LAKE VIRGINIA

LAKE MANAGEMENT PLANNING STUDY

Prepared for:

LAKE VIRGINIA MANAGEMENT DISTRICT

MAY 1992

AYRES ASSOCIATES

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Prepared by:

AYRES ASSOCIATES

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Ayres Project No. 3113.00
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LAKE VIRGINIA
LAKE MANAGEMENT STUDY

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LAKE VIRGINIA
LAKE MANAGEMENT STUDY

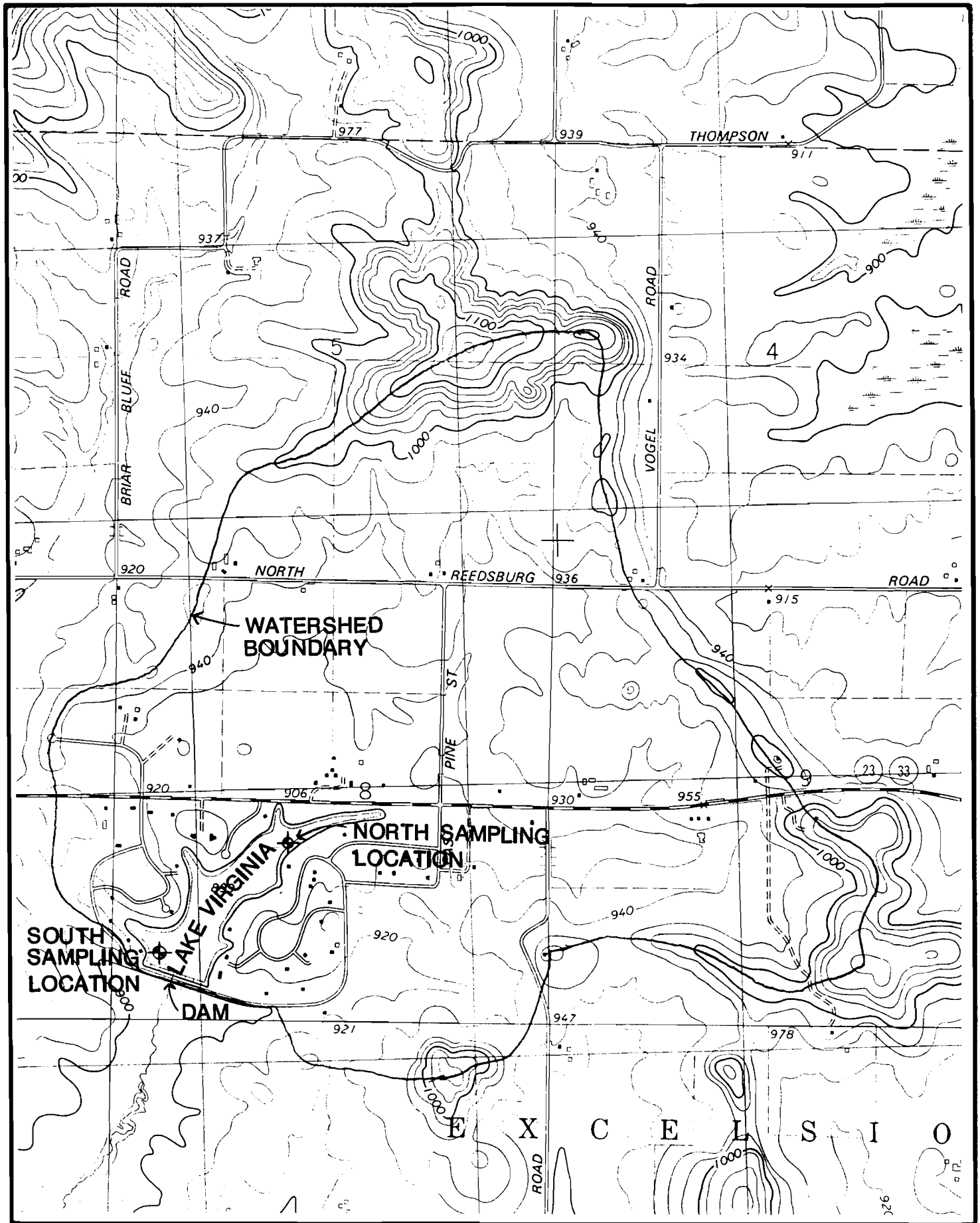
Site Description

Lake Virginia is located approximately two miles east of Reedsburg, Wisconsin in Sauk County. The 35 acre lake is created by an earth embankment dam approximately 800 feet in length. The dam was constructed in 1970. The watershed has a total drainage area of 1,190 acres and consists mainly of agricultural land including three barnyards. Figure 1 shows a map of the watershed. An aeration system was installed prior to 1985 to maintain oxygen levels in the lake. Two fish kills of unknown cause occurred in 1991. In the past several years, weeds have spread throughout the lake and are becoming a nuisance. Also, water levels have been three feet below normal pool level.

Water Quality

Water quality issues include nutrient loadings, dissolved oxygen levels, water clarity, and weeds(macrophytes). Phosphorus and nitrogen have been introduced to the lake from agricultural runoff, septic systems, and other sources and have led to water quality deterioration such as algae and weeds. Water quality is often measured by concentrations of total phosphorus and chlorophyll a and by Secchi depth readings. Secchi depth measures the clarity of the water by measuring the depth at which a black and white disk is visible. Chlorophyll a is a measure of algae present in the water.

Water samples were taken periodically at the north and south shores by the DNR in 1991 and analyzed for several water quality parameters. Figure 1 shows the locations at which the samples were taken. Table 1 shows selected data that were obtained through laboratory analyses of the samples. Complete results of the sampling and analyses are contained in Appendix B.



LAKE VIRGINIA LAKE MANAGEMENT PLANNING STUDY	Drn. By: R.FANDEL Chk. By: D.STEINES Date: MAY 1992 AYRES ASSOCIATES	WATERSHED MAP	FIGURE 1

Table 1
Lake Virginia Water Quality Data

