Aquatech Systems

10 September 1990

Mr. Phil Bakken
Iron Range Resources and Rehabilitation Board
Highway 53 South
P.O. Box 441
Eveleth, MN 55734

Dear Phil:

I've enclosed the updated memorandum. The memorandum has a new addendum which more precisely describes the metabolite loadings of the mine pit. I've also enclosed additional copies of the technical drawings, should you need them.

Thanks for your patience and I will be in touch with you soon to make sure that we have satisfied all your needs.

Yours sincerely,

Charles Magowan

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Addendum

Metabolite discharge loading from an Aquatech Systems land-based fish farm

Introduction

In the land-based fish farm the fishes' solid and dissolved excretory products and uneaten feed are present in the water as it leaves the tanks.

The following tables disclose the potential nutrient loading of flow through waters. Results are based on full scale studies conducted at Aquatech Systems research station in Averøy, Norway.

Biomass and Loading

The farm's biomass changes throughout the year. Metabolite production will also vary and present an annual pattern. Because the use of oxygenation, strict water distribution, and current control reduces the total water flow requirement, it is appropriate to present nutrient loading in micrograms per liter, kg. per month, and total per annum.

The metabolite loadings for the Minnesota project are based on a farm with annual production of 520 metric tons which has an average biomass of 345.756 metric tons. Calculations are based on environmental data from the Hibbing area. These figures are proprietary and should only be distributed on a need to know basis.

Annual Farm Biomass/ Flow through Variation

Month	Farm Biomass	Flow through (liters/min)	Flow through (US gpm)
JAN	432000	108000	28530
FEB	418000	104500	27610
MAR	372000	93000	24570
APR	294000	73500	19420
MAY	260000	65000	17170
JUN	256000	64000	16910
JUL	256000	64000	16910
AUG	260000	65000	17170
SEP	334000	83500	22060
OCT	410000	102500	27080
NOV	427000	106750	28200
DEC	430000	107500	28400
MEAN:	345756	86440	28400

Metabolite Loadings of Flow through Water
(in micrograms per liter)

Phosphate (PO_4-P)	Nitrate+Nitrite (NO_3-N+NO_2-N)	Ammonia (NH_4-N)	Chemical O_2 Demand (COD)
73	124	116	640

Monthly Metabolite Loadings
(in kg. per month)

Month	Phosphate	Nitrate+Nitrite		Ammonia	Chem. O_2 Demand
JAN	340	577	543	2986	
FEB	330	558	525	2889	
MAR	293	497	468	2571	
APR	231	392	370	2032	
MAY	204	347	327	1797	
JUN	201	342	322	1769	
JUL	201	342	322	1769	
AUG	204	347	327	1797	
SEP	263	446	420	2309	
OCT	322	547	515	2834	
NOV	336	570	537	2951	
DEC	338	574	541	2972	

Mean Monthly and Annual Metabolite Loadings

	Phosphate (PO_4-P)	Nitrate+Nitrite (NO_3-N+NO_2-N)	Ammonia (NH_4-N)	Chem.O_2 Demand (COD)
Mean Monthly (kg./mo.)	272	462	435	2390
Total Annual (kg. /yr.)	3263	5539	5217	28676

Variability of Predicted Metabolite Values

While the metabolite loading values have been derived from data obtained on the Aquatech Systems farm in Norway and are presented as exact values, their accuracy may be affected by one or more of the following factors:

Changes in metabolite production in fresh water (cf. seawater)

Temperature variability from predicted values leading to biomass variations.

Variations in feed constituents and quality

Stock variability with regard to assimilatory capability

Advances in water treatment technology

In order to provide flexibility for the abovementioned considerations, a range of $\pm$5% should considered for the values shown in the tables above.

The Iron World Pit in the Perspective of Metabolite Production

While the annual metabolite production from the proposed land-based fish farm may represent a significant organic input, it must be considered in relation to the water volume of the mine pit.

The 1988 bathymetric map prepared by Daryl Arola of DNR Fisheries shows the Iron World Pit to have had a total water volume of over 48,390,000 cubic meters (12,785 million US gallons) then and information suggests the volume is increasing by 2 million cubic meters per year.

The metabolite loading plan presented earlier shows that approximately 93% of the entire 1988 pit volume will pass through the land-based farm once per year and that the resultant loading of the pit, as mg. per cubic meter or micrograms per liter would be:

Phosphate (PO_4-P)	Nitrate+Nitrite (NO_3-N+NO_2-N)	Ammonia (NH_4-N)	Ammonia (COD)	Chemical O_2 Demand
67	114	108	593	

Aquatech Systems

Aquatech Systems, Inc.

Feasibility Study

Potential Successfulness of land-based, high-density fin fish rearing systems using abandoned iron mine pits as water resources

Prepared for the Iron Range Resources and Rehabilitation Board

Authors:
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INTRODUCTION

Phil Bakken of the Iron Range Resources and Rehabilitation Board and Kjell Knudsen of the Center for Economic Development, University of Minnesota at Duluth met the Aquatech Systems project team in August 1989 at the AquaNor conference in Trondheim, Norway.

Following the conference, Messrs. Bakken and Knudsen visited the Aquatech Systems A/S research station at Langøyneset, Averøy.

IRRRB and Aquatech Systems, Inc. agreed to share the expenses of a feasibility study of the potential successfulness of a land-based, high density, fin fish rearing system which would use the abandoned Iron World mine pit as a water resource. The completion date for the study is June 30, 1990.

