APPENDIX C – INVESTIGATION AND ANALYSIS

PHYSICAL ENVIRONMENTAL SETTING

Climate. Sources of runoff within the watershed include 1) surface runoff from snowmelt or excessive rainfall and 2) subsurface flow from shallow and deep groundwater sources. A typical runoff sequence for this region of Minnesota includes 1) a long duration snowmelt runoff, 2) flashy growing season runoff from high intensity thunderstorm events, and 3) fall low volume/peak flow events. As can be expected, there are exceptions - the fall of 2004 and fall of 2005 had significant runoff amounts compared to typical years. Table 1C displays the monthly averages for Detroit Lakes Region.

Table 1C - Precipitation, Temperature, and Runoff Data[1] for the Detroit Lakes Region

Month	Average Temp (deg F)	Precip (inches)	Precip (% of yearly total)	Runoff (watershed inches)	Runoff (% of yearly total)
January	6.1	0.76	2.9%	0.34	5.3%
February	13.7	0.57	2.2%	0.32	5.0%
March	26.9	1.15	4.4%	0.46	7.2%
April	43.0	1.54	5.8%	0.89	13.9%
May	56.9	2.97	11.3%	0.84	13.2%
June	64.6	4.41	16.7%	0.68	10.7%
July	69.3	4.03	15.3%	0.56	8.8%
August	67.9	3.67	13.9%	0.47	7.4%
September	58.0	3.02	11.5%	0.45	7.1%
October	45.7	2.50	9.5%	0.50	7.8%
November	27.6	1.10	4.2%	0.47	7.4%
December	12.4	0.64	2.4%	0.40	6.3%
Total (Avg for Temp)	41.0	26.36	100%	6.38	100%

LAND USE and LAND COVER

Historically the Pelican River Watershed (PRW) was a heavily forested area characterized by late succession hardwood species, predominately Oak and Maple. As settlers moved into the area these forest began to be harvested for timber production. Because of the fertile soils provided by forested and wetland areas, large portions of the region were cleared and drained for agricultural production. The success of the forestry and agriculture industry in addition to the aesthetic quality of the region continued to draw people to the region, and thus increased the industrial and urban areas across the landscape.

Today, the PRW is a heterogeneous landscape dominated by surface water (33%), agriculture (30%) and deciduous forest (21%) (Table 2C, Figure 1C). The developed areas in the watershed and surrounding region have increased over time and will most likely to continue into the future.

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[1] Precipitation and temperature data from NOAA Publication "Climatography of the United States No. 81". Uses 1971-2000 data from the Detroit Lake Climate Station. Runoff values from USGS Stream Gage Station No. 05244000 Crow Wing River at Nimrod (1,030 square mile drainage area) - 1940 - 2003.

Figure 1C – Land Cover

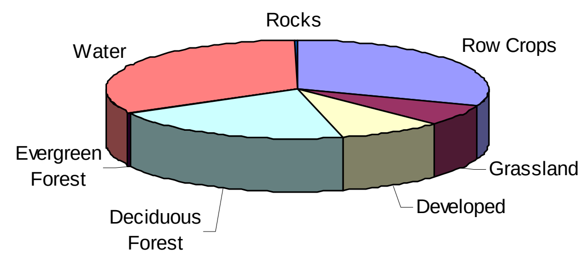


Table 2C – Land Cover

Land Cover/Land Use	Acreage
Water	15,084
Row Crops	14,042
Deciduous Forest	9,658
Developed	4,074
Grassland	3,119
Rocks	66
Evergreen Forest	58

Agriculture. Becker County has a well established agricultural economy (Table 3C). According to the 2002 Census of Agriculture, the county was home to 1,254 farms totaling 416,554 acres. The number of farms has increased since 1997 however the acres in farmland have declined slightly. Livestock accounted for roughly half of the 2002 cash receipts (35th in the state), while crops were just close behind at 45%. The livestock population of Becker County is dominated by cattle, with beef cattle ranking 17th overall for the state. Crops are comprised of corn, soybean and small grains. Wheat and soybeans produced the largest harvest in terms of total bushels, while hay harvests ranked 12th in the state.

Table 3C - Descriptive Statistics for Becker County Farms

Farm Demographics 1/	1997	2002	Crops - 2003	Acres Harvested	Yield	Production	Rank
Number of Farms	1,210	1,254	Corn, Bu.	12,900	101	1,302,900	66
Total Land in Farms, Acres	442,673	416,554	Soybeans, Bu.	85,500	26	2,223,000	47
Average Farm Size, Acres	366	332	All Wheat, Bu.	57,100	55	3,140,500	10
Total Cropland, Acres	310,414	294,964	Oats, Bu.	5,100	63	321,300	17
Average Age of Farmers	51.6	53.8	All Hay, Tons	45,400	2.3	106,300	12
Cash Receipts - 2002 2/	**1,000 $**	**Rank**	**Livestock**			**Number**	**Rank**
Crops	50,397	47	Hogs and Pigs (December 1, 2003)			9,500	54
Livestock	56,456	35	Cattle (January 1, 2004)			31,000	24
Government Payments	4,482	44	Beef Cows (January 1, 2004)			7,500	17
Total	111,335	42	Milk Cows (January 1, 2004)			6,500	22

1/ 2002 MN Census of Agriculture
2/ 2005 dollars

Prime Farmland. Looking closely at the soils within the watershed boundary, roughly half of the acreage (22,554 acres) is either prime farmland, of statewide importance, or prime farmland if drained, Table 4C.

Table 4C - Acres of Prime or Statewide Importance Farmland

Farmland Rating	Acres
Not prime farmland	23,557
Farmland of statewide importance	15,307
All areas are prime farmland	5,429
Prime farmland if drained	1,817
Total*	46,110

**Total acres are based on watershed boundaries and not the entire county*

Livestock Assessment. During the summer of 2004, NRCS conducted a livestock assessment for the UPRW project area. The assessment noted the following:

- Only 2 active dairies are within the watershed boundary and both dairies were viewed as non-contributors to the phosphorus concerns along the Pelican River.
- Many poultry operations were identified within the watershed. Each site indicated that they had signed a contract to deliver 100% of their litter to the Fiber Watt plant being built in Benson, MN.
- Because the poultry litter is or will be leaving the watershed, the litter does not appear to be a significant contributor of phosphorus.
- Lastly, the assessment concluded that in the recent past, more farms were raising livestock. This could indicate that the animals may become a contributor of phosphorus. Currently the animal unit numbers and the nutrient runoff plans found during the assessment revealed that the existing livestock and poultry industries are not a major contributor to the phosphorus peaks detected.

HYDROLOGY

Surface Water. The Upper Pelican River flows through the following lakes: North Floyd, Big Floyd, Little Floyd, Little Detroit and Big Detroit. Information was obtained from Lake Finder available through Minnesota Department of Natural Resources (MN DNR)[2]. Table 5C displays information about each lake, North Floyd and Big Floyd are considered one basin, and Little and Big Detroit are considered as another in this table.

Table 5C - Water Level Data

BASIN NAME	Little Floyd	Big Floyd	Detroit
Period of Record	04/06/1943 to 10/07/2006	10/23/1956 to 10/27/2003	08/25/1943 to 05/20/2006
# of readings	1337	324	3619
Highest recorded	1355.7 ft (04/22/1997)	1356.5 ft (07/29/1993)	1335.78 ft (07/11/1998)
Lowest recorded	1353.54 ft (09/25/1970)	1353.61 ft (10/23/1956)	1333.34 ft (10/02/1974)
Average water level	1354.55 ft	1354.69 ft	1334.09 ft
OHW elevation	1354.8 ft	1354.8 ft	1334.3 ft

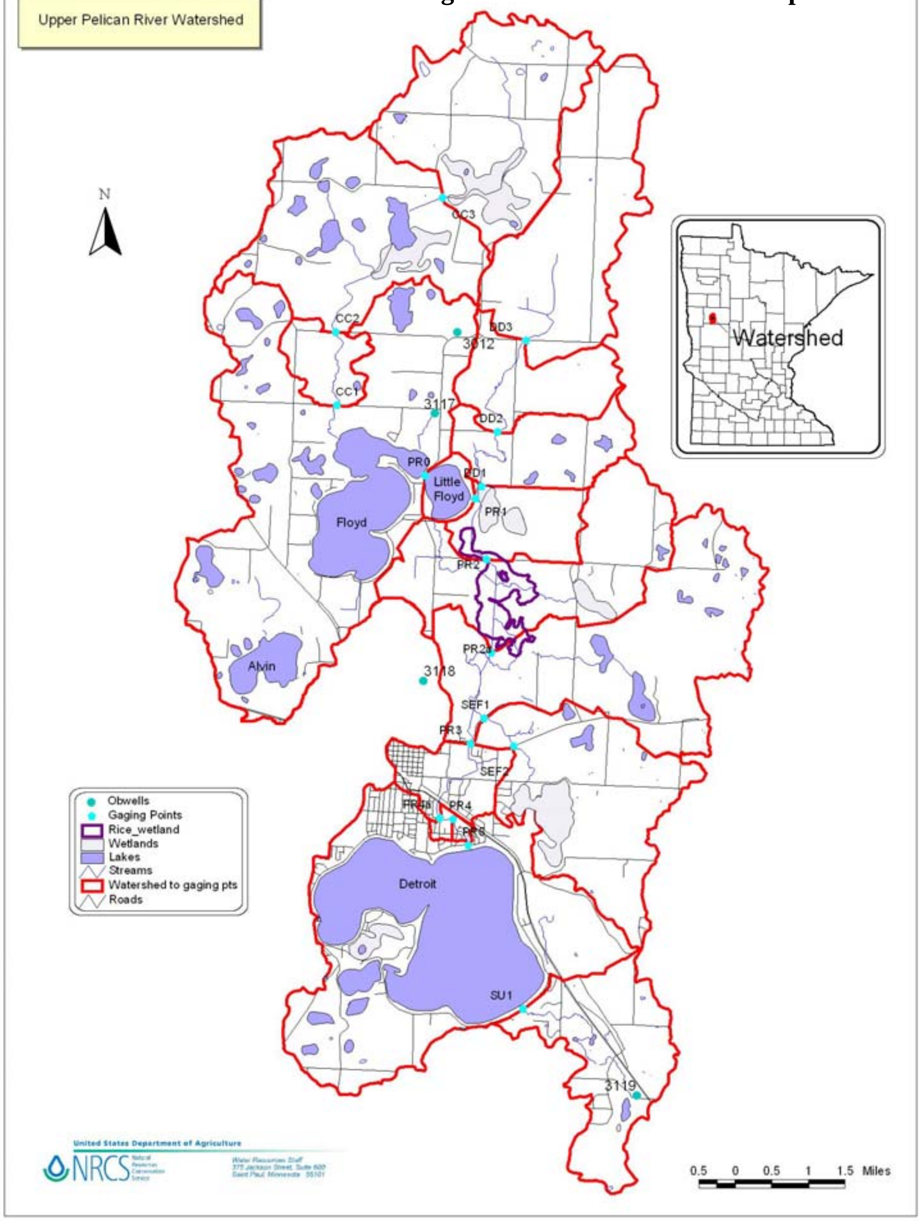
[2] Lake Finder website: www.dnr.state.mn.us/lakefind/index.html

Additional lake data has been collected and summarized in Table 6C. The data below is compiled from various sources which include: PRWD, MN DNR, and MPCA.

Table 6C - Lake Data

	Big Floyd	North Floyd	Little Floyd	Big Detroit	Little Detroit
DNR Lake ID	03-387a	03-387b	03-386	03-381a	03-381b
Surface Area (GIS)	862	298	217	2076	941
Shoreline Length (miles)	5.5	3.6	2.2	7.7	4.8
Lake Area					
% less than 15 ft deep	70	w/BF	47	40	90
% less than 10 ft deep	65.6	44.5	43.0	37.5	73.2
Average depth (ft)	11.8	16	14.6	18.4	8.5
Maximum depth (ft)	26	31	22	82	16
Number of outlets	1	1	2	1	2
Number of inlets	1	2	1	4	1
Inflow (annual ac-ft)	N/A	6428	11478	6000	6000
Inflow (annual million of cubic meters)	N/A	7.9	14.2	7.4	7.4
Residence time (days)	N/A	271	104	2287	487
Shoreline with no modification (%)	10	61	17	19	6
Retaining Walls	101	3	14	80	35
Sand blanketed shoreline (%)	18	2	7	10	14
Rip-rapped shoreline (%)	19	4	11	34	21
Boats	361	16	60	337	270
Personal watercraft	33	2	2	64	48
First Tier Residence including RV's	183	21	80	236	158
Second Tier Residence	65	6	28	96	320
Total Phosphorus–summer average(ug/L)					
1995	23	40.4	38	26.3	28
1996	14.8	25	20	19.8	16
1997	19.5	35	20	22.6	29.3
1998	16	36.8	30	36.7	34.8
1999	17.4	30.2	27	23.5	19.8
2000	14	36.7	19.3	24.3	18.2
2001	19.1	27.8	22.2	30.4	25
2002	15	29	19	26	21
2003	11.8	25.4	21	22.5	23.5
Secchi – summer average (ft) 1995	10	9.5	7	8.3	8.6
1996	7.9	7.5	-	10.9	11.3
1997	11.5	6	7.4	8.5	9.2
1998	11.8	6.9	7.4	7.3	8.8
1999	13.5	7.9	9.4	6.3	9.7
2000	12.3	7.6	9.5	9.5	11.7
2001	13	8	11	9	10
2002	10.3	8.6	14.3	10.7	11.8
2003	9	7.8	8.9	11.1	11.8

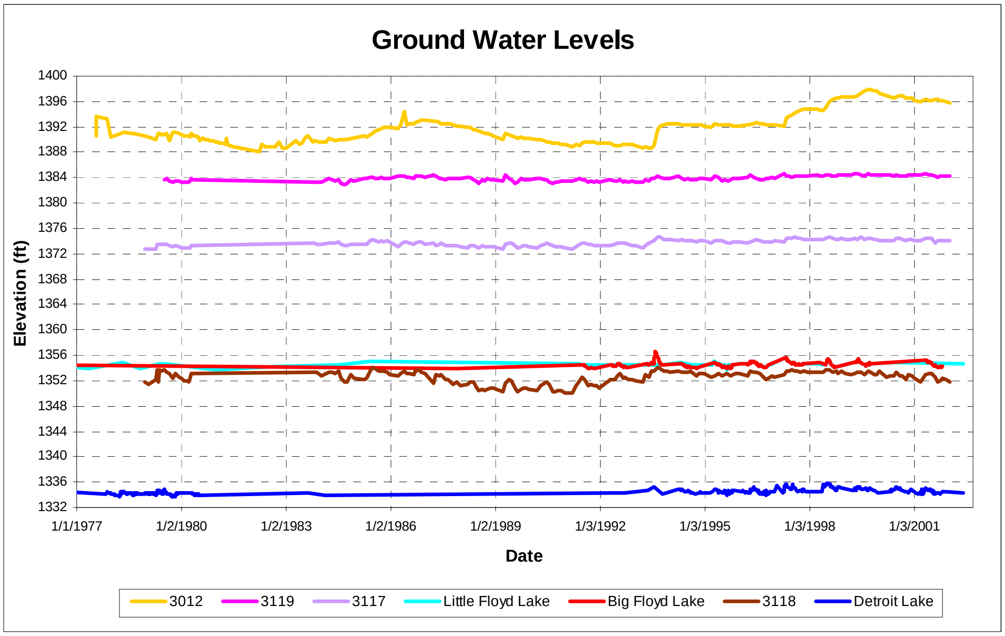
Figure 2C - Obwell Location Map



Groundwater. Minnesota Department of Natural Resources has a network of observation wells (obwells) established around the state. The obwells are monitored to estimate the groundwater movement and can be used to determine the groundwater recharge rates within the area around the well. Figure 2C shows the obwell network within the watershed which includes 4 monitoring locations in or near UPRW- wells numbered #3012, #3117, #3118, & #3119.

These wells indicate that the groundwater is generally moving through the UPRW in a south-southwestern direction, Figure 3C. The volume of groundwater movement has not been estimated for the watershed. Besides the wetlands and lakes acting as groundwater recharge areas, the surface landlocked area would also contribute to the groundwater flow.

Figure 3C - Past Groundwater Levels



PELICAN RIVER WATERSHED AND HYDROLOGIC MODELING

The magnitude of peak flows and duration of runoff from snowmelt and rainfall depends on the type of hydrologic system. For the Upper Pelican River Watershed, flows are stored then released from lakes and wetlands along the river's main course resulting in long duration/low peak discharges for a watershed of its size. Figure 4C is a schematic representation of how runoff moves throughout the watershed.

