When normalizing this data, the results for TKN levels are more pronounced. Although the high energy basin received less feed, its effluents contained significantly more TKN. No significant changes were seen in the normalized TAN data.

Figures were developed to explore the possibility that effluent suspended matter and nitrogen levels were related. As shown in Figures 11 and 12, there were no apparent relationships between TSS and nitrogen in the forms of TKN and TAN.

When comparing TKN and TAN values for each sampling event, a positive correlation was identified. As shown in Figure 13, a trend of increasing TAN values in response to increasing TKN levels was observed.

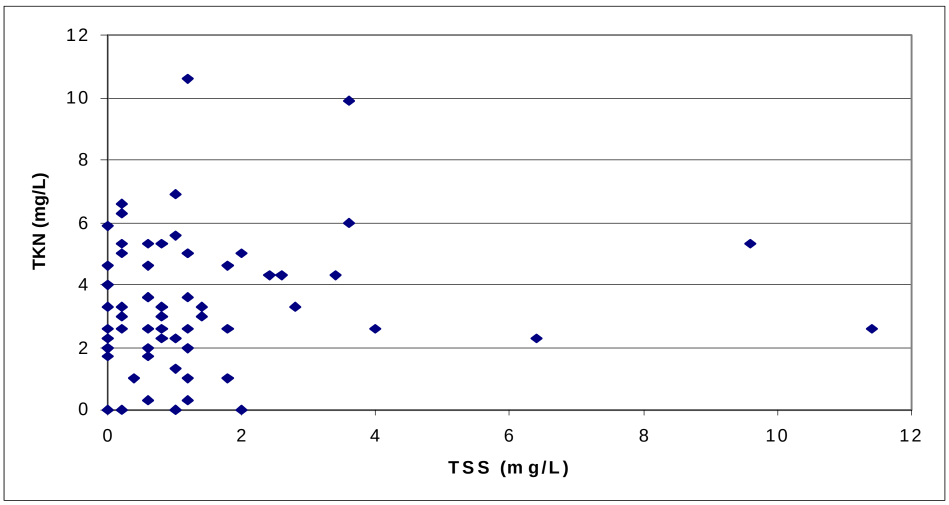

Figure 11. TSS versus TKN at Farm A.

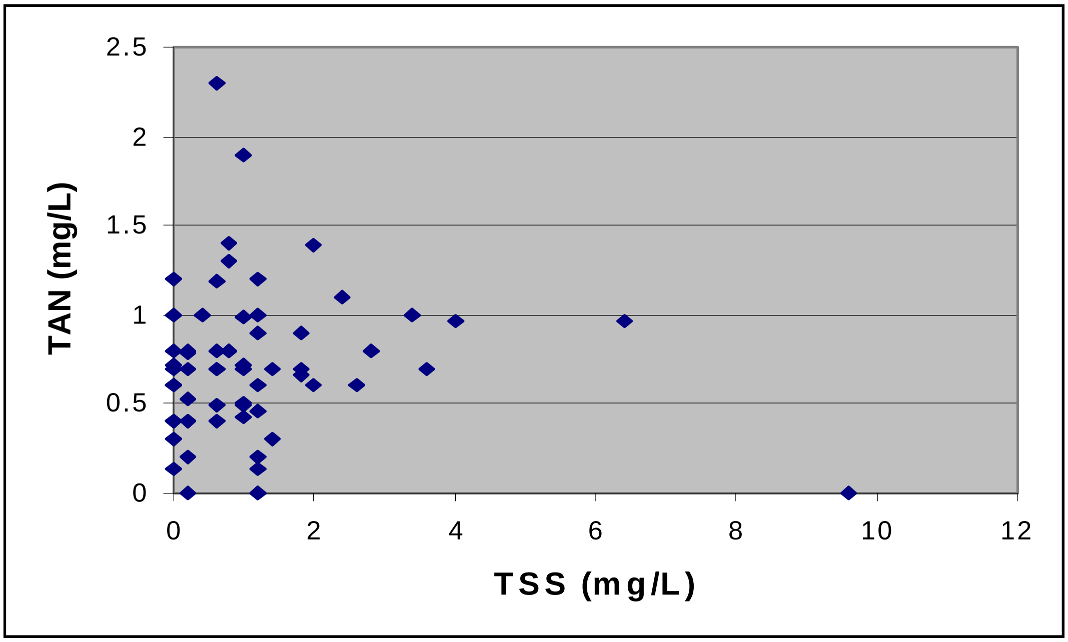

Figure 12. TSS versus TAN at Farm A.

