WWE
MEMORANDUM

To: Big Dry Creek Watershed Association Steering Committee

From: Wright Water Engineers, Inc.
Jane Clary and Dave Mehan

Date: June 9, 2003

Re: Supplemental Biological and Selected Water Quality Data Exploration 1997-2001

INTRODUCTION

In 1999, Wright Water Engineers, Inc. (WWE) completed an evaluation of chemical, physical and biological data collected from Big Dry Creek during 1997-1998. The findings of this evaluation were provided in "Integrated Analysis of Habitat, Macroinvertebrate, Fish, Flow and Selected Water Quality Parameters on the Main Stem of Big Dry Creek" (WWE 1999). The purpose of this initial assessment was to develop an understanding of the factors influencing aquatic life in the creek and to determine whether a more stringent unionized ammonia standard was necessary to protect the Johnny darter. The report also provided recommendations for improvements to the monitoring program.

During late 2002, the Big Dry Creek Watershed Association Steering Committee determined that an update to the WWE (1999) report would be appropriate since five years of biological data were now available for the creek. As a result, this technical memorandum provides a supplemental evaluation to the WWE (1999) report. This memorandum compares the findings from the five-year data set to the WWE (1999) report and further explores possible trends with regard to the biological data. Key relationships explored in this memorandum include:

1) Trends over time

2) Findings related to the artificial substrate sampling

3) Effects of flow on macroinvertebrate and fish indices

4) Relationship between new selenium data and macroinvertebrate and fish communities.

Reader familiarity with the previous WWE (1999) report is assumed, as well as familiarity with the various Aquatics Associates reports that summarize the biological results (Aquatics Associates 1998, 1999a, 1999b, 2002). Figure 1 provides a map of the sampling locations included in this report. The approach, findings, discussion, conclusions and recomendations for this technical memorandum follow.

APPROACH

Consistent with the general approach used in the WWE (1999) report, potential relationships between fish and macroinvertebrate community health indices, habitat and selected water quality and flow parameters were explored. The biological sample sets included in this review are summarized in Table 1. In addition to the biological data, water quality and flow data sets were retrieved from the Big Dry Creek water quality database for the three-month period prior to and/or including the sampling event. For the spring samples, January through March data were retrieved. For the fall samples, August through October data were retrieved. The average values of the water quality parameter or flow for each time period were then calculated for purposes of data exploration. The "raw data" used in this analysis are included in Attachment 1 of this report.

Table 1
Sample Sets Collected on Big Dry Creek

Sample Type	1997	1998	1999	2000	2001
Macroinvertebrates					
Kick	Spring/Fall	Spring/Fall	Spring	Spring/Fall	Spring/Fall
Hess	Spring/Fall	Spring/Fall	Spring	Spring	--
Artificial Substrate	--	--	--	Fall	Fall
Fish	Spring/Fall	Fall	Fall	Fall	Fall
Habitat	Spring	--	--	Fall	Fall

Brief explanations of several terms used throughout this technical memorandum include:

- Sample Collection Techniques: With regard to benthic macroinvertebrates, three sample collection methods have been used at various times during the last five years:

  - "Kick" samples were collected by using a hand-held kick net with a mesh size of 425 microns to collect samples from representative habitat types including pool, riffle, run and bank areas.

  - "Replicate" or "Hess" samples were collected in shallow riffle areas only using a modified Hess sampler, equipped with 250 micron Nitex mesh, which samples a standard unit area, allowing for determination of macroinvertebrate densities (Aquatics Associates 1998).

  - Artificial substrate samples were collected using Hester-Dendy samplers at the reference site bdc1.5 and four sites downstream of the wastewater treatment plants. Three Hester-Dendy samplers were installed at each location for a four-week colonization period, and samplers were retrieved concurrent with the kick net sampling event each fall (Aquatics Associates 2002).

- Habitat Scores: Overall habitat scores for each monitoring location were developed following EPA protocols by WWE (WWE 1999) for the 1997 data set and by Aquatics Associates (2002) for the 2000/2001 data sets. Nine standard parameters were used to develop an overall habitat score at each monitoring location. These parameters address characteristics in three categories including: substrate and instream cover, channel morphology, and riparian and bank structure. These parameters are weighted to emphasize the most biologically significant parameters. Each parameter is rated poor, fair, good or excellent and assigned a numeric value. These scores are then totaled and compared to a reference site to develop a final habitat ranking. A reference site is used to normalize the assessment to the "best attainable" situation. Habitat scores increase as habitat quality increases.

One issue with regard to the habitat scores used in this analysis is that the habitat rating procedure and size of the scores changed between 1997 and 2000/2001. The 1997 ratings were based on the EPA (1989) method which has a maximum score of 135, while the 2000/2001 ratings were based on the EPA (1998) method which has a maximum rating of 200. Therefore, a proportional constant of 1.48 (i.e., 200/135=1.48) was applied to the 1997 ratings so that the 1997 and 2000/2001 scores could be examined as one data set.

- Invertebrate Community Index (ICI): Just as overall habitat scores are developed based on scoring several individual parameters then relating these to a reference site for development of an overall habitat score, an overall measure of benthic macroinvertebrate community health is the "Invertebrate Community Index" (ICI). Following EPA's Rapid Bioassessment Protocol III, individual parameters (metrics) used to calculate the ICI for a monitoring location include taxa richness, modified Hilsenhoff biotic index, ratio of scrapers to filtering collectors, ratio of EPT (Ephemeroptera, Plecoptera, Trichoptera) and Chironomidae abundance, percent contribution of dominant taxon, community similarity index and ratio of shredder functional feeding group to total number of individuals collected. (See EPA [1998] for more information on these metrics.) For purposes of the data analysis that follows, the ICI is used to represent benthic community health. Individual metrics are not included in the discussion in order to limit the scope of data analysis, consistent with the WWE (1999) approach. The Aquatics Associates (1998, 1999a, 1999b, 2002) reports should be referenced for more information on the individual metrics.

- Index of Biotic Integrity (IBI) for Fish: The IBI serves as an integrated analysis of fish metrics associated with EPA's Rapid Bioassessment Protocol V (EPA 1989). The IBI is calculated by using 13 metrics that measure characteristics such as species richness and composition, trophic composition, and fish composition and condition. The overall IBI is assigned based on comparison to a reference site. EPA (1989) should be referenced for more detail on individual metrics. The IBI is an adaptable index, allowing the choice of metrics and scoring criteria on a regional basis.

Correlation analyses were used as a screening tool to identify potential statistically significant relationships among selected variables. The correlation coefficient ("r") value indicating a statistically significant relationship varies with the sample size (Mendenhall and Ott 1976). For most of the correlation analyses, a sample size greater than 30 existed, so $r \geq 0.34$ indicated a statistically significant relationship at the 95 percent level of confidence. For smaller sample sizes, larger r values are required to be statistically significant. For example, for habitat scores ($n = 23$), $r = 0.41$ and for artificial substrate samples ($n = 10$), $r = 0.63$. A negative value for r indicates an inverse relationship between variables.

Correlation analyses were performed for the following parameters:

- Unionized ammonia, iron, total suspended solids (TSS), dissolved selenium
- Flow
- Habitat Scores
- Macroinvertebrate Invertebrate Community Index (ICI) scores for Hess, kick and artificial substrate samples
- Fish Index of Biotic Integrity (IBI) scores
- Location (general upstream to downstream trends)
- Season (for kick samples only)

With regard to the seasonal evaluation, only kick net macroinvertebrate samples were evaluated for seasonal trends because they had four data sets in the fall and five data sets for the spring, making a seasonal evaluation possible. By contrast, the majority of the fish data were collected in the fall (five out of six sets), and both of the artificial substrate data sets were collected in the fall, making seasonal evaluation less meaningful. Twice as many Hess samples were collected in the spring (four out of six) as the fall, so seasonal evaluations were not pursued for the Hess samples.

Following correlation analysis, scatter plots of the data were developed to further explore relationships among variables. Using Excel, linear regression analyses were then performed for each of the scatter plots. In several cases, log-normal plots were also explored, but because they did not significantly improve the statistical relationships, they are not included in this technical memorandum. Because of the limited scope of this memorandum, WWE did not delve into more complicated statistical approaches such as multiple regression analysis, although these analyses could be performed in the future.

FINDINGS

Figure 2 plots trends over time for the ICI kick, ICI Hess, ICI artificial substrate and IBI fish scores. Implications of these plots are provided in the discussion section of this memorandum.

Table 2 contains a matrix showing linear correlation coefficients (r values) between the sets of independent and dependent variables analyzed. The values of r that are considered to be statistically significant based on the various sample sizes are highlighted in yellow. A bulleted text summary of the table follows, along with identification of figures that provide scatter plots and the linear regression analysis. A discussion of these findings is provided in the next section of this memorandum. In reviewing the correlation coefficients below, it is important to remember that correlation does not necessarily imply cause. For example, it is unlikely that fish community health is improved by higher selenium concentrations, even though the r value for this relationship is statistically significant.