A watershed hydrologic model has been developed for use in the planning phase of this project. The model is used in conjunction with nutrient concentration data to simulate total loadings at various points in the watershed for with and without project conditions. The continuous model uses daily runoff values from the GLEAMS water quality model[3] to create hydrographs. These hydrographs are then in turn routed through the hydrologic system accounting for storage and evaporation. The model was set up to simulate runoff conditions for the period 1961 through 2001 using Detroit Lakes precipitation records from that same period. A typical set of simulated hydrographs for the watershed is shown in Figure 5C. This Figure shows the "hydrologic buffering" effects of storage (lakes/wetlands) on runoff hydrographs (compare Campbell Creek and Outflows from Little Floyd).

[3] The GLEAMS model was used to determine the non-point source nutrient loadings for the watershed.

Figure 4C - Upper Pelican Routing Schematic

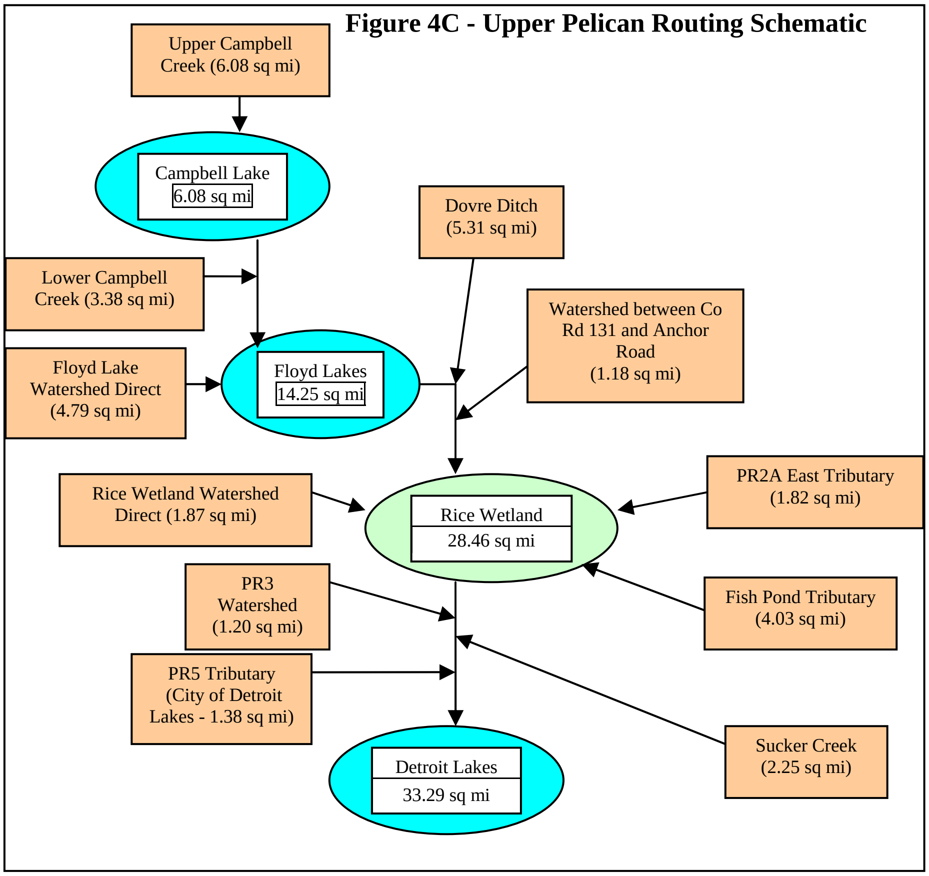
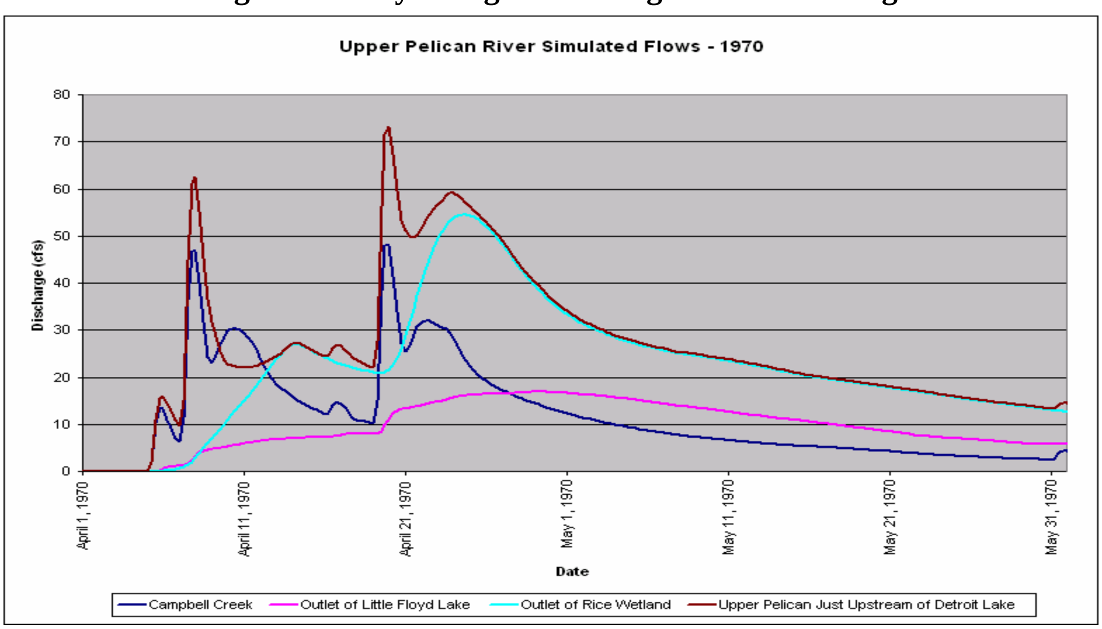


Figure 5C - Hydrologic Buffering Effects of Storage



In Figure 6C, the watershed boundary developed by NRCS and used in the project is shown. The map displays the entire Upper Pelican River Watershed, monitoring station locations, and sub watershed boundary. Figure 6C also identifies areas that do not contribute to the overland flow and are considered landlocked areas (yellow highlighted areas).

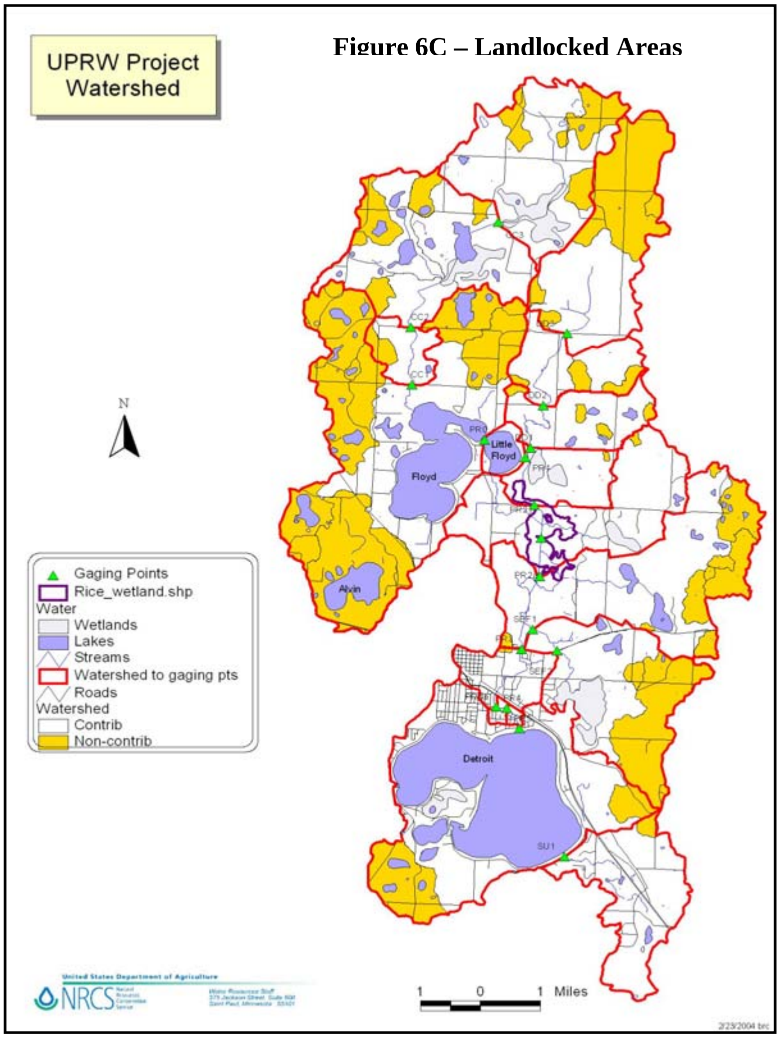


Figure 6C – Landlocked Areas

<u>Inundation Area/Duration Effects</u>. Hydrologic impacts of restoring two wetland areas within the Upper Pelican Project area were analyzed. The two proposed restoration areas are 1) the main Rice Lake Wetland and 2) Lower Rice Wetland (drained wet meadow/floodplain between Rice Lake Outlet and Upper Pelican River upstream of the confluence with Sucker Creek). The duration analysis estimates general water surface elevations and pool areas using the simulated runoff hydrographs for the period 1961 - 2001.   Results are summarized below.

The analysis includes two wetland restorations using weir type outlet structures to raise water levels above the current drained condition:

1. Rice Lake Outlet Structure - Weir Type Structure with a runout elevation of 1352.0 feet located at current ditched outlet.

2. Lower Wetland Structure - Weir Type Structure with a runoff elevation of 1350.0 feet located just upstream of the confluence with Sucker Creek.

The analysis summarizes the ponding effects in terms of percent of time a given water surface elevation or pool area is exceeded. Plots of these results were produced for 4 general pool areas. These are referenced as:

- Zone 1 - Area upstream of Anchor Road.
- Zones 6-7 - Area between Anchor Road and Rice Lake “midpoint” peninsula.
- Zones 3-5 - Area between Rice Lake “midpoint” peninsula and Rice Lake outlet.
- WL US 34 - Area between Rice Lake outlet and Lower Wetland outlet structure.

The elevation/duration data and graphs were developed by tracking how long water would be at certain elevations using daily simulation hydrographs for the period of record 1961-2001. The area/duration graphs were created by simply converting the elevations to areas using the zone’s elevation/area relationship.

Below is an example elevation/duration graph, figure 7C, for zone 1. An example of interpreting this graph would be: Elevation 1352.5 is exceeded about 4% of the time during the simulation period 1961-2001 for the current conditions. With the two wetland restoration structures in place, elevation 1352.5 is exceeded about 20% of the time using the same hydrographs from the 1961-2001 simulation period. Figures 8C, 9C, and 10C are similar graphs for duration.

Figure 7C - Duration Effects Upstream of Anchor Road

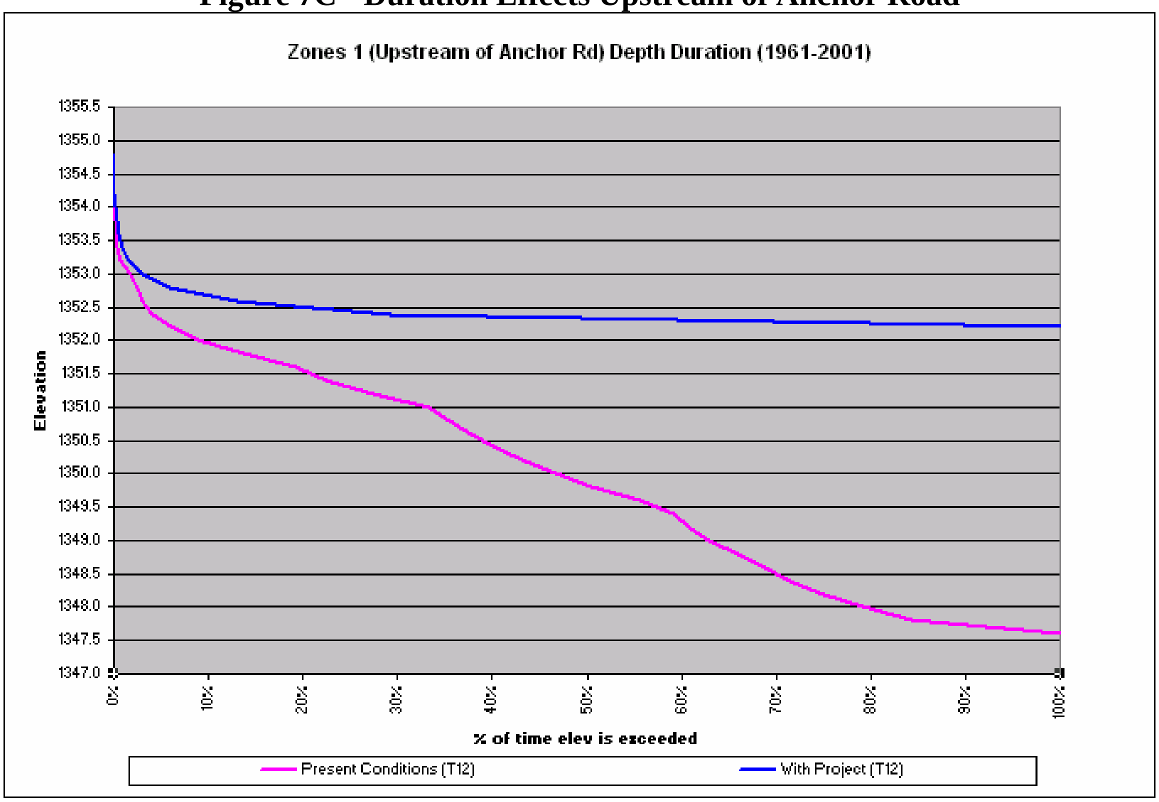


Figure 8C - Duration Effects Upstream of Main Rice Wetland (North Pool)

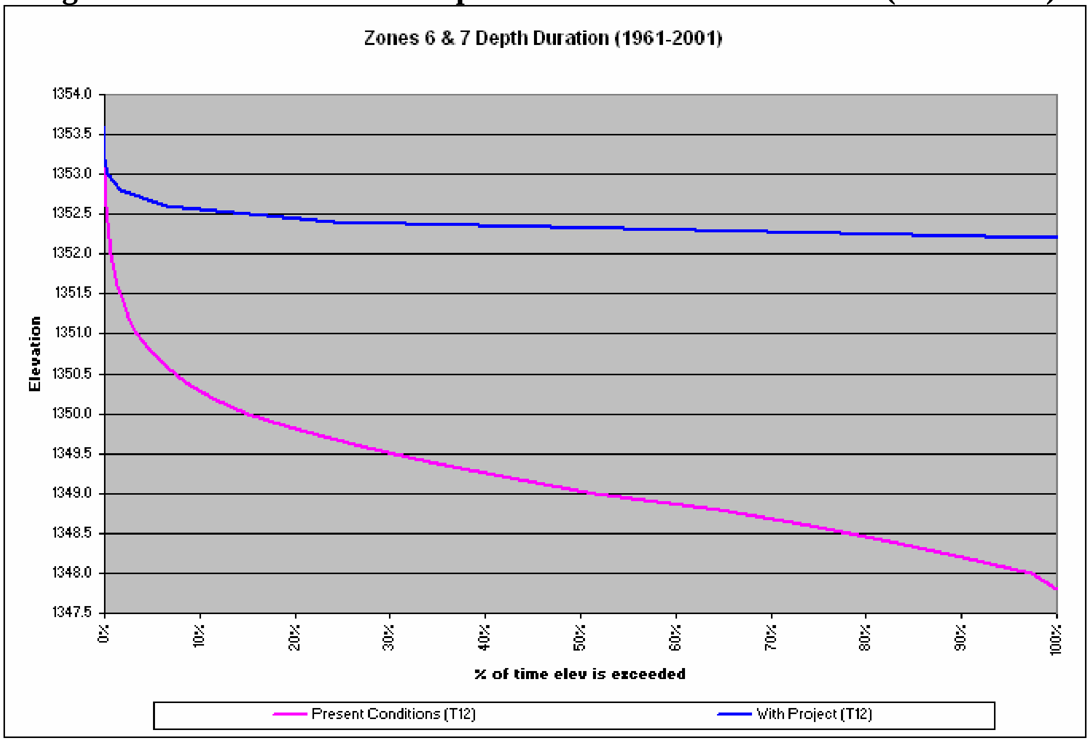


Figure 9C - Duration Effects of Main Rice Wetland (South Pool)