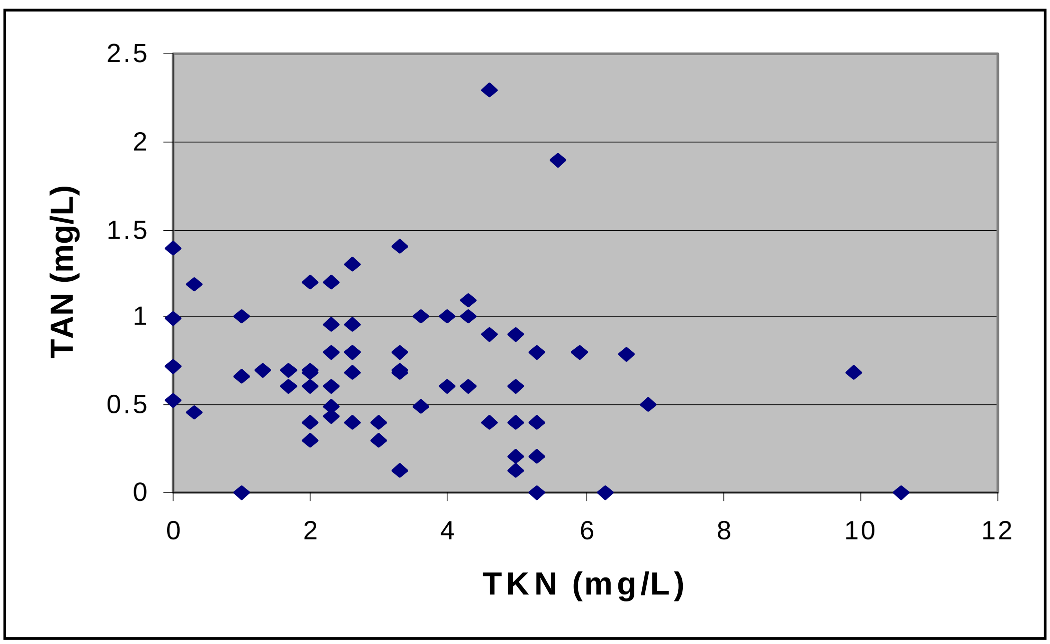

Figure 13. TKN versus TAN at Farm A.

Chapter 4. Methods and materials – Farm B

4.1 Site Description/Experimental Setup

The site characteristics for Farm B are listed in Table 2. As previousl mentioned, the only differences between the two facilities are the modern constructi (concrete basins and drained sediment traps) and the increased attention given to basin cleaning at Farm B. These two aspects of Farm B made this site ideal for replication o the study conducted at Farm A. At the site, four average size basins were set aside for this experiment. Each basin had a length of 29.5 meters, a width of 2.4 meters, and an average depth of 0.5 meters. The four basins were set up as two separate basin trains (i.e. two basins per train in series). One train received the standard grower feed from the previous study and the other received the high energy feed.

Each basin was cleaned on a weekly basis. To start the cleaning, a drain would be opened at the end of the basin, which diverted the flow to receiving waters. This prevented solids from entering downstream raceways. Two employees would then sweep the basin and slowly work their way to the end.

Flow rates for these basins were measured by using weir readings, as at Farm A. These weir readings proved that flow through this experimental train was equal across al four basins. For each sampling event, the flow was within the range of 344 – 400 gallons per minute (gpm). A simple schematic of the experimental setup is shown in Figure 14.