Table 2

Correlations Between Selected Independent and Dependent Variables on Big Dry Creek

	Un-ionized Ammonia	Flow	Iron	Se, Dissolved	TSS	Habitat (adj)	Year	Season	Location	ICI Kick	ICI Hess	ICI Art. Substrate	IBI Fish
Un-ionized Ammonia	1.00												
Flow	0.26	1.00											
Iron	0.73	0.41	1.00										
Se, Diss	-0.21	-0.20	-0.13	1.00									
TSS	0.56	0.64	0.78	-0.23	1.00								
Habitat (adj)	-0.66	-0.47	-0.40	0.43	-0.69	1.00							
Year	-0.17	-0.22	-0.17	-0.37	-0.08	0.58	1.00						
Season	0.25	-0.30	0.17	-0.09	0.11	-0.61	0.00	1.00					
Location	0.36	0.64	0.36	-0.09	0.64	-0.66	-0.03	0.00	1.00				
ICI Kick	-0.23	-0.14	-0.20	0.30	-0.32	0.50	-0.32	-0.50	-0.51	1.00			
ICI Hess	-0.28	-0.13	-0.10	0.62	-0.12	0.92	-0.37	-0.58	-0.45	0.86	1.00		
ICI Art. Substrate	-0.19	-0.68	-0.57	0.60	-0.77	0.71	-0.42	NA	-0.85	0.65	NA	1.00	
IBI Fish	-0.02	-0.36	-0.32	0.45	-0.33	0.13	0.09	0.06	-0.26	0.32	0.37	-0.01	1.00
Sample Size	69	66	70	35	63	23	74	74	74	61	40	10	44

Table Note: Highlight indicates statistically significant correlation based on values calculated for various sample sizes (Mendenhall and Ott 1976). Note that statistically significant "r" values vary based on sample size, so what appears to be a relatively low r value such as 0.34 may be statistically significant for large sample sizes, but not statistically significant for smaller sample sizes.

To summarize the table above and as confirmed in the scatter plots, statistically significant relationships based on correlation analysis included the following:

- ICI Kick:
  - Positively correlated with habitat, ICI Hess and ICI artificial substrate.
  - Inversely correlated with location. (Higher at upstream locations.)
  - Seasonal variation indicated lower scores in the spring.
- ICI Hess:
  - Positively correlated with ICI kick, and habitat.
  - Inversely correlated with location. (Higher at upstream locations.)

- ICI Artificial Substrate:
  - Positively correlated with ICI kick and habitat.
  - Inversely correlated with flow and TSS.
  - Inversely correlated with location. (Higher at upstream locations.)
- IBI Fish:
  - Inversely correlated with flow.
  - Positively correlated with selenium.
- Habitat (Figures 3a-3d):
  - Positively correlated with ICI Hess, ICI kick and ICI artificial substrate.
  - Inversely correlated with TSS, flow, unionized ammonia.
  - Inversely correlated with location. (Higher at upstream locations.)
- Unionized Ammonia (Figures 4a-4d):
  - No statistically significant correlation with ICI/IBI scores.
  - Positively correlated with iron and TSS.
  - Inversely correlated with habitat.
  - Positively correlated with location, increasing in a downstream direction.
- TSS (Figures 5a-5d):
  - Inversely correlated with ICI artificial substrate and habitat.
  - Positively correlated with flow, iron and unionized ammonia.
  - Positively correlated with location, increasing in a downstream direction.
- Flow (Figures 6a-6d)
  - Inversely correlated with artificial substrate ICI, fish and habitat
  - Positively correlated with TSS and iron
  - Positively correlated with location, increasing in a downstream direction.
- Iron (Figure 7a-7d):
  - Positively correlated with TSS, unionized ammonia and flow.
  - No statistically significant correlation with ICI/IBI scores.
  - Positively correlated with location, increasing in a downstream direction.

- Selenium:
  - Positively correlated with fish IBI scores.
  - Not significantly correlated to location.
- Location:
  - ICI scores are inversely correlated with location, with upstream locations have higher scores for kick, Hess and artificial substrate samples.
  - IBI scores are not statistically significantly correlated with location.
  - Positively correlated with unionized ammonia, flow, iron and TSS (all increase in a downstream direction).

Discussion

The discussion below addresses 1) trends over time, 2) factors influencing the biologic community, and 3) comparison of the five-year data set to the WWE (1999) findings.

Trends Over Time

Trends over time for the overall biological community are unclear. Specifically, as shown in Figure 2, the macroinvertebrate community, as measured by the kick ICI scores, appeared to decrease in overall health over the five-year period. In contrast, the fish community health, as indicated by IBI scores, improved between 1997 and 2000, but declined in 2001. Biological community health decreases in 2001 could potentially be explained by the severe drought affecting Colorado. However, correlations between fish IBI and benthic ICI scores are inversely related to flow (i.e., community scores generally increase at lower flows). Intuitively, however, it would be reasonable to expect some influence of the drought on the aquatic community. Biological data for 2002 will be useful in further evaluating the possible influence of drought, and trends with the biological communities in the creek.

Statistically significant trends over time for TSS, unionized ammonia, iron, and flow were not present based on the data set included in this analysis. Only two full years of selenium data were available; therefore, trends over time for selenium are not considered to be meaningful.

Factors Influencing the Biological Community

Factors influencing the biological community are discussed according to sample types: kick, Hess and artificial substrate for macroinvertebrates and fish. This is followed by additional discussion on habitat and flow.

Kick Samples

The macroinvertebrate kick ICI scores (n = 61) are statistically significantly correlated with habitat (r = 0.50), but not the selected water quality or flow variables. The kick ICI scores were more strongly correlated with the 1997 habitat scores (r = 0.86) than the 2000/2001 habitat scores. (This is after adjusting the 1997 scores by a factor of 1.48.) The kick ICI scores also showed a statistically significant inverse relationship with location (r = -0.51), with upstream locations having higher scores.

Kick scores were also correlated with season, with the spring samples having lower ICI scores. When examining the spring and fall ICI scores separately, habitat continues to be the dominant factor impacting each season (r = 0.86, r = 0.50). In the spring, flow (r = -0.45) and TSS (r = -0.36) also showed statistically significant inverse correlations with the kick scores. During the spring, selenium (r = 0.64) also showed a positive correlation to the ICI scores, although this relationship is counterintuitive. More specifically, it is unlikely that higher selenium concentrations improve macroinvertebrate health. Location was also important in both the spring and the fall, with upstream sites generally showing higher scores.

Positive correlations between selenium and the kick ICI scores (and the fish IBI scores discussed below) may be explained by the covariation between habitat scores and selenium (r = 0.43). Locations with better habitat typically have higher selenium concentrations than locations with poorer habitat. While it is unlikely that higher selenium concentrations are improving fish and benthic communities, these data suggest that selenium concentrations are at least not having an adverse impact on aquatic life.

Hess Samples

The Hess samples (n = 40) were collected from the spring of 1997 through the spring of 2000. These samples were strongly correlated with habitat (r = 0.92). The Hess samples showed the strongest relationship to habitat of all of the biologic community samples. This makes sense because the Hess samples are collected from riffles, the quality of which are well reflected in the habitat score while kick samples are collected from all habitat types present. The Hess samples showed inverse correlations with location, with the upstream-most sites having higher ICI scores, indicating a healthier macroinvertebrate community. Hess scores were also correlated with season, with the spring samples having lower ICI scores, as was the case for the kick samples; however, seasonal variation was not further explored since the kick ICI scores have a larger sample size with more even distribution between the spring and fall.

Artificial Substrate Samples

In keeping with the recommendation of the WWE (1999) report, Hester Dendy artificial substrate samplers were installed at five sites along the creek in 2000 and were sampled in the fall of 2000 and spring of 2001. These samplers greatly reduce or eliminate the confounding effects of substrate on the macroinvertebrate community. Since substrate type becomes a constant, differences noted in the community at various locations must be due to water quality or possibly flow. Table 2 indicates that ICI values from the Hester Dendy samplers were significantly inversely related to flow and TSS, which tended to increase in a downstream direction, as shown in Figure 8. In other words, locations with higher flow and TSS concentrations had poorer macroinvertebrate communities. Locations with higher flow and TSS concentrations increase in a downstream direction.

Additionally, the positive correlation between the artificial substrate and the ICI kick scores suggests that there are factors affecting the benthic community that are not habitat related. However, the artificial substrate and kick samples do not have a common statistically-significant independent variable based on the correlations. For example, the artificial substrate samples are most strongly correlated with TSS (r = -0.77), but the kick samples do not show a statistically significant correlation with TSS (r = -0.32, with r = -0.34 necessary to be statistically significant for this sample size).

Another interesting aspect of the correlations is that the artificial substrate scores were fairly strongly correlated with habitat (r = 0.71); this is counterintuitive since the artificial substrate samples should reduce the influence of habitat. This is likely due to the fact that both habitat and water quality decrease in a downstream direction. It may also be due to other aspects of the habitat score reflected in this correlation that are not substrate-based. For example, the habitat scores include metrics such as flow/velocity, pool/riffle and run/bend ratios, bank vegetation and streamside cover; the influence of these metrics is not completely removed by artificial substrate samplers. It should be noted, however, that most of the metrics in the overall habitat scores are effectively removed by the artificial substrate samplers (e.g., bottom substrate, embeddedness, channel alteration, bottom scouring, bank stability, etc.).

