FINAL REPORT

DEC 2 0 2002

1999 Project Abstract
For the Period Ending June 30, 2001

TITLE: Sustainable Aquaculture Development in Minnesota
PROJECT MANAGER: Ying Ji
ORGANIZATION: Minnesota Department of Agriculture
ADDRESS: 90 W. Plato Blvd, St. Paul, MN 55107
WEB SITE ADDRESS: http:\\www.mda.state.mn.us
FUND: Future Resources Fund
LEGAL CITATION: ML 1999, Ch. 231, Sec. 16, Subd. 7(l).

APPROPRIATION AMOUNT: $185,000 – $116,300 returned = $68,700

Abstract:

This is a two-part project, demonstration of aquaponics production of fish and vegetables in an urban environment in cooperation with the University of Minnesota and a pilot study of ozone application in large recirculating aquaculture systems with MinAqua Fisheries. The first part failed to get started because of lack of suitable urban greenhouse by community gardening enthusiasts and lack of suitable collaborators with the university.

The second part was partially successfully carried out. Three batches of tilapia fingerlings were tested on the impact of ozone application in recirculating tilapia fingerling systems. Test results indicated that ozone application had a clear impact on improving water quality by lowering both suspended solids and biological oxygen demand. Total suspended solids went from 4.5 mg/ml to 2.1 mg/ml after about two months of ozone treatment and stayed at that level thereafter. Biological oxygen demand decreased from 13.7 mg/ml to 2.1 mg/ml after three months of treatment.

Impact of ozonation on fish growth was mixed. First two batches of fish had an improved feeding conversion ratio (FCR) at about 0.9 pound of feed per pound of fish growth. FCR for third batch is about the same as that without ozonation (1.3). Mortality rate was higher in the ozonated system (10.4%) than in the unzonated system (7.8%). The test was not completed because of a lightning storm that damaged ozone generator before the testing was completed. New testing is still on going and will be completed by June 2003.

Results and demonstration have been shared with various groups from within as well as outside of Minnesota. Visitors who toured the ozone application on site have been very impressed by how much clearer the water is in the ozonated system.

Date of Report: July, 2002
LCMR Final Work Program Report

I. PROJECT TITLE: Sustainable Aquaculture Development in Minnesota

Project Manager: Ying Ji
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Total Biennial Project Budget:

$LCMR:	$185,000	**$Match**:	$50,000 (in kind)
$RETURNED:	$116,300		
BUDGET AFTER RETURN: $68,700			
- $LCMR Amount Spent:	$50,000	**- $Match Amount Spent:**	$50,000
= $LCMR Balance:	$00	**= $Match Balance**:	0

A. Legal Citation: ML 1999, Chap. 231, Sec. 16, Subd. 7(l).

Appropriation Language: $130,000 is from the future resources fund to the commissioner of agriculture in cooperation with the University of Minnesota to develop, demonstrate, and evaluate prototypes of aquaponic systems that operate in an urban environment and use a combination of aquacultural and hydroponic techniques to produce fish and plants for human consumption. $55,000 is from the future resources fund to the commissioner of agriculture in cooperation with the MinAqua Fisheries Cooperative, with assistance from the University of Minnesota, for the purchase, operation, and demonstration of ozonation equipment for water treatment and conditioning in large recirculating aquaculture systems. These appropriations are available until June 30, 2002, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program. As a condition of receiving this appropriation, MinAqua Fisheries Cooperative must agree to pay to the state a royalty. Notwithstanding Minnesota Statutes, section 116P.10, the royalty must be two percent of the gross revenues accruing to MinAqua Fisheries Cooperative from this application of ozonation technology. Receipts from the royalty must be credited to the fund.

II. and III. FINAL PROJECT SUMMARY

This is a two-part project, demonstration of aquaponics production of fish and vegetables in an urban environment in cooperation with the University of Minnesota and a pilot study of ozone application in large recirculating aquaculture systems with MinAqua Fisheries. The first part failed to get started because of lack of suitable urban greenhouse by community gardening enthusiasts and lack of suitable collaborators with the university.

The second part was partially successfully carried out. Three batches of tilapia fingerlings were tested on the impact of ozone application in recirculating tilapia fingerling systems. Test results indicated that ozone application had a significant impact on improving water quality by lowering both suspended solids and biological oxygen demand. Total suspended solids went from 4.5 mg/ml to 2.1 mg/ml after about two months of ozone treatment and stayed at that level thereafter. Biological oxygen demand decreased from 13.7 mg/ml to 2.1 mg/ml after three months of treatment.