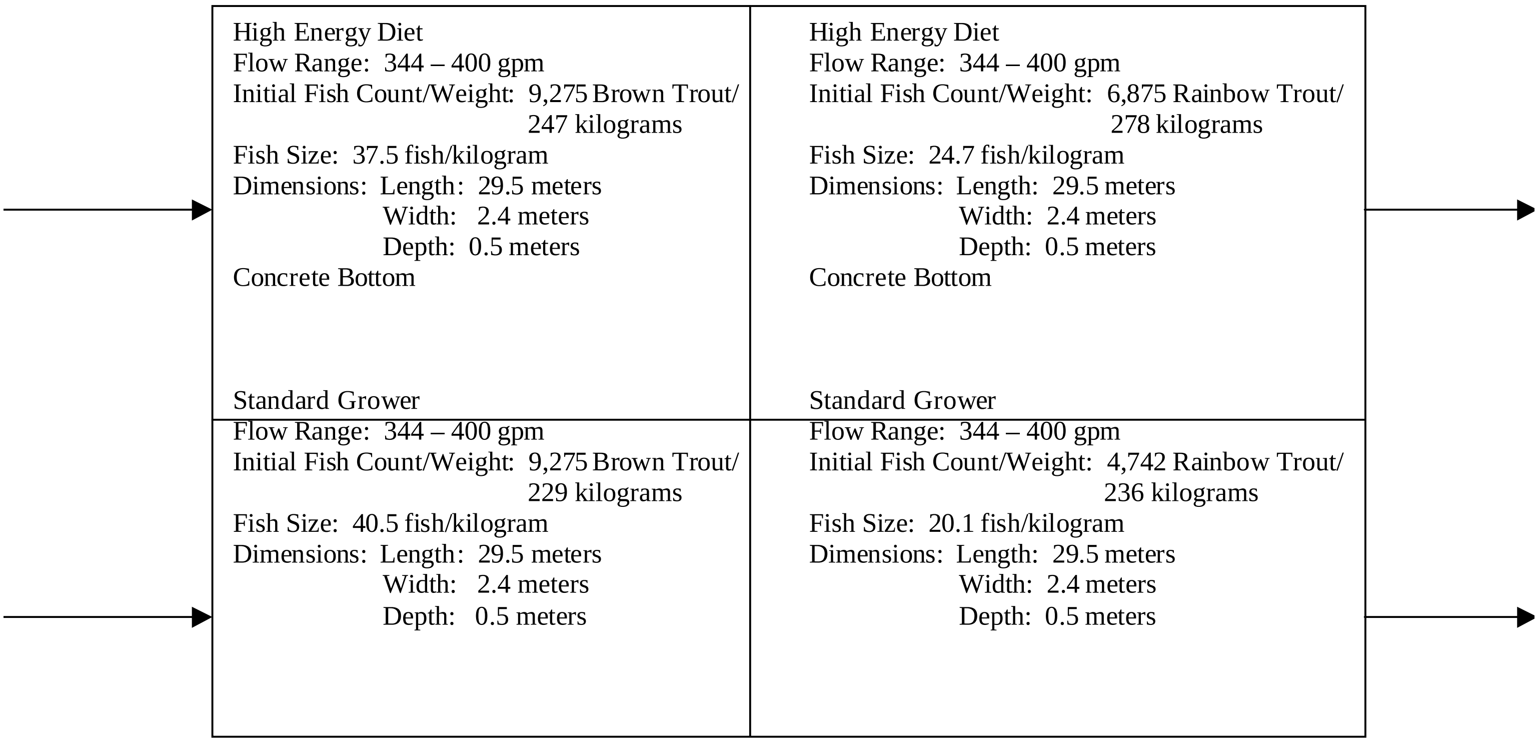

Figure 14. Schematic of experimental basins at Farm B.

The nutritional content of these different feeds is listed in Table 3. As with Farm A, daily feeding rates for these basins was determined by referring to a suggested feeding guide supplied by Ziegler Brothers, Inc. The fish were fed one-third their daily allowance three times a day. This experimental feeding protocol was initiated on June 24, 1998, and sampling began July 2, 1998.

4.2 Sampling and Monitoring

TSS, TKN, and TAN levels were monitored at Farm B. The main purpose of this study was to study the solids content of these raceways, while eliminating an interference from earthen bottoms that may have been present at Farm A. Initial water quality samples indicated that influent water quality to the experimental basins had a lower solids content than that of Farm A. The weekly cleaning of the basins also helped to limit solids accumulation at the bottom of the raceways. These two major factors wer essential in achieving the goals of this study at Farm B. Samples were collected on a bi-weekly basis.

4.3 Fish Inventories/Feed Records

The facility staff kept records for fish densities and feeding rates. Inventories were taken on a monthly basis. Based on these data, feeding rates were adjusted in order to account for fish growth. Because the daily feeding rates for the two experimenta trains were similar over the span of the study, these data were not normalized as before, on the basis of feed rate.