Date Sampled	Total Phosphorus (mg/l)	Dissolved Oxygen (mg/l)	Chlorophyll a (ug/l)	Secchi Depth (m)
2-12-91				
North	0.207	7.6	54	-
South	0.157	9.2	49	-
4-2-91				
North	0.103	10.7	31	0.67
South	0.109	11.7	36	0.55
6-13-91				
North	0.320	11.0	23	1.6
South	0.201	12.4	40	1.6
7-15-91				
North	0.290	10.2	12	1.6
South	0.390	9.2	8	2.3
9-5-91				
North	0.330	9.2	8	1.4
South	0.360	8.2	15	1.5

Water quality indices have been established based on total phosphorus and Secchi depth. Water quality is considered poor for total phosphorus concentrations above 0.050 mg/l and very poor for concentrations above 0.140 mg/l. Water quality is considered poor for Secchi depth readings less than 1.5 m and very poor for readings less than 0.9 m. Based on these indices, the water quality for Lake Virginia would be considered poor to very poor.

Water quality computer simulation models were used to assess the nutrient loads in the watershed and the water quality impact due to changes in the nutrient loads. Results of the models are shown in Table 2. The models were used to estimate the total annual phosphorus load based on measured total phosphorus, chlorophyll a, and Secchi depth readings. Results indicate that the total annual phosphorus load is in the range of 400 to 600 kg. The models were again used to predict the total phosphorus, chlorophyll a and Secchi depth readings for a given phosphorus loading. Results indicate that water quality could be increased significantly by reducing the phosphorus load by 50%, resulting in a water quality index of fair.

Table 2
Water Quality Model Results

	Model 1	2	3	4
Phosphorus Load = 100 kg/yr				
Total phosphorus(mg/l)	0.040	0.044	0.064	0.050
Chlorophyll *a* (mg/l)	0.016	0.017	0.030	0.021
Secchi depth (m)	1.44	1.37	1.05	1.25
Phosphorus Load = 200 kg/yr				
Total phosphorus(mg/l)	0.081	0.088	0.128	0.081
Chlorophyll *a* (mg/m^3)	0.042	0.047	0.083	0.043
Secchi depth (m)	0.90	0.85	0.66	0.90
Phosphorus Load = 400kg/yr				
Total phosphorus(mg/l)	0.162	0.175	0.257	0.126
Chlorophyll *a* (mg/l)	0.116	0.130	0.226	0.081
Secchi depth (m)	0.56	0.53	0.41	0.67
Phosphorus Load = 600 kg/yr				
Total phosphorus(mg/l)	0.243	0.263	0.385	0.161
Chlorophyll *a* (mg/m^3)	0.208	0.233	0.406	0.115
Secchi depth (m)	0.43	0.41	0.31	0.56
Phosphorus Load = 800 kg/yr				
Total phosphorus(mg/l)	0.323	0.350	0.513	0.190
Chlorophyll *a* (mg/l)	0.316	0.354	0.616	0.145
Secchi depth (m)	0.35	0.33	0.26	0.51