Fish Samples

The fish IBI scores (n = 44) were statistically significantly inversely correlated with flow (r = -0.36) and positively correlated with selenium (r = 0.45). More specifically, fish IBI scores were higher at locations with lower flows. Flow is correlated with stream location (r = 0.64), with upstream sites having lower flows. Flow is also correlated with habitat (r = -0.47), with higher habitat scores at locations with lower flows. (See the kick ICI discussion for an explanation of the selenium-IBI relationship.)

Although a seasonal evaluation of the fish data has limited value because only one spring fish sampling event was conducted out of six sampling events, the spring sample was positively correlated with flow (r = 0.70). This is interesting because the annual and fall samples show inverse correlations to flow, which is counterintuitive. One possible explanation is that spring flows in the creek may be of better quality than the flows in the fall.

Habitat Scores

The 1997 habitat scores are much more strongly correlated to the both the fish IBI and benthic ICI scores than are the 2000/2001 habitat scores (even after adjusting the scores to account for method changes). Overall, habitat scores show an inverse correlation with location (r = -0.66), with upstream locations showing higher habitat scores. This would be expected in Big Dry Creek as it transitions from a foothills to a plains stream with an associated increase in sediment load, reduction in quality of riffles and habitat diversity, etc.

Flow

In general, for a relatively small and possibly flow-limited creek like Big Dry Creek, higher values of IBI and ICI scores would be expected with more flow. As shown in Table 2 and on Figures 5a-5d, ICI and IBI values were inversely correlated with flow. Further analysis indicates that other parameters including TSS, iron and ammonia, which could affect aquatic life, are directly related to flow and this could explain why ICI and IBI values were inversely related to flow. More specifically, concentrations of these parameters are higher at higher flows, adversely affecting the macroinvertebrate and fish communities. The effect of flow and associated parameters on the health of aquatic communities is greatest downstream on the creek where these concentrations are generally higher.

Comparison of Five Year Data Set to the WWE (1999) Evaluation

Analysis of the expanded database generally confirms the major findings of the WWE (1999) report, although some relationships that appeared relatively strong in the 1999 evaluation weakened in the larger data set. A comparison of the 1999 conclusions to the five-year data set includes these findings:

- The nature of the aquatic communities in the creek is affected by more than one factor, and the factors change in magnitude and importance along the creek.

- Macroinvertebrate results are similar for Hess and kick samples. The strong correlation (r = 0.86) between their ICI scores supports the Watershed Association's decision to limit sampling efforts to one protocol (kick) to be more cost-effective with the sampling program.

- Seasonal variation for the kick samples continued to occur, with lower scores in the spring.

- As was the case in the WWE (1999) report, the macroinvertebrate ICI scores were directly related to habitat quality. This is shown on Figure 3a-d where the strongest relationship occurs with ICI values from Hess samples Fish scores were less strongly related to habitat than macroinvertebrates in both the WWE (1999) report and the five-year data set, although the relationship was stronger in WWE (1999) than the five-year data set.

- In the WWE (1999) report, considerable attention was given to the Johnny darter, whose occurrence was not significantly correlated to unionized ammonia concentrations. Since ammonia concentrations have continued to be low (i.e., below the stream standard of 0.1 mg/L) since 1998 and show no significant relationship to fish or macroinvertebrates, the Johnny darter was not focused on in this technical memorandum.

- In the WWE (1999) report, benthic ICI's were inversely correlated to several water quality parameters analyzed which included lead, unionized ammonia, iron and TSS. Benthic ICIs typically showed stronger and more consistent correlations to water quality parameters than the fish IBI's. In the five-year data set, only the artificial substrate samples showed a statistically significant correlation to any of the water quality parameters, and in that case, only TSS (see Figure 6d). (Note: Lead was not explored in this technical memorandum because it has been consistently below stream standards since 1995. Although unionized ammonia has also been below its stream standard, it was retained in this analysis due to the Colorado Division of Wildlife's concern regarding potential aquatic life impacts. Iron was included in this analysis because is has periodically exceeded its stream standard of 1 mg/L, which is in place for protection of aquatic life.)

- The effect of flow on macroinvertebrate and fish communities was not clear in the 1999 study, where correlations with flow and ICI and IBI values were weak. As discussed above, flow was more strongly related to the quality of the macroinvertebrate and fish communities for the five-year data set.

- The covariation between TSS, iron, unionized ammonia, flow and habitat observed in WWE (1999) continued to exist in the five-year data set. In general, these water quality constituents had higher concentrations at locations with lower habitat scores and higher flows. One difference between the five year data set and the WWE (1999) data set is that with the exception of TSS and the artificial substrate samples, these water quality constituents were not significantly correlated with macroinvertebrate and fish community scores.

Conclusions

1. No single variable explains trends in ICI/IBI scores on Big Dry Creek.

2. Upstream locations generally have higher quality fish and benthic communities than downstream locations. Upstream locations also generally have higher habitat scores, better water quality and lower flows.

3. Habitat appears to be the most consistent influence on benthic ICI scores.

4. Fish IBI scores are not strongly related to the variables explored.

5. Seasonal variation was evident for the kick ICI scores, with spring samples showing lower scores.

6. Unionized ammonia does not appear to be affecting the fish and benthic communities, based on concentrations present in the creek during the spring and fall of the last five years. Unionized ammonia concentrations on the creek are generally below the stream standard.

7. Iron does not appear to be affecting the fish and benthic communities, even though iron periodically exceeds the stream standard.

8. Dissolved selenium does not appear to be adversely affecting the fish and benthic communities, based on the limited sample size reviewed.

9. Artificial substrate samples showed stronger relationships to flow, TSS and location than did the other benthic samples, indicating that factors other than habitat appear to be influencing the aquatic community. In other words, habitat alone does not fully explain benthic community health.

Recommendations

1. Continue the current biological monitoring program including these aquatic parameters: a) the benthic community through kick samples in the spring and fall; b) artificial substrate samples in the fall; c) the fish community in the fall; and d) habitat. These recommendations are made in the context of the evolving regulations and guidance of the Colorado Water Quality Control Division related to assessment of aquatic communities and the potential relevance of these aquatic life data with regard to Big Dry Creek's relationship to the 303(d) list.

2. Utilize the information collected over the last five years in combination with data available for comparable streams on the Front Range to develop "expected conditions" for upper and lower Big Dry Creek. The "expected condition" forms the basis for an assessment of whether or not the aquatic community is impaired. The reference sites used in the Aquatics Associates reports are a key component in developing expected conditions, but these data need to be compared to other data sources for similar streams along the Front Range.

3. Once expected conditions are developed, consider developing thresholds of impairment for the aquatic community. In other words, what percent change (e.g., 25%, 50%) in the expected condition indicates impairment for the Big Dry Creek aquatic life community?

4. Continue to actively participate in and monitor progress and changes related to Colorado's 303(d) listing methodology to ensure that Big Dry Creek's monitoring program is consistent

with regulatory expectations of the CWQCC and EPA. In particular, the Watershed Association should be familiar with these references:

a. CWQCD's "Proposed Aquatic Life Classification System and Potential Regulatory Implications," March 10, 2003 draft.

b. EPA's Consolidated Listing Methodology (CALM) guidance, see http://www.epa.gov/owow/monitoring/calm.html.

c. EPA's 2002 Integrated Water Quality Assessment Report guidance, see http://www.epa.gov/owow/tmdl/2002wqma.html.

d. EPA's 2002 March Clarification, see http://www.epa.gov/owow/tmdl/guidance/biochange20302.pdf