Chapter 5. Results – Farm B

5.1 TSS Discharges

From July 2, 1998 to July 30, 1998, 12 different samples were taken of both the influent and effluent of each of the four basins. By comparing the discharges of two basins receiving the standard grower feed to those basins receiving the high energy feed, a significant difference was seen. In each of the 24 comparisons, discharges of TSS fro the standard grower basin exceeded those from the high energy basins. Figure 15 shows each basin's discharge for each sampling event. The average for the standard grower basin discharges was 3.7 $\pm$ 4.0 mg/L TSS, while the high energy basin effluents averaged 0.3 $\pm$ 0.5 mg/L TSS. Figure 16 displays these results. These results showed a significan difference between basins receiving standard grower and those receiving high energ feed at the 95% confidence level. An analysis of the two influents showed no significan differences between the two at the 95% confidence level, and each contained relatively low TSS levels, rarely approaching 1.0 mg/L.

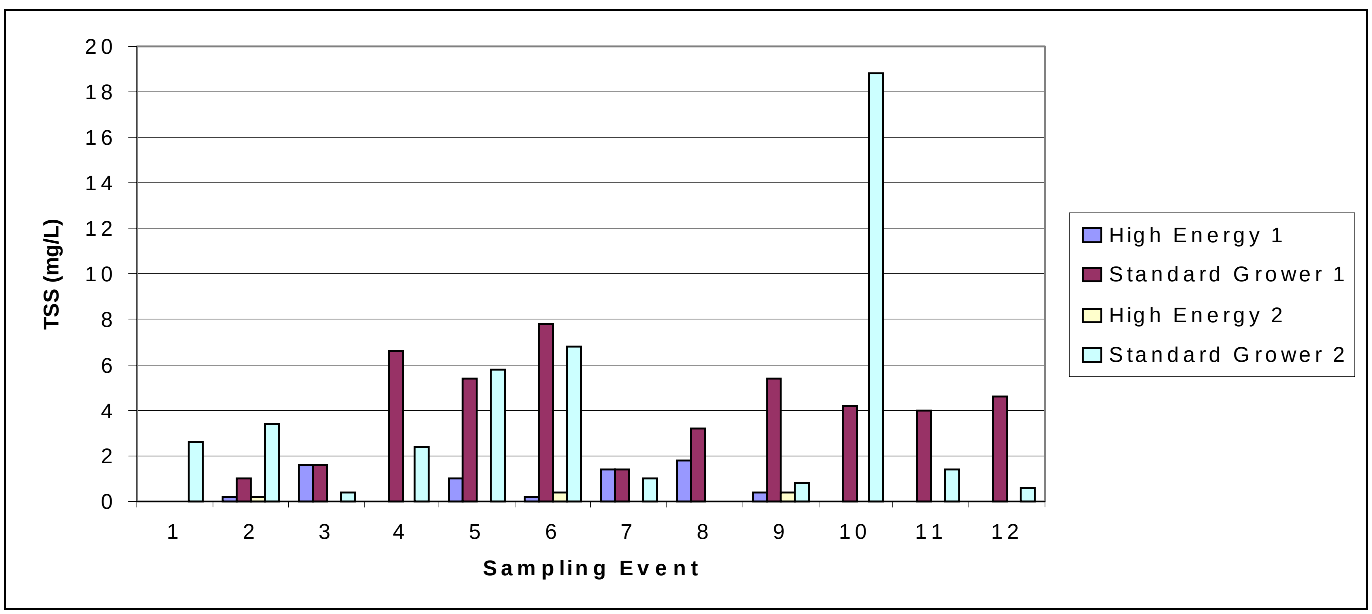

Figure 15. TSS discharges for two standard grower basins and two high energy basins at Farm B.