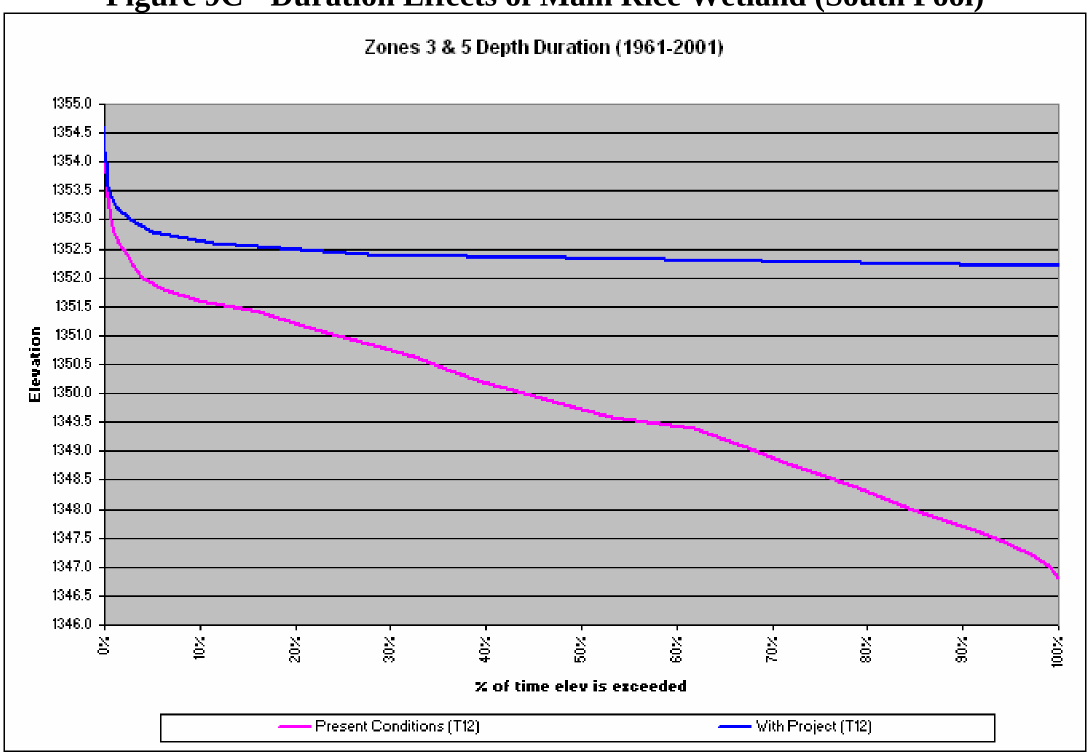
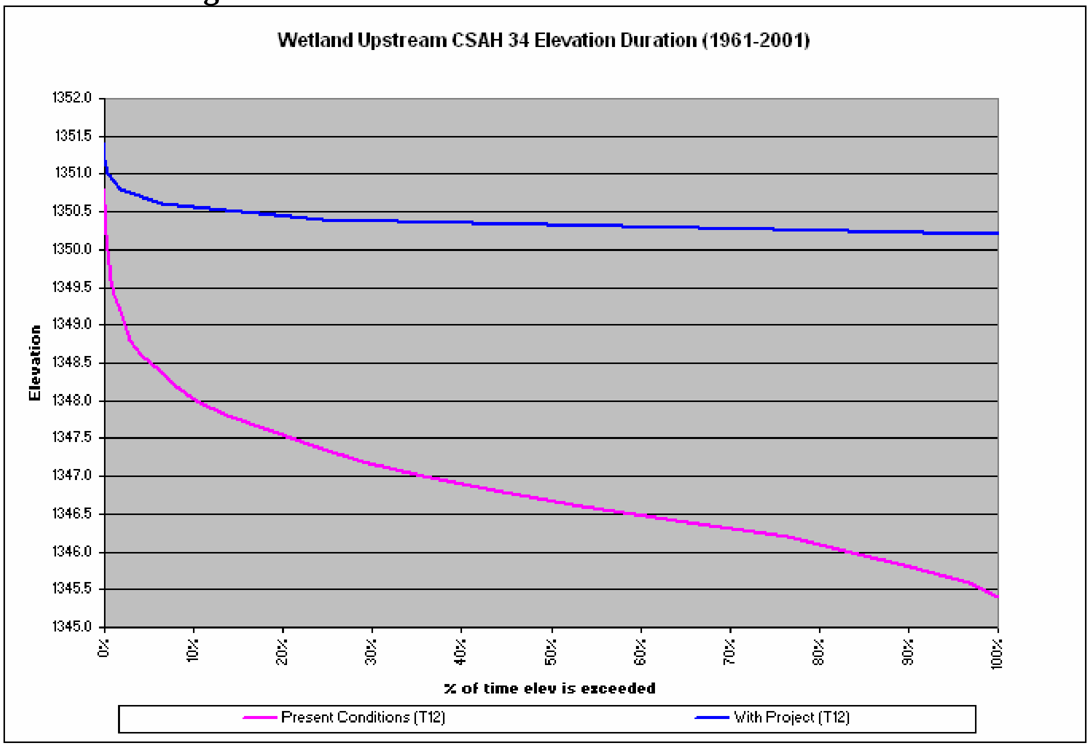
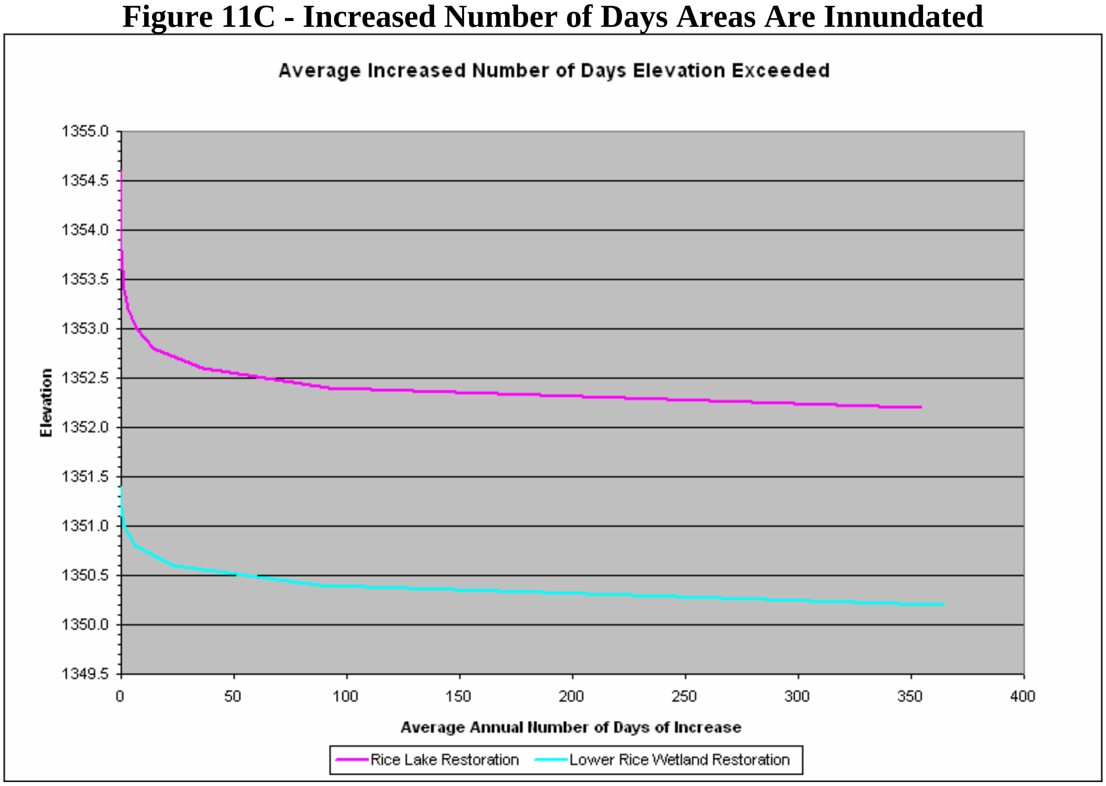


Figure 10C - Duration Effects Lower Rice Restoration



A general graph was made showing the average annual number of days a given elevation would be exceeded for the main and lower Rice Wetland restorations. Plots for Zones 1, Zones 3/4, and Zones 6/7 were similar (zones upstream of the main Rice Wetland Restoration) so they are shown as one on this general graph.

Figure 11C - Increased Number of Days Areas Are Innundated



An example interpretation of this graph would be: For the main Rice Lake Wetland Restoration, elevation 1350.5 would be exceeded an average of 65 days longer with the restoration compared to present condition. Assuming an increase of 5 days or less is considered a minimal impact, elevations above 1353.0 for main Rice Lake Wetland would be considered having insignificant duration effect. For Lower Rice Lake Wetland, this elevation of insignificant duration effect would be elevation 1350.8

Besides the increased time of inundation, the instantaneous water surface elevation obtained during storm a event is something that was estimated for current and post project conditions. Figure 12C displays the wetted perimeter for baseflow conditions. Figure 13C displays the wetted perimeter for a snowmelt 2 year event. Figure 14C displays the wetted perimeter for a snowmelt 10 year event. Figure 15C displays the wetted perimeter for a snowmelt 100 year event.