SCOPE AND SERVICES OF THE FEASIBILITY STUDY

The feasibility study analyses:

a) parameters

b) assessment of professional services, technical support, suppliers of equipment and labor

c) evaluation of raw materials

d) legal issues

e) technical appendices including project drawings

f) economic models

The study defines an appropriate and sustainable project. Because of the political sensitivity to nutrient loading of the mine pit waters, Aquatech has emphasized analysis of its technology's ability to comply with State and federal water quality regulations.

Additionally, the study describes Aquatech Systems, Inc., its subsidiaries, and the Company's technology.

The Company proposes the creation of a joint venture named **Salminn, Inc.** to be financed by Aquatech Systems, Inc., its joint venture partner(s) and the IRRRB.

AQUATECH SYSTEMS, INC.

Aquatech Systems, Inc. is a high technology aquaculture company organized to build and operate land-based fish farms. Using proprietary technology developed at its research station in Langøyneset, Norway Aquatech achieves a variety of quality, competitive, and ecological advantages over other grow out systems for salmonids.

The Company employs forty-nine people and is an equal opportunity employer. Three out of seven Company officers represent minority groups.

Aquatech's products include land-based, high density, fin fish rearing systems, fish, and fish waste products.

Aquatech Systems, Inc. is a public Canadian company. It owns two subsidiaries: Aquatech Systems U.S.A., Inc., a Washington State corporation, and Aquatech Systems A/S a stock corporation organized under the laws of the Kingdom of Norway.

Aquatech Systems A/S was founded in 1985. The Company operates a 310 metric ton capacity ongrowing farm for salmonids, two research laboratories, and a processing plant for value added salmon products. The Norwegian company is responsible for research and development, sales of laboratory analytical services and training services.

Recent Developments

The Company has introduced the first retail organic fish products. The fish products have less saturated fat than conventionally farmed salmonids. The products are marketed under the **Nordic Light** brand.

The Company is the first aquaculture company to obtain an all risk fish stock insurance policy with no upper limit on stocking density. The Company has reared fish at densities exceeding 164 kilos per cubic meter. This is four to twelve times the stocking density achieved by competitors. Consequently, Aquatech is the low cost producer in the salmon farming industry.

The Company has established itself as a technology and quality leader in aquacultural engineering services. Recent work includes project studies in Iceland, Norway, Spain, and the United States in addition to a substantial expansion of existing capacity in Norway.

The Company has also taken a leadership position with respect to the environmental sensitivity of its rearing system.

The Aquatech Systems technology

The Company's land-based farm is an intensive, closed system. Initially, water is taken from depth by large capacity pumps. The water is led through a manifold and oxygenated on its way to each of the production tanks. After flowing through the production tanks, the water passes through a purification system and into a common discharge pipeline where the water is filtered before it is returned the the main water body (i.e. mine pit).

Large capacity pumps help maximize water quality, thus eliminating barriers to productivity. This is a key advantage over other technologies. The oxygenation system is a patented, revolutionary technology conceived by Union Carbide and refined for aquacultural and marine applications by Aquatech Systems. The system consists of a deep shaft bored into the surrounding rock which has on the inlet water side a high pressure water pump which brings the water pressure up to 3.5 bar. The depth of the shaft is 25 meter+. The depth increases the water pressure an additional 2.5 bar. Therefore, the pressure at the bottom of the shaft is 6 bar. The shaft itself has a concentric inner tube with

restrictors fitted. At the top of this central tube is a patented jet device which injects liquid oxygen towards the bottom of the shaft where it immediately dissolves into the surrounding water. The oxygenated water then rises up the outer shaft annulus to be collected at the top and introduced into the main water supply. Because the first limiting factor of stocking density is dissolved oxygen, this supersaturation technology is a critical advantage which makes high density rearing of fish possible. It also ameliorates the effects of the fishes' oxygen demands.

The high water quality permits high productivity but creates an extra husbandry demands; automated process control is vital to successful operation of the system. The Aquatech Systems computerized monitoring and control software and instrumentation are unique to aquaculture. The system analyses over 1,400 inputs per second and runs the plant safely while providing and managing data for business systems. The computer system provides continuous surveillance and security. A user friendly interface ensures convenient operations.

The biomasses achieved in the Aquatech System have forced the Company to develop special husbandry techniques. Fish are introduced to the production tanks at an average weight of sixty grams. They are reared on to market size faster and more efficiently than competing technologies because of the high quality control inherent in the system. Among the efficiencies, Aquatech's livestock have feed conversion ratios of better than .9:1; they actually eat less food than they grow on themselves. This is 40% more efficient than the average net pen farm. Because feed costs can exceed 40% of operating costs this efficiency provides a critical advantage to the Aquatech System.

Aquatech includes administration buildings; stores for feed, ice, and packaging; and waste disposal structures in its design plans.

The superior technology and husbandry give Aquatech advantages of quality, financial, and process control. The system is friendly from both the fishes' and the farmers' points of view.

The system is environmentally friendly because it provides a point source discharge. This permits effluent treatment and and accurate monitoring of nutrient loading. The removal of the waste products provides a high value organic fertilizer. As currently developed, the waste water treatment technology filters all effluent greater than sixty microns in size.