Water Quality Simulation Models:
1 Dillon & Rigler(1974)
2 Vollenweider(1975)
3 Vollenweider(1976)
4 Bachman & Canfield(1979)

By controlling the nutrient loading in the watershed, water quality could be improved. Nutrients enter the lake with stormwater runoff and sediments from barnyards, cropland, and fertilized lawns. The watershed is part of a Priority Watershed Program, which may provide funding for installation of best management practices that would limit the amount of nutrients transported to stormwater runoff. Controlling nutrients and sediment will also help control the spread of weeds in the lake. Weed growth is probably aggravated by low water levels in the lake (discussed later in this report). Weed growth is related to sunlight as well as nutrient availability. Low lake levels have allowed sunlight penetration to areas not previously exposed, hence increased weed growth. The weeds could be removed by chemical or mechanical means and then controlled by improving water quality.

The Sauk County Land Conservation Department has a land use inventory that includes the Lake Virginia watershed. The data has not yet been published. This data may prove useful in identifying possible sources of incoming nutrients. The information should be reviewed when considering projects under the priority watershed program and best management practices.

Oxygen levels do not appear to be a problem based on the data collected in 1991. Oxygen levels are well above that which is required to sustain most game fish. The lowest dissolved oxygen concentration recorded from the 1991 samples was 7.6 mg/l. Generally, game fish require dissolved oxygen concentrations of at least 4 to 5 mg/l. The high dissolved oxygen in Lake Virginia is likely a result of the aeration device. Without the aerators, dissolved oxygen could be depleted in the winter due to low inflows coupled with weed decay which consumes oxygen. Fish kills in 1991 were likely caused by something other than low oxygen levels such as bacteria or disease.

Water Levels

Water levels in Lake Virginia have consistently been about three feet below normal the past few years. A generalized water budget was developed for the watershed to determine possible causes for the low water levels. The water budget components included precipitation, runoff, evaporation, groundwater flow, and surface water outflow. Precipitation, runoff, and evaporation were estimated from published data. A water balance equation was written setting outflows equal to inflows. Inflows consist of precipitation, runoff, and groundwater flow. Outflows consist of evaporation, discharge from the dam, and groundwater flow. Discharge from the dam(spillway, toe drains, and leakage) was measured during a site visit in November. During the site visit, no water was flowing over the spillway stoplogs. All flow downstream of the dam was from the toe drains and other leaks. The water budget calculations are summarized in Table 3. Figures 2 and 3 show the results graphically.

Table 3
Lake Virginia Annual Water Budget

Component	Inflow(acre-ft)	Outflow(acre-ft)
Runoff	921	-
Direct Precipitation	96	-
Evaporation	-	67
Discharge(at dam)	-	40
Groundwater	-	910
Totals	1017	1017

The water budget indicates that losses to groundwater have caused lake levels to drop. This is supported by the geologic and well construction reports for the area. The geology consists of a fine to medium sandstone very near the ground surface. Drawings of the dam indicate that material was excavated from the lake bottom to construct the embankment, possibly