Figure 12C – Base Flow, Wetted Perimeter

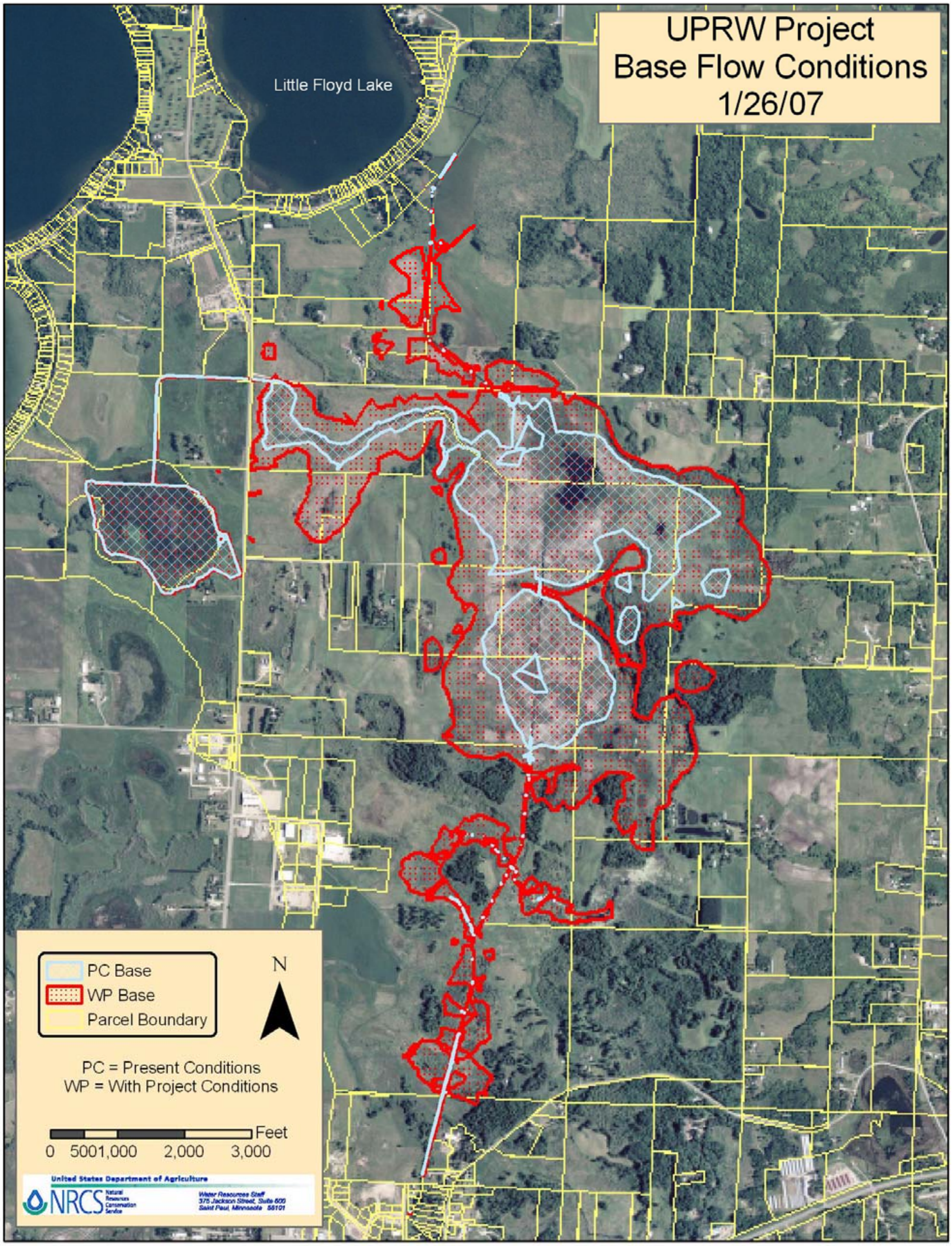


Figure 13C – 2 Year Event, Wetted Perimeter

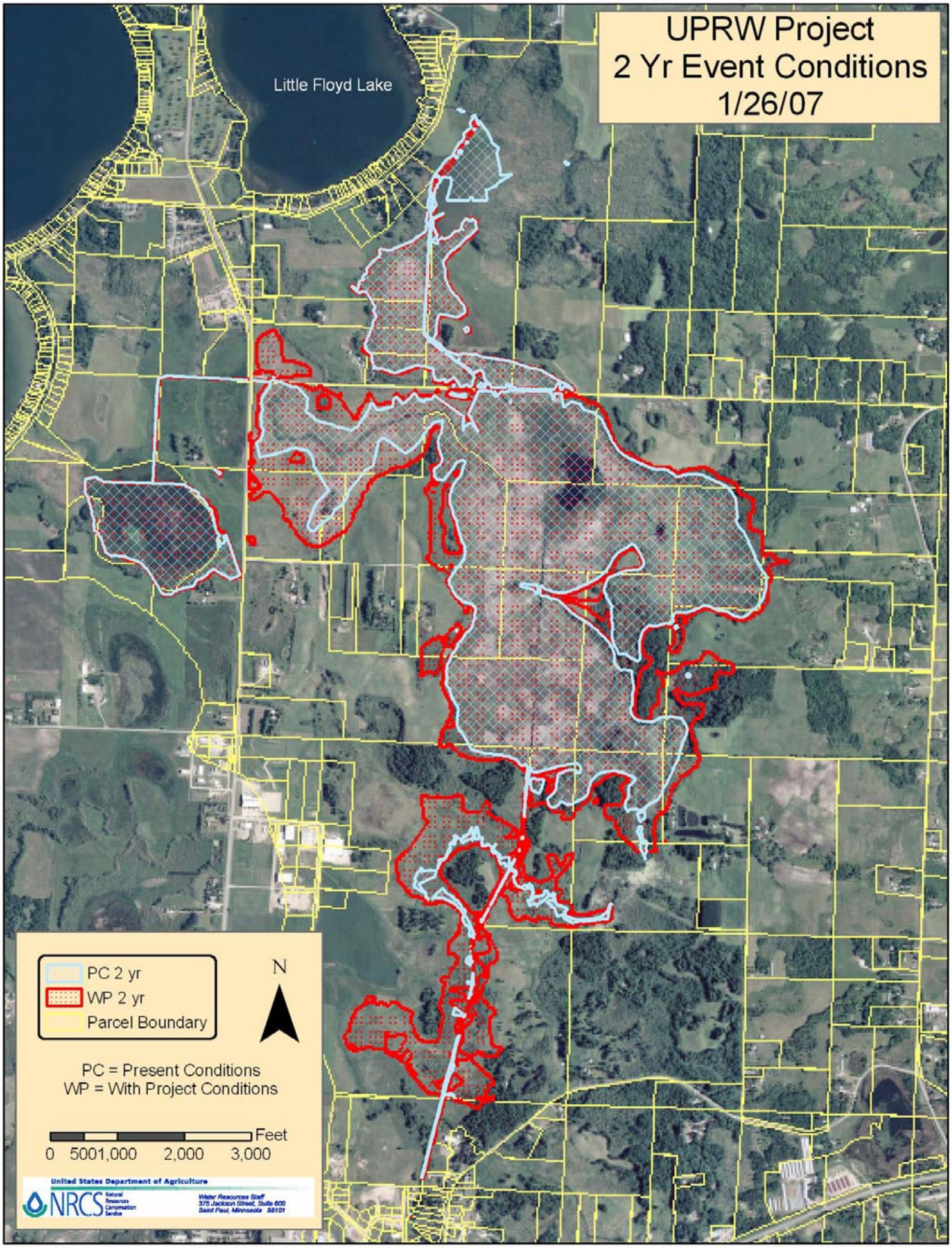


Figure 14C – 10 Year Event, Wetted Perimeter

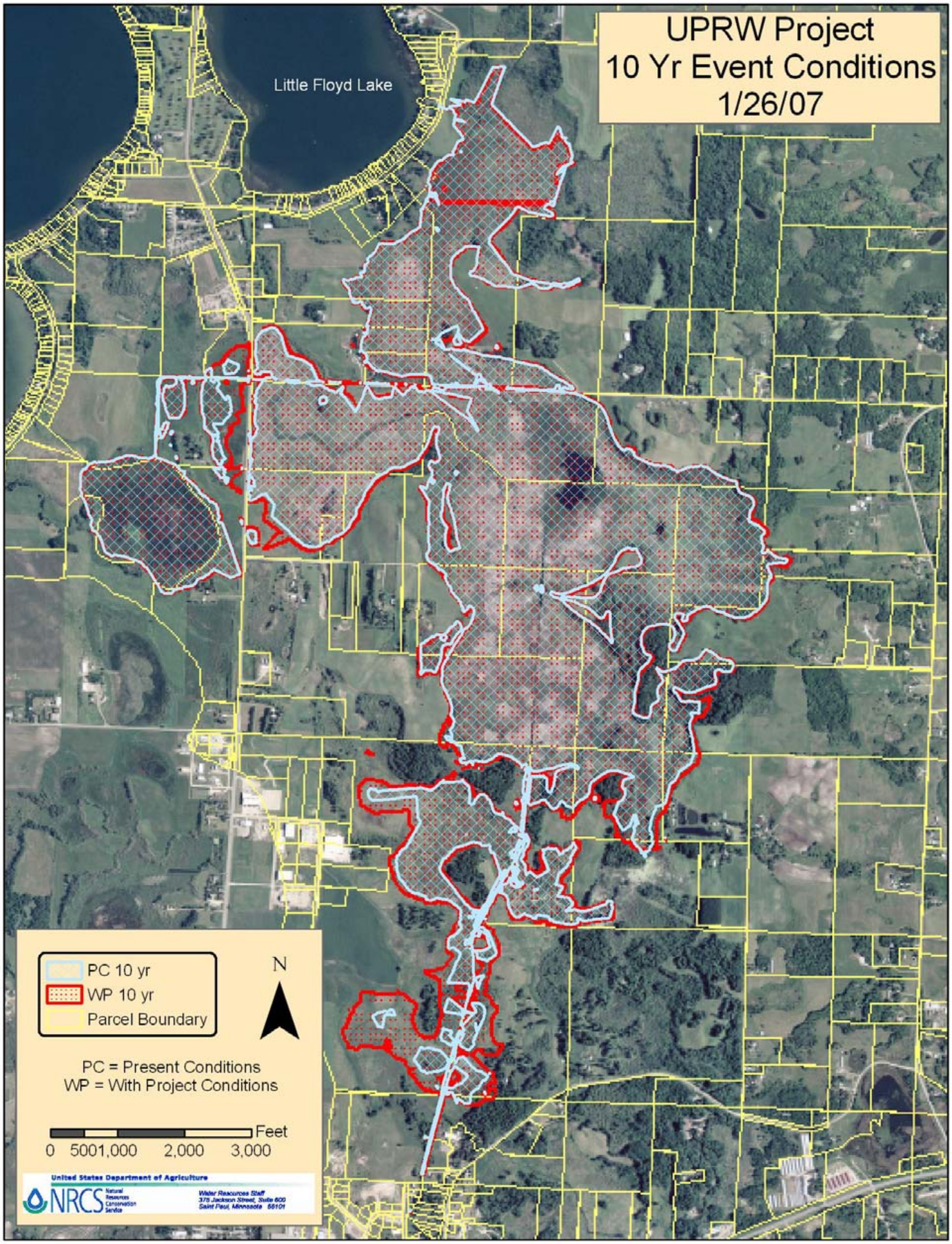
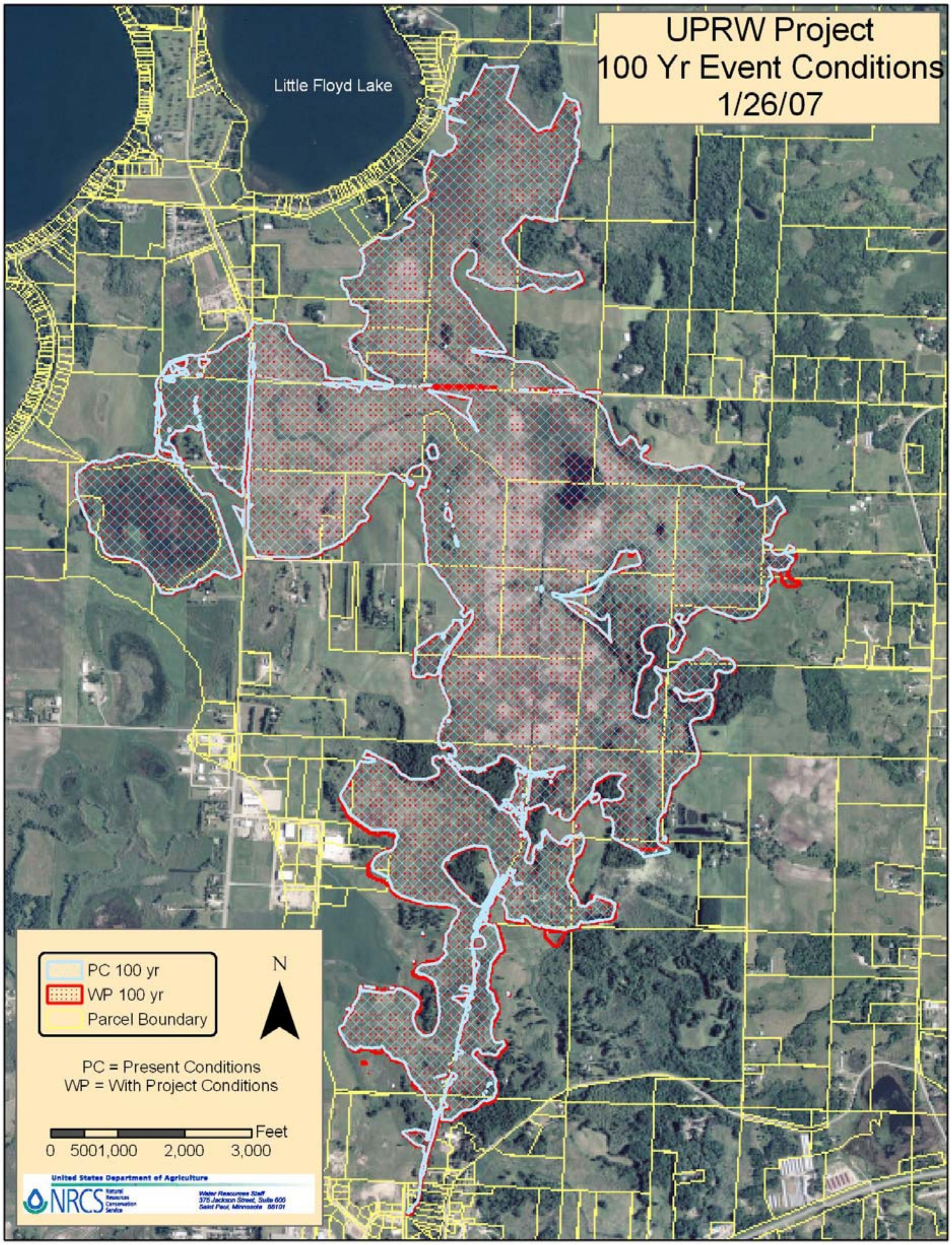


Figure 15C – 100 Year Event, Wetted Perimeter



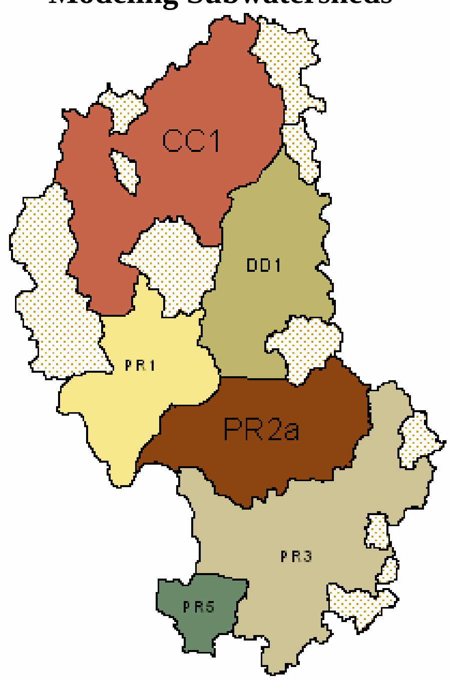
WATER QUALITY AND ASSOCIATED PROBLEMS

The Pelican River Watershed (PRWD) and Minnesota Pollution Control Agency (MPCA) have been collecting water quality samples throughout the watershed since 1995 through the Clean Water Partnership Program (CWP). Through detailed analysis of this data, the sponsors have identified the trend in P loadings and resulting water quality impacts. This section summarizes the aforementioned work and then discusses in detail recent advances in the water quality research.

Non-Point Source Assessment

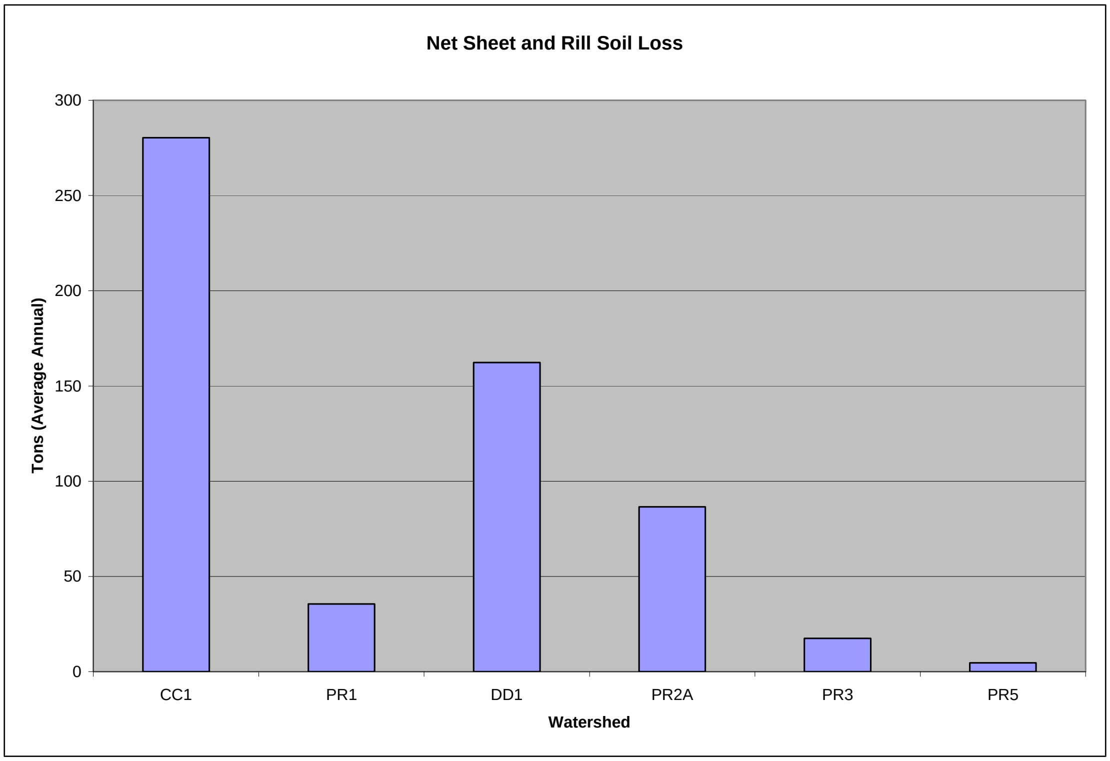
The magnitude of non-point sources of phosphorus was estimated using the GLEAMS Water Quality model. This model estimates "edge of field" amounts of soil loss and nutrients (Phosphorus and Nitrogen). The model takes into account land use, soil type, vegetation, and land slope. For cropland, it includes rotations, tillage practices, and fertilization amounts (amount, timing, and method). Climate variables, including precipitation (rain and snow, temperature, and ET) are use to "drive" the model. Daily values of the climate period from 1961 through 2001 (41 years) are used to generate runoff, soil losses, and movement of nutrients from the land surface. From the long term record, results are expressed as "average annual". A delivery ratio was used to convert accumulated "edge of field" estimates to subwatershed loading. Figure 16C shows the subwatersheds modeled while Figures 17C and 18C display estimated sediment and phosphorus loadings at the ends of each subwatershed (prior to flowing through lakes and/or large wetlands).

Figure 16C - GLEAMS Non-Point Source Modeling Subwatersheds



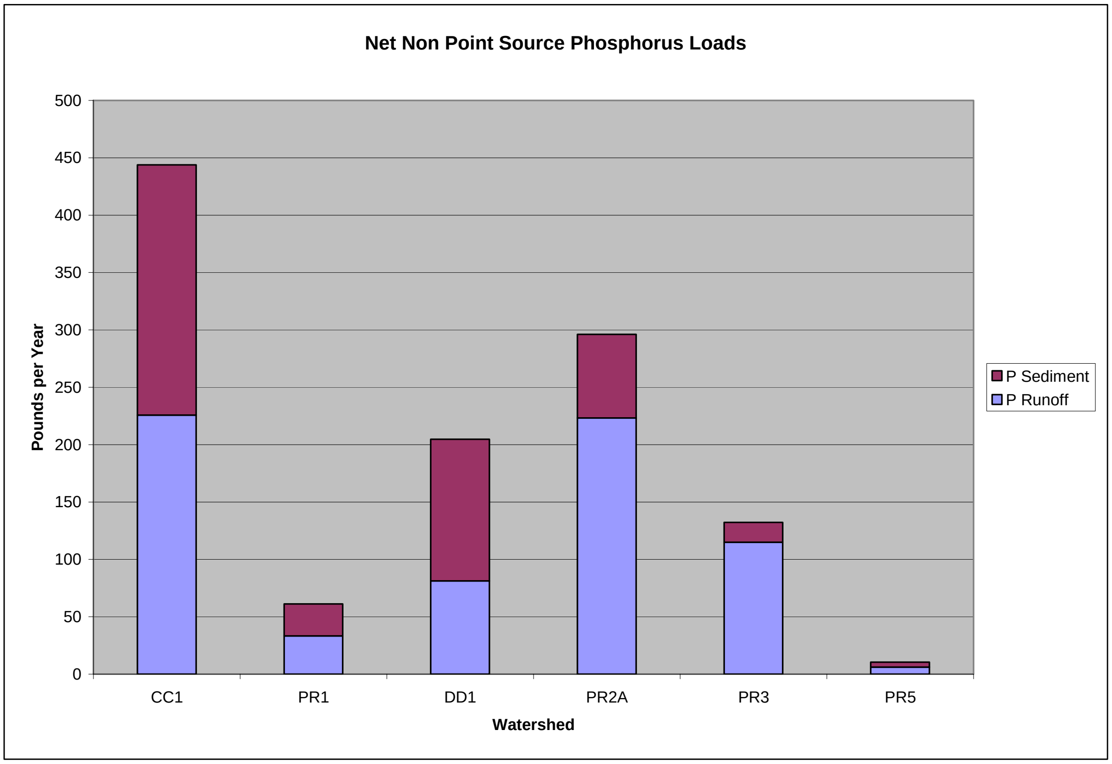
Comparing the non-point source results from GLEAMS[4] with PWRD Monitoring Results, it is possible to estimate loading due to "other sources" (i.e. lake internal loadings, mineralization of wetlands, streambank erosion, point sources, etc.). Figures 19C, 20C and 21C display these estimates based upon percentage, for CC1 (outlet of Campbell Creek), PR1 (outlet of Little Floyd), and PR3 (Pelican River at CSAH 34). The figures display Total Phosphorus source proportions. Ortho Phosphorus sources were similar (within 5%).

Figure 17C - Estimated Average Annual Sediment Loading by Subwatershed



[4] Lake/wetland deposition effects of Floyd Lakes and Rice Wetland were estimated to be 80% for $P_{sediment}$ and 40% for $P_{soluable}$

Figure 18C - Estimated Average Annual Phosphorus Loading by Subwatershed



It appears that Total Phosphorus Other Sources for Campbell Creek (62%) likely include streambank erosion and phosphorus from the partially drained Campbell Lake. Total Phosphorus Other Sources for at Floyd Lake Outlet (73%) may be due to internal loading. Total Phosphorus Other Sources for Pelican River at CSAH 34 (92%) is mainly due to loading from drained Rice Wetland.

Phosphorus loadings. PRWD and MPCA established water quality monitoring site within the watershed. These sites were used to calculate the average phosphorus concentrations (ppb) and calculate the annual phosphorus loading (tons) to the various lakes. Figure 22C displays the average loadings over 1998-2000.