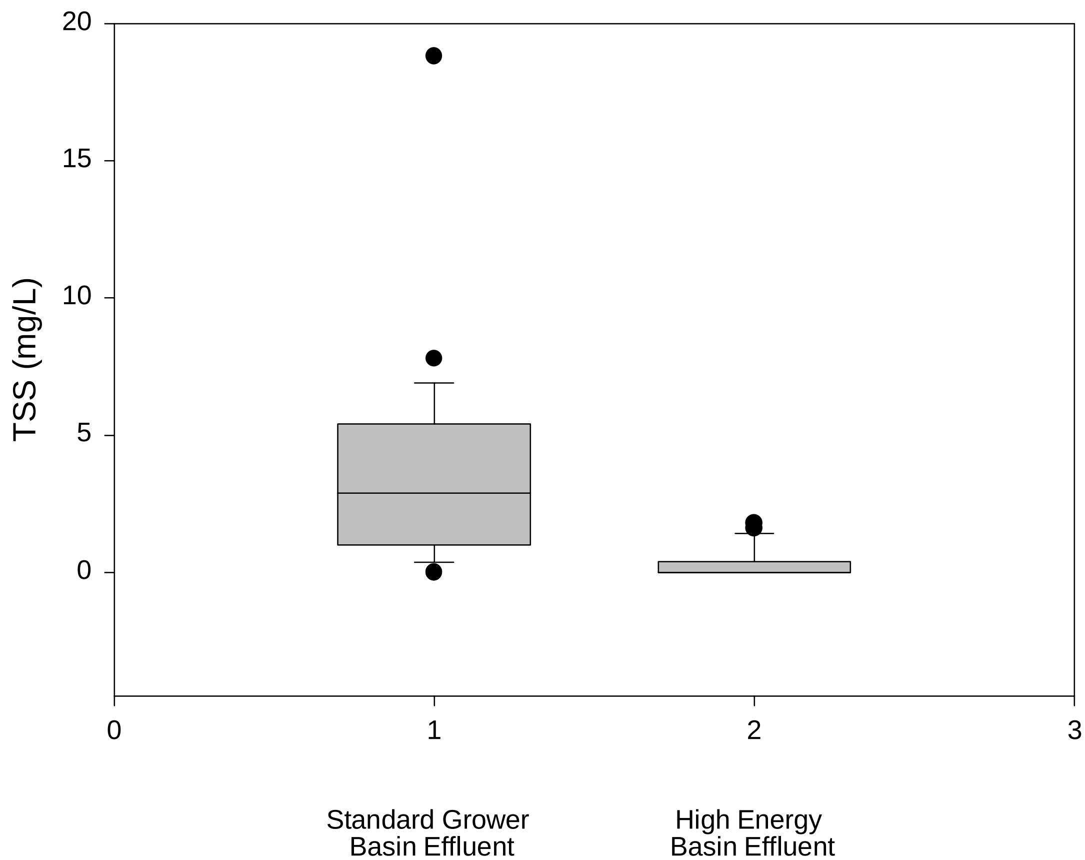

Figure 16. Box plot showing the statistical values for the standard grower feed basin effluents and the high energy feed basin effluents.

Two, 24-hour composite samples were taken at the end of each treatment train to determine the average TSS levels leaving the basins over an entire day. The average for the standard grower basin composites was 4.3 mg/L TSS, while the high energy basin composites averaged 0.4 mg/L TSS.

5.2 Basin Cleaning Experiment

On August 28, 1998, cleaning of the experimental basins was studied. The focus of this experiment was directed towards identifying TSS peaks in the effluents, and examining how long these elevated solids levels lasted during these cleanings. Fro this, a general idea of how long flow would have to be diverted during cleanings could be established. It must be noted, however, that these results are site specific and this stud would have to be replicated at individual facilities. These differences are related to the number of personnel involved, the amount of time for each cleaning, the amount of solids accumulated in each basin, and flow rate.

Figures 17 and 18 show the high TSS spikes that occur during routine cleaning operations. When cleaning the basin receiving the standard grower, it took approximately twice as long for solids levels to subside to normal background levels. Approximately 25 minutes were required for TSS concentrations to return to normal in the standard grower basin, whereas only 13 minutes passed before solids levels sufficiently subsided in the high energy basin. The difference in times was due to the fac that higher levels of solids accumulated in the standard grower basin than the basin receiving the high energy feed. At Farm B, a previous study revealed that basins receiving the standard grower feed took a significantly greater amount of time to clean than those receiving the high energy feed (Swartz, 1998.)