LAKE VIRGINIA LAKE MANAGEMENT STUDY

LAKE INFLOWS

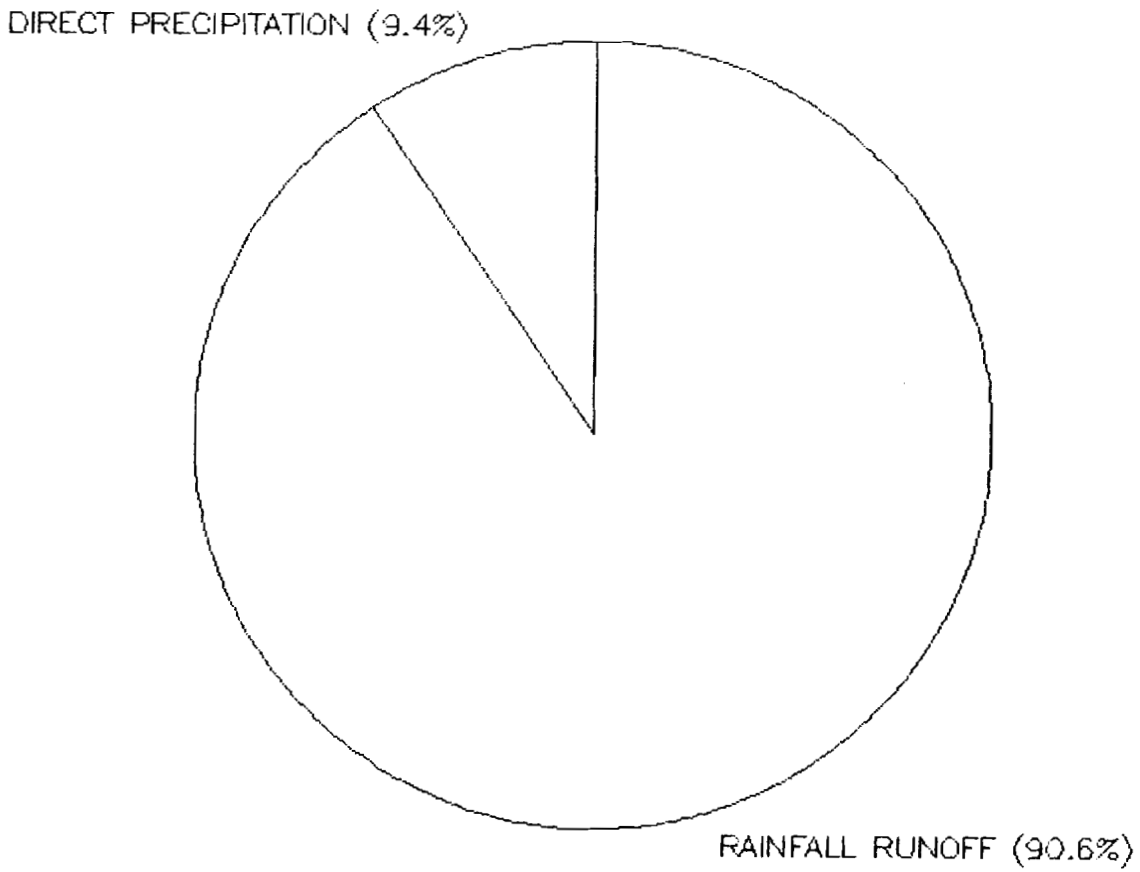


FIGURE 2

LAKE VIRGINIA LAKE MANAGEMENT STUDY

LAKE OUTFLOWS

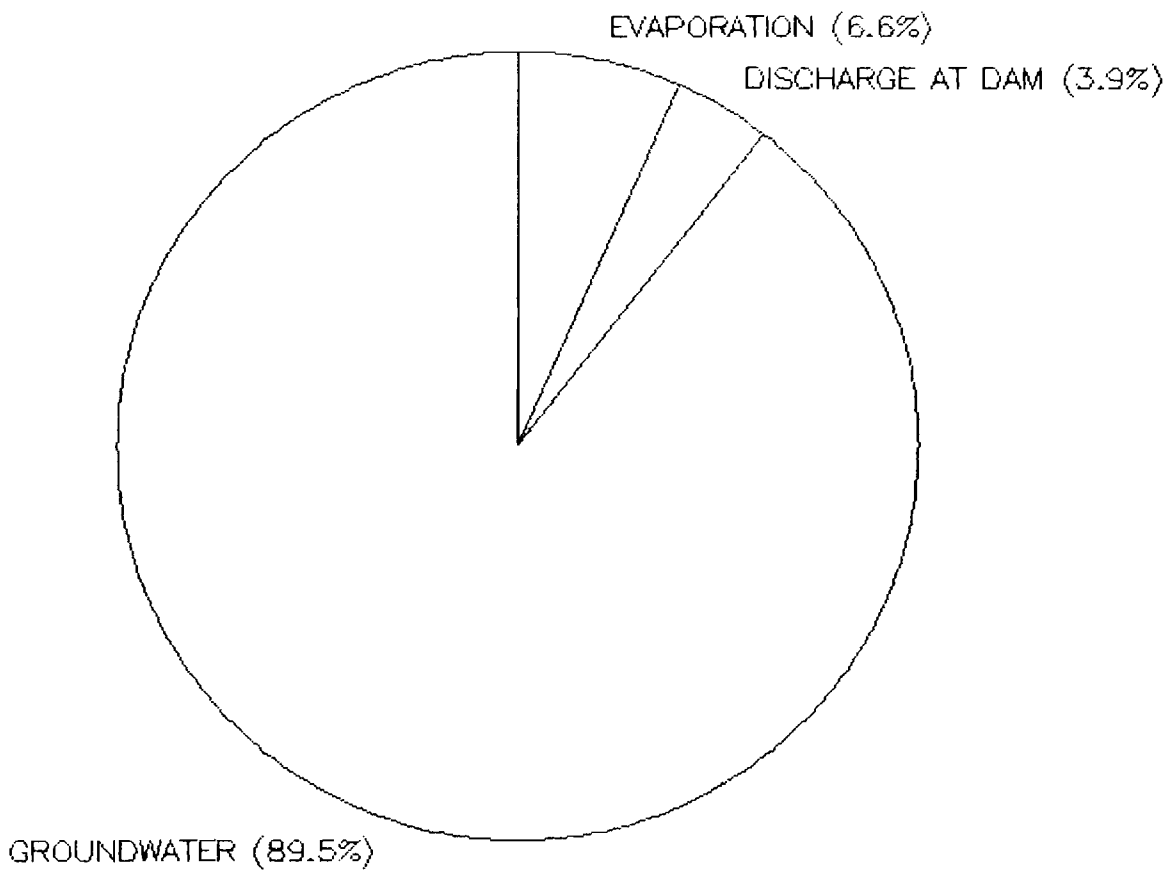


FIGURE 3

exposing the sandstone and providing a seepage area for water to escape. Computations indicate that such a sandstone is capable of transmitting fairly high flow rates. The dam is leaking as all dams do, but the leak is not nearly as significant as groundwater outflow. The total leakage accounts for less than four per cent of the total outflow.

Well construction reports indicate static water levels are generally about 15 feet below the ground surface. This indicates that the groundwater and lake levels coincide or nearly coincide. Fluctuating groundwater levels to a point below normal lake level may have caused the lake levels to drop. It is possible that the drought in the late 1980's caused the groundwater level to drop and the lake level followed, and that the groundwater level has not yet fully recovered. It is also possible that the wells around the lake are drawing the water levels down to some degree. It would be interesting to actually measure water levels in several wells around the lake and compare that to the lake level.

Summary

Water quality for Lake Virginia is generally poor based on observations and water samples. Water quality models indicate that the water quality could be improved by controlling the amount of phosphorus entering the lake in runoff and sediments. This may be achieved by applying best management practices in coordination with the priority watershed program. The Land Use Inventory for Sauk County may help identify possible nutrient sources. Dissolved oxygen levels in the lake appear to be high enough to sustain a healthy game fish population and the aerators should continue to be operated. Water levels in the lake have been consistently below normal recently. It appears that this could be a result of fluctuating groundwater levels due to the recent drought or as a result of water being drawn out through wells around the lake. Should the lake district desire to identify the problem and a potential solution, further investigation will be required. This may include groundwater monitoring wells, soil borings, geophysical surveys, and/or other investigations.

Conclusions

Based on the results of the water samples and analyses and the water budget calculations, the following conclusions can be made:

1. High in-lake phosphorus levels contribute to poor water quality and weed growth.
2. Dissolved oxygen levels are adequate to support the fishery.
3. Low lake levels are not impacted significantly be leakage through the dam.
4. Low lake levels are most likely related to low groundwater levels and/or outflow from the lake to the groundwater.