EXECUTIVE SUMMARY

The development of a land-based, high density, fin fish rearing system which uses mine pit water resources is technically and economically feasible. Minnesota has several advantages and disadvantages which require consideration. Barring unforeseen difficulties, the Iron World site can provide a competitive location. Most of the advantages relate to competitive operating costs. Disadvantages relate to extra startup costs and suboptimization of technological, economic, and natural resources.

The most significant advantage is transportation. Because over 90% of the Atlantic salmon consumed in the U.S. is shipped at costs of up to $1.70 per kilo and the current final sales prices of fresh fish for first receivers range between $7.70-$9.35 per kilo, transportation cost control is critical. A related benefit is the lack of duty, which is 5% of the export value (approximately $0.26 per kilo). In connection with the duties, the FDA is targeting imports of Norwegian, Swedish, and Dutch fish for listeria. A listeria inspection automatically

requires the importer to freeze or discard the entire shipment (which cuts values up to 50-100% from fresh prices) and may delay delivery by three weeks. Because these inspections are randomly assigned it is difficult to predict their impact.

There is a shortage of high quality fish products in the United States and the Midwest. Seafood consumption has risen from 12.3 lbs. per capita in 1982 to 19.4 lbs per capita in 1989. Nationwide demand for Atlantic salmon (salmo salar) products exceeds 25,000 metric tons (2206 lbs. per metric ton). The projected per annum production of 522 metric tons by Salminn, Inc. will require 2% penetration of the market.

The Iron Range tailings basins also present an ideal opportunity to market fish waste byproducts as an alternative to current tailings basin stabilization techniques. Waste byproducts will not provide a significant revenue source but may contribute to goodwill. Prices for fish waste vary between $20 per ton for raw waste to $200 per ton for value added fish waste products. Not only does Minnesota have substantial areas which need reclamation, the State also has a large peat resource; peat can be combined with fish waste to produce a superior fertilizer. It can also accumulate wastes, especially phosphorus.

Wages in Minnesota are very competitive, especially against Scandinavian standards. The ongrowing unit will provide six full time jobs. The Aquatech Systems fish farming technology is highly labor efficient. Compared to net pen technology, the system requires one fourth the labor costs. However, the sophistication of the system requires skilled workers whereas net pen facilities can be maintained by semiskilled workers. Although the ongrowing unit does not create significant employment in its own right, it would create over fifty jobs when hatchery and processing operations are considered.

Raw materials are competitively priced in Minnesota. Compared with European sources, feed costs are 25-40% lower in Minnesota. Because feed can account for over 40% of operating costs, this is an important savings. Feed costs vary widely from year to year. Electricity is inexpensive. Oxygen is also competitively priced. The necessity of developing a hatchery will permit significant long term savings on juveniles.

The use of mine pit waters minimizes risks due to diseases and parasites.

Several researchers claim cold waters cause salmonids to lay down relatively higher levels of Omega 3 fatty acids. This would create a health oriented marketing benefit against warmer water salmon sources (especially Canada, Washington, Maine).

Financing available through public assistance programs can enhance competitiveness. As a general rule, public assistance in the U.S. is rare; however, it is growing in the aquaculture industry. Opportunities in the Asia and Europe often provide 15-80% of project development costs, and low interest financing on the balance. Depending upon the business cycle, the developer is typically responsible for 0-20% of the development cost. Furthermore, foreign countries have established their assistance programs as matters of industrial and agricultural policy; this eliminates a lot of the case-by-case hassles which U.S. developers face. Interest rates on lines of credit vary widely, from less than 7% in France to over 30% in Iceland.

There are also several important disadvantages to developing in Minnesota. The most significant obstacle to development is the absence of a large volume source of high quality juvenile Atlantic salmon. Accordingly, the development of a hatchery as a source of raw materials is a must if the project is to go forward. Alternatively, another species may be considered. While the Company's expertise centers on Atlantic salmon, the Company has

operational experience with halibut, trout, arctic char, and turbot. Aquatech Systems also has experience with hatchery design and control systems. Therefore, these additional risks are not an unacceptable challenge to Aquatech's capabilities.

Development costs for modern hatcheries approximate $1.5-$3.0 million depending on capacity. This is a large concern considering that the Iron World ongrowing unit is budgeted to cost approximately $2.8 million (plant and equipment only). The hatchery is the subject of the Salminn, Inc. Business Plan.

In conjunction with the hatchery, it may also be advisable to develop a separate disease control center.

Nutrient loading regulations impose restraints. The most serious restriction concerns the standard for phosphorus loading. Current regulations do not make allowances for accumulation from wild sources of phosphorus. For example, the farm could be in control but a visiting flock of ducks could contribute enough phosphorus over time to place the farm in violation of standards. These risks are unquantifiable. Because the phosphorus emissions from an Aquatech Systems farm are unlikely to affect quality or production, and because the phosphorus is unlikely to migrate out of the pit, and because the instability of the pit water surface prevents the immediate implementation of tertiary treatment structures, such as sand filters, the Company recommends that the development obtain a variance from existing phosphorus emission standards. Phosphorus levels can be further reduced than in the design submitted as part of this study through the use of hydroponics or sand filters; however, these systems increase development and pumping costs, and diminish performance. Performance is compromised because of the need to stay below thresholds for several other nutrients-- the design already suboptimizes the water resource. Suboptimization sacrifices economies of scale.