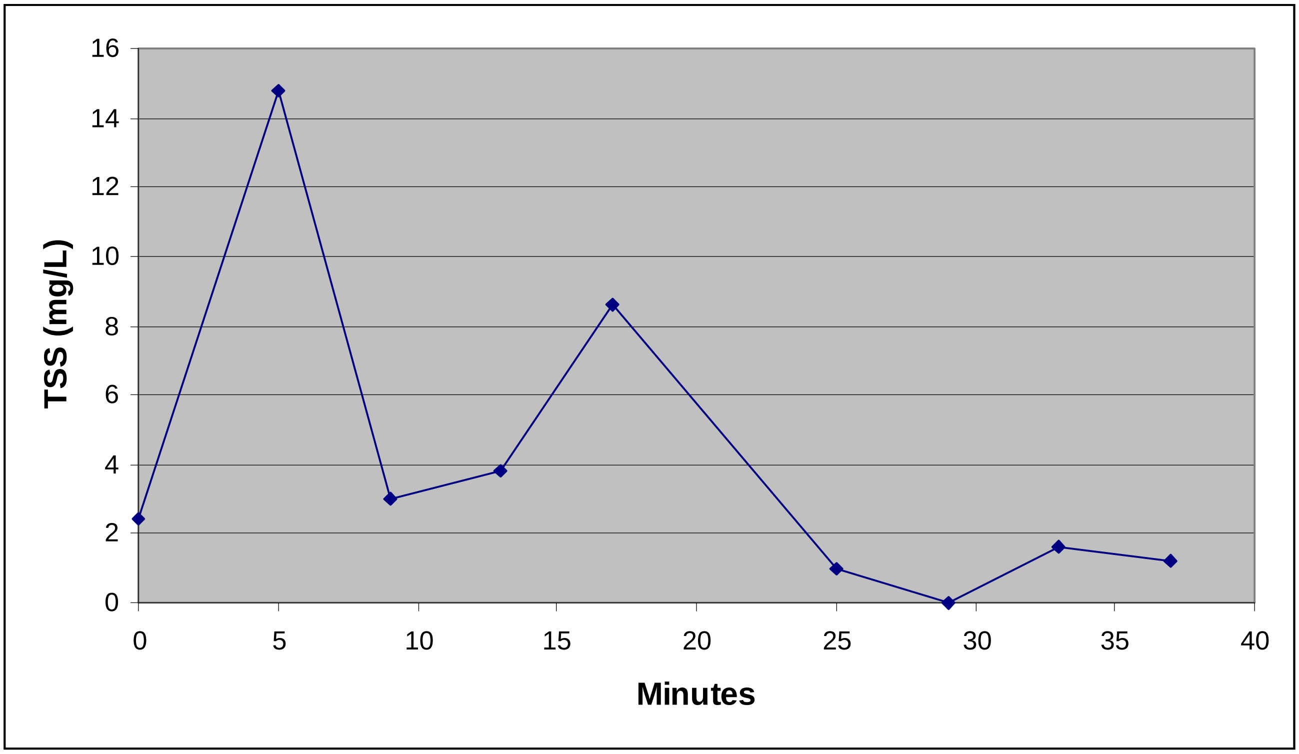

Figure 17. TSS levels during the cleaning of a standard grower feed basin at Farm B.

