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APPENDIX D

Watershed Analysis WiLMS Results

Date: 2/7/2018 Scenario: Plum Lake Watershed Current

Lake Id: Plum Lake

Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 3783.0 acre

Total Unit Runoff: 14 in.

Annual Runoff Volume: 4413.5 acre-ft

Lake Surface Area <As>: 1074 acre

Lake Volume <V>: 23776 acre-ft

Lake Mean Depth <z>: 22.1 ft

Precipitation - Evaporation: 5.5 in.

Hydraulic Loading: 11756.3 acre-ft/year

Areal Water Load <qs>: 10.9 ft/year

Lake Flushing Rate <p>: 0.49 1/year

Water Residence Time: 2.02 year

Observed spring overturn total phosphorus (SPO): 20.4 mg/m³

Observed growing season mean phosphorus (GSM): 14.1 mg/m³

% NPS Change: 0%

% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High	
		Loading (kg/ha-year)				Loading (kg/year)			
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0	0
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0	0
Pasture/Grass	316	0.10	0.30	0.50	8.6	13	38	64	
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0	0
Rural Res (>1 Ac)	15	0.05	0.10	0.25	0.1	0	1	2	
Wetlands	1763	0.10	0.10	0.10	16.0	71	71	71	
Forest	1689	0.05	0.09	0.18	13.8	34	62	123	
Lake Surface	1074.0	0.10	0.30	1.00	29.2	43	130	435	

POINT SOURCE DATA

Point Sources	Water Load (m ³ /year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %	
West Plum Lake Subwatershed	1050000	0.0	32	0.0	7.2	
Aurora Lake Subwatershed	3750000	0.0	72	0.0	16.1	
Star Lake Subwatershed	3650000	0.0	37	0.0	8.3	

SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.3	0.5	0.8	
# capita-years	67			
% Phosphorus Retained by Soil	98	90	80	
Septic Tank Loading (kg/year)	0.40	3.35	10.72	0.8

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	358.2	984.5	1554.7	100.0
Total Loading (kg)	162.5	446.6	705.2	100.0
Areal Loading (lb/ac-year)	0.33	0.92	1.45	0.0
Areal Loading (mg/m ² -year)	37.38	102.75	162.26	0.0
Total PS Loading (lb)	0.0	310.8	0.0	31.6
Total PS Loading (kg)	0.0	141.0	0.0	31.6
Total NPS Loading (lb)	261.5	378.8	572.9	67.7
Total NPS Loading (kg)	118.6	171.8	259.8	67.7

Phosphorus Prediction and Uncertainty Analysis Module

Date: 2/7/2018 Scenario: 292

Observed spring overturn total phosphorus (SPO): 20.4 mg/m³

Observed growing season mean phosphorus (GSM): 14.1 mg/m³

Back calculation for SPO total phosphorus: 0.0 mg/m³

Back calculation GSM phosphorus: 0.0 mg/m³

% Confidence Range: 70%

Nurenberg Model Input - Est. Gross Int. Loading: 0 kg

Lake Phosphorus Model	Low	Most Likely	High	Predicted	% Dif.
	Total P	Total P	Total P	-Observed	
	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	
Walker, 1987 Reservoir	5	15	24	1	7
Canfield-Bachmann, 1981 Natural Lake	7	14	20	0	0
Canfield-Bachmann, 1981 Artificial Lake	7	14	19	0	0
Rechow, 1979 General	2	7	10	-7	-50
Rechow, 1977 Anoxic	8	21	33	7	50
Rechow, 1977 water load<50m/year	3	9	15	-5	-35
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	5	14	23	-6	-29
Vollenweider, 1982 Combined OECD	5	12	18	-5	-29
Dillon-Rigler-Kirchner	3	8	13	-12	-59
Vollenweider, 1982 Shallow Lake/Res.	4	10	14	-7	-41
Larsen-Mercier, 1976	5	13	20	-7	-34
Nurnberg, 1984 Oxidic	3	9	14	-5	-35

Lake Phosphorus Model	Confidence		Parameter Fit?	Back Calculation (kg/year)	Model Type
	Lower Bound	Upper Bound			
Walker, 1987 Reservoir	8	23	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	4	40	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	4	40	FIT	1	GSM
Rechow, 1979 General	3	10	FIT	0	GSM
Rechow, 1977 Anoxic	11	31	FIT	0	GSM
Rechow, 1977 water load<50m/year	4	14	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	6	24	FIT	0	SPO
Vollenweider, 1982 Combined OECD	5	21	FIT	0	ANN
Dillon-Rigler-Kirchner	4	12	L	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	4	17	FIT	0	ANN
Larsen-Mercier, 1976	7	19	Pin	0	SPO
Nurnberg, 1984 Oxidic	4	15	FIT	0	ANN