Figure 19C - Campbell Creek (CC1) Total P Sources

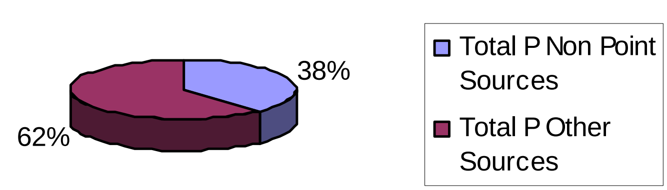


Figure 20C - Floyd Lake Outlet (PR1) Total P Sources

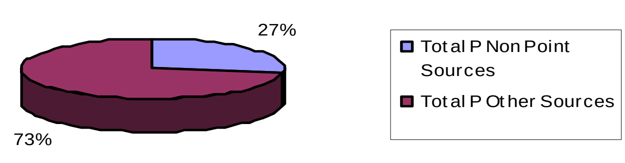


Figure 21C - Pelican River at CSAH 34 (PR3) Total P Sources

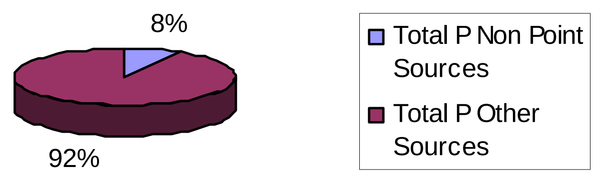
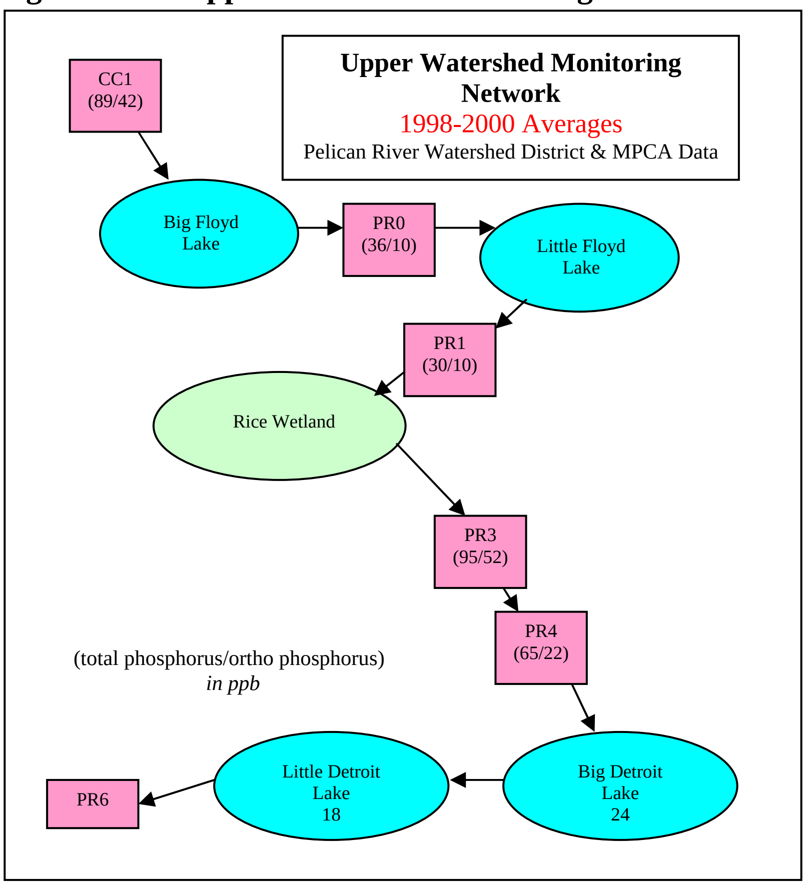


Figure 22C – Upper Watershed Monitoring Network



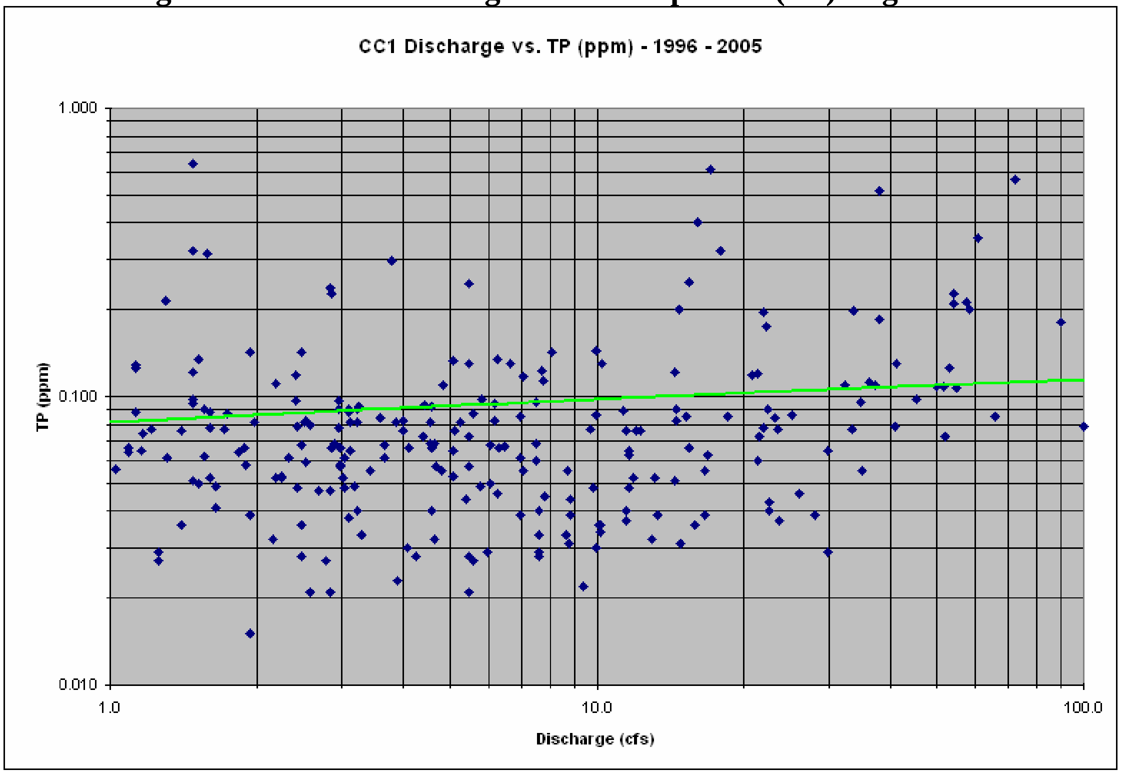
UPDATING OF ORIGINAL FLUX WATER QUALITY MODELING

The FLUX program was used to estimate stream nutrient loadings at CC1, PR1, PR3, and PR4 monitoring points in the Upper Pelican River project area (see Appendix A - Project Map for locations). The program has 6 different methods for estimating loading grab sample data sets. The method most appropriate for a particular site is dependent on the amount of data collected, the hydrologic characteristics of the watershed (flashy vs. steady flows), and nutrient loading characteristics (variation by season and/or discharge, strong background sources such as sewage treatment discharge). The method used for the Upper Pelican River Project is Method 6 - Regression Applied to Individual Flows. Input for this method includes:

- paired discharge/water quality grab samples taken throughout the year
- continuous flow record[5] during the loading season (ice out in spring to freeze up in fall/winter)

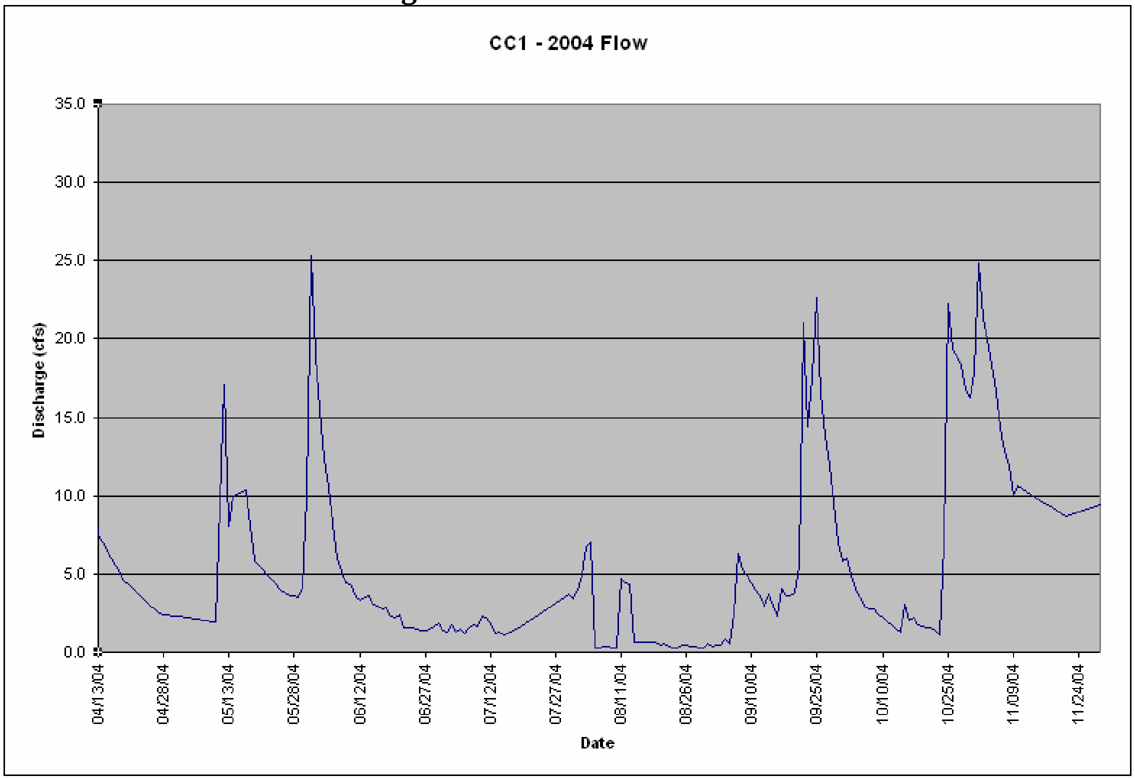
Basically, the paired discharge/water quality grab samples taken by the PRWD are used to develop a discharge/concentration (ppb/cfs) regressions for each site which is then applied to the continuous flow record for that station to develop a loading (kgs of TP or OP). Figures 23C show the discharge/concentration regression and for CC1 while Figure 24C shows a portion of the continuous flow record (2004).

Figure 23C - CC1 Discharge/Total Phosphorus (TP) Regression



[5] The PRWD maintained two CR10 continuous stage recorders. One at CC1 and the other at PR4 (switched to location PR3 in 2005). Continuous flows at PR1 (outlet of Little Floyd Lake) were estimated from a combination of PRWD grab sample day lake level measurements and MnDNR lake level monitoring. PR3 continuous flows were estimated by interpolating between weekly grab sample day flow estimates and checking for consistency by comparing with PR4 flows.

Figure 24C - CC1 2004 Flow



Loadings and concentrations quoted in the main watershed plan come from the original FLUX analysis performed by MPCA for use in the 2002 CWP Working Paper. The data set used for that analysis was from 1996 through 2000. To confirm that this analysis was still reasonable, the original FLUX data set was updated with the 2001 - 2005 data and re-run. Tables 7C and 8C below compare the differences in concentrations and loads using the 2 different periods of data.

The only site with a significant difference in *concentrations* between the two data sets is PR4 for ortho-phosphorus. For *loads*, the differences are more significant but are likely due to the way the continuous flow records were developed for each data set[6].

The most significant statistic related to this watershed plan's problem identification is the percent increase between PR1 (outlet of Little Floyd) and PR3 (Pelican River downstream of Rice Lake Wetland). Here, as shown in Table 9C, this percentage is reasonably consistent for both concentration and load for both data sets with the exception of ortho-phosphorus load (757% vs. 1259% increase).

The conclusion from analyzing the effect of additional years of data is that the original 2002 CWP Working Paper statements regarding nutrient loadings are valid. Further modeling (i.e. BATHTUB in-lake modeling) using updated data would not significantly improve the overall watershed water quality analysis. Based on this, it was decided to use data and conclusions from the original report to support the current watershed plan's formulation process.

[6] Significant number of "holes" were filled for the 1996 - 2005 data sets by interpolating values between actual recorded values. The original 1996 - 2000 data set would assumed that flows continue steady through the period without data.

Table 7C- FLUX Results (Concentrations) by Data Set Period of Record

	Total Phosphorus Concentration (ppb)			Ortho Phosphorus Concentration (ppb)		
	1996 - 2000 Data Set	1996 - 2005 Data Set	% change	1996 - 2000 Data Set	1996 - 2005 Data Set	% change
CC1	89	111	25%	42	50	19%
PR1	30	28	-7%	10	9	-10%
PR3	95	85	-11%	52	56	8%
PR4	65	67	3%	22	37	68%

Table 8C - Results (Loads) by Data Set Period of Record

	Total Phosphorus Load (kgs)			Ortho Phosphorus Load (kgs)		
	1996 - 2000 Data Set	1996 - 2005 Data Set	% change	1996 - 2000 Data Set	1996 - 2005 Data Set	% change
CC1	1250	585	-53%	600	260	-57%
PR1	500	335	-33%	175	110	-37%
PR3	2750	2280	-17%	1500	1495	0%
PR4	2400	1590	-34%	900	900	0%

Table 9C - Percent Increase in TP and OP between PR1 and PR3

	Percent Increase in Total Phosphorus Between PR1 and PR3		Percent Increase in Ortho Phosphorus Between PR1 and PR3	
	1996 - 2000 Data Set	1996 - 2005 Data Set	1996 - 2000 Data Set	1996 - 2005 Data Set
Concentration	217%	204%	420%	522%
Load	450%	581%	757%	1259%

Determining Lake's Future With- and Without-Project Conditions

Current, Future With-Project, and Future Without-Project in-lake phosphorus estimates are based on data analysis found in MPCA's "Water Quality Assessment of the Upper Pelican River Watershed" - 2002. See Results and Discussion - Modeling Summary/Goal Summary section of that report for details.

Big and Little Detroit Lake

Current In-Lake TP Conc:	18-24 ppb (Little, Big Detroit respectively)
Future With-Project In-Lake TP Conc:	20 ppb
Future Without-Project In-Lake TP Conc:	40 ppb

North Floyd Lake

Current In-Lake TP Conc:	37 ppb
Future With-Project In-Lake TP Conc:	30 ppb
Future Without-Project In-Lake TP Conc:	52 ppb

Big and Little Floyd Lakes

Current In-Lake TP Conc:	14-20 ppb (Big, Little Floyd respectively)
Future With-Project In-Lake TP Conc:	25 ppb
Future Without-Project In-Lake TP Conc:	20-28 ppb

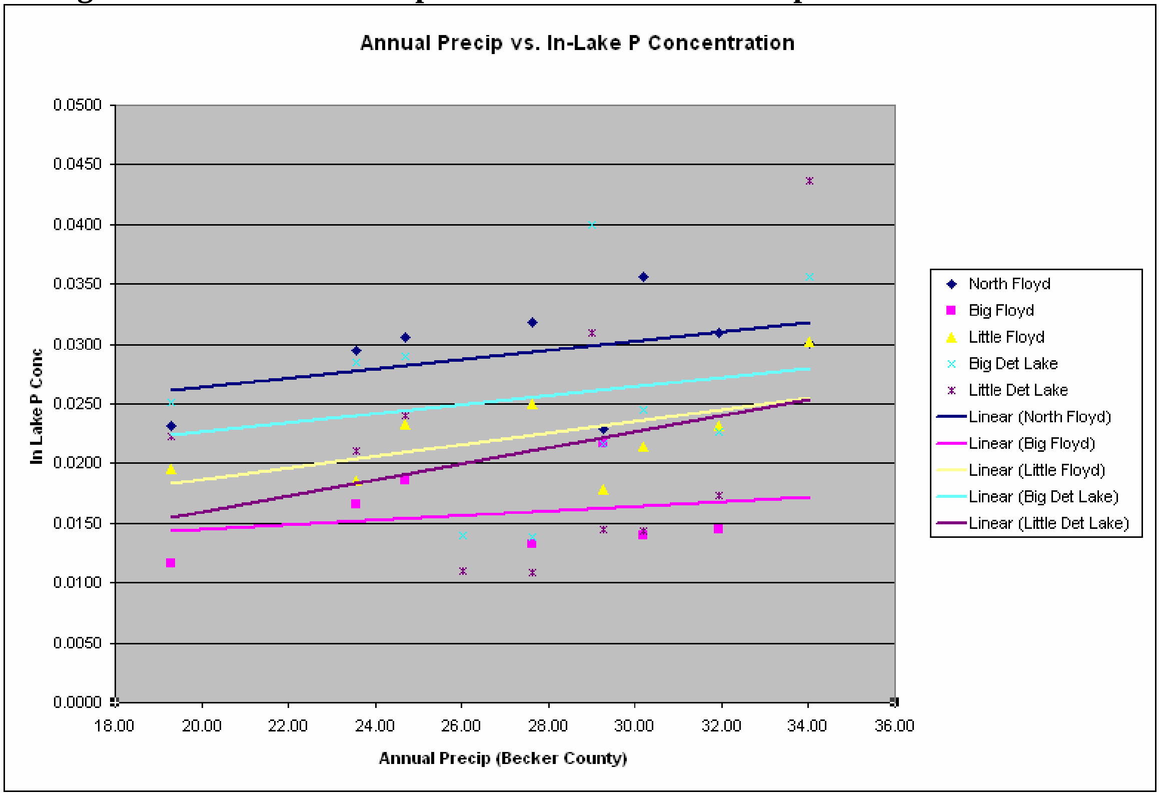
Future With-Project: Assumes P_{total} concentrations at PR3 (Upper Pelican River at Hwy 34) and CC1 (Campbell Creek just upstream of North Floyd Lake) are reduced 50% (95 ppb to 40-50 ppb for PR3 and 89 ppb to 40-50 ppb for CC1).