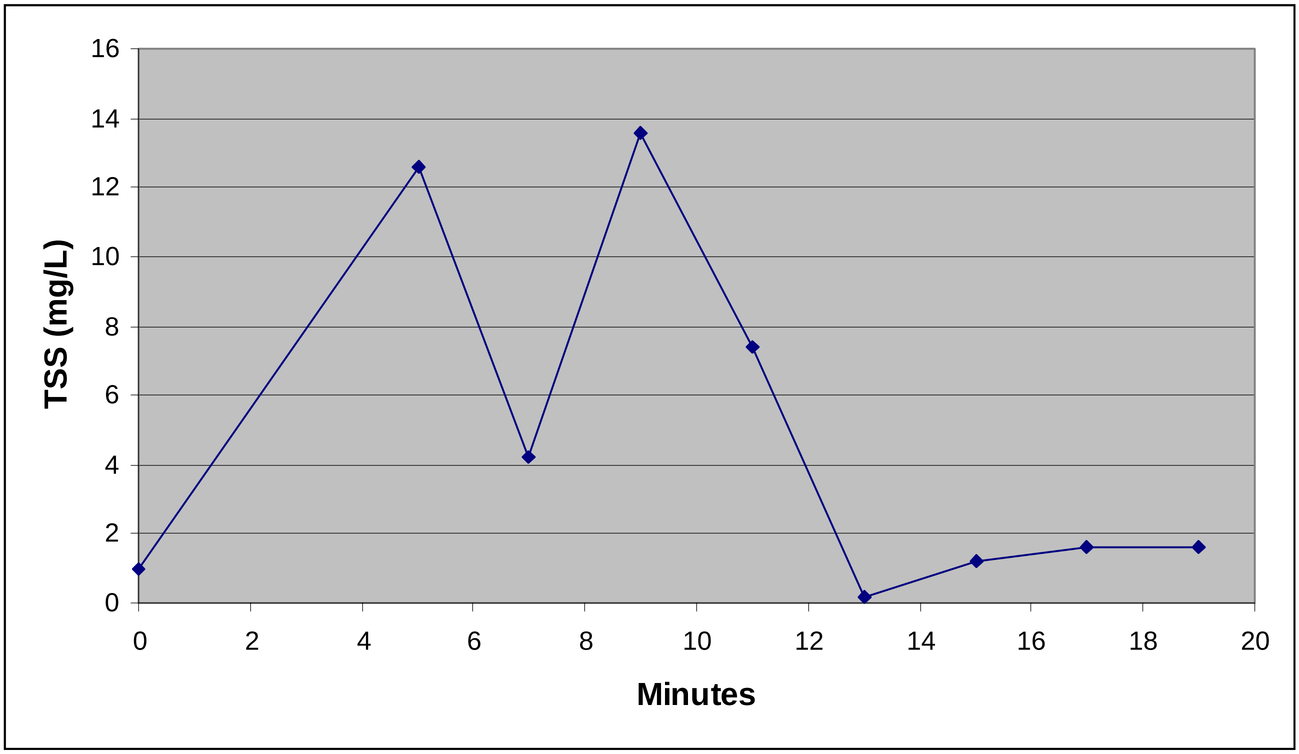

Figure 18. TSS levels during the cleaning of a high energy basin at Farm B.

5.3 Nitrogen

In establishing a relationship between nitrogen (TKN, TAN) and TSS concentrations, results similar to that of Farm A were observed. Although there was a positive correlation between TKN and TAN, both of these parameters were independen of TSS concentration

Chapter 6. Discussion

At both farms, TSS discharges from basins receiving the high energy feed were significantly lower than those from basins receiving the standard grower for the majority of samples taken. Because there was no considerable difference in TSS between the influents of these basins, these results at both farms point strongly to the use of a high energy feed as a means of reducing solids discharges.

At Farm A, the one basin receiving the standard grower experienced a drastic reduction in TSS discharges after receiving the high energy feed over a two week period. This reduction in TSS discharges coupled with the switch in diets further supports the theory that the use of a high energy feed may reduce TSS discharges from trout raising facilities.

In order to properly identify the mechanism by which the use of a high energy feed can reduce solids discharges, all TSS data at Farm A were normalized per the amount of feed given to each basin. If no significant difference was observed between the normalized effluent TSS levels, the reduction in solids discharges would be primarily attributed to the lesser amount of feed given to the high energy basin. However, since the effluent TSS levels from the two basins still showed a difference after normalization, the increased digestibility of the high energy feed must be held responsible for a portion of the solids reduction observed.

By taking the monthly averages of this normalized data, the trend of decreasing TSS per kilogram of feed for the standard grower basin at Farm A was apparent. As the summer months neared, the normalized values for the standard grower approached those of the basin receiving the high energy feed. In analyzing this data, it may be concluded that the standard grower's digestibility is similar to that of the high energy feed at higher feeding rates, increased water temperature (average summer temperature: 15 degrees Celsius, average winter temperature: 8 degrees Celsius), and larger fish sizes.

At Farm A, an estimate of solids production within each basin by waste feed and fecal matter was made by subtracting influent TSS from effluent TSS. The differences in TSS values within each basin revealed that a higher amount of solids were present in the standard grower basin. Although there is a possibility that some of the solids discharges can be attributed to resuspension of particles from general facility activities (i.e., feeding, harvesting, fish movement, basin maintenance), precautions were taken not to excite fish before sampling or to sample during these farm activities. The negative values observed in this analysis can be attributed to the settling of solids within the basin. The differences between the two basins at Farm A further suggest that the use of a high energy feed can help in reducing TSS discharges from trout farms.

The size distribution of solids discharged from each basin at Farm A was also studied through the use of a particle size analyzer. In two separate trials, it was found that both effluents had a high proportion of solids in the 5 – 30 micron range.

At both farms, no strong positive correlation could be made between solids concentrations and nitrogen (i.e., TKN and TAN). From this, one can conclude that a solids separation process effectively removing TSS would not accomplish significan reductions in nitrogen.