Recommendations

The following recommendations are made regarding future practices in the watershed and further studies that may help improve water quality in Lake Virginia:

1. Cooperate with officials performing the priority watershed project and promote best management practices in the watershed to minimize nutrient loading on the lake.
2. Promote judicious application of fertilizer on lawns.
3. Further investigate low lake levels by performing a groundwater analysis to determine the relationship between groundwater and lake levels.
4. Continue weed harvesting as an interim solution to improve water quality.

References

Clayton, Lee and John W. Attig, "Geology of Sauk County, Wisconsin", Wisconsin Geological and Natural History Survey, Information Circular 67, 1990.

Canfield, D. E., and R. W. Bachman, "Prediction of Total Phosphorus Concentrations, Chlorophyll a, and Secchi Depths in Natural and Artificial Lakes", Canadian Journal of Fisheries and Aquatic Sciences, Vol. 38 No. 4, 1981.

Hindall, S. M. and R. G. Borman, "Water Resources of Wisconsin - Lower Wisconsin River Basin", U.S. Geological Survey, Hydrologic Investigations Atlas HA-479, 1974.

Wisconsin Department of Natural Resources, Lake Virginia Water Sample Lab Analyses, 1991.

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#30 of 68 on 03/19/91, unseen)

Id: Point/Well/..: 172 Field #: V2 Route: WR12
Collection Date: 02/12/91 Time: 14:30 County: 57 (Sauk)
From: LAKE VIRGINIA NORTH SHORE
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 1.0 Feet
Account number: WR047 Collected by: MARSHALL/CUTTS
Waterbody/permit/..: 1278700
Date Received: 02/12/91 Labslip #: IB065565 Reported: 03/14/91

CHLOROPHYLL A UNCORRECTED	54	UG/L
PH,LAB	7.10	SU
TOTAL PHOSPHORUS, PERSULFATE, LOW LEVEL	0.207	MG/L
TEMPERATURE FIELD	1.3	C
DISSOLVED OXYGEN FIELD	7.6	MG/L
CLOUD COVER %	50	%

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#31 of 68 on 03/19/91, unseen)

Id: Point/Well/..: 172 Field #: V1 Route: WR12
Collection Date: 02/12/91 Time: 14:30 County: 57 (Sauk)
From: LAKE VIRGINIA SOUTH SHORE
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: MARSHALL/CUTTS
Waterbody/permit/..: 1278700
Date Received: 02/12/91 Labslip #: IB065566 Reported: 03/14/91

CHLOROPHYLL A UNCORRECTED	49	UG/L
PH,LAB	7.10	SU
TOTAL PHOSPHORUS, PERSULFATE, LOW LEVEL	0.157	MG/L
TEMPERATURE FIELD	1.5	C
DISSOLVED OXYGEN FIELD	9.2	MG/L
CLOUD COVER %	50	%

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#20 of 27 on 04/26/91, unseen)

Id: 573059 Point/Well/..: 173 Field #: V1 Route: WR12
Collection Date: 04/02/91 Time: 13:25 County: 57 (Sauk)
From: LAKE VIRGINIA NORTH END
Description: RUN LOW LEVEL P, IF > .2 MG/L RUN HIGH LEVEL
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: MARSHALL
Date Received: 04/03/91 Labslip #: IB077456 Reported: 04/25/91

PH LAB	7.5	SU
ALKALINITY	58.	MG/L
CALCIUM, ICP	16.	MG/L
CHLORIDE	30.	MG/L
CHLOROPHYLL A UNCORRECTED	30.56	UG/L
COLOR TRUE PT-CO	15.	SU
HARDNESS, CALCULATION METHOD	75.	MG/L
IRON, ICP	0.06	MG/L
MAGNESIUM, ICP	8.	MG/L
MANGANESE, ICP	<40.	UG/L
AMMONIA-N	0.029	MG/L
NITRATE PLUS NITRITE-N	0.018	MG/L
TOTAL KJELDAHL NITROGEN	1.6	MG/L
TOTAL PHOSPHORUS, PERSULFATE, LOW LEVEL	0.103	MG/L
DISSOLVED PHOSPHORUS, LOW RANGE	0.007	MG/L
POTASSIUM, ICP	10.	MG/L
SILICA DISSOLVED, LOW RANGE	0.6	MG/L
SODIUM, ICP	14.	MG/L
SULFATE, HIGH RANGE	19.	MG/L
TOTAL SOLIDS	178.	MG/L
TOTAL VOLATILE SOLIDS	58.	MG/L
SUSPENDED SOLIDS	8.	MG/L
TURBIDITY	3.1	NTU
TEMPERATURE FIELD	9.1	C
DISSOLVED OXYGEN FIELD	10.7	MG/L
SECCHI DEPTH	.67	M