Impact of ozonation on fish growth was mixed. First two batches of fish had an improved feeding conversion ratio (FCR) at about 0.9 pound of feed per pound of fish growth. FCR for third batch is about the same as that without ozonation (1.3). Mortality rate was higher in the ozonated system (10.4%) than in the unzonated system (7.8%). The test was not completed because of a lightning storm that damaged ozone generator. Testing is still on going and will be completed by June 2003.

IV. OUTLINE OF PROJECT RESULTS:

Result 1. Establishment and demonstration of sustainable, community-based aquaponics production of high quality food in an urban environment. The pursuit of this result was aborted. As a concept, this was a great proposal. But in implementation, it met much difficulty.

About 40 community gardening groups were identified through the Sustainable Resources Center. A request for a proposal with instructions on writing the proposal and invitations to attend an informational meeting was sent out. About 30 people, representing at least 10 community groups, attended the meeting on August 12, 1999. Project plans including project goals, specifics of an aquaponics system and the intent to solicit community collaborator(s) were presented.

People who attended the meeting had high praises of the project and commended the University for conducting such a project and the LCMR for funding it. It was also pointed out though that community gardeners are highly independent. One attendee at the meeting compared working with a group of community gardeners to herding cats.

Four proposals were received from groups that wanted to participate in the project. Seward Neighborhood Group (SNG) was the successor of the competitive proposal process for their organization, their connection to public school, additional funding to construct a greenhouse, and the availability of physical space for the project.

As negotiations were near completion and physical work on the project was about to start, SNG decided to withdraw from the project because their internal managers on the project were unable to agree on many of the issues such as long term sustainability, and economic viability of this type of operation. There was also a dispute over how independent of their green house should be of the modern technological advancements such as a steady power supply. Our attempts to answer these questions were not satisfactory due to lack of previous track records. With time passed working with SNG and lack of a completely suitable alternative collaborator, we decided to abort this part of the project. As a result of this abortion, $116,300 of the $125,000 appropriated for the University of Minnesota was returned to Future Resources Fund. The University expenditures on this project were estimated as $8,700. The actual came out to be $9,616.54.

LCMR Budget:	$13,700	Match:	$0
Balance:	$13,700	Match Balance:	$

Result 2. Application and demonstration of ozonation as water treatment and conditioning in large recirculating aquaculture systems. This was a joint effort between the Minnesota Department of Agriculture and the MinAqua Fisheries. The objective is to design and test ozonation systems for water treatment and conditioning in large recirculating aquaculture systems to determine the optimum design and to access the economic benefit.

A. Background Information about MinAqua Fisheries.

MinAqua Fisheries is a Minnesota cooperative comprised of over three hundred Minnesota farmers with its location in Renville, MN. The coop is organized under IRS code as a value added entity by processing soybeans to fish. Many "value–added" cooperatives were formed in the nineties to increase farmers' profits such as ethanol plants, soybean processing plants, an egg laying and processing company, and several large hog farms. Renville has been very successful in establishing value added cooperatives.

In addition to being next to other successful farmer cooperatives, Renville also provides MinAqua with a unique resource, the waste heat from the nearby beet sugar plant. This enables them to successfully raise their selected species of fish, tilapia. Tilapia requires water temperatures of 80–85^{o}F to have a reasonable growth. Tilapia was selected as the fish species of choice because of its diets for maximizing the utilization of soybeans and because of market conditions. Available labor, competitive feed stuffs, and other resources enhanced the opportunity for a viable business in Renville. Construction for MinAqua began in April of 1997 and was completed in March of 1998. The first fish were marketed in March of 1998. The farm is made of primarily two 320' x 120' fish barns with nearly two million gallons of water within the facility.