Water and Nutrient Outflow Module

Date: 2/7/2018 Scenario: 253

Average Annual Surface Total Phosphorus: 14.1mg/m³

Annual Discharge: 1.18E+004 AF => 1.45E+007 m³

Annual Outflow Loading: 431.0 LB => 195.5 kg

Date: 2/7/2018 Scenario: West Plum Lake Watershed Current

Lake Id: West Plum Lake

Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 699.0 acre

Total Unit Runoff: 14 in.

Annual Runoff Volume: 815.5 acre-ft

Lake Surface Area <As>: 71 acre

Lake Volume <V>: 178 acre-ft

Lake Mean Depth <z>: 2.5 ft

Precipitation - Evaporation: 5.5 in.

Hydraulic Loading: 848.0 acre-ft/year

Areal Water Load <qs>: 11.9 ft/year

Lake Flushing Rate <p>: 4.76 1/year

Water Residence Time: 0.21 year

Observed spring overturn total phosphorus (SPO): 0.0 mg/m³

Observed growing season mean phosphorus (GSM): 31.8 mg/m³

% NPS Change: 0%

% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		Loading (kg/ha-year)				Loading (kg/year)		
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	94	0.10	0.30	0.50	26.8	4	11	19
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	2	0.05	0.10	0.25	0.2	0	0	0
Wetlands	142	0.10	0.10	0.10	13.5	6	6	6
Forest	461	0.05	0.09	0.18	39.4	9	17	34
Lake Surface	71.0	0.10	0.30	1.00	20.2	3	9	29

POINT SOURCE DATA

Point Sources	Water Load (m ³ /year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %
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SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.3	0.5	0.8	
# capita-years		0.0		
% Phosphorus Retained by Soil	98	90	80	
Septic Tank Loading (kg/year)	0.00	0.00	0.00	0.0

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	48.0	94.0	192.4	100.0
Total Loading (kg)	21.8	42.7	87.3	100.0
Areal Loading (lb/ac-year)	0.68	1.32	2.71	0.0
Areal Loading (mg/m ² -year)	75.85	148.44	303.79	0.0
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	41.7	75.0	129.1	100.0
Total NPS Loading (kg)	18.9	34.0	58.6	100.0

Phosphorus Prediction and Uncertainty Analysis Module

Date: 2/7/2018 Scenario: 291

Observed spring overturn total phosphorus (SPO): 0.0 mg/m³Observed growing season mean phosphorus (GSM): 31.8 mg/m³Back calculation for SPO total phosphorus: 0.0 mg/m³Back calculation GSM phosphorus: 0.0 mg/m³

% Confidence Range: 70%

Nuremberg Model Input - Est. Gross Int. Loading: 0 kg

Lake Phosphorus Model	Low	Most Likely	High	Predicted	% Dif.
	Total P	Total P	Total P	-Observed	
	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	
Walker, 1987 Reservoir	17	33	67	1	3
Canfield-Bachmann, 1981 Natural Lake	16	30	55	-2	-6
Canfield-Bachmann, 1981 Artificial Lake	15	27	46	-5	-16
Rechow, 1979 General	5	9	19	-23	-72
Rechow, 1977 Anoxic	18	35	72	3	9
Rechow, 1977 water load<50m/year	14	28	58	-4	-13
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	14	24	43	8	50
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	11	19	36	3	19
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxidic	6	13	26	-19	-60

Lake Phosphorus Model	Confidence		Parameter	Back	Model
	Lower	Upper			
	Bound	Bound		(kg/year)	
Walker, 1987 Reservoir	20	57	z	0	GSM
Canfield-Bachmann, 1981 Natural Lake	9	86	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	8	78	FIT	1	GSM
Rechow, 1979 General	5	16	FIT	0	GSM
Rechow, 1977 Anoxic	21	60	FIT	0	GSM
Rechow, 1977 water load<50m/year	16	49	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	12	44	FIT	0	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	10	35	FIT	0	ANN
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxid	7	23	FIT	0	ANN

Water and Nutrient Outflow Module

Date: 2/7/2018 Scenario: 252
Average Annual Surface Total Phosphorus: 31.8mg/m³
Annual Discharge: 8.48E+002 AF => 1.05E+006 m³
Annual Outflow Loading: 70.3 LB => 31.9 kg

Date: 2/7/2018 Scenario: Star Lake Watershed Current

Lake Id: Star Lake

Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 1590.0 acre

Total Unit Runoff: 14 in.