The Company forecasts that its development will remain in compliance with regulations for one decade. Thereafter, phosphorus would accumulate beyond currently permissible levels unless tertiary filters are employed. Application of tertiary filters should wait until the pit water level stabilizes.

Climate requires the construction of a housing for the ongrowing unit. This housing will cost $1.1 million which is nearly 40% of the project development cost.

Cold water slows the growth rate of fish. It also slows the rate at which fish recover from stress.

No on-site slaughtering is possible.

The graded road may pose delivery problems in winter.

Heavy metals in the water may compromise the environment for fish. At certain concentrations, mineralization of the water can hasten growth. Adult fish are less adversely affected than fry or eggs. The survival of stocked and farmed salmonids in other local pits indicates that the water does not contain toxic mineral levels.

Instability of the water level may one day require investment in dewatering technology (pumps, etc.). This raises capital and operating costs. Capital costs could approach $144,000 and running costs $60,000 on a worst case basis.

In conclusion, it will be a challenge to start the Salminn, Inc. project. Once started, it can operate competitively. The project requires vertical integration beyond the ongrowing farm. The Company has several waste water treatment options; the recommended pathway is suboptimization of the water resource, long term investment in tertiary treatment technologies, and a variance on phosphorus restrictions. The project is not a significant employer in its own right, but does create large opportunities for suppliers and processors.

An outline of the investment is as follows (USD 000)

Hatchery	2,400
hatchery working capital	600
Ongrowing unit	2,800
working capital	2,100
disease control center	500
working capital	200
processing plant	2,000
working capital	500
Training	750
Research and development	400
Total investment	**12,250**

Note: The bottlenecks in the aquaculture industry are most severe at the ongrowing stage. Accordingly, the hatchery and processing plants are budgeted to support the expansion of the business to three ongrowing units.

Aquatech has established that there is unfilled demand for several early life cycle products (eggs, fry) for several species. Accordingly, the hatchery will operate initially as a significant profit center. In later years, the hatchery's capacity will be increasingly directed towards supplying the expanding needs of the Salminn ongrowing unit(s).

Minnesota has excess processing capacity. New investment in processing capacity is not absolutely necessary. New investment in processing can shorten the product development time and enhance quality control. Aquatech Systems has not yet determined what proportion of existing local processors comply with kosher regulations. At present, all Aquatech Systems fish products are strictly kosher.

TECHNICAL DISCUSSION

Parameters

The Iron World mine pit is located within the Mesabi Range of northeastern Minnesota (approx 47.5N, 93.0W). It is situated in a predominantly coniferous forest.

The area's economy focuses upon the development of iron and taconite resources. The open pit mining technique employed has left behind a series of pits, many of which, over time, have filled in with high quality water. The water quality of several pits has already proven adequate to support commercial rearing of salmonids. Aquatech preliminarily concludes that heavy metal levels are not toxic to fish. Dissolved oxygen readings are satisfactory. Water temperatures are acceptable, although temperatures consistently above 6 Celsius would be preferred. Outside of temperature fluctuations, water quality is stable. Once nutrient loading begins, water quality will fluctuate more than at present. This fluctuation will not affect operations.

Access to the pits is provided by grade roadways. These roadways may vary in their utility, depending upon climatological factors.

Perhaps eighteen of the region's pit may be suitable for commercial scale fish rearing. Of these eighteen, five are owned by Minnesota Aquafarms.

The mining industry has created a large number of tailings basins. These tailings basins are currently a challenge to reclaim given the local lack of high quality nitrogenous fertilizers.

The pit waters are supplied from the nearby Hibbing Divide. The Hibbing Divide supplies a subcontinent sized area with oligotrophic quality water. While this water is ideal for raising salmonids, it is also ideal for drinking. Accordingly, the Minnesota Pollution Control Agency maintains stringent water quality regulations.

The area is also well known for its recreational fisheries. The regional preoccupation with various valuable game species borders on the maniacal. This encourages Aquatech to conclude that the local culture has the proper degree of fish sensitivity.

The power supply in adequate, consistent, and inexpensive. Power rates per kilowatt hour are $0.05. Additionally, Minnesota Power operates a steam generating plant in Cohasset and has an abundant waste heat resource which can be used to support siting of a hatchery and enhance growth rates during early life cycle stages.

Topography

The topography of the pit is as follows:

0-20	ft.=	8,036,610	cubic meters
20-40	ft.=	7,100,553	" "
40-60	ft.=	6,421,696	" "
60-80	ft.=	5,544,668	" "
80-100	ft.=	4,933,271	" "
100-120	ft.=	4,229,130	" "
120-140	ft.=	3,512,319	" "
140-160	ft.=	2,673,246	" "
160-180	ft.=	2,057,646	" "
180-200	ft.=	1,905,847	" "
200-220	ft.=	999,302	" "
220-240	ft.=	640,903	" "
240-260	ft.=	337,324	" "
TOTAL		**48,392,515**	" "

This volume contains 12,875,000,000 gallons of water.

Mean depth= 110 feet

75% of this volume is under 120 ft. deep.

The Iron World pit covers 1,317,477 square meters, or 326 acres.

The pit water levels are unstable. Annual level increases should be at least five feet per year. The level should continue to rise for several years. Consequently, over time, the water resource will be significantly increased, assisting compliance with water quality regulations. Additionally, pumping costs will decline.