Future Without-Project (Detroit Lakes): Assumes no reduction in loadings/concentrations from PR3 and internal P recycling within Big Detroit Lake becomes significant. Report implies that current phosphorus loading is "priming" bottom sediments for future internal loading in the future ("… if a relatively modest level internal phosphorus recycling were to occur (e.g. 50 percent of the measured Lake Sallie level), the in-lake concentrations … would be on the order of 40 ug P/L.". Also, precipitation for the region appears to be increasing - 30 year normal for Detroit Lakes were 23.78", 24.32", and 26.36" for the periods 1951-1980, 1961-1990, and 1971-2000 respectively. Increased precipitation will translate into increased phosphorus loadings. See plot below for relationship between Becker County Annual Precipitation and monitored in-lake phosphorus concentrations for the period 1995 - 2004.

Future Without-Project (Floyd Lakes):

Assumes same circumstances that apply to Detroit Lakes will apply to Floyd Lakes (internal loading begins to occur + precipitation increases). That percentage change for Detroit Lakes, going from current to future without-project, was 40% (24 ppb to 40 ppb).

Figure 25C – Annual Precipitation versus in-lake Phosphorus Concentrations



WETLANDS AND WILDLIFE

Wetlands

Figure 26C illustrates the current National Wetland Inventory (NWI) mapping of wetlands by acres within the watershed. There are approximately 13,252 acres of wetlands mapped by NWI within the watershed, which includes the State of Minnesota Frank Wildlife Management Area (WMA) of approximately 351 acres.

Efforts were made to estimate the 'present' and 'with project' wetland types within the Rice Lake Wetland Complex. A HEC-RAS computer model was created for the Rice Lake Wetland Complex area. This model was used to estimate the wetted perimeter for 'present' and 'with project' conditions. For a comparison between 'present' and 'with project' conditions, the normal pool elevation at baseflow was used.

Table 10C displays the NWI type in acres, added at each depth. At 'present' conditions, the fringe area includes the area 7 inches (0.59') above the baseflow surface water elevation around the outside of the wetland. Rice Lake Wetland Complex is approximately 434 acres without project.

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Figure 26C - National Wetland Inventory Mapping of Watershed

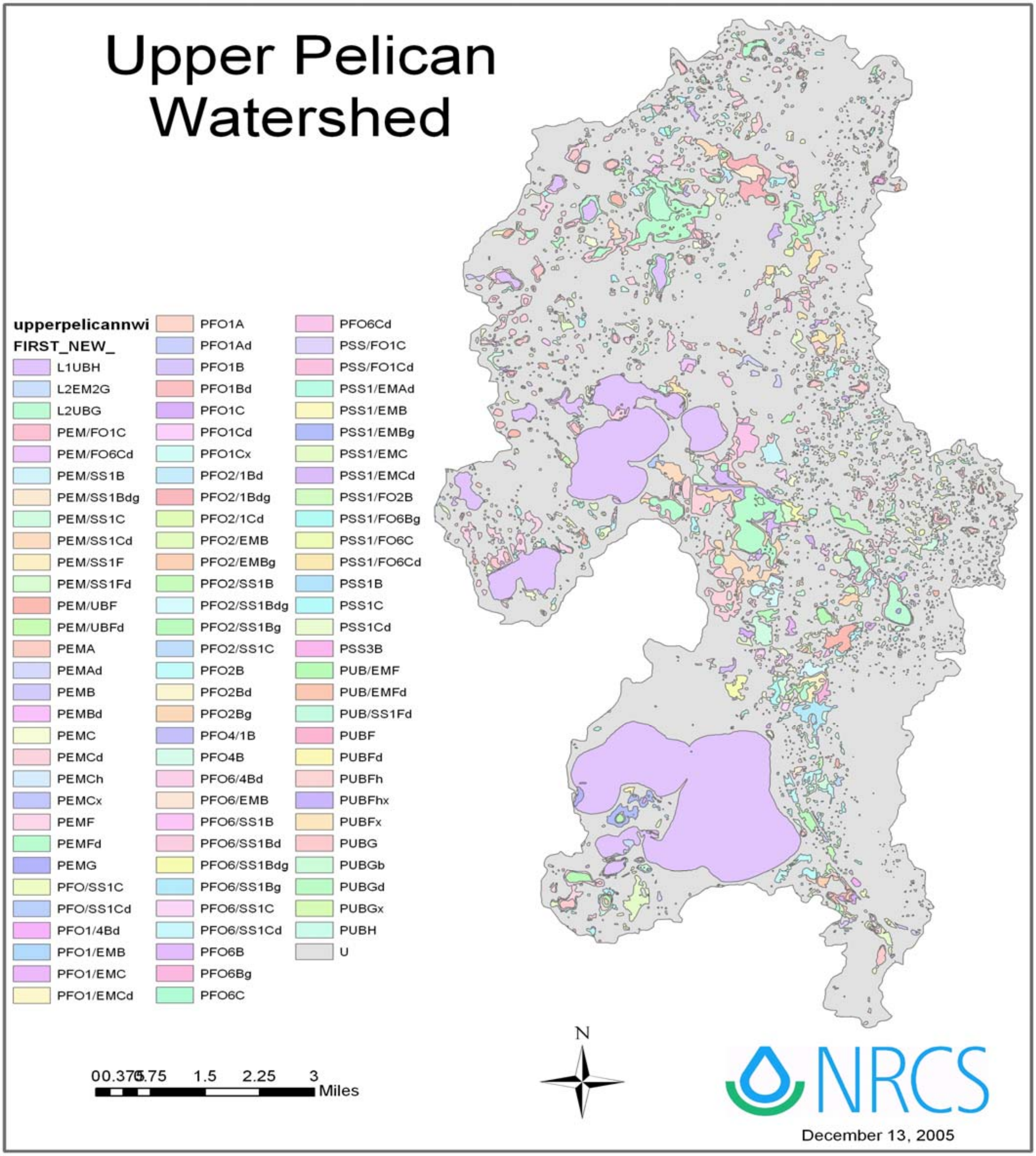

Table 10C – Present Wetland Conditions

		Present Condition							
		0.59' Above Water	Gains per Depth (ac)						
NWI Type	Wetland Type	Surface	0.5'	1'	2'	3'	4'	Over 4'	Total (ac)
PEM/SS1Cd	3/6	Not broken into different types, but included within fringe	14.5	2.9	0.0	0.0	0.0	0.0	17.4
PEM/SS1Fd	3/6		7.0	0.0	0.0	0.0	0.0	0.0	7.0
PEMA	1		0.0	0.0	0.0	0.3	0.0	0.0	0.4
PEMAd	1		0.0	0.0	0.0	0.0	0.0	0.0	0.0
PEMC	3		0.1	0.0	0.0	0.0	0.0	0.0	0.1
PEMCd	3		6.7	4.0	3.9	1.5	0.0	0.0	16.1
PEMFd	3		119.2	44.3	24.9	9.3	3.4	0.0	201.2
PFO1Cd	7		0.1	0.0	0.0	0.0	0.0	0.0	0.1
PFO6/SS1Bd	7/8		0.4	0.0	0.0	0.0	0.0	0.0	0.4
PSS1/EMCd	6		17.0	1.5	0.1	0.0	0.0	0.0	18.7
PSS1Cd	6		0.0	0.0	0.0	0.0	0.0	0.0	0.0
PUBFd	4		0.3	0.1	0.1	0.0	0.5	0.0	1.1
PUBGd	5		1.8	0.0	0.2	0.2	3.6	0.0	5.8
Fringe	n/a	166.0							166.0
		166.0	167.1	52.9	29.2	11.4	7.6	0.0	
								Total	434.2

To estimate the 'with project' conditions, the U.S. Army Corps of Engineers definitions were used as guidelines to determine shallow and deep marshes. Those definitions are below.

Shallow Marshes: Hydrology shall consist of saturation to the surface, to inundation by up to 6 inches of water, for a minimum of 60 consecutive days or two periods of 30 consecutive days or four periods of 15 consecutive days, during the growing season under normal to wetter than conditions (70 percent of years based on most recent 30-year record of precipitation). During the growing season, inundation by up to 18 inches of water following the 2-year or greater storm/flood event is permissible provided that the duration does not exceed 30 days (e.g., water depth drops from 18 inches to 6 inches within the 30 days).

Deep Marshes: Hydrology shall consist of inundation by 6 to 36 inches of water throughout the growing season, except in drought years (driest 10 percent of most recent 30-year period of precipitation record).

The ‘present’ and ‘with project’ conditions were summarized using the same definitions. Table 11C displays the results of this summary and shows that at ‘with project’ conditions, the project will result in a net gain of wetland size and function and requires no additional compensation or mitigation.

Table 11C – Wetland, Present and With Project Conditions

	Present Conditions (ac)	With Project (ac)
Fringe [1]	166.0	244.0
Shallow Marshes [2]	167.1	107.9
Deep Marshes [3]	101.1	544.1
Total	434.2	896.0

Wildlife. Becker County provides habitat to many harvestable big and small game species: White-tailed Deer, Black Bear, Hungarian partridge, Ruffed Grouse, Sharp-tailed Grouse, Woodcock, Prairie Chicken, Pheasant, Wild Turkey, Grey Squirrel, Fox Squirrel, Snowshoe Hare, White-tailed Jack Rabbit, and Eastern Cottontail Rabbit.

Major species of waterfowl hunted within the watershed: Mallards, Gadwall, American Widgeon, Green & Blue Winged Teal, Northern Shoveler, Northern Pintail, Greater and Lesser Scaup, Wood Duck, Redhead, Canvasback, American Coot, and Canada Goose.

Major species of furbearers both hunted and trapped within the watershed: Mink, Beaver, Badger, Coyote, Bobcat, Red & Gray Fox, Short & Long-tailed Weasel, Stripped & Spotted Skunk, Opossum, Muskrat, Raccoon.

Fisheries and Aquatic Habit. Cattails dominant the shallow water habitat of the wetlands including the Frank Wildlife Management Area within the watershed. Cattails are not known to be influenced by crowding, shading or toxic associations of other plants. Rather, cattails often appear to impose at least some of these conditions on other plants, depending upon the water depth. Birds are not known to use any part of the adult cattails for food. Blue, Snow, and Canada Geese do feed on the cattail rhizomes. Muskrats are the single most important biological factor affecting the abundance of cattails. Where water depths are sufficient to allow muskrats to live in winter, they often maintain an acceptable balance of emergent cattails and open water. Cattails become the greatest problem in shallow areas where muskrats cannot survive the winter, which may be the case in the Rice Creek Wetland in the Frank WMA south of Anchor Road.

Another problem facing some lakes in the watershed is the growing abundance of nuisance exotic species, especially, Flowering Rush, and Curly Leafed Pondweed., These plants replace native species, alter shoreline sedimentation patterns, interfere with boating, swimming and fishing, cause shoreline damage, and hardship to shoreline residents.

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[1] For ‘present’ conditions, the fringe area includes the area 7 inches (0.59’) above the baseflow surface water elevation around the outside of the wetland. For ‘with project’ conditions, the fringe area includes the area 5 inches (0.43’) above the baseflow surface water elevation around the outside of the wetland.
[2] For ‘present’ and ‘with project’ conditions, shallow marshes is the area that has water between zero and 6 inches (0.5’) deep.
[3] For ‘present’ and ‘with project’ conditions, deep marshes is the area that has water between 6 inches and maximum estimated depth, which is greater than 36 inches.

Flowering Rush was probably introduced by accident in the mid-1970’s in Dead Shot Bay (Curfman Lake). From there it has spread throughout Big and Little Detroit, down the Pelican River into Muskrat, and now into Sallie and Melissa. Flowering Rush, declared an “Undesirable Exotic Species” by the State of Minnesota in 1993, is found in only a few other places in the state. It has a very aggressive root system, and apparently spreads by the accidental transplant of root-fragments.

Curly-Leafed Pondweed is found in many lakes in Minnesota, and is widespread in Big and Little Detroit Lakes. An annual plant with an unusual growth habit, it germinates from seed in the fall, grows under the ice in the winter, and matures in May or June. When it dies the plants break off from their stem, float to the surface, form large mats, and eventually reach shore, causing great hardship to shoreline residents, boaters and fishermen. In extreme cases, the decaying weed masses can deplete oxygen and cause the deaths of many small fish.

Table 12C - Federal and State Listed Threatened, Endangered, and Special Concern (SPC) animal and plant species listed in Becker County, MN

SPECIES	COMMON NAME	STATUS
Haliaeetus leucocephalus	Bald Eagle	Federal Threatened State SPC (Species of Special Concern)
Canis lupus	Gray Wolf	Federal Threatened
Acipenser fulvescens	Lake Sturgeon	State SPC
Ammodramus nelsoni	Nelson’s Sharp-Tailed Sparrow	State SPC
Asio flammeus	Short-Earde Owl	State SPC
Buteo lineatus	Red-Shouldered Hawk	State SPC
Coturnicops noveboracensis	Yellow Rail	State SPC
Cygnus buccinator	Trumpeter Swan	State Threatened
Dendroica cerulea	Cerulean Warbler	State SPC
Etheostoma microperca	Least Darter	State SPC
Gallinula chloropus	Common Moorhen	State SPC
Lasmigona compressa	Creek Heelsplitter Mussel	State SPC
Ligumia recta	Black Sandshell	State SPC
Limosa fedoa	Marbled Godwit	State SPC
Notropis anogenus	Pugnose Shiner	State SPC
Oarisma powesheik	Powesheik Skipper	State SPC
Oxyethira ecornuta	A *Species* of Caddisfly	State SPC
Phalaropus tricolor	Wilson’s Phalarope	State Threatened
Botrytchium campestre	Prairie Moonwort	State SPC
Carex Scirpoidea	Northern Singlespike Sedge	State SPC
Carex sterilis	Sterile Sedge	State Threatened
Cirsium Hillii	Hills’s Thistle	State SPC
Cladium mariscoides	Twig Rush	State SPC
Cypripedium arietinum	Ram’s-Head Lady’s Slipper	State Threatened
Cypripedium candidum	Small White Lady’s Slipper	State SPC
Drosera anglica	English Sundew	State SPC
Eleocharis olivacea	Olivaceous Spike-Rush	State Threatened
Eleocharis rostellata	Beaked Spike-Rush	State Threatened
Gaillardia aristata	Blanket Flower	State SPC
Gentianella armarella spp. acuta	Felwort	State SPC
Malaxis monophyllos var. brachypoda	White Adder’s-Mouth	State SPC
Malaxis paludosa	Bog Adder’s Mouth	State Endangered
Minuartia dawsonensis	Rock Sandwort	State SPC
Najas gracillima	Thread-Like Naiad	State SPC
Rhynchospora capillacea	Hair-Like Beak-Rush	State Threatened
Ruppia maritima	Widgeon-Grass	State SPC
Scleria verticillata	Whorled Nut-Rush	State Threatened
Sparganium glomeratum	Clustered Bur-Reed	State SPC

SOCIOECONOMICS

Economic Characteristics. The primary economic sectors in Becker County are agriculture, tourism, manufacturing and forestry. The City of Detroit Lakes has a lower unemployment rate than Becker County and the state of MN. Looking more closely at the sector in the economy, IMPLAN software lists the following sectors as the top 10 employers in the county (Table 13C).