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#21 of 27 on 04/26/91, unseen)

Id: 573059 Point/Well/..: 173 Field #: V2 Route: WR12
Collection Date: 04/02/91 Time: 13:15 County: 57 (Sauk)
From: LAKE VIRGINIA SOUTH END NEAR DAM
Description: RUN LOW LEVEL P, IF > .2 MG/L RUN HIGH LEVEL
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: MARSHALL
Date Received: 04/03/91 Labslip #: IB077457 Reported: 04/25/91

PH LAB	7.7	SU
ALKALINITY	58.	MG/L
CALCIUM, ICP	16.	MG/L
CHLORIDE	29.	MG/L
CHLOROPHYLL A UNCORRECTED	35.65	UG/L
COLOR TRUE PT-CO	15.	SU
HARDNESS, CALCULATION METHOD	75.	MG/L
IRON, ICP	0.08	MG/L
MAGNESIUM, ICP	8.	MG/L
MANGANESE, ICP	<40.	UG/L
AMMONIA-N	0.017	MG/L
NITRATE PLUS NITRITE-N	<0.015	MG/L
TOTAL KJELDAHL NITROGEN	1.6	MG/L
TOTAL PHOSPHORUS, PERSULFATE, LOW LEVEL	0.109	MG/L
DISSOLVED PHOSPHORUS, LOW RANGE	0.005	MG/L
POTASSIUM, ICP	11.	MG/L
SILICA DISSOLVED, LOW RANGE	0.7	MG/L
SODIUM, ICP	14.	MG/L
SULFATE, HIGH RANGE	19.	MG/L
TOTAL SOLIDS	182.	MG/L
TOTAL VOLATILE SOLIDS	64.	MG/L
SUSPENDED SOLIDS	12.	MG/L
TURBIDITY	3.2	NTU
TEMPERATURE FIELD	7.4	C
DISSOLVED OXYGEN FIELD	11.7	MG/L
SECCHI DEPTH	.55	M

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#12 of 16 on 07/09/91, unseen)

Id: Point/Well/..: Field #: V1 Route: WR12
Collection Date: 06/13/91 Time: 11:00 County: 57 (Sauk)
From: VIRGINIA AMBIENT MONITORING
To: LAST/SORGE
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: LAST/SORGE
Waterbody/permit/..: 1278700
Date Received: 06/13/91 Labslip #: IB100880 Reported: 07/08/91

CHLOROPHYLL A UNCORRECTED	23	UG/L
PH,LAB	10.10	SU
TOTAL PHOSPHORUS	0.32	MG/L
TEMPERATURE FIELD	25.0	C
DISSOLVED OXYGEN FIELD	11.0	MG/L
SECCHI DEPTH	1.6	M
CLOUD COVER %	0	%

Id: Point/Well/..: Field #: V2 Route: WR12
Collection Date: 06/13/91 Time: 11:30 County: 57 (Sauk)
From: VIRGINIA AMBIENT MONITORING
Description: FIELD # ON LABSLIP SAYS F2 INSTEAD OF V2.
To: LAST/SORGE
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: LAST/SORGE
Waterbody/permit/..: 1278700
Date Received: 06/13/91 Labslip #: IB100881 Reported: 06/26/91

CHLOROPHYLL A UNCORRECTED	40	UG/L
PH,LAB	9.90	SU
TOTAL PHOSPHORUS, PERSULFATE, LOW LEVEL	0.201	MG/L
TEMPERATURE FIELD	25.0	C
DISSOLVED OXYGEN FIELD	12.4	MG/L
SECCHI DEPTH	1.6	M
CLOUD COVER %	0	%

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#3 of 22 on 08/06/91, unseen)

Id: Point/Well/..: 172 Field #: V1 Route: WR12
Collection Date: 07/15/91 Time: 13:00 County: 57 (Sauk)
From: LAKE VIRGINIA AMBIENT MONITORING
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: SORGE
Waterbody/permit/..: 1278700
Date Received: 07/15/91 Labslip #: IC005660 Reported: 08/05/91