A current of 1,000 to 3,000 gallons per minute flows through the pit. This current is responsible for the long term infilling of the mine pit. Because water does flow through the mine pit, there is local concern that nutrient loading may contaminate potential drinking resources.

POLLUTANTS AND WASTE DISPOSAL

One disadvantage of mine pit water is that it is static. Stasis permits accumulation of excessive waste products. It also results in undesirable flesh quality; the fish get flabby. It is therefore critical to the long term success of any salmonid development that the operators enhance water quality prior to and following use by fish. While it is technically feasible to degrade water quality more than initially proposed by Aquatech Systems and then implement a program to establish an ecosystem which will equilibrate water quality (the Let's Make a Lake strategy), it is not recommended. It is also possible to fallow pit water resources and use several pits in succession (the Pit 'N' Run strategy). This is also not recommended.

Reasons for recommending against such measures include:

a) Such measures will consistently produce low quality product where salmonids are concerned due to failure to provide adequate water flow.

b) Let's Make a Lake cannot achieve compliance with existing water quality regulations.

c) Other resource users will oppose such techniques to the extent that there is competition for the resource.

d) The methods are less efficient.

e) Monitoring procedures are inaccurate and costly.

f) The techniques may require the use of piscicides or explosives to control populations. Aquatech opposes the use of piscicides and certainly takes exception to exploding fish.

g) The techniques may require chemical water treatment.

A similar situation developed in Norway with sea enclosure technology. Aside from the inhumanity of the explosive husbandry techniques, the results were uneconomic and erratic.

It is up to the State to determine whether it should be lawful to transform pit waters into "lakes". For now, only intensive, closed systems can comply with existing regulations for the long term at commercial scale. Rotation of pits combined with extremely low stocking densities may solve some of the problems associated with open culture systems, such as net pens.

At the same time Aquatech contends that the existing water quality regulations may retard the growth of the aquaculture industry in northeastern Minnesota. Available treatment technologies may prove uneconomic, or restrict opportunities to highly capitalized operators. It is reasonable to request the sale of a property right on the waters of the State within the pit, provided there is not strategic competition for the resource. On balance, Aquatech sympathizes with the aquaculturists who content that the water bodies are artificial and that the water quality restrictions are unrealistic. If the water is actually contributing to the municipal water supply, then drinking water standards make sense. Where the water is merely "passing through" heavy restrictions are not warranted. A farmer who raises salmonids and heavily pollutes the water resource will not be a farmer long. Accordingly, Aquatech recognizes the need for aquaculturists to do their utmost to operate their businesses as net environmental contributors rather than detractors. Given the instability of the pit, the Salminn pollution controls represent the maximum possible effort to comply with regulations.

Concerning specific nutrients, the permit restrictions are as follows:

1. Potential effluent limitations for receiving waters with adequate dilution or controlled seasonal discharges (applicable to hatchery):

   5-day carbonaceous biochemical oxygen demand (CBOD5): 25 mg/l

   Total suspended solids: 30 mg/l

   pH: 6.0 to 9.0 standard units

Phosphorus: 1 mg/l or less when the discharge affects a lake or other static body of water

Ammonia-N: Total ammonia as N, 1 mg/l or less depending on the receiving water

Unspecified toxic or corrosive substances: None at levels acutely toxic to humans or other animals or plant life

2. Receiving water without adequate dilution to protect water quality standards (cf. mine pits)

CBOD5: 5 mg/l

Limits are set to maintain water quality standards as set forth in Minn. rules pt. 7050.0220; prevent nuisance conditions in accordance with Minn. rules pt. 7050.0210, subp. 2, and be consistent with the nondegradation requirements of Minn. rules pt. 7050.0185.

The Minnesota Pollution Control Agency favors the use of case by case evaluations of aquaculture developments.

Additionally, the U.S. Environmental Protection Agency has notified MPCA that mine pit aquaculture operations are subject to federal NPDES permit requirements.

METABOLITE LOADING OF THE DISCHARGE FROM ONGROWING UNIT

Introduction

In the land-based fish farm the excretory products of the fish, both solid and dissolved, together with any uneaten feed, are present in the water as it leaves each tank.

The Aquatech Systems tank, having a circular design and a sloping bottom to a central discharge and a flow pattern created by the water inlet, is specifically designed to rapidly eliminate wastes and prevent their dissolution or build up and fouling of the environment.

While the mechanical filtration system removes 90% of the solid matter in the discharge water, and hence reduces the phosphate, nitrate, and BOD loading of the water, it cannot remove metabolic products in solution.

Biological filtration methods can remove additional pollution; however, there is no system which can economically serve an Aquatech Systems salmonid development because of the extreme and optimum flow rates Aquatech uses to maintain process quality. The proposed biomass in the farm changes throughout the year as growth, slaughtering, and restocking takes place. Metabolite production will also vary and will present a cyclical annual pattern. Accordingly, MPCA's decision to take only an annual water quality sample will aid compliance with regulations.

In contrast to traditional fish farming procedures, the use of oxygenation, strict water distribution, and current control in the tanks means that in an advanced land-based fish farm, the total water flow through requirement is reduced. The technique also permits the attainment of a flesh quality which net pens cannot match.

The discharge loadings shown below are for a farm producing approximately 522 metric tons (1,150,801 lbs.) annually and thus, in accordance with the production plan, having a mean biomass load of 433,800 kg.