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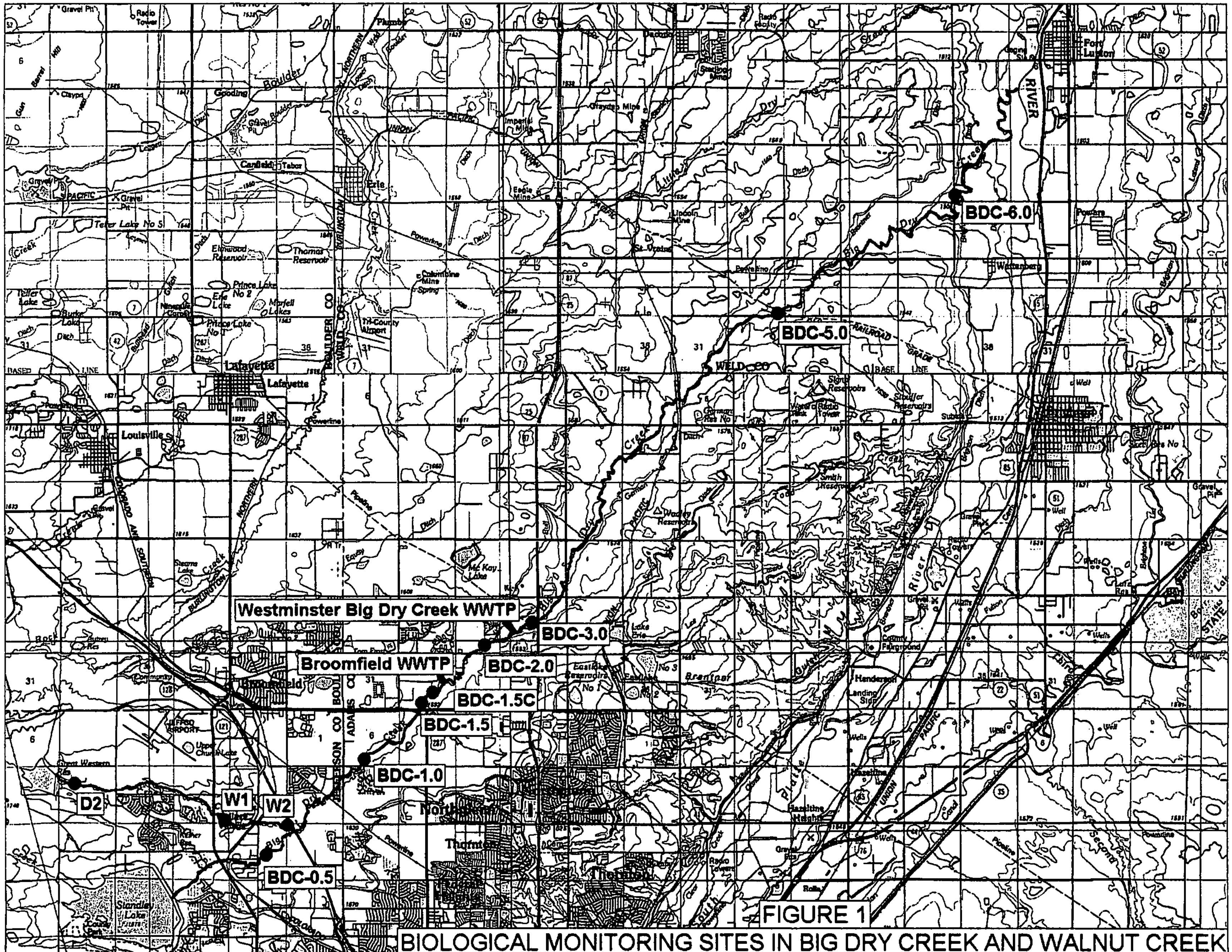

FIGURE 1

BIOLOGICAL MONITORING SITES IN BIG DRY CREEK AND WALNUT CREEK

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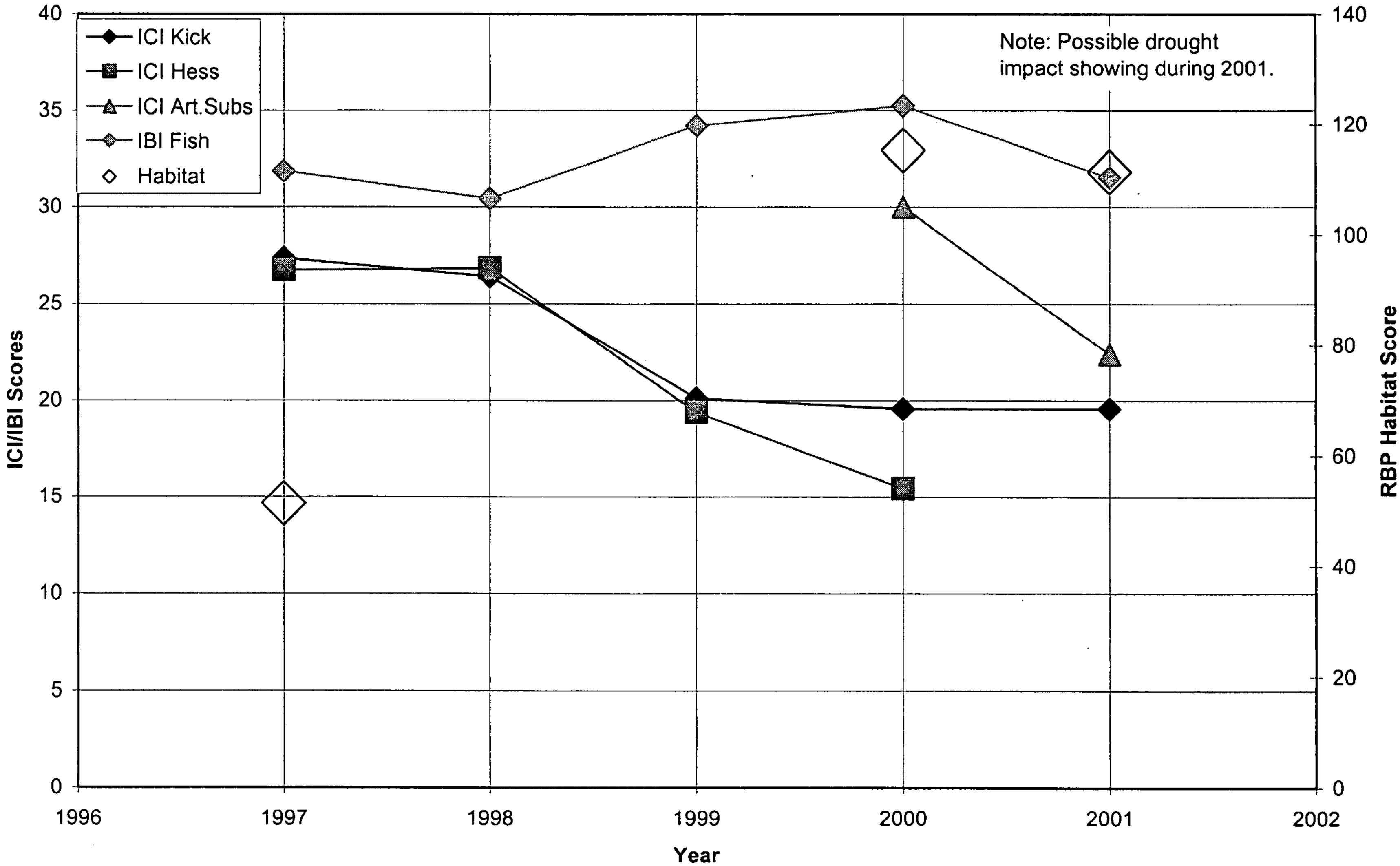
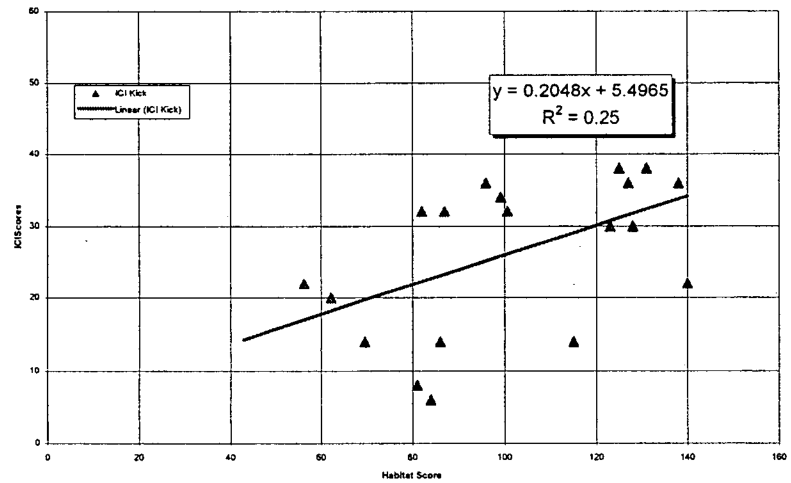
Figure 2
Big Dry Creek Biological Trends Over Time