Annual Runoff Volume: 1855.0 acre-ft

Lake Surface Area <As>: 1240 acre

Lake Volume <V>: 28092 acre-ft

Lake Mean Depth <z>: 22.7 ft

Precipitation - Evaporation: 5.5 in.

Hydraulic Loading: 2956.0 acre-ft/year

Areal Water Load <qs>: 2.4 ft/year

Lake Flushing Rate <p>: 0.11 1/year

Water Residence Time: 9.50 year

Observed spring overturn total phosphorus (SPO): 20.7 mg/m³

Observed growing season mean phosphorus (GSM): 10.7 mg/m³

% NPS Change: 0%

% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		Loading (kg/ha-year)				Loading (kg/year)		
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	220	0.10	0.30	0.50	10.1	9	27	45
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	6	0.05	0.10	0.25	0.1	0	0	1
Wetlands	627	0.10	0.10	0.10	9.6	25	25	25
Forest	737	0.05	0.09	0.18	10.2	15	27	54
Lake Surface	1240.0	0.10	0.30	1.00	57.1	50	151	502

POINT SOURCE DATA

Point Sources	Water Load (m ³ /year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %
Little Star Lake Subwatershed	657000	0.0	33	0.0	12.5

SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.3	0.5	0.8	
# capita-years	17			
% Phosphorus Retained by Soil	98	90	80	
Septic Tank Loading (kg/year)	0.10	0.85	2.72	0.3

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	219.6	581.1	1386.1	100.0
Total Loading (kg)	99.6	263.6	628.7	100.0
Areal Loading (lb/ac-year)	0.18	0.47	1.12	0.0
Areal Loading (mg/m ² -year)	19.85	52.52	125.29	0.0
Total PS Loading (lb)	0.0	72.8	0.0	12.5
Total PS Loading (kg)	0.0	33.0	0.0	12.5
Total NPS Loading (lb)	108.7	174.5	273.8	87.2
Total NPS Loading (kg)	49.3	79.2	124.2	87.2

Phosphorus Prediction and Uncertainty Analysis Module

Date: 2/7/2018 Scenario: 290

Observed spring overturn total phosphorus (SPO): 20.7 mg/m³Observed growing season mean phosphorus (GSM): 10.7 mg/m³Back calculation for SPO total phosphorus: 0.0 mg/m³Back calculation GSM phosphorus: 0.0 mg/m³

% Confidence Range: 70%

Nuremberg Model Input - Est. Gross Int. Loading: 0 kg

Lake Phosphorus Model	Low	Most Likely	High	Predicted	% Dif.
	Total P	Total P	Total P	-Observed	
	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	
Walker, 1987 Reservoir	9	24	57	13	121
Canfield-Bachmann, 1981 Natural Lake	8	15	25	4	37
Canfield-Bachmann, 1981 Artificial Lake	9	16	25	5	47
Rechow, 1979 General	2	4	10	-7	-65
Rechow, 1977 Anoxic	10	26	63	15	140
Rechow, 1977 water load<50m/year	2	6	15	-5	-47
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	8	22	52	1	5
Vollenweider, 1982 Combined OECD	7	16	33	0	0
Dillon-Rigler-Kirchner	6	17	41	-4	-19
Vollenweider, 1982 Shallow Lake/Res.	5	13	27	-3	-19
Larsen-Mercier, 1976	7	18	42	-3	-14
Nurnberg, 1984 Oxidic	5	14	34	3	28

Lake Phosphorus Model	Confidence		Parameter	Back	Model
	Lower	Upper			
	Bound	Bound	Fit?	Calculation	Type
				(kg/year)	
Walker, 1987 Reservoir	13	46	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	5	43	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	5	46	FIT	1	GSM
Rechow, 1979 General	2	8	L qs	0	GSM
Rechow, 1977 Anoxic	14	50	FIT	0	GSM
Rechow, 1977 water load<50m/year	3	12	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	10	44	FIT	0	SPO
Vollenweider, 1982 Combined OECD	7	31	FIT	0	ANN
Dillon-Rigler-Kirchner	9	33	P L qs p	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	6	25	FIT	0	ANN
Larsen-Mercier, 1976	10	34	P Pin	0	SPO
Nurnberg, 1984 Oxid	7	28	FIT	0	ANN

Water and Nutrient Outflow Module

Date: 2/7/2018 Scenario: 251

Average Annual Surface Total Phosphorus: 10.7mg/m³

Annual Discharge: 2.96E+003 AF => 3.65E+006 m³

Annual Outflow Loading: 82.2 LB => 37.3 kg

Date: 2/7/2018 Scenario: Little Star Watershed Current

Lake Id: Little Star Lake

Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 417.0 acre

Total Unit Runoff: 14 in.