Table 13C - Ten Largest Employment Sectors in Becker County (total employees and percent of total workforce)

Industry	Employment	% Total
Food services and drinking places	1,326	7%
State & Local Non-Education	1,252	6%
State & Local Education	1,112	6%
General merchandise stores	689	3%
Truck transportation	638	3%
Civic, social, professional and similar organ	509	3%
Real estate	484	2%
Commercial and institutional buildings	472	2%
Nursing and residential care facilities	468	2%
Grain farming	393	2%

Recreation. Recreation and tourism is the driving force of the Detroit Lakes economy. The ideal location of the city in relation to the lakes within the PRWD provides excellent access for swimming boating, fishing, wildlife watching and many more recreational activities. In addition to outdoor recreation, the city provides tourist activities such as shopping and dining, and is host to several outdoor festivals and celebrations.

To date there has been no formal estimate on the number of visitors to the PRWD, not to mention specific lakes. However, in order to generate the estimated benefits resulting from a PL-566 project, an estimate of annual visitors was needed. Using data on the Becker County revenues resulting from tourism, the IMPLAN economics sector model and existing literature on recreational behaviors it is estimated that over 637,000 tourist visit Detroit Lakes annually. Of these annual visitors roughly 35% participate in water based recreation (swimming, boating or fishing) and would be directly impacted through changes in water quality.

Conservation and Economics. In Minnesota, wildlife viewing is a $400 million per year industry. It is an industry that benefits from the protection and management of natural habitats without degrading or using up our natural resources. Local communities can reap economic benefits of expanding their appeal and lengthening their tourism seasons by creating public wildlife viewing areas.

Property Values. The median value of a home in Detroit Lakes was roughly five thousand dollars lower than Becker County. However, the majority of lakefront homes in the PRWD, especially on Big and Little Detroit Lakes, far exceed this median value. Contributing factors to these higher value lakefront housing values are amenities such as lake access, aesthetics, and water quality of the lakes. If water quality were to decline financial impacts would be realized through the housing market.

ECONOMIC ANALYSIS OF THE PREFERRED ALTERNATIVE

Baseline Water Quality Conditions. As discussed in the main body of the reports, PRWD has identified water quality impairments to Little Floyd, North Floyd, Big Floyd, Big Detroit, and Little Detroit Lakes. The primary impairment is periodic nuisance algae blooms that occur due to excessive nutrient loadings. The primary nutrient of concern has been identified as phosphorus. Currently, North Floyd Lake exceeds the Minnesota Pollution Control Agency's (MPCA) Lake Phosphorus Criteria, for fully supporting swimmable uses (30 - 40 ppb total phosphorus). At this concentration, it is estimated that nuisance algal blooms would be limited to 10 to 25% of the time during the summer. The remaining lakes are within the upper bound of the criteria, however, slight increases in phosphorus loading could easily "tip" these lakes into a degraded category. The potential increases in total phosphorus loading is a legitimate concern because of 1) future phosphorus release from lake sediments, 2) temporary or permanent increased future precipitation, and 3) the effects of increased urbanization within the watershed[7].

Baseline Recreation. Under current conditions, water based recreation in the City of Detroit Lakes continues to be the major component of its economy. For the purposes of this plan it was estimated that close to 300,000 individuals visit Detroit Lakes annually for swimming, boating and fishing.[8] As long as lake water quality does not deteriorate, it is assumed that this level of visitation would continue into the future. However, if algal blooms become more frequent or severe, which is predicted in the future absent any form of action, visitation would decline. The recommended plan would work to stabilize water quality, with the potential for improvement from current conditions. Details on how visitation estimates were generated are provided here.

Baseline Recreation Levels. The first step in estimating visitation to the Detroit Lakes area was to conduct a literature review of any and all research that had already been completed. Additionally, several trips were taken to interview local leaders to determine if any information existed that documented historic visitation rates. After an extensive review and interview process, it was determined that to date, no formal estimate on the number of visitors to the Pelican River Watershed District area, not to mention specific lakes, was available.

With a limited budget and timeframe, a survey of potential visitors or other data collection process was not a viable option. Existing data had to be used to formulate some type of estimate on annual visitation. During the literature review process, several tourism studies conducted by The University of Minnesota Extension Service – Tourism Center (UM-TC) were discovered. These studies detailed the spending patterns of visitors to Detroit Lakes and the surrounding areas, though did not attempt to qualify actual visitation rates. Additionally, Dr. Erkilla, one of the principle investigators of the tourism studies, had data on revenue projections taken from a regional economic model developed for Becker County. It was possible to disaggregate this data into individual economic sectors. With the assistance of Dr. Erkilla, the data was collected, the recreation receipts disaggregated, and updated to current dollars.

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[7] During the period 1990-2000, the City of Detroit Lakes has increased in population by 11% while Becker County has seen an 8% increase.

[8] Big and Little Detroit Lakes are the only lakes within the PRWD considered in the benefits analysis. Although recreation activities occur on the other lakes in the PRWD, it is assumed that these activities are dominated by local recreators.

Using the data on recreation revenue in the county and the visitor spending patterns, estimates on total visitation were developed. Using IMPLAN, an economic sector model, and the visitor spending patterns, we were able to translate the county tax revenues from recreational sources to visitation numbers. IMPLAN is a model that tracks economic activity through all sectors included in a set universe, which for this analysis, was limited to Becker County. Using the recreation tax revenue figures from the REMI model, and information on what visitors spent their money on while on a trip to the area, the model is able to calculate the number of visitors needed to account for the revenues, based on specific spending patterns. The total amount of spending by visitors in Becker County amounted to $245 million (inflated from 1995 dollars) for the county. The research by UM-TC revealed that the average visitor group spends $287 per day on a typical trip to the Detroit Lakes area (Table 14C). [9] Using this information and the IMPLAN model, it was estimated that 2.6 million visitation days are taken to Becker County each year.

Table14C - Breakdown of Visitor Spending

Lodging	$137.10
Restaurants/Bars	$49.40
Transportation (incl. gas)	$24.20
Groceries	$14.80
Shopping	$43.20
Recreation or Attractions (incl. guides or outfitting)	$11.00
Miscellaneous	$7.40
Total	$287.10

The next step in estimating baseline visitation was to determine the proportion of these visitors attributable to Detroit Lakes. To do this, all lodging options in the county were obtained from the Recreation and Tourism Board of MN. Of the total number of hotels, motels, bed and breakfasts, campgrounds and any other type of visitor accommodations in Becker County, 27% were located in Detroit Lakes (Table 15C). Using this information, it was assumed that the same percentage of total county visitation was attributable to Detroit Lakes (705,090 visitor days). UM-TC reported that the typical visitor spends 2.4 days while in the Detroit Lakes area. Thus, it was determined that nearly 300,000 people visit Detroit Lakes annually.

Table 15C - Becker County and Detroit Lakes Lodging and Visitation

Becker County Total Lodging	59
Detroit Lakes Total Lodging	16
% Lodging in DL	27%
IMPLAN Visitor Days Estimate	2,600,000
DL Visitor Days	705,085
# of Visitor Days/Visitor	2.4
DL Total Visitation	293,785

[9] Mean number of people included in the spending estimates was 3.55. This was accounted for in the IMPLAN analysis.

Combining the survey results of visitors to the Detroit Lakes area and the Minnesota Outdoor Recreation participation Study, it was determined that 43% fish, 34% boat, and 23% swim while visiting.[10] Assuming a summer season of 97 days (June 1st thru September 5th.), results in 1320 fishers, 1056 boaters, and 704 swimmers on average for any given summer day.

Baseline Property Values, Local environmental factors often influence people's choice of housing. It has been demonstrated that individuals place high value on having nice views or parks nearby, or on having high water or air quality in their neighborhoods. As environmental quality declines or increases, property values are likely to follow the trend. Although not necessarily in direct contact with the water, the landowners can experience negative impacts from increased bloom frequency and intensity through a decline in property values. If a lake that is known for its excellent water quality begins to experience a decline, the demand for waterfront property would follow. As long as water quality remains at current levels, there will be no related negative impacts on housing values.

Future without project conditions

Future Water Quality. At the current time, it was not possible to accurately predict the future in-lake phosphorus concentrations absent the project. Without having a projection of the expected increase of future phosphorus levels, the following scenarios were used in the benefit analysis: 1) a 10 year linear increase of in-lake phosphorus concentrations from the baseline, 24 ppb, to a future in-lake concentration of 40 ppb (6.6% increase/year), 2) a 25 year linear increase from the baseline to future in-lake concentration of 40 ppb (2.66%/year), and 3) a 50 year linear increase from baseline to future in-lake concentration of 40 ppb (1.33% increase/year). These scenarios were developed using best available information and consultation with MPCA. Detailed information can be found in the water quality section above.

Future Recreation. As in-lake phosphorus concentrations increase, the probability of algal blooms also increases, thus reducing recreational opportunities. Using projections of phosphorus levels and probability of algal blooms from the MPCA, it is possible to estimate the number of recreational days lost annually based on the in-lake phosphorus predictions presented above. It was assumed that swimmers would be affected by lower intensity blooms, while more severe blooms would have to occur before fishers and boaters were affected. As conditions continue to degrade over time, absent the project, more recreational opportunities would be lost. For example, if in-lake phosphorus levels increased by 36% (which is projected in year 27 using scenario 4 from above) 5 swimming days, 1 boating and 1 fishing day would be lost. Discussed in the baseline visitation estimation above, each of these days has an associated number of recreators participating in one of the activities. These future visitation days lost are tracked over the life of the project. If the project were to be implemented, phosphorus and recreation levels would be maintained, thus these days lost, absent the project, are the recreation damages avoided, or project benefits.

Using the total visitation days lost over the projected time period (100 years is the estimated project lifetime) and the monetary value of a swimming, fishing, or boating day, the total recreation benefits of the project can be estimated. User day values were obtained from USFS 2005 and were updated to current

[10] According to the MN Recreation Participation Study, recreation activities for individuals traveling over ½ hour from home equated to 15% fishing, 12% boating, and 8% swimming. However, based on the assumption that all visitors to Detroit Lakes participate in at least one of these activities during a typical visit, these percentages were scaled up proportionately to account for 100% visitation (43% fish, 34% boat and 23% swim),

(2006) dollars. The values used in the analysis are as follows; swimming = $23/day, boating = $31/day, and fishing = $34/day. This dollar value represents consumer surplus, or how much the individual values the experience of participating in the specific type of recreation. The present value of the recreational benefits totaled $2.4 million, or an average annual value of $126,000.

Future Property Values. In addition to the recreational benefits resulting from the project, there are also benefits that will be realized by the waterfront property owners. The housing value component of project benefits is calculated as the marginal impact degraded water quality has on waterfront property values. To estimate these benefits the baseline housing values were compared to projected reductions due to the decline in water quality. Typically hedonic price analysis of property values is conducted to estimate these impacts. However after obtaining property sales information from the county assessor's office, results of the regression analysis were inconclusive. This result is related primarily to the lack of water quality data. The limited water quality did not show enough variation to determine statistical relationships to sales values. For this reason the property analysis had to rely on the results of previous research. During the literature review process of this analysis, a study conducted by Krysel *et al* 2003 estimated the impacts of water quality on property values in the Mississippi Headwaters Region. One of the counties and its associated lakes included in the analysis was Hubbard County. Hubbard County is adjacent to Becker on the eastern border. The estimated values in the Krysel *et al* study were able to be transferred to this study because Hubbard and Becker Counties share similar geographic and socioeconomic characteristics. In their report, Krysel *et al* estimate the value of a 1 meter decrease in secchi disk readings on the value per frontage foot for 6 lakes in Hubbard County (Table 16C).

Table 16C - Value of Water Quality Decline in Hubbard County Lakes

Hubbard County Lakes	$/FF for 1M Decrease
4th Crow Wing	$ 23.00
8th Crow Wing	$ 27.30
Belle Taine	$ 33.90
Fish Hook	$ 82.80
George	$ 39.00
Long	$ 2.70
Average	$ 34.80

Using information obtained from the Becker County tax assessor's office, data on predicted phosphorus levels, and the estimated values of changes in water quality on housing values, the property value benefits for Detroit Lakes were estimated. A simple average value for $/FF impact for a 1 meter decrease in secchi depth was used in the benefits transfer. Using the predicted increase of in-lake phosphorus levels described earlier, it is revealed the phosphorus levels "peak" and level off at 40 ppb, or year 50. Based on a phosphorus concentration of 40 ppb for lakes in this region, MPCA data suggests that secchi disk readings to be 2 meters. The baseline secchi disk reading for Detroit Lakes was estimated to be 2.8 meters, resulting in a decline of 0.83 meters if the project were not installed. Based on an average $/FF for a 1 meter decline and total frontage feet for Detroit Lakes, the estimated value of maintaining water quality to these homeowners totaled $2,480,000 (present valve (PV) of $214,000), or an average annual value of $11,100.

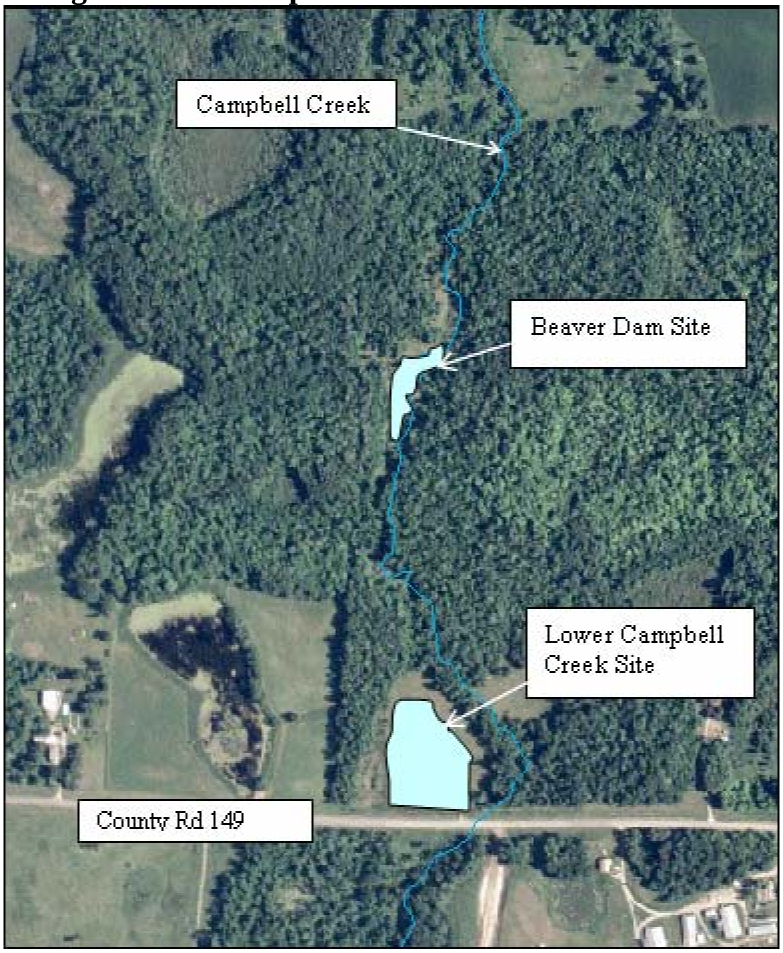
Total Benefits. The total benefits for the project are the sum of the recreational and housing values. The recreational values are a stream of benefits from year 1 to 101 that are discounted to present value and then for the purposes of the watershed plan converted to an average annual value. Over the project lifetime these benefits had a present value of the recreational benefits totaled $2.4 million, or an average annual value of $126,000. The housing values are estimated at year 50 when in-lake phosphorus levels peak and then level off. The impact of the predicted decline on water quality is evaluated at year 50 and then discounted to present value, and again converted to an average annual value. The estimated value of maintaining water quality to these homeowners totaled $2,600,000 at year 50. Once discounted, the present values equals $214,000, or an average annual value of $11,100. Combining the recreational and housing values, the present value of total benefits is $2.66 million, or an average annual value of $137,300.

Campbell Creek Sediment Basins

One of the Watershed Plan's goals is to reduce total phosphorus loadings to North Floyd Lake by 50%. Achieving this reduction will involve treatment of Campbell Creek, the major contributor of runoff and sediment to North Floyd Lake. Based on PRWD monitoring data and water quality modeling, a large percentage of Campbell Creek's phosphorus is associated with sediment. The drainage area upstream of North Floyd Lake has the highest percentage of highly erodible cropland within the entire Upper Pelican River Project area. Sediments from cropland usually have high levels of nutrients attached. Also, the reach of Campbell Creek between monitoring stations CC2 and CC1 is a significant source of streambank erosion and floodplain/channel scour due to the steep grade. Although sediments from streambank and floodplain/channel scour may not have high levels of phosphorus attached at their source, dissolved phosphorus will attach to these sediments as they become entrained within the stream. Because of these factors, the strategy for controlling total phosphorus loadings from Campbell Creek is based on reducing sediment loads to North Floyd Lake.

Two potential sediment basin sites were analyzed for reducing suspended loads from Campbell Creek into North Floyd Lake. These will be referred to as the Lower Campbell Creek Sediment Basin (LCCSB) and the Beaver Dam Site Sediment Basin (BDSSB). See figure 27C for locations.