PH LAB	10.4	SU
ALKALINITY	55.	MG/L
CHLOROPHYLL A UNCORRECTED	12	UG/L
NITRATE PLUS NITRITE-N	ND (LOD=0.007	MG/L)
TOTAL PHOSPHORUS	0.29	MG/L
TEMPERATURE FIELD	27	C
DISSOLVED OXYGEN FIELD	10.2	MG/L
SECCHI DEPTH	1.6	M
CLOUD COVER %	75	%

Id: Point/Well/..: 172 Field #: V2 Route: WR12
Collection Date: 07/15/91 Time: 13:30 County: 57 (Sauk)
From: LAKE VIRGINIA AMBIENT MONITORING
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: SORGE
Waterbody/permit/..: 1278700
Date Received: 07/15/91 Labslip #: IC005661 Reported: 07/26/91

PH LAB	10.1	SU
ALKALINITY	54.	MG/L
CHLOROPHYLL A UNCORRECTED	8	UG/L
NITRATE PLUS NITRITE-N	ND (LOD=0.007	MG/L)
TOTAL PHOSPHORUS	0.39	MG/L
TEMPERATURE FIELD	26.6	C
DISSOLVED OXYGEN FIELD	9.2	MG/L
SECCHI DEPTH	2.3	M
CLOUD COVER %	75	%

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#31 of 44 on 10/23/91, unseen)

Id: Point/Well/..: Field #: V1 Route: WR12
Collection Date: 09/05/91 Time: 10:30 County: 57 (Sauk)
From: VIRGINIA, NORTH END
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: LAST/SORGE
Date Received: 09/05/91 Labslip #: IC027425 Reported: 10/22/91

PH LAB	9.6	SU
ALKALINITY	62.	MG/L
CHLOROPHYLL A UNCORRECTED	8	UG/L
AMMONIA-N	0.007	MG/L
detected between 0.005 (LOD) and 0.019 (LOQ) MG/L		
NITRATE PLUS NITRITE-N	ND (LOD=0.007 MG/L)	
TOTAL KJELDAHL NITROGEN	1.3	MG/L
TOTAL PHOSPHORUS	0.33	MG/L
TEMPERATURE FIELD	22.1	C
DISSOLVED OXYGEN FIELD	9.2	MG/L
SECCHI DEPTH	1.4	M
CLOUD COVER %	40	%

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790
Inorganic chemistry (#32 of 44 on 10/23/91, unseen)

Id: Point/Well/..: Field #: V2 Route: WR12
Collection Date: 09/05/91 Time: 10:30 County: 57 (Sauk)
From: VIRGINIA, SOUTH END
To: MARSHALL
DNR Source: Surface Water
FITCHBURG Sample depth: 0.5 Meters
Account number: WR047 Collected by: LAST/SORGE
Date Received: 09/05/91 Labslip #: IC027426 Reported: 10/22/91

PH LAB	9.3	SU
ALKALINITY	60.	MG/L
CHLOROPHYLL A UNCORRECTED	15	UG/L
AMMONIA-N	0.017	MG/L
detected between 0.005 (LOD) and 0.019 (LOQ) MG/L		
NITRATE PLUS NITRITE-N	ND (LOD=0.007 MG/L)	
TOTAL KJELDAHL NITROGEN	1.5	MG/L
TOTAL PHOSPHORUS	0.36	MG/L
TEMPERATURE FIELD	22.1	C
DISSOLVED OXYGEN FIELD	8.2	MG/L
SECCHI DEPTH	1.5	M
CLOUD COVER %	40	%

Secchi Disk Depth Readings
Taken by Lake Virginia Management District

Date	Depth in Meters
6-24-91	2.1
	1.5
7-01-91	2.1
	1.8
7-09-91	1.8
	1.1
7-23-91	2.1
	1.2
7-30-91	1.5
	2.4
8-07-91	2.4
	1.8
8-12-91	2.4
	2.1
8-21-91	2.7
	1.8
8-28-91	1.5
	2.1
9-17-91	1.2
	1.2
9-25-91	1.8
	1.8