Annual Runoff Volume: 486.5 acre-ft

Lake Surface Area <As>: 101 acre

Lake Volume <V>: 447 acre-ft

Lake Mean Depth <z>: 4.4 ft

Precipitation - Evaporation: 5.5 in.

Hydraulic Loading: 532.8 acre-ft/year

Areal Water Load <qs>: 5.3 ft/year

Lake Flushing Rate <p>: 1.19 1/year

Water Residence Time: 0.84 year

Observed spring overturn total phosphorus (SPO): 0.0 mg/m³

Observed growing season mean phosphorus (GSM): 51.7 mg/m³

% NPS Change: 0%

% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High	
		Loading (kg/ha-year)				Loading (kg/year)			
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0	0
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0	0
Pasture/Grass	49	0.10	0.30	0.50	18.4	2	6	10	
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0	0
Rural Res (>1 Ac)	6	0.05	0.10	0.25	0.8	0	0	1	
Wetlands	115	0.10	0.10	0.10	14.4	5	5	5	
Forest	247	0.05	0.09	0.18	27.8	5	9	18	
Lake Surface	101.0	0.10	0.30	1.00	37.9	4	12	41	

POINT SOURCE DATA

Point Sources	Water Load (m ³ /year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %

SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.3	0.5	0.8	
# capita-years	5			
% Phosphorus Retained by Soil	98	90	80	
Septic Tank Loading (kg/year)	0.03	0.25	0.80	0.8

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	35.0	71.3	165.0	100.0
Total Loading (kg)	15.9	32.4	74.8	100.0
Areal Loading (lb/ac-year)	0.35	0.71	1.63	0.0
Areal Loading (mg/m ² -year)	38.84	79.16	183.11	0.0
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	25.9	43.7	73.1	99.2
Total NPS Loading (kg)	11.8	19.8	33.2	99.2

Phosphorus Prediction and Uncertainty Analysis Module

Date: 2/7/2018 Scenario: 289

Observed spring overturn total phosphorus (SPO): 0.0 mg/m³Observed growing season mean phosphorus (GSM): 51.7 mg/m³Back calculation for SPO total phosphorus: 0.0 mg/m³Back calculation GSM phosphorus: 0.0 mg/m³

% Confidence Range: 70%

Nurenberg Model Input - Est. Gross Int. Loading: 0 kg

Lake Phosphorus Model	Low	Most Likely	High	Predicted	% Dif.
	Total P	Total P	Total P	-Observed	
	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	
Walker, 1987 Reservoir	16	33	76	-19	-37
Canfield-Bachmann, 1981 Natural Lake	15	26	50	-26	-50
Canfield-Bachmann, 1981 Artificial Lake	14	24	42	-28	-54
Rechow, 1979 General	3	6	14	-46	-89
Rechow, 1977 Anoxic	19	39	89	-13	-25
Rechow, 1977 water load<50m/year	10	21	47	-31	-60
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	12	22	44	-4	-15
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	9	18	37	-8	-31
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxidic	6	12	27	-40	-77

Lake Phosphorus Model	Confidence		Parameter	Back	Model
	Lower	Upper			
	Bound	Bound		(kg/year)	
Walker, 1987 Reservoir	19	62	z	0	GSM
Canfield-Bachmann, 1981 Natural Lake	8	75	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	7	69	FIT	1	GSM
Rechow, 1979 General	3	11	FIT	0	GSM
Rechow, 1977 Anoxic	23	72	FIT	0	GSM
Rechow, 1977 water load<50m/year	12	39	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	11	42	FIT	0	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	9	34	FIT	0	ANN
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxidic	6	23	FIT	0	ANN

Water and Nutrient Outflow Module

Date: 2/7/2018 Scenario: 250

Average Annual Surface Total Phosphorus: 51.7mg/m³

Annual Discharge: 5.33E+002 AF => 6.57E+005 m³

Annual Outflow Loading: 71.6 LB => 32.5 kg