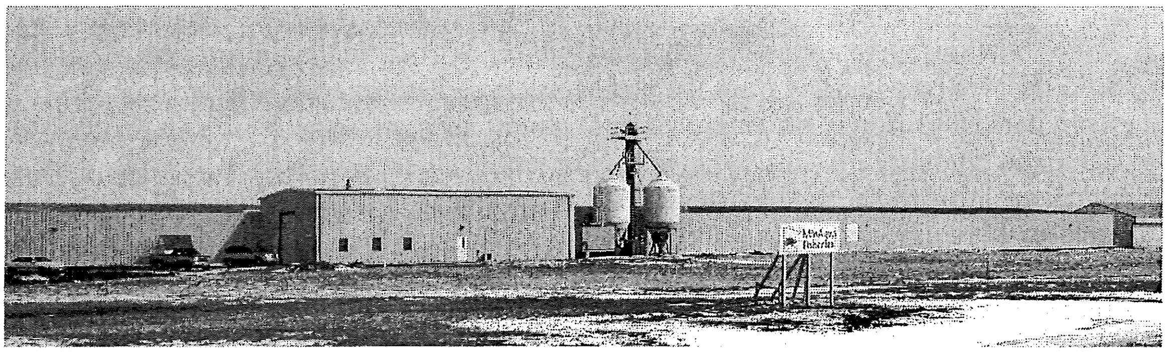

Figure 1: Outside View of MinAqua Fisheries

B. Design and Function of MinAqua

MinAqua is the second largest tilapia facility in North America. It employs a technology called recirculating aquaculture systems, where water is re–used every 30 minutes to an hour by a combination of biological and physical treatments. The facility consists of 24 33,000 gallon concrete tanks for fish grow-out space, 16 5,000 gallon tanks for fingerling rearing, 6 biological filters and 16 settling tanks. The total water volume in the whole systems is about 2,000,000 gallons.

MinAqua purchases fingerlings at 0.30 grams. At this stage, the fish are placed in 5,000 gallon tanks for early development. The company purchases approximately 175,000 fingerlings per month and places them in the fingerling tanks in batches. After growing for three months, the fish are transferred to larger tanks for final grow-out. After another four months of growth, the fish are sold to Asian grocery stores and restaurants live through direct marketing and through distributors in heavily Asian populated cities such as New York, Toronto, etc.

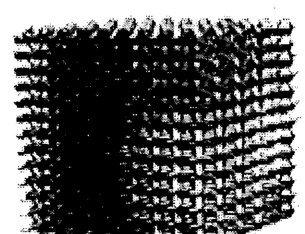

Figure 2. Bio-Strata

Every 6 of the 24 33,000 gallons tanks are grouped together to make a recirculating system. Water from the fish grow-out tanks is fed through gravity to settling tanks where solids from fish waste is settled out with the help of tube settlers, a honey comb material called bio-strata where water is forced to go through small channels to aid the settlement of solids. Water from settling tank is pumped to biological filters where ammonia, a substance that is toxic to fish is converted to nitrate or nitrite. Water that is clean of solids and ammonia is then oxygenated before returning to fish. Oxygenation is accomplished by injecting liquid oxygen at the bottom of 100' U-tubes to aid the dissolvability of oxygen. Water re-entering fish tank contains 6–10 mg/liter of oxygen. Water is recirculated in all grow-out tanks in this fashion and in 16 fingerling tanks in a similar fashion every 35 to 45 minutes. New make–up water from wells and city water totaling 150,000–175,000 gallons per day. 5-10% make-up water per day is the standard for the better operated recirculating systems.

The replaced water is discharged out of the building from the settling tanks carrying the

Figure 3: MinAqua Fish Grow-out Tanks

settled solids into an outside settling pond. Liquid portion of the discharge enters the Renville sewer treatment system, where it is treated prior to discharging into the environment. Twice each year, the holding pond is agitated and slurry is applied on farmers' fields to take advantage of its fertilizer value.

Although the design of the system is very functional and fully complies with permit requirements from the Minnesota Pollution Control Agency, it was a goal to pursue methods and technology which could potentially improve effluent water quality and provide a better environment in which fish could grow and thrive. Better water quality could potentially improve feed conversions and decrease death losses.

With these goals in mind, MinAqua approached LCMR for a grant to study the effects their recirculating aquaculture systems. This study was funded from the Future Resources Fund.

C. Ozonation System Design and Testing

Dr. Brian Brazil of then Virginia Polytech Institute, now with US Fish and Wildlife, regarded as an expert in ozone technology as applied to aquaculture systems, was retained as a consultant in the design of the equipment and the experiments to test ozone at MinAqua. Dr. Brazil initiated preliminary tests to assess the feasibility of conducting the study intended with ozone. Initial results indicated that indeed ozone had the potential to improve water quality and perhaps affect fish performance. Based on the preliminary tests, the testing protocol was developed.