Total ammonia (NH4-N):	.742 mg/l
Total Phosphorus (PO4-P):	.087 mg/l
Nitrate+Nitrite (NO3-NO2-N):	.794 mg/l
Chemical Oxygen Demand (COD):	.041 mg/l

See addendum

Oxygen level of discharge water

The Aquatech Systems farm uses closely controlled, active oxygenation by high purity liquid oxygen to provide the fish with their metabolic needs. In order to provide suitable environment, the water leaving the tanks will always be above fishes' minimum tolerance level. The level is pre-set by the operator. For now, this is best represented by a level of 6 mg/l and therefore, all discharge water will be at or above this value.

The filtration system

Aquatech Systems intends to use a Wheel filtration system for the separation of solid wastes from the outflow water. This filter was designed to cope with high volumes of water and has been widely used in the aquaculture industry. It has been tested for aquacultural use by the Norwegian authorities and has also been used successfully within other industrial and governmental operations in which high water volumes require treatment.

The manufacturer has conducted aquaculture and has produced a range of models.

Trials conducted by Aquatech Systems on the Wheel system as installed at the research station with mesh sizes 1,600 and 355 microns have shown that the efficiency of particle removal will vary slightly in relation to the husbandry practices and activity of the biomass but that a mean value of 90% removal is realistic.

Further handling of separated solids

The solids separated from the main discharge water by the filtration system, and the filter spray water are to be led under gravity feed to a sedimentation basin of similar design to that found in municipal sewage works and suitably dimensioned to manage the maximum flow of sludge water. Sludge may be thickened to speed sedimentation.

The collection rate of the sludge at the deeper end of the sedimentation basin should be speeded by the installation of a slow speed, submerged scraper. Wastes will be pumped to a decanter centrifuge for final dewatering.

A continuous decanter centrifuge is used on fish waste sludge from the filtration system at the Aquatech R&D station in Norway. The resultant solids show between 25-30% dry matter. This material is suitable for sale or disposal.
The overflow water from the sedimentation basin may be further cleaned through a filter to ensure that a very low load of suspended material escapes the sedimentation procedure. This flow will be of sufficiently high quality to warrant its dilution with the rest of the discharge from the farm.

The clarified liquid discharge from the centrifuge, having been in contact with the sludge for a longer period, will have a higher load of dissolved material.

Use of medicated feed

Aquatech diminishes the likelihood of diseases by using vaccinated stock and the latest husbandry techniques while maintaining environmental quality. Nevertheless, it is impossible to rule out the possibility of a disease outbreak.

Because all stock are easily observed in a land-based farm, any problems can be identified and treated at an early stage. Tanks are generally not interconnected and water is not reused, so individual tanks can be quarantined and separately treated.

The most common form of treatment of bacterial diseases of fish is through application of antibiotics incorporated into the feed. Antibiotics are not routinely given as a prophylactic as is the case on net pen farms. To do so would jeopardize the organic status of the fish products.

Concerns exist that uneaten feed containing antibiotics may pass into the aquatic environment. In sensitive enclosures, such as the pits, Aquatech advocates additional handling procedures; the coupling of a mobile filter unit with extremely fine mesh to any tank receiving medicated feed ensures that wastes are efficiently removed and are handled separately form the main sludge volume.

Use of pesticides

It is unlikely that the mine pit's water resource will develop ectoparasites. Pesticides (primarily immersion treatments of degradable chemicals) are available, but Aquatech opposes their use; it is better to prevent infestation in the first place.

Cleaning

It is generally not possible to empty tanks merely for cleaning. Chemical cleaning is neither possible nor desirable. Aquatech recommends using a combined rotating brush and vacuum device which can service full tanks without causing undue stress to the fish. Wastes are directed to the filters.

Long term issues

While per annum nutrient loading will be within MPCA guidelines, bioaccumulation may eventually take water quality readings over MPCA limits. This is particularly true of nutrients which do not migrate out of the pit.

To quote form "Nutrient Enrichment of Ground Water From Septic Tank Disposal Systems" (Dudley, Stephenson 1973)

> Soils can fix large amounts of phosphorus...most forms of phosphorus are fixed by a combination of adsorption, replacement reactions involving a change in crystalline structure, and precipitation reactions in which soluble phosphates react with iron, aluminum, or calcium to form insoluble compounds (Polta, 1969). In addition, phosphorus present in the soluble orthophosphate form...may be converted by certain bacteria to insoluble forms. Several researches have found that although phosphorus is present in septic tank effluent in concentrations exceeding 20 mg/l... it is usually not present in significant concentrations in ground water adjacent to the system (Polta, 1969; and Preul, 1964).

Additionally, because farmers have no guarantees from Mother Nature that She will not contribute phosphorus from Her own resources, it is difficult for aquaculturists to comply with phosphorus water quality regulations for all time. Therefore, Aquatech submits that it has already taken all possible precautions while staying within the Laws of Nature and Economics and that the MPCA should consider granting a variance from existing phosphorus regulations. Because the rate of infilling can be expected to fluctuate (it should decline over time) it is not clear whether the pit will finish filling in before or after the discharge accumulates sufficient phosphorus to warrant disciplinary action.

The State should consider:

1. Establishing an Aquaculture Enterprise Zone with relaxed water quality standards or other offsets which compensate for financial burden of water treatment technology.