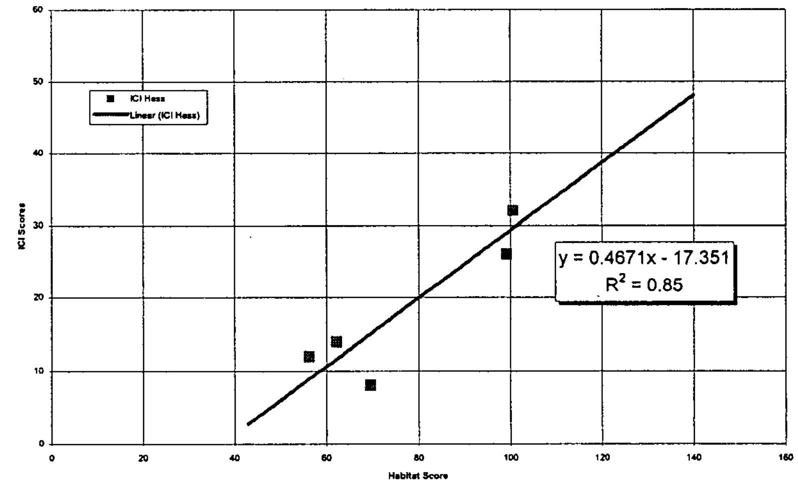


Figures 3a-3d
ICI/IBI Scores vs. Habitat
Big Dry Creek

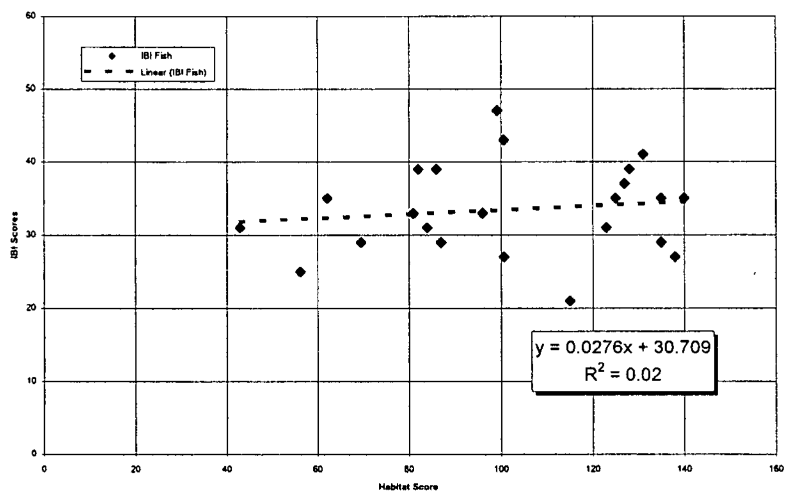
ICI Kick v. Habitat



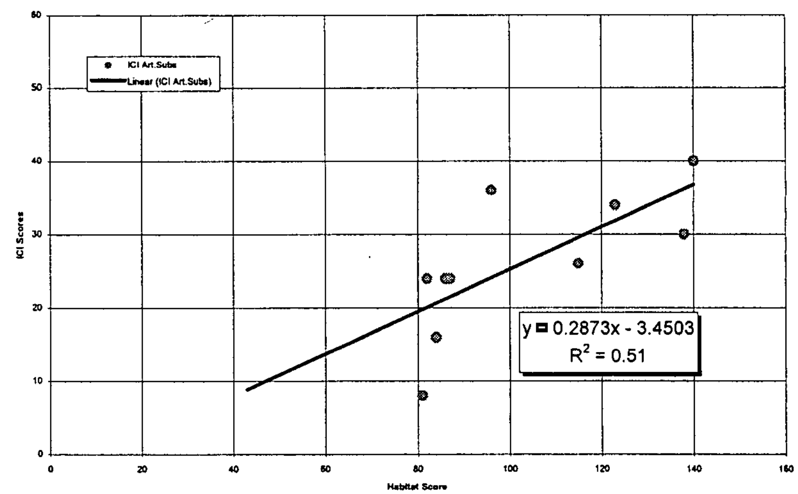
ICI Hess v. Habitat



IBI Fish Scores v. Habitat



Artificial Substrate ICI Scores v. Habitat

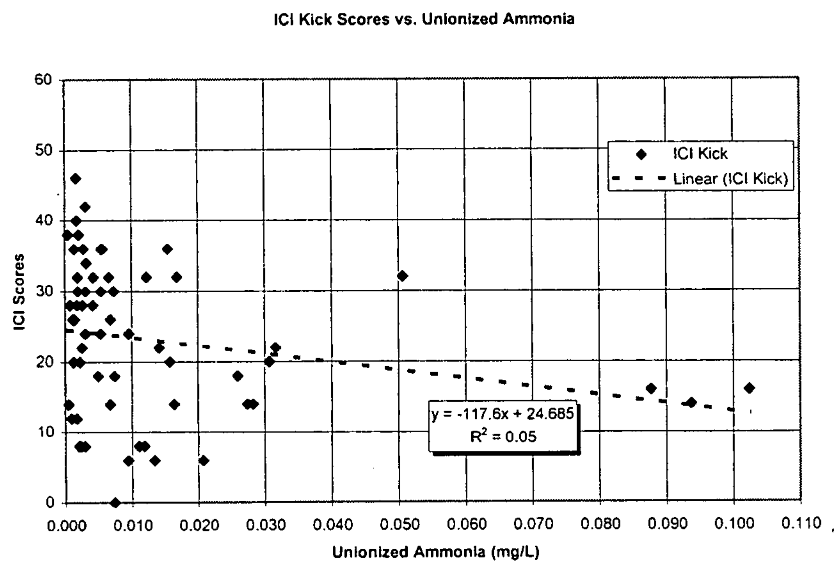


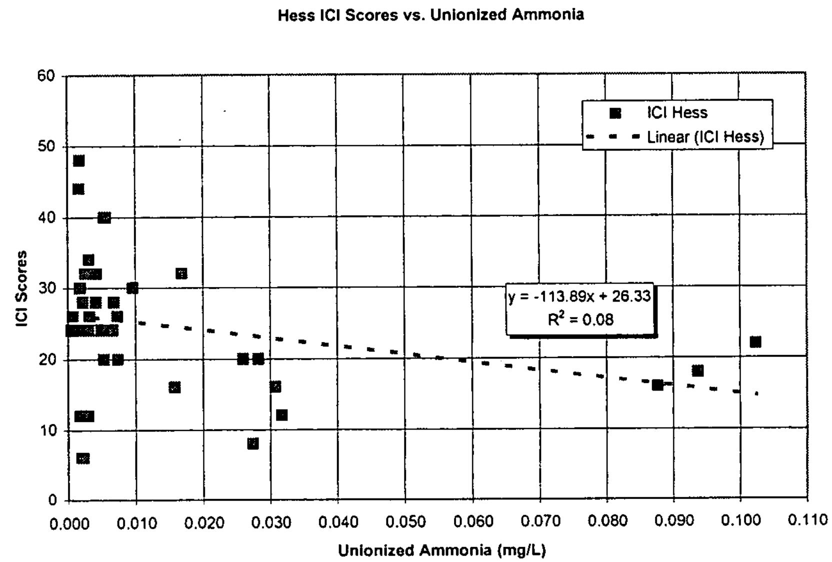
summary analysis (draft final).xls
Fig2Habitat Plots