One of the two fingerling systems (8 fingerling tanks each) was chosen as experimental group and the other as the control. Due to the dosage needed in order for ozone to be effective, funding only allowed conduct of ozone testing in fingerling systems. Larger grow-out systems would have required much larger ozone generating capacity.

An ozone generator capable of producing 12 to 14 pounds was purchased from Ozonia of North America. Ozone Solutions, an ozone applications firm and also a sales agent for Ozonia of North America, installed the equipment according to our study designs. The equipment came without UL listing. Local electric code called for UL listing. This was resolved when the unit later on was struck by lightning and it was UL listed when it was sent out for repair from the lightning damage.

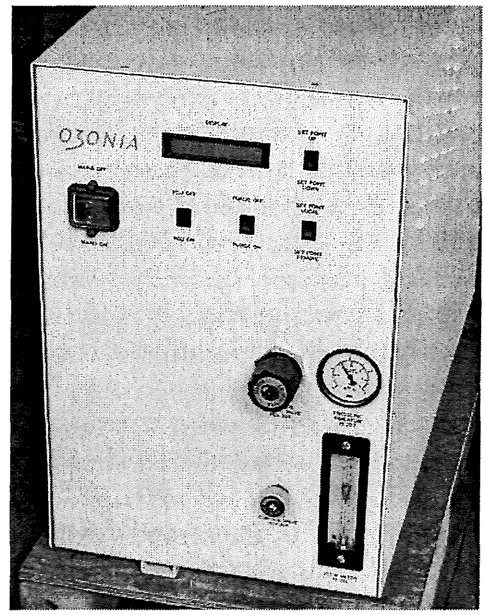

Figure 4. Ozone Generator

This generator is supplied with pure oxygen from an on-farm oxygen generator. Ozone generated from pure oxygen was injected into down stream of the water flow in the U-tube through ozone resistant verturi injectors. Dosage was determined as 15 to 20 grams of ozone per kilogram of feed per day. The ozone injection strategy was selected because it utilizes existing facilities and the U-tube provides an excellent method for ozone gas transfer.

Water quality parameters of total ammonia nitrogen (TAN), nitrite (NO2), nitrate (NO3), acidity (pH), temperature, total suspended solids (TSS) and biological oxygen demand (BOD) were measured before the start of ozonation and maintained there after on a regular basis. All these parameters except TSS and BOD were monitored as a routine measure to ensure that fish had an optimum environment to grow. Ozonation was not expected to affect these parameters one way or another.

In addition, microbial counts of total, aeromonas and beta strep were also measured before the start of ozonation as well as on a continual basis after ozonation started. Aeromonas and beta strep are bacteria that are known to cause diseases in tilapia operations.

Three batches of fingerlings were tested over time. The first batch of 85,000 fish with an average size of 3 inches came in on Feb. 28, 2002 and was divided into two groups. Each group was stocked into one of the 8 fingerling tanks in the ozonated and unozonated systems. The remaining fingerling tanks contained fish from previous stockings. After about 3 and half months of being raised in these fingerling tanks, fish from ozonated system was stocked into the grow-out tanks on June 26, 2002 and 85% of the fish from unozonated system on May 31, 2002 and remaining 15% on June 4, 2002. When fish are moved from fingerling to grow-out tanks depended upon whether they are ready in size and on availability of space in grow-out tanks that depended on sales in the market place.

Figure 5. Tilapia Fingerling Ready for Grow-out

The second batch of the same number of fish came on March 21, 2002. They were also stocked into one of each ozonated and unozonated systems at an equal quantity. ¾ of the fish from the ozonated system were stocked into the grow-out tanks on June 10, 2002 and remaining on July 15, 2002. 2/3 from unozonated system were stocked on July 4, 2002 and the remaining on July 15, 2002.

The third batch came in on May 2, 2002. This batch of fish was divided into three groups. The inventory in the non-ozonated system was such that ozonated system needed more fisn to balance out the load. Two groups totaling 60,575 fish were stocked into two of the 8 tanks in the ozonated system and one group (27,725 fish) was stocked into the non-ozonated system. One tank of fish from the ozonated system was stocked for grow-out on Aug. 6, 2002 and the other on Sept. 25, 2002. Fish from the unozonated system was stocked on Aug. 13, 2002.