2. Selling a property right on the waters of the State contained in the Iron World mine pit to Salminn, Inc.

3. Adopting a system of free market pollution controls in the mine pits to provide incentive for investment in pollution control technology. Under such a system, the company's tax is influenced by its pollution emissions.

4. Subsidizing the installation of additional pollution control technology.

5. Sponsoring the investment in pollution control as a research experiment.

6. Promoting aquaculture in less sensitive water bodies until more effective technology becomes available.

Aquatech notes that IRRRB continues to distribute economic development literature on the subject of aquaculture in which the Board represents that the mine pits are "ideally suited to net pen aquaculture". This is incorrect. The pits are poorly suited to support net pen aquaculture regardless of regulations. When regulations are considered, mine pits and long term net pen aquaculture are *ipso facto* mutually exclusive. Aquatech recommends that IRRRB rewrite its literature to exclude any misleading mention of net pen aquaculture, and/or seek legislative variances/ establish economic development zones exempt from current regulations. The new literature should also discuss water quality regulations. The private sector will make its own conclusions.

Other possibilities

Hydroponics can reduce nutrient loadings. Given the climate, year round hydroponics may require the growing of species which tolerate wide temperature swings, such as conifers. In concert with fish waste fertilizer, these seedlings could assist the reforestation of tailings basins. For purposes of this analysis, Aquatech is not in the tree growing business.

Use of sand filters can also assist the filtration. These filters are costly. Because the mine pit site specifically imposes significant additional startup costs, and because of water level instability, Aquatech favors avoiding the sand filters for now. The sand filters may be augmented by a combination of peat moss and hydroxy apitite crystals; both these substances accumulate phosphorus.

CLIMATE

The most significant climatological aspect of the Iron World site is temperature. The area temperatures over '82-'88 show consistently severe winters and short hot summers. Over the period temperatures ranged between -37 and 90 F. Area weather data indicate that subfreezing temperatures may occur from September until May.

The water temperature at the Salminn intake point is projected to range between 4 and 12 degrees C (39-54F).

The area is prone to high winds which can create extreme climates for workers, livestock, and components.

Cold weather is more of a hazard than warm weather. The cold will not cause unacceptable temperatures at the intake point but it will freeze the surface of the pit lake. This freezing makes it essential for the farm to have a consistent and reliable oxygen generating technology, such as the Deep Shaft Oxygenator. High flow rates inside the tanks will prevent the formation of surface ice but small volumes of water will freeze quickly, posing a hazard to employees and damaging equipment and instruments. Cold weather grading hazards employees and animals.

The Iron World site requires a housing for the ongrowing farm. Because of construction costs, only a high stocking density design can prove economical. The structure will be comparable in size to a modern day supermarket. Its construction should account for 40%

of the total ongrowing farm development costs-- good news for local contractors, bad news for the owners. Extreme climate and the enclosures required to counter it will eliminate some options in the development of Minnesotan aquaculture.

AVAILABILITY OF PROFESSIONAL SERVICES, TECHNICAL SUPPORT, EQUIPMENT, LABOR

Services and Support

The Salminn, Inc. Iron World development will require the services of a general contractor. Aquatech Systems has received an indication of interest from the Butler Research and Development Co. to serve the project in this capacity.

Due to earlier aquaculture projects, there is ample technical support and equipment available. Certain components will require three month lead times for ordering.

The U.S. aquaculture industry is primarily aided by the National Oceanographic and Atmospheric Administration, which is sequentially overseen by the Departments of Agriculture, Interior, and Commerce, while agencies such as U.S. Fish and Wildlife, Bureau of Indian Affairs, Environmental Protection Agency are also influential. Within Minnesota, the aquaculture industry has recently been assigned to the Department of Agriculture after formerly falling under the jurisdiction of the Minnesota Department of Natural Resources. MPCA and IRRRB have also influenced development of aquaculture in the State. The State is home to a number of Native American tribes with fishing expertise.

The complete Salminn development will have both table fish and natural resource applications. It will also have considerable technical and economic demonstration value which may attract interest from the Business Innovation Center, University of Minnesota and its Center for Economic Development, Natural Resources Research Institute. Many of these agencies are able to provide financial as well as technical support. This support helps compensate for the high risks historically associated with aquaculture as well as aid the industry in meeting unfilled demand for product.

Support from Minnesota's economic development agencies and research oriented facilities can dramatically speed the development of aquaculture in the State. It has yet to be determined which agencies and programs will commit themselves to the long term support of the industry.

To a certain extent, Salminn's needs are unique; no other fish farm in the world confronts equivalent challenges. With regard to aquaculture process control and efficiency of ongrowing facilities for salmonids, Aquatech is undisputably the industry leader; therefore it must be self-sufficient for now in many areas of technical support.

Aquatech Systems recommends that the State evaluate the establishment of vocational and technical training programs in the field of aquaculture. Such training programs are a leading reasons for the rapid development of the industry in Norway and the U.K. The U.S. has some world class higher education programs for marine biology and oceanography but has yet to create top ranked aquaculture programs. This creates an opportunity for the State of Minnesota.