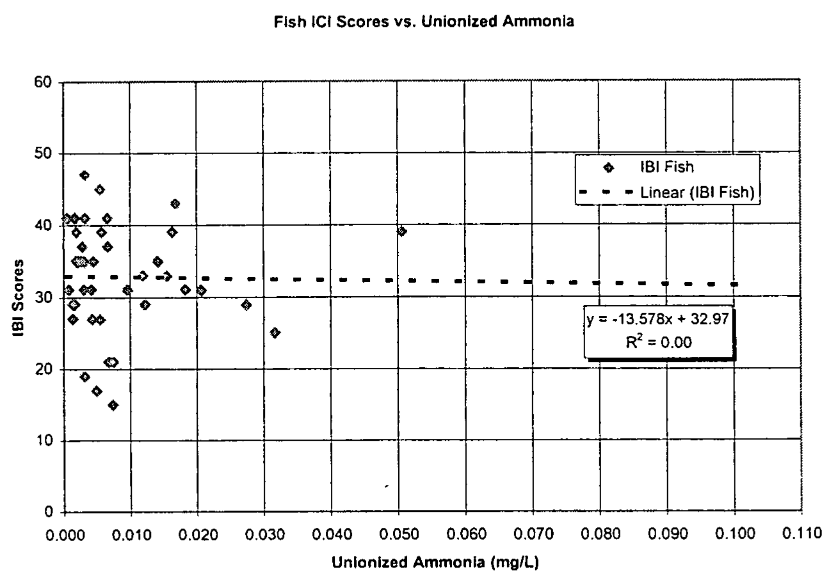
Wright Water Engineers, Inc.
8/9/2006

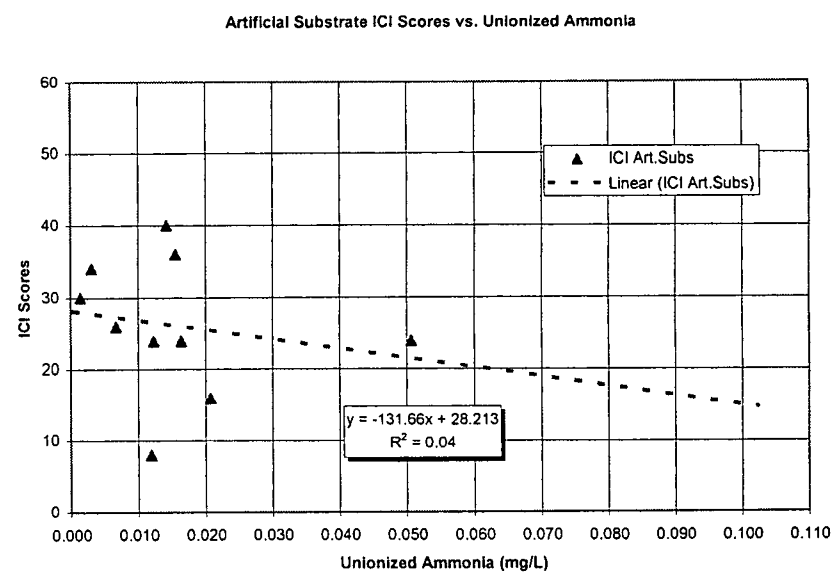
Des. by: jkc

Figues 4a-4d
IBI ICI Scores vs. Unionized Ammonia



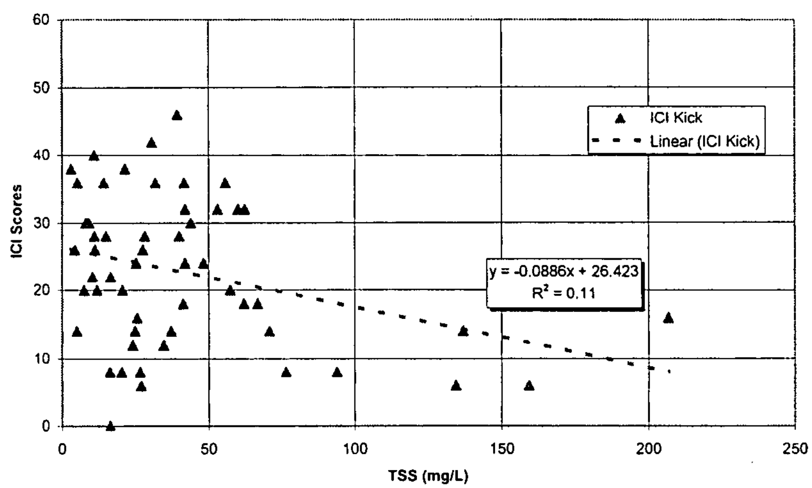




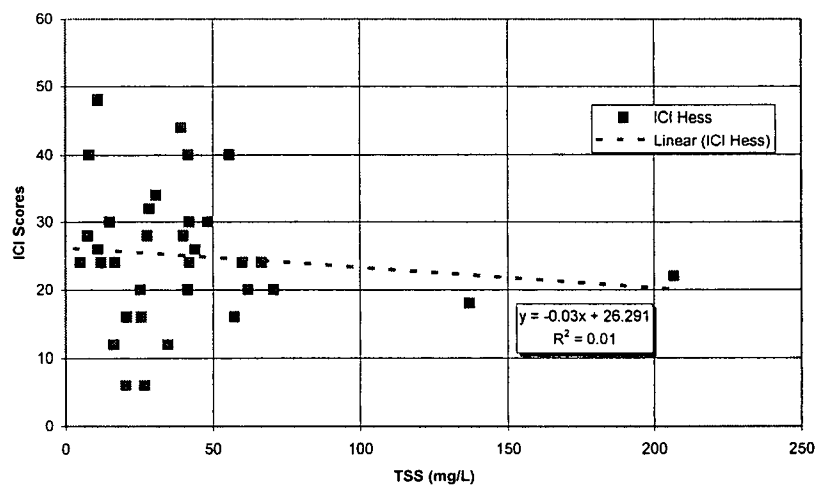


Figures 5a-5d
ICI/IBI Scores vs. TSS

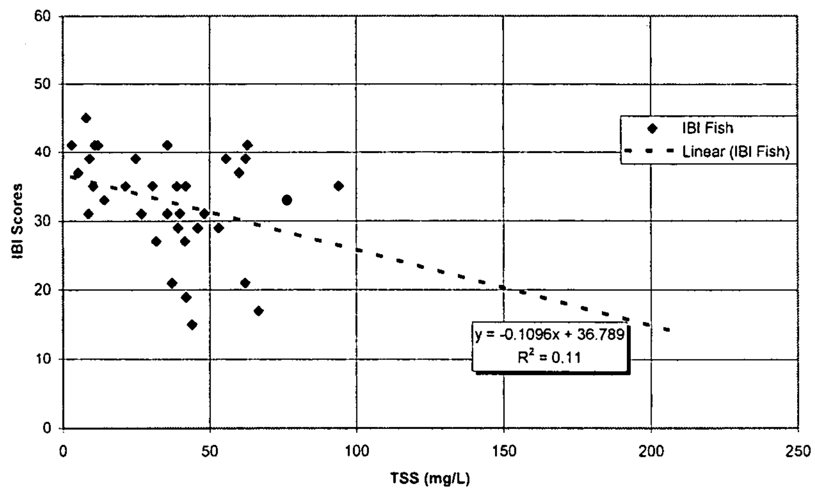
Kick ICI Scores vs. TSS



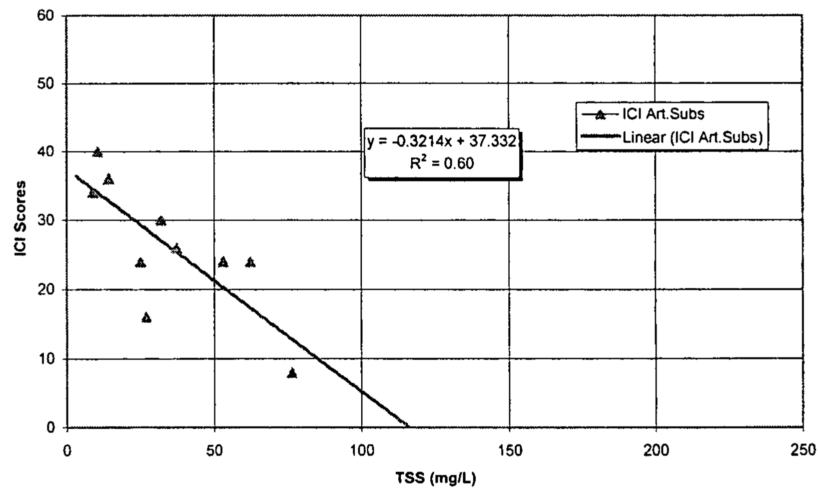