In late June of 2002, a lightning storm hit Renville area and the ozone generator was damaged. The unit had to be sent out to New Jersey for repair and was subsequently sent to Canada for the equivalent of UL listing to comply with local electric codes. The unit came back and resumed its service at the end of September.

Because of the lightning damages, only batch one was tested with ozone application throughout the whole duration of the test. Batches 2 and 3 completed after ozone generator went out. Therefore the data generated are not completely wholesome. MinAqua has volunteered to continue the testing of ozone impact for another 3 batches or so and will complete this second phase in May or June 2003. An update of this report will be given accordingly.

D. Results and Discussion

During the testing, all systems had functioned normally except the lightning damage to the ozone generator. The regular parameters of water quality in both ozonated and unozonated systems are shown in Table 1. All parameters are well within what is considered a good environment for tilapia growth. Testing from before the start of ozone application indicates that there was not significant shift in water quality as measured by total ammonia nitrogen, nitrite, nitrate, pH, temperature, dissolved oxygen and alkalinity. More data is available on these parameters, but only those corresponding to the data

Table 1. Selected Water Quality Parameters before and after the start of Ozonation

	Before Ozonation		After Ozonation					
	Ozonated System	UnOzone System	Ozonated System			Un-Ozonated System		
			3/4/02	4/11/02	5/6/02	3/4/02	4/11/02	5/6/02
TAN (g/l)	3.0	2.6	3.0	2.2	1.2	2.6	2.0	0.6
NO2 (g/l)	0.03	0.31	0.03	0.13	0.05	0.31	0.31	0.28
NO3 (g/l)	118	138	118	107	62	138	115	116
PH	6.5	6.2	6.5	6.6	6.6	6.2	6.9	6.6
Temp (oF)	81	78	81	78	80	78	83	80
DO (g/l)	11.5	11.4	11.5	11.9	14.8	11.4	11.6	15.1
Alk (g/l)	122	89	122	99	195	89	249	82

Table 2. Additional Water Quality Parameters before and after the Start of Ozonation

	Before Ozonation (2/11/02)		After Ozonation					
	Ozonated System	UnOzone System	Ozonated System			Un-Ozonated System		
			3/4/02	4/11/02	5/6/02	3/4/02	4/11/02	5/6/02
TSS (g/l)	4.5	9.3	4.5	2.1	2.1	9.3	6.7	15.6
BOD (g/l)	13.7	14.6	13.7	9.2	2.1	14.6	15.6	15.5
Microbial Counts								
TCC (col/ml)	40,000	50,000	40,000	20,000	100,000	100,000	100,000	100,000
Armns (col/ml)	10,000	9,000	0	5,000	15,000	0	20,000	15,000
Beta S. (col/ml)	1,000	3,000	0	0	0	0	0	0

points on suspended solids, biological oxygen demand, bacterial counts and fish growth are given. No statistics are performed because these parameters are not expected to be and they were not affected by application of ozone.

Data on total suspended solids, biological oxygen demand and bacterial counts are given in table 2. Both total suspended solids and biological demand in ozonated systems are much lower than they are in the unozonated system. Ozonation reduced TSS to half of what the system started with and kept it at a much lower level than in the unozonated systems. Biological oxygen demand was reduced from 13.7 g/liter to 2.1g/liter over the period of about 5 months while the unozonated system maintained a consistent level about 15 g/liter. Ozonated system continued to have lower suspended solids and lower biological oxygen demand after ozone generator had gone out of service. Statistical analysis was not performed on these water quality data because there are too few data points and that there is a time effect as TSS and BOD declined over a period of time.

Ozone effect on microbial counts is less clear. While ozone may seem to have reduced total bacterial counts in the first and second batches, the third batch had similar bacterial counts as in the unozonated or in the systems prior to the start of ozonation. Ozone levels of 15-20 g/kilogram of feed fed per day do not leave significant enough residual ozone in the system to have a meaningful impact on the bacterial loading. Beta strep was not detected in any of the systems because this bacteria, although it is the number one cause of tilapia diseases, is not carried through water. Ozone application may not have any impact one way or another on this bacteria without significantly higher dosages that may also do damage to its host, the fish.

Table 3 presents the results of fish performance in the ozonated and unozonated systems. Contrary to what was anticipated that better water quality would result in lower mortality, mortality rate was higher in the ozonated system (10.4%) than in the unozonated (7.8%). Statistical analysis yielded in a P value of 0.047. Feed conversion ratio, defined as number of pounds of feed taken to grow a pound of fish, was tested as not significantly different. P value was 0.162 or 16.2%, not significant at 5% level.