Equipment

Cost estimate for land based farm (5000 cubic meters rearing volume)
(all figures in USD 000)

Building	1,103
Intake/outlet pipes	260
Tanks/work bridge	225
Control and monitoring	220
Distribution piping	175
Pumps and frequency system	165
Groundwork	150
Filter and cleaning system	110
Miscellaneous equipment	110
Pump well/pump house	82
Valves	72
Oxygenation system	50
Electrical work/equipment	47
Steelwork	35
Back up pumps	35
TOTAL	$2,839

Labor

Labor is competitive in northeastern Minnesota. The Salminn ongrowing unit will require the services of six individuals, initial wages and benefits are planned as follows:

1. Senior manager: $54,000
2. Junior manager: $44,000
3. Administrator: $30,000
4. Farm hands (x3): $17,000

Skill levels for the managers must be high. Aquaculture operations are ill suited to remote control from a central station. They require competent managers who are able to make their own decisions. Motivation for all workers must be high because the proper husbandry practices are critical to the success of the project. All employees must be computer literate. All the jobs except for Administrator require the employees to be strong and physically fit because heavy lifting is required.

Aquatech encounters training difficulties; the technology and husbandry techniques employed are proprietary to the Company and are revolutionary. Aquatech must train its employees. The training facilities are in Norway. Training time is approximately ten months, although for manager level employees, several years of experience is recommended. Employees must be capable of relocating temporarily to Norway. Training costs are high due to the high cost of living in Scandinavia and the need to provide temporary accommodations.

It will also be necessary for Aquatech Systems to provide its own trouble shooting technical consulting services. Initially, this will require the presence of one of the Company's experienced fish masters.
Aquatech Systems U.S.A., Inc. provides all its employees with health plan coverage. This coverage does not at present extend to spouses. All employees are eligible for participation in an Employee Stock Ownership Plan. Additionally, employees shares in a bonus pool equal to 8% of profits net of 6% of shareholder equity.

RAW MATERIALS

Juveniles

This is a major stumbling block to the initiation of development. While the State and private hatcheries do produce salmonids, there is not enough supply to meet Salminn's needs. furthermore, Aquatech is particular about the quality of juveniles it will accept. It is one thing to raise fry for restocking purposes and quite another to raise them for table fish; each product will have a distinct feature/benefit matrix which describes its fitness for use. The need to build a hatchery and raise juveniles considerably increases development costs and postpones the construction of the ongrowing unit. In the long run it will provide a wider array of strategic options and improve quality control.

MDNR has stringent regulations governing the introduction of early life cycle fish products. The best solution for Salminn is to start at the beginning with the development of a hatchery. The Cohasset Steam Generating Plant operated by Minnesota Power is a potential site. Minnesota Power and MDNR have already demonstrated the potential of the location with an experimental rearing of Atlantic salmon, rainbow trout, and channel catfish.

Juvenile Atlantic salmon can be produced for $1.17 per 60 gram juvenile. This is a competitive production cost.

Feed

A variety of producers are available to meet the Company's needs at competitive prices. Quality is high. A range of products for all life cycle stages is available, Medicated feeds are available. Several of the feed producers which serve the region are expanding their capacity.

Oxygen

The Linde division of Union Carbide is able to serve the Company's needs. The Company has had a long relationship with Linde. Due to the seminal role of Linde in the development of the Deep Shaft Oxygenator, Linde is the preferred provider.

LEGAL

A fish farm license is required. It costs $250 per annum and is issued by the DNR Bureau of Licenses.

An Importation, Transportation, and Stocking Permit is required. It is issued at no cost by the DNR Section of Fisheries.

An aeration permit is required. It is issued at no cost by the DNR Section of Fisheries.

A National Pollution Elimination Discharge System permit is required. It is issued by the MPCA Division of Water Quality at a cost dependent on the specific facility. Permits from MPCA require 180 day lead time.

State of Minnesota DNR Commissioners order No.2328 prescribes regulations for the maintenance and operation of private fish hatcheries and fish farms. Aquatech Systems does not anticipate difficulties in complying with the regulations contained therein.

CONCLUSION

The Salminn, Inc. ongrowing unit can be a successful and profitable business with long term opportunities for residents of the Mesabi Range. Technical factors pertaining to the development of multiple ongrowing units are not the limiting factors. The Salminn, Inc. ongrowing development is not ready to go as a stand alone development. It will require improvement of the existing aquaculture infrastructure and/or consideration of other species. The development should not immediately encounter legal difficulties, although, over the very long term, it may accumulate enough phosphorus to warrant action by MPCA. Capital development costs are higher than ideal due to climatological factors and the lack of the other vertical stages in the business. Operating costs should be amongst the lowest in the country due to an abundance of resources. Depending on financing terms, the development should reach profitable operations three years after the introduction of juveniles to the ongrowing unit. The presence of tailings basins presents an unique opportunity for the demonstration of the biodynamic properties of the Aquatech Systems technology. Aquatech Systems recommends the continued pursuit of the opportunity presented by the mine pits and the resources of the State of Minnesota.

The next logical steps are:

1. The State should refine its aquaculture planning and determine its political and financial commitment to the development of the aquaculture industry.

2. A feasibility study should be prepared which addresses the business and technical factors influencing the development of a hatchery at the Cohasset Steam Generating Plant.

3. Aquatech Systems, Inc. should prepare a business plan for an integrated fish business including a hatchery, disease control center, ongrowing unit(s), and processing plant. In conjunction with the IRRRB and its joint venture partner(s) it should prepare a financing package which addresses the competitive realities of the aquaculture industry and the special needs associated with mine pit development.

4. Aquatech Systems, Inc. should prepare an economic impact statement to accompany the Salminn, Inc. business plan.