Hess ICI Scores vs. TSS



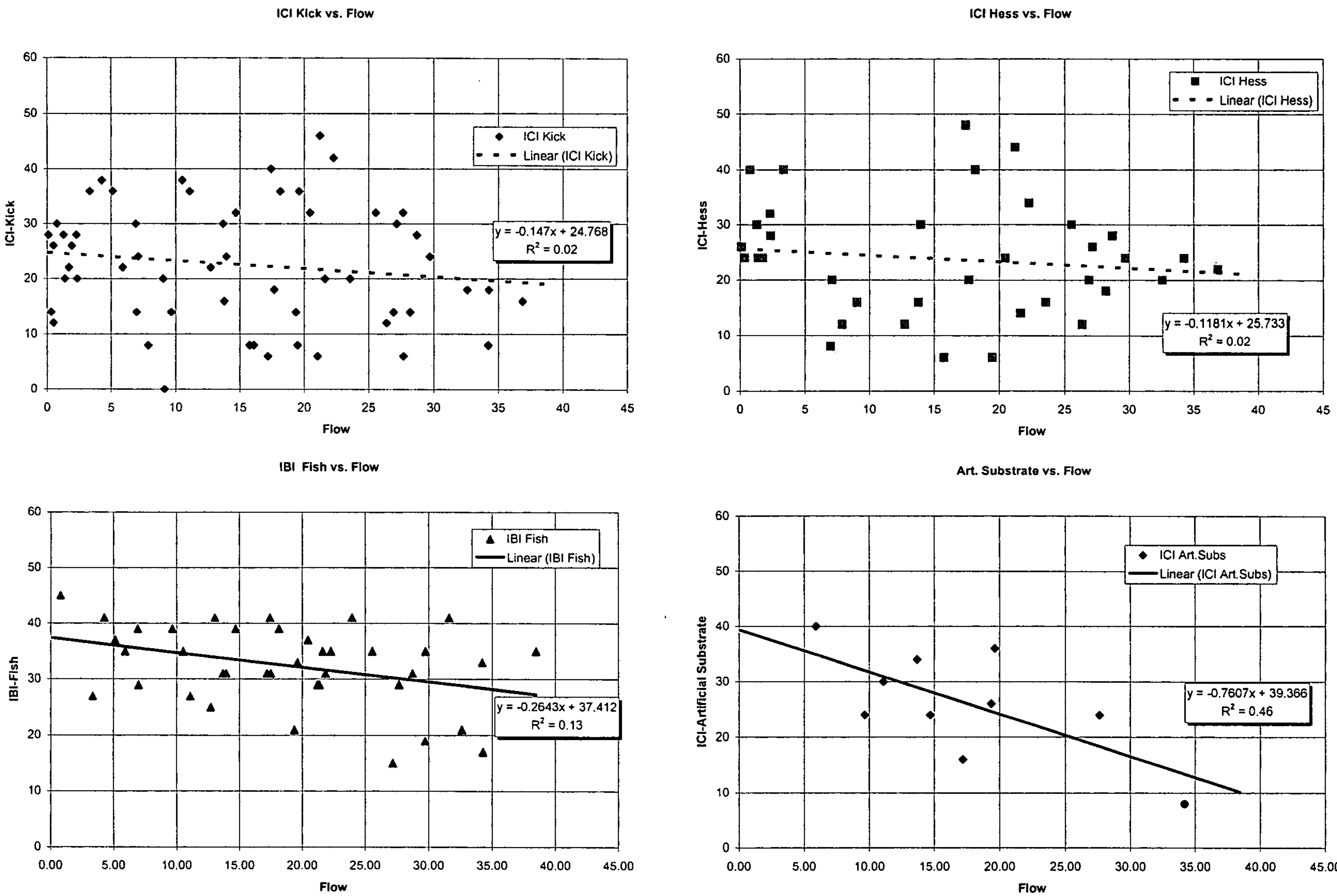
Fish IBI Scores vs. TSS



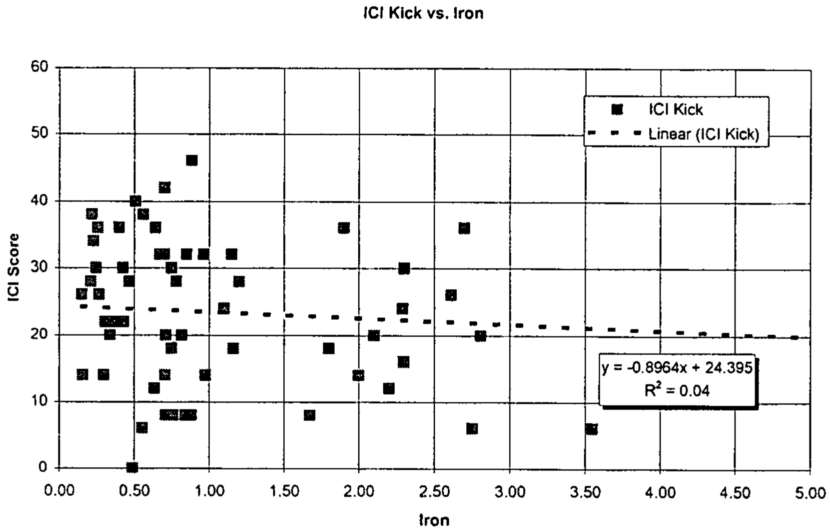
Artificial Substrate ICI Scores vs. TSS

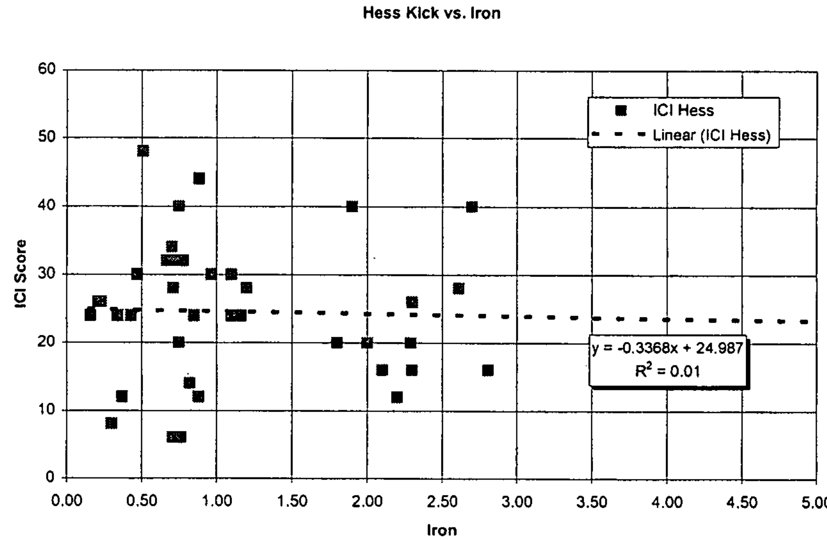


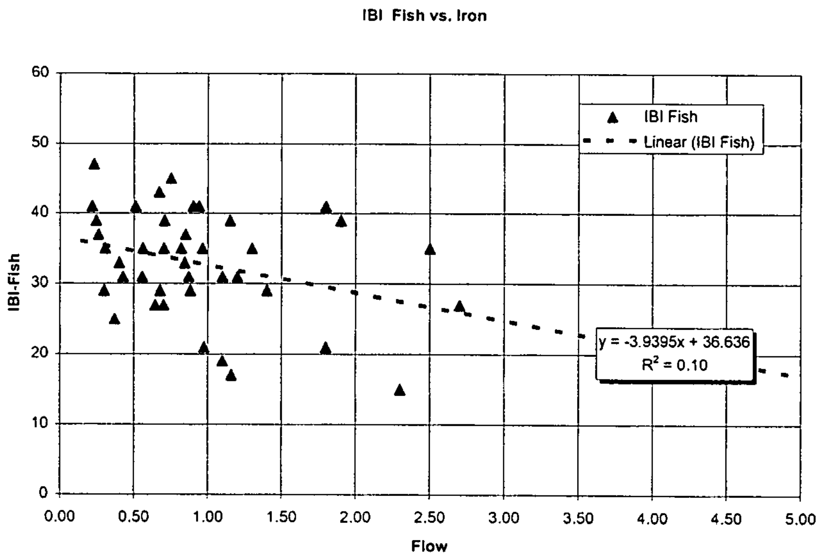
Figures 6a-6d
ICI/IBI Scores vs. Flow



Figures 7a-7d
ICI IBI Scores vs. Iron







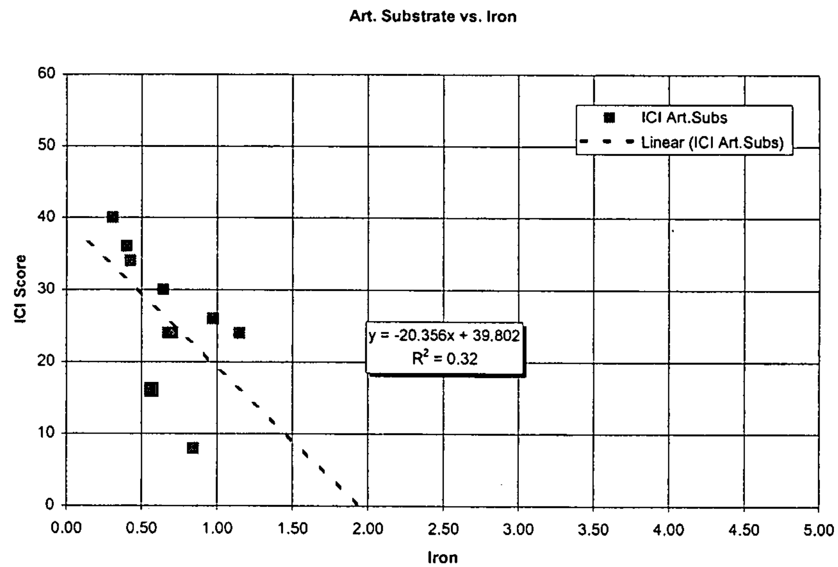
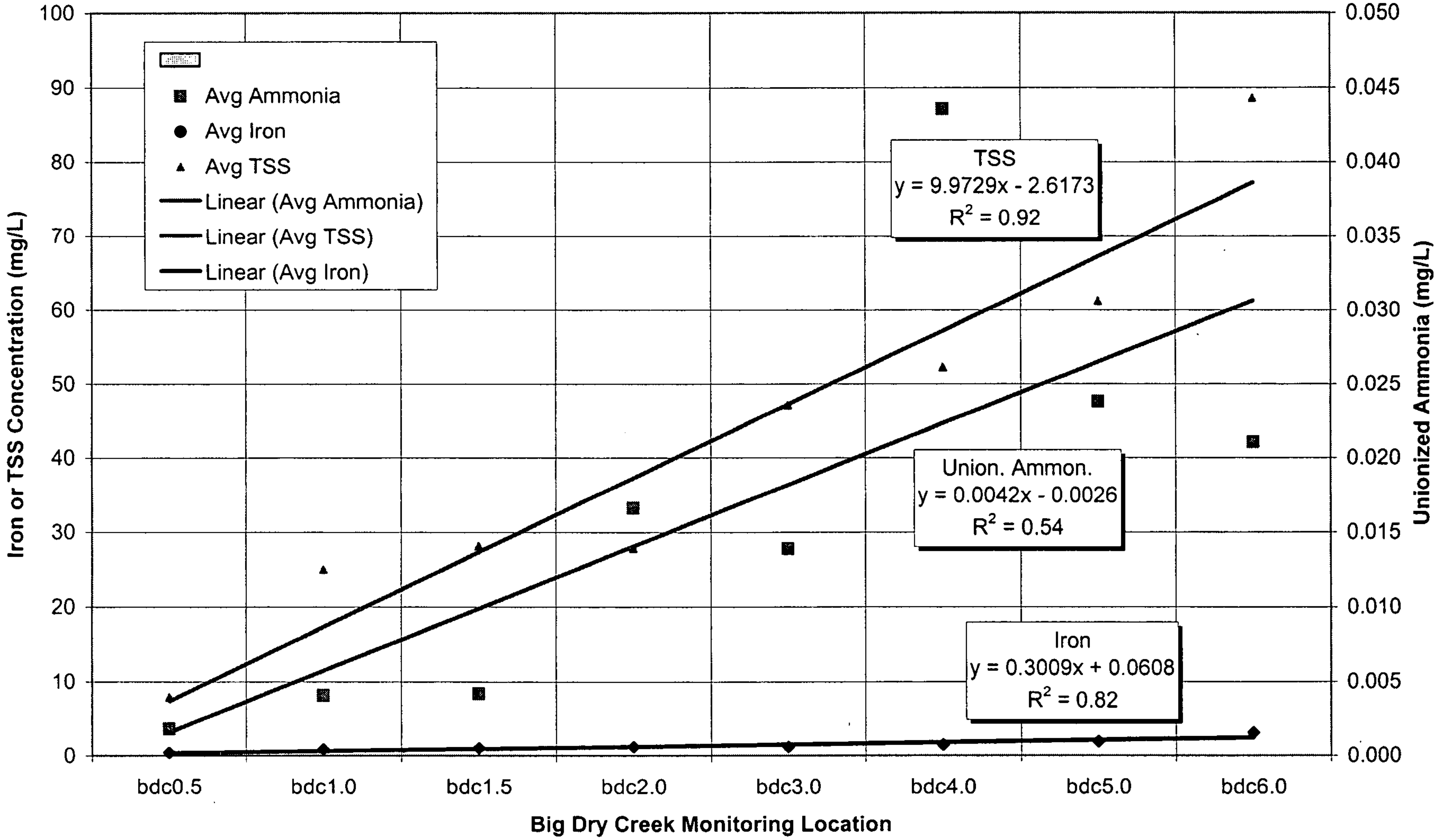