Although the two experimental trains at Farm B were similar in construction, fish number, and average fish size, it took nearly twice as long for solids discharges to return to normal levels. For facilities that plan to divert flows to settling basins during cleanings, the use of a high energy feed could lead to a significant reduction in settling basin sizing. The aforementioned cleaning event at Farm B serves as a good example. While a basin receiving a standard grower feed would need to divert 10,000 gallons during typical conditions, only 5,200 gallons would be redirected while cleaning a high energy basin. This difference could prove valuable to farms required to implemen BMPs where space or economic constraints exist. It must be noted that these figures represen an average cleaning event for a specific farm, and studies must be conducted on a site specific basis in order to apply this concept appropriately.

These results s rongly support the use of a high energy feed as a means for improving the effluents of trout farms. Through the implementation of this practice, trou farms can significantly reduce the amount of solids discharged to receiving waters. Although this simple practice does not fully address all the problems facing aquacultural operations today, its implementation should be regarded as a crucial step in trout farms meeting regulatory expectations.

Chapter 7. Conclusion

Thus, the conclusions derived from this study are as follows:

1. Although the discharges from the two facilities participating in this study can be characterized as a high flow with a low solids content, they are susceptible to spikes in TSS and TKN, especially during times of high farm activity (i.e., feeding, harvesting, cleaning).

2. At each facility, the use of a high energy feed was responsible for a significan reduction in TSS discharges while significantly increasing the amount of TKN found in the effluents.

3. At each farm, no positive correlation was found between effluent suspended matter (TSS) and nitrogen (in the forms of TKN and TAN).

References

American Public Health Association (APHA), American Water Federation, 1995. *Standard Methods For the Examination of Water and Wastewater,* 19th edition. APHA, Washington D.C.

Axler, Richard, Larsen, Christen, Tikkanen, Craig, McDonald, Michael, Yokom, Shane, and Aas, Peter, " Water quality issues associated with aquaculture: A case study in mine pit lakes." *Water Environment Research*, 68(6), 995-1011 (1996).

Axler, R.P., Tikkanen, C., Henneck, J., Schuldt, J., and McDonald, M.E., "Characteristics of Effluent and Sludge from Two Commercial Rainbow Trout Farms in Minnesota.", *The Progressive Fish-Culturalist*, 56, 25-32 (1994).

Bergheim, A. and Cripps, S.J., "Effluent Management: Overview of the European Experience." *Proceedings of the Second International Conference on Recirculating Aquaculture."* July 1998, Roanoke, Virginia: 233-245.

Cripps, Simon J., "Serial particle size fractionation and characterization of an aquacultural effluent." *Aquaculture*, 133, 323-339 (1995).

Heinen, J.M., Hankins, J.A., and Adler, P.R. "Water quality and waste production in a Recirculating trout-culture system." *Aquaculture Research*, (27) 699-710 (1996).

Idaho Department of Environmental Quality (IDEQ) (1991). *Idaho Waste management Guidelines for Aquaculture Operations.* Idaho Department of Health and Welfare, Division of Environmental Quality, Twin falls, ID.

Loch, David D., West, Jerry L., Perlmutter, Daniel G., "The effect of trout farm effluen on the taxa richness of benthic macroinvertebrates." *Aquaculture*, (147), 37-55 (1996).

Minnesota Department of Agriculture (1990), "Aquaculture: The Wave of the Future." Aquaculture News (Minnesota Department of Agriculture, St. Paul, MN).

Schwartz, M. F. and Boyd, C.E., "Effluent quality during harvest of channel catfish from watershed ponds." *The Progressive Fish-Culturalist*, 56, 25-32 (1994).

Shireman, Jerome V. and Cichra, Charles E., "Evaluation of aquaculture effluents." *Aquaculture,* (123), 55-68 (1994).

Summerfelt, S.T., "An Integrated Approach to Aquaculture Waste Management in Flowing Water Systems." *Proceedings of the Second International Conference on Recirculating Aquaculture*, July 1998, Roanoke, Virginia: 253-263.

Swartz, Tim, Personal communication. (1998)

Yoo, K.H., Masser M.P., and Hawcroft, B.A., "An In-pond Raceway System Incorporating Removal of Fish Wastes." *Aquacultural Engineering*, 14 (1995), 175-187.

Zeigler Brothers, Incorporated. Technical Information. Personal communication. (1998)

APPENDIX A – Farm A Data