22	21
7	0	LEFT	995.23	147.7	19	19
7	0	LEFT	995.23	147.7	19	19
7	0	RIGHT	995.23	147.7	19	22
7	0	RIGHT	995.23	147.7	19	19
8	0	LEFT	995.19	158.6	24	20
8	0	LEFT	995.19	158.6	24	19
8	0	RIGHT	995.19	158.6	24	22
8	0	RIGHT	995.19	158.6	24	20

TEMP* = TEMPERATURE

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