Table 3. Effect of Ozone on Fish Performance

	Ozonated			Un-Ozonated		
Stock Date	2/25/02	3/21/02	4/17/02	2/25/02	3/21/02	4/17/02
# of Fish	42,500	42,500	60,575	42,500	42,500	27,725
Mortality (%)	10.8	9.7	10.6	7.7	6.4	9.3
	Average: 10.4			Average: 7.8		
	T test: T = 12.2 P=0.047, Significant at 5% level					
Feed Fed (lbs)	5,583	4,300	10,800	5,650	5,830	4,340
Feed Con. Rate	0.89	0.88	1.31	1.2	1.66	1.26
	Average: 1.03			Average: 1.37		
	T test: T = 9.6 P=0.162, Not Significant at 5% level					

It is apparent that during the test period, ozone had a positive effect in decreasing total suspended solids, decreasing biological oxygen demand. Results on fish performance were mixed. In all three groups, mortalities were higher in the ozonated fish. Feed conversions were better in the ozonated fish for two of the three groups tested. It also appears that rates of gain may be better in the ozonated fish since group two fish were stocked into production tanks approximately three weeks sooner than non–ozonated fish.

Conclusions that may be drawn from the tests include that water quality is improved for total suspended solids by 55% in the ozonated system and biological oxygen demand is improved by 29% in the ozonated system. This was expected and the appearance of the water in the ozonated system was much clearer compared to the non–ozonated system. It is not surprising that ozone did not have a significant impact on bacterial loading since ozone concentrations were not high enough to be bactericidal and also the major pathogen responsible for mortalities is not passed through the water but from fish to fish. What is surprising is that more mortalities occurred in the ozonated fish than in the non–ozonated fish.

While this test concluded a clear water quality benefit from the application of ozone, the economic benefit of ozonation, if any, has not been shown on the three groups of fish tested. While some tests showed improvement in feed conversions and rates of gain, increased death losses in the ozonated fish may offset the possible gains from ozonation.

LCMR Budget:	$55,000	Match:	$50,000
Balance:	$000	Match Balance:	$000

V. DISSEMINATION: The project setup, information, and results have been shared with various groups and parties. To date, the following entities have toured through the facility and ozone application:

1. Houghton Hill Farms – Lonsdale, MN
2. Nelson Aquaculture Farms – Lakota, ND
3. University of Minnesota – Aquaculture Department
4. St. Croix Aquaculture – Danbury, WI
5. North American Fish Farmers Cooperative – Binford, ND
6. Northern Tilapia – Ontario, Canada
7. Aquasafra Inc. – Bradenton, FL
8. Valadco Farmers Coop – Renville, MN
9. West Virginia Sea Grant Institute
10. Alexandria Technical College – Aquaculture Department
11. Several Minnesota High Schools with Aquaculture Projects
12. Tour for U. S. Representative from Minnesota

Groups that have toured the facility while ozone generator is operating had the benefit of visual evidence of clearer water indicating a better water quality. This facility and the ozone application will continue to be open to interested parties for dissemination of information.

VI. CONTEXT:

A. **Significance:**

1. Aquaponics. A recent report on the role of urban agriculture in promoting sustainable cities documents that urban farming of vegetables, fish, and other foods is a rapidly growing part of the world's food supply, and that this trend includes cities in industrial nations (United Nations 1996). This project involves people from local community gardening and other self sufficiency projects so that the technical design and operation is feasible for future application by these groups into environmentally sustainable production, harvest, and distribution of food from the system. As an environmental education tool, this project will teach participants and other community residents how integrated food production systems allow humans to harness the ecological recycling capabilities of living organisms. This system will be a continuous hands-on demonstration of food production coupled with waste and energy reuse.

This project will incorporate aquaculture/hydroponics systems along with urban community gardening so that the aquaculture/hydroponics/community-garden complex will: 1) reduce the waste entering into the environment by energy and nutrient recycling, 2) provide high quality fresh foods for human consumption, and 3) increase property value through urban greenery and aquarium installations. If this project is successful, as anticipated, the design and advisory council structure will likely set an example to other community gardening groups with suitable sites.