Figure 8
Water Quality Parameters vs. Location



Attachment 1
Big Dry Creek Data
1997-2001

Year	Date	Location	Stream Mile Relative to Standley Lake	Union. Ammonia	Flow	Iron	Se, Diss	TSS	Habitat	Adjusted Habitat	ICI Kick	ICI Hess	ICI Art.Subs	IBI Fish
1997	Spring 1997	bdc0.5	1.5	0.003		0.23			67	99	34	26		47
1997	Spring 1997	bdc1.0	4.3	0.017		0.67			68	101	32	32		43
1997	Spring 1997	bdc1.5	5.8	0.004		0.70			68	101	32	32		27
1997	Spring 1997	bdc2.0	7.7	0.027	6.98	0.30			47	70	14	8		29
1997	Spring 1997	bdc3.0	8.7	0.032	12.72	0.37			38	56	22	12		25
1997	Spring 1997	bdc5.0	16.9	0.018	17.50	0.87			29	43				31
1997	Spring 1997	bdc6.0	22.7		21.63	0.82			42	62	20	14		35
1997	Fall 1997	bdc0.5	1.5	0.005	0.78	0.75		8			30	40		45
1997	Fall 1997	bdc1.0	4.3	0.006	18.15	1.90		56			36	40		39
1997	Fall 1997	bdc1.5	5.8	0.005	3.34	2.70		42			36	40		27
1997	Fall 1997	bdc2.0	7.7	0.007	27.16	2.30		44			30	26		15
1997	Fall 1997	bdc3.0	8.7	0.004	28.71	1.20		40			28	28		31
1997	Fall 1997	bdc5.0	16.9	0.010	13.95	1.10		48			24	30		31
1997	Fall 1997	bdc6.0	22.7	0.007	32.58	1.80		62			18	20		21
1998	Spring 1998	bdc0.5	1.5	0.002	2.35	0.71		8			20	28		
1998	Spring 1998	bdc1.0	4.3	0.005	7.10	2.29		25			24	20		
1998	Spring 1998	bdc1.5	5.8	0.007		2.61		28			26	28		
1998	Spring 1998	bdc2.0	7.7	0.088	13.77	2.30		26			16	16		
1998	Spring 1998	bdc3.0	8.7	0.031	23.56	2.81		57			20	16		
1998	Spring 1998	bdc5.0	16.9	0.094	28.19	9.71		137			14	18		
1998	Spring 1998	bdc6.0	22.7	0.102	36.88	16.43		207			16	22		
1998	Fall 1998	bdc0.5	1.5	0.002	17.43	0.51		11			40	48		41
1998	Fall 1998	bdc1.0	4.3	0.003	22.28	0.70		31			42	34		35
1998	Fall 1998	bdc1.5	5.8	0.002	21.21	0.88		39			46	44		29
1998	Fall 1998	bdc2.0	7.7	0.003	29.71	1.10		42			24	24		19
1998	Fall 1998	bdc3.0	8.7	0.002	25.55	0.96		42			32	30		35
1998	Fall 1998	bdc5.0	16.9	0.007	20.46	0.85		60			32	24		37
1998	Fall 1998	bdc6.0	22.7	0.005	34.26	1.16		67			18	24		17
1999	Spring 1999	bdc0.5	1.5	0.001	0.11	0.21		11			28	26		
1999	Spring 1999	bdc1.0	4.3	0.002	1.29	0.47		15			28	30		
1999	Spring 1999	bdc1.5	5.8	0.003	2.30	0.78		28			28	32		
1999	Spring 1999	bdc2.0	7.7	0.016	9.02	2.10		21			20	16		
1999	Spring 1999	bdc3.0	8.7	0.020	20.56	0.37		21						
1999	Spring 1999	bdc5.0	16.9	0.026	17.67	0.75		41			18	20		
1999	Spring 1999	bdc6.0	22.7	0.028	26.91	2.00		71			14	20		
1999	Fall 1999	bdc0.5	1.5	0.001	13.04	0.94	0.002	12						41
1999	Fall 1999	bdc1.0	4.3	0.001	21.86	1.10	0.002	36						31
1999	Fall 1999	bdc1.5	5.8	0.001	21.36	1.40	0.002	46						29
1999	Fall 1999	bdc2.0	7.7	0.004	29.73	1.30	0.002	39						35
1999	Fall 1999	bdc3.0	8.7	0.007	31.59	0.90	0.006	36						41
1999	Fall 1999	bdc5.0	16.9	0.003	23.94	1.80	0.010	63						41
1999	Fall 1999	bdc6.0	22.7	0.003	38.46	2.50	0.002	94						35
2000	Spring 2000	bdc0.5	1.5	0.001	0.35	0.16	0.002	5			14	24		
2000	Spring 2000	bdc1.0	4.3	0.001	1.40	0.34	0.006	12			20	24		
2000	Spring 2000	bdc1.5	5.8	0.003	1.73	0.43	0.005	17			22	24		
2000	Spring 2000	bdc1.5C	6.2											
2000	Spring 2000	bdc2.0	7.7	0.003	7.89	0.88	0.002	16			8	12		
2000	Spring 2000	bdc3.0	8.7	0.002	19.48	0.76	0.002	27			8	6		
2000	Spring 2000	bdc5.0	16.9	0.002	15.75	0.71	0.002	20			8	6		
2000	Spring 2000	bdc6.0	22.7	0.002	26.36	2.20	0.004	35			12	12		
2000	Fall 2000	bdc0.5	1.5	0.000	4.27	0.22	0.006	3	131	131	38			41
2000	Fall 2000	bdc1.0	4.3	0.003	5.12	0.26	0.010	5	127	127	36			37
2000	Fall 2000	bdc1.5	5.8	0.014	5.91	0.31	0.005	10	140	140	22		40	35
2000	Fall 2000	bdc1.5C	6.2						135	135				35
2000	Fall 2000	bdc2.0	7.7	0.003	13.69	0.43	0.005	9	123	123	30		34	31
2000	Fall 2000	bdc3.0	8.7	0.016	19.61	0.40	0.002	14	96	96	36		36	33
2000	Fall 2000	bdc5.0	16.9	0.016	9.66	0.71	0.004	25	86	86	14		24	39
2000	Fall 2000	bdc6.0	22.7	0.021	17.19	0.56	0.002	27	84	84	6		16	31
2001	Spring 2001	bdc0.5	1.5	0.001	0.50	0.15	0.003	4			26			
2001	Spring 2001	bdc1.0	4.3	0.001	0.50	0.64	0.003	24			12			
2001	Spring 2001	bdc1.5	5.8	0.001	1.94	0.27	0.003	11			26			
2001	Spring 2001	bdc1.5C	6.2											
2001	Spring 2001	bdc2.0	7.7	0.007	9.15	0.49	0.002	16			0			
2001	Spring 2001	bdc3.0	8.7	0.013	21.04	3.55	0.002	134			6			
2001	Spring 2001	bdc5.0	16.9	0.011	16.09	1.67	0.002	94			8			
2001	Spring 2001	bdc6.0	22.7	0.009	27.67	2.75	0.002	159			6			
2001	Fall 2001	bdc0.5	1.5	0.002	6.92	0.25	0.001	9	128	128	30			39
2001	Fall 2001	bdc1.0	4.3	0.002	10.52	0.56	0.001	22	125	125	38			35
2001	Fall 2001	bdc1.5	5.8	0.001	11.10	0.64	0.002	32	138	138	36		30	27
2001	Fall 2001	bdc1.5C	6.2						135	135				29
2001	Fall 2001	bdc2.0	7.7	0.007	19.37	0.97	0.001	37	115	115	14		26	21
2001	Fall 2001	bdc3.0	8.7	0.012	27.65	0.68	0.001	53	87	87	32		24	29
2001	Fall 2001	bdc5.0	16.9	0.051	14.70	1.15	0.001	62	82	82	32		24	39
2001	Fall 2001	bdc6.0	22.7	0.012	34.20	0.84	0.001	76	81	81	8		8	33