From October 1999 to September 2000, the University of Minnesota will be funded by the U.S.D.A., North Central Regional Aquaculture Center to develop methods for rearing native sunfish and hybrids in closed aquaculture systems. Results from that study will be available to help in the design and operation of the aquaponics system.

2. Water conditioning with ozonation. Recently a farmer owned, value added cooperative, MinAqua Fisheries, was formed to raise tilapia in Renville, Minnesota. Phase one construction of MinAqua Fisheries Cooperative includes a $5 million investment.

Tilapia was selected as the culture species because the market conditions are such that it is the most profitable and reliable species raised in recirculating aquaculture systems. The Minnesota Department of Natural Resources (DNR) considers tilapia a regulated exotic species. In general a farmer can import and raise tilapia on his or her farm with an importation permit from DNR if he or she can demonstrate that the fish will be raised in an indoor facility and barriers are sufficient to stop fish from escaping into the natural environment. In Minnesota, tilapia can only survive in indoor facilities due to their high temperature requirement. MinAqua Fisheries has been issued such a permit and is in good standing in compliance with the terms and conditions of the permit. Should future market conditions change so that another species emerges as a more profitable candidate, it is conceivable that the cooperative would switch species in their operation.

This state of the art facility utilizes recirculating aquaculture technology. It is the most environmentally friendly technology for aquaculture production. It is a very intensive operation with use of pure oxygen and efficient water recycling and waste collection systems. Such intensive systems conserve water and afford the ease of waste management.

Under conditions of such high production intensity, dissolved organic matter tends to accumulate which may cause water quality problems in the production system. Utilization of ozone in these systems will recondition the water by precipitating dissolved organic matter and micro-flocculating colloidal organic matter. Ozonation may also oxidize dissolved organic matter and small sized particles, therefore reduce the organic load in the fish culture systems as well as at the discharge. Water conditioning by ozonation will increase the sustainability of large intensive aquaculture systems by increasing the degree of water reuse and reduction of waste production. The development and successful employment of this technology will help establish environmentally sound aquaculture production and expand Minnesota's rural economy.

B. **Budget Context**: A 1993 LCMR project, Alternative Aquaculture Methods, looked into the basic production technology using recirculating aquaculture systems for fish production in the northern climate. MinAqua Fisheries Cooperative employs similar technology as was studied in that project. Several of the MinAqua's founders were also involved, to a varying degree, in the 1993 study. Since completion of that study, we have received funding for other related studies as listed below. The 1993 project also served as information base for this project proposal.

1. LCMR project, Alternative aquaculture methods, $230,000, studied the basic systems of recirculating aquaculture technology.

2. Minnesota Technology Inc., Suspended solids in recirculating aquaculture systems; $36,000, studied the behavior of suspended solids in recirculating aquaculture systems and how to remove them.

3. U.S.D.A. North Central Regional Aquaculture Center (NCRAC), Aquaculture wastes and effluents, $23,500, characterization of aquaculture waste effluents, their effects on fish, and how to reduce the waste discharge.

4. U.S.D.A NCRAC, Culture technology of walleye; $42,600, studied culture of walleye in recirculating aquaculture systems.

5. University of Minnesota, Walleye culture: comparison of loading densities in integrated aquaculture/hydroponics recirculating systems, $1,000.

6. MinAqua Fisheries Cooperative, approximately $5,000,000 for Renville tilapia production facility, utilizing recirculating aquaculture technology for large commercial scale production by a farmer owned cooperative.

7. U.S.D.A. NCRAC, Sunfish culture in recirculating systems; $30,000.

VII. COOPERATION:

Ira R. Adelman--University of Minnesota, Department of Fisheries and Wildlife, St. Paul. Responsibilities include: oversight and management of the aquaponics objective, no salary will incur for his time. Total amount of funds that will be contracted to him (the University) will be $9,616.

Mel Stocks--MinAqua Fisheries Cooperative, Renville. Responsibilities include: oversight and management of ozone systems' purchase, installation and operation. No salary will incur for his time. Total contracted amount will be $50,000.

Melinda Hooker--Sustainable Resources Center, Minneapolis. In-kind contribution for advice and organization of citizen participation in aquaponics systems.

VIII. LOCATION:

The aquaponics component of this project was attempted to start in metro areas of the Twin Cities. The cooperating community gardening group was to be the Seward Neighborhood Group, and possibly the Phillips Neighborhood Group, both in Minneapolis.

The ozonation component occurred in Renville, MN.