Figure 27C - Campbell Creek Sediment Basin Sites



Lower Campbell Creek Sediment Basin

In general, the LCCSB site is located just NW of the Campbell Creek/County Road 149 Crossing in an existing pasture. Two configurations were analyzed:

1. Flow Through type structure - all streamflows would pass through the sediment basin. This option is referred to as LCCSB-Flow Through, figure 28C.

2. Off Channel Diversion type structure - only a portion of streamflows are routed into the sediment basin. This option is referred to as LCCSB-Diversion.

For both configurations, outflows from the sediment basin would be returned back into Campbell Creek just upstream from Country Road 149 via an outlet structure(s)[11]. Figure 2 shows a plan view of the Flow Through sediment basin configuration. The only difference between the two configuration types are the lateral and in-stream weir lengths.

[11] Preliminary designs assume two outflow structures. Two outflow structures reduce sediment basin "short circuiting" and re-suspension of sediments.

Figure 28C - Lower Campbell Creek Sediment Basin Plan View

<u>Inflow Structure.</u> A lateral weir parallel to the Campbell Creek would divert flows into the sediment basin. In addition to the lateral weir, a small weir would be built directly in Campbell Creek approximately 50 feet downstream of the lateral weir. For the LCCSB-Flow Through configuration, the in-stream structure weir bays would have stoplogs in place during the diversion season (snowmelt through July 1st) forcing all water through the sediment basin. For the LCCSB-Diversion configuration, the in-stream structure is configured such that diversion of stream flow begins at approximately 5 cfs[12]. The LCCSB-Diversion configuration allows approximately 50-70 percent of the annual runoff volumes to bypass the sediment basin and continue downstream.

<u>Sediment Pool.</u> A sediment storage pool would be created by excavating and reshaping existing topography down to an elevation of 1379.0. Stormwater storage/sediment settling would be within the excavated permanent pool area in addition to above ground storage created by a 1,700 foot long containment dike. The dike would have a top elevation of approximately 1388.0 (maximum routed pool elevation + 3 feet) making it approximately 8 feet high at its maximum height. The 3.25 acre permanent pool would be 3.5 feet deep creating 11 acre-feet of storage for sediment.

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[12] For perspective, of the PRWD's flows during grab sampling, 44% were less than 5 cfs.

Approximately 100 feet downstream of the lateral weir, within the sediment basin, a 250 foot long rock "leveler" would be constructed. The purpose of the rock leveler is to spread out the flow evenly across the sediment basin, enhancing sediment settling characteristics. The rock would have a top elevation of 1383.0 and be about 4 feet high. The area between the lateral inlet weir and rock leveler is referred to as the sediment basin forebay.

Outlet Structure. The outlet structure(s) are assumed to have a pipe barrel/riser configuration. The riser and pipe have 4 foot and 3 foot diameters respectively. Weir flow on the riser(s) would control pool elevations. The weir crest(s) would be set at 1383.0. The structure(s) would outlet into the road ditch north of County Road 149. The LCCSB-Flow Through configuration would require two structures while the LCCSB-Diversion configuration would only have one structure. One advantage in having two outlet structures is the flows spread out more across the sediment pool, enhancing sedimentation and reducing potential re-suspension of sediments.

Bypass Flows. The LCCSB-Diversion configuration can control the amount flow that enters the sediment basin by manipulating the in-stream stop log structure. Since much of the sediment load on Campbell Creek generally comes during the period between spring snowmelt to the end of June[13], the diversion of flows for this configuration could be set to occur only during this period. The lateral weir structure stop logs could be used to "close" the sediment basin off from July through the end of the growing season.

The LCCSB-Flow Through configuration would not be manipulated to control bypass flows. All stream flows would flow through the sediment basin. The lateral weir structure, however, could be shut off with stop logs to allow for cleanout, maintenance, etc. of the sediment basin/outlet structures.

Beaver Dam Site Sediment Basin (BDSSB)

This site is located approximately 1,000 feet upstream of the LCCSB. This portion of Campbell Creek has a natural widening of its floodplain compared with upstream and downstream conditions where more entrenched conditions exist. There is evidence to suggest that a large beaver dam existed on this site at one point. Because of the beaver dam's pool, the area does not have many mature trees in the floodplain and is open. This area is currently used for pasturing. See figure 29C below.

BDSSB Outlet Structure. The BDSSB would be an on-stream type structure. All flows would pass through the structure. The outlet structure for this site would be located near the abandoned/breached beaver dam and have a 50 foot long open weir spillway with a crest elevation of approximately 1392.0. The weir length is designed to reduce bounce and potential plugging from debris. The embankment and outlet structure would be tie into existing valley side walls and be approximately 200 foot long. The top of the embankment would be set at approximately 1396.0, which is about 7 feet above the existing floodplain.

[13] From July forward, upland soil erosion and runoff is less (canopy + increased ET reduce soil movement and runoff amounts). An analysis of PRWD monitoring data show that, on the average, 75% - 85% of the annual suspended sediments and total phosphorus load occurs prior to July 1.

Figure 29C - Looking Upstream at Beaver Pond Site

<u>BDSSB Sediment Pool.</u> The BDSSB sediment pool would extend approximately 750 feet upstream and be about 100 feet wide. The pool would have an average depth of 3 feet and surface of 1.5 - 2.0 acres. The pool depth at the outlet structure would be 4.5 feet (distance from weir crest to existing floodplain). Minor earthwork would be required within the pool area to create a more level bottom and fill in the existing channel in order to enhance sediment deposition and reduce flow "short circuiting" and re-suspension. The structure would have an effective sediment capacity of approximately 2 acre-feet of sediment storage capacity.

<u>Effects of LCCSB and BDSSB Sediment Basins</u>

Procedures outlined in "Stormwater Wet Detention Pond Design for Water Quality Benefits" by Robert Pitt, Ph.D., P.E. (1993) were used to estimate the effects of sediment basins on Campbell Creek. Both the LCCSB and BDSSB structures were designed as "wet" (permanent pool) type detention basins. This type of structure provides more reliable settling characteristics than dry type sediment basins.

Trapping efficiency was estimated using the "upflow velocity" procedure as described by Pitt. Essentially, settling velocity of sediments is a function of particle size. For a given flow through a sediment basin, an upflow velocity is determined (V_{basin} = outflow/basin surface area). All particles with settling velocities greater than or equal to V_{basin} settle out. Assuming a suspended sediment particle size distribution, the percentage of particles trapped can be calculated.

Suspended sediment particle size distribution for Campbell Creek has not been determined. Pitt however describes several distributions from several upper Midwest and Ontario analyses. Trapping efficiency analyses of the LCCSB and BDSSB sites was performed assuming three different distributions: NURP[14], Midwest[15], and Low[16]. Results of the sedimentation analysis results are presented as a range using these three different distributions. Assuming the Midwest particle size distribution resulted in the most sedimentation while Low showed the least sedimentation. Prior to final design, it is suggested that an actual distribution be determined for Campbell Creek.

PRWD discharge monitoring was used to develop 6 hour time step hydrographs for the 1996 - 2004 runoff seasons. The discharge data was entered into a spreadsheet where upflow velocities (Q/pool surface area), sediment size settled, and percentage of suspended sediments deposited are calculated for each 6 hour time step[17]. Finally, the results from each 6 hour time step were summed to get the total percentage of sediment settled out for the year. Since percentage of suspended sediment deposited is a function of particle distribution, three different percentages of total suspended sediments were determined (NURP, Midwest, and Low).

The analysis was conducted assuming 5 scenarios:

1. BDSSB In Place
2. LCCSB-Diversion In Place
3. BDSSB + LCCSB-Diversion In Place
4. LCCSB-Flow Through In Place
5. BDSSB + LCCSB-Flow Through In Place

Tables 18C, 19C, and 20C below summarize the routing/sedimentation results for 1996 - 2004 for each of the scenarios by suspended sediment distribution. Figure 30C, 31C, and 32C display these results in graphical form.

Sediment Basin Design Life. The FLUX program was used to estimate Campbell Creek average annual sediment loading using paired PRWD SS/discharge data from 1996 through 2005. The FLUX estimate was approximately 100 tons per year with an average concentration of 17.4 ppm. Table 17C summarizes estimated fill in time, by scenario, assuming a NURP suspended sediment distribution[18].

[14] Average of all NURP (National Urban Runoff Program) studies.
[15] Two NURP projects located in Champaign, Illinois and Washtenaw County, Michigan
[16] From Eastern US Sediment studies assuming low solids
[17] For the LCCSB-Diversion scenario, an unsteady flow HEC-RAS model was developed to split these hydrographs into "bypass" flows (flows going past the sediment basin's inlet without treatment) and sediment basin flows (flows going through the sediment basin).
[18] All sediment basins fill in time estimates assume load of approximately 100 ton/yr (0.087 AF/yr assuming 52.5 #/cu ft submerged sediment density).

Table 17C - Estimated Sediment Basin Fill Time - (NURP Distribution)

Scenario	Years to Fill In	
	BDSSB	LCCSB
BDSSB Only	54	N/A
LCCSB - Diversion Only	N/A	504
BDSSB + LCCSB - Diversion	54	873
LCCSB - Flow Through Only	N/A	198
BDSSB + LCCSB - Flow Through	54	344

Discussion and Recommendations. The Upper Pelican River Watershed plan objective of reducing total phosphorus to North Floyd Lake relies on watershed upland treatment, streambank stabilization, and sediment basins. Pitt estimates that the percentage total phosphorus control is 0.60 of the suspended sediment control for wet detention ponds. For example, a sediment basin with a suspended sediment reduction of 75% would reduce total phosphorus by approximately 45% (= 75% * 0.6). Reducing total phosphorus in Campbell Creek 50% would require approximately an 85% reduction in suspended sediments. If upland treatment and streambank stabilization measures are in place, a 20% reduction in suspended sediment load seems reasonable. This leaves approximately a 65% reduction in suspended sediment required by the sediment basin(s).

Assuming a NURP type suspended sediment distribution, the LCCSB-Flow Through only scenario would achieve this. It is recommended that the LCCSB-Flow Through only structure, in addition to upland treatment and streambank stabilization, be included in the Campbell Creek total phosphorus reduction plan. The addition of the BDSSB to this only adds an additional 13% to the total suspended sediment control. The additional cost and difficulty of access for construction/operation and maintenance does not justify this additional component.

As mentioned earlier in this report, the trapping efficiency of the sediment basins is a function of the distribution size of the suspended sediment. The above recommendation assumes a NURP type distribution. It is recommended that, during the 2007 monitoring season, 3 field samplings be made, during low, medium, and high flow, to estimate actual suspended sediment distribution. If the actual distribution is more aligned with a “low” type distribution, then it may be necessary to investigate the option of adding on the BDSSB to the LCCSB-Flow Through alternative (assuming a “low” distribution, this option, scenario 5, gives 58% sediment control).

This analysis and design is based strictly on hydrology and hydraulics. Any final proposal will include environmental components such as wetland vegetation, perimeter planting, and structure (islands, depth variation, shelves, etc.)

Table 18C - Sediment Trapping Efficiencies by Scenario - NURP Suspended Sediment Distribution

Scenario:	Estimated % SS Reduced by Year by Scenario (**NURP SS Distribution**)									
	1996	1997	1998	1999	2000	2001	2002	2003	2004	**Average**
1. BDSSB Only	36%	35%	42%	36%	38%	38%	57%	54%	44%	**42%**
2. LCCSB-Diversion Only	31%	26%	32%	27%	29%	28%	6%	21%	27%	**25%**
3. BDSSB+LCCSB-Diversion	56%	51%	61%	54%	56%	55%	60%	64%	59%	**57%**
4. LCCSB-Flow Through Only	60%	51%	65%	54%	60%	57%	93%	74%	60%	**64%**
5. BDSSB+LCCSB-Flow Through	74%	68%	80%	71%	75%	74%	97%	88%	77%	**78%**

Figure 30C - Sedimentation Estimates Assuming NURP Particle Size Distribution

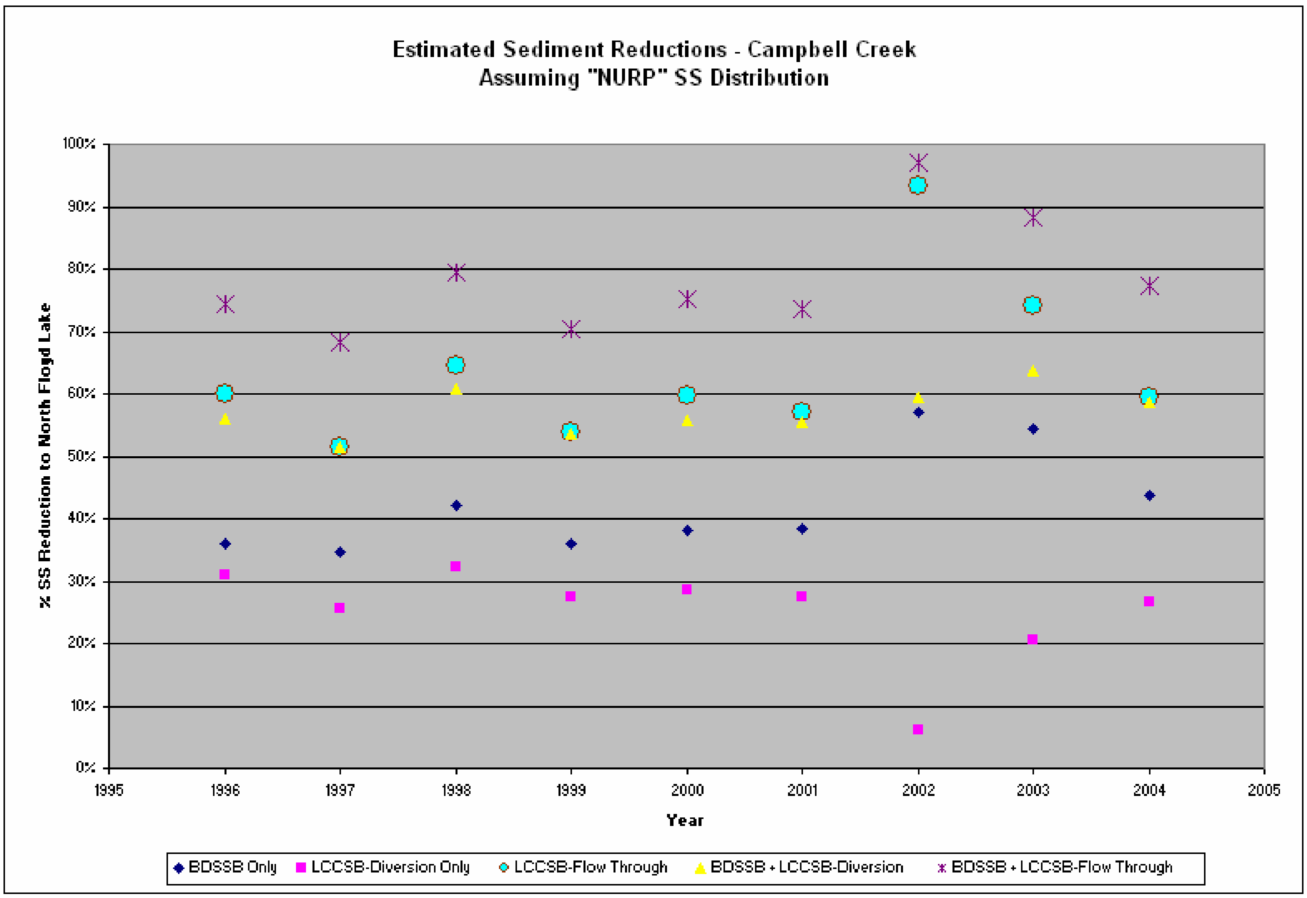

Table 19C - Sediment Trapping Efficiencies by Scenario - Midwest Suspended Sediment Distribution

Scenario:	Estimated % SS Reduced by Year by Scenario (**Midwest Distribution**)									
	1996	1997	1998	1999	2000	2001	2002	2003	2004	**Average**
1. BDSSB Only	67%	65%	73%	67%	69%	69%	83%	81%	73%	**72%**
2. LCCSB-Diversion Only	45%	41%	44%	42%	41%	41%	6%	26%	38%	**36%**
3. BDSSB+LCCSB-Diversion	82%	79%	85%	81%	81%	81%	84%	86%	83%	**83%**
4. LCCSB-Flow Through Only	86%	81%	88%	83%	86%	85%	98%	92%	86%	**87%**
5. BDSSB+LCCSB-Flow Through	96%	93%	97%	95%	95%	95%	100%	99%	96%	**96%**

Figure 31C - Sedimentation Estimates Assuming Midwest Particle Size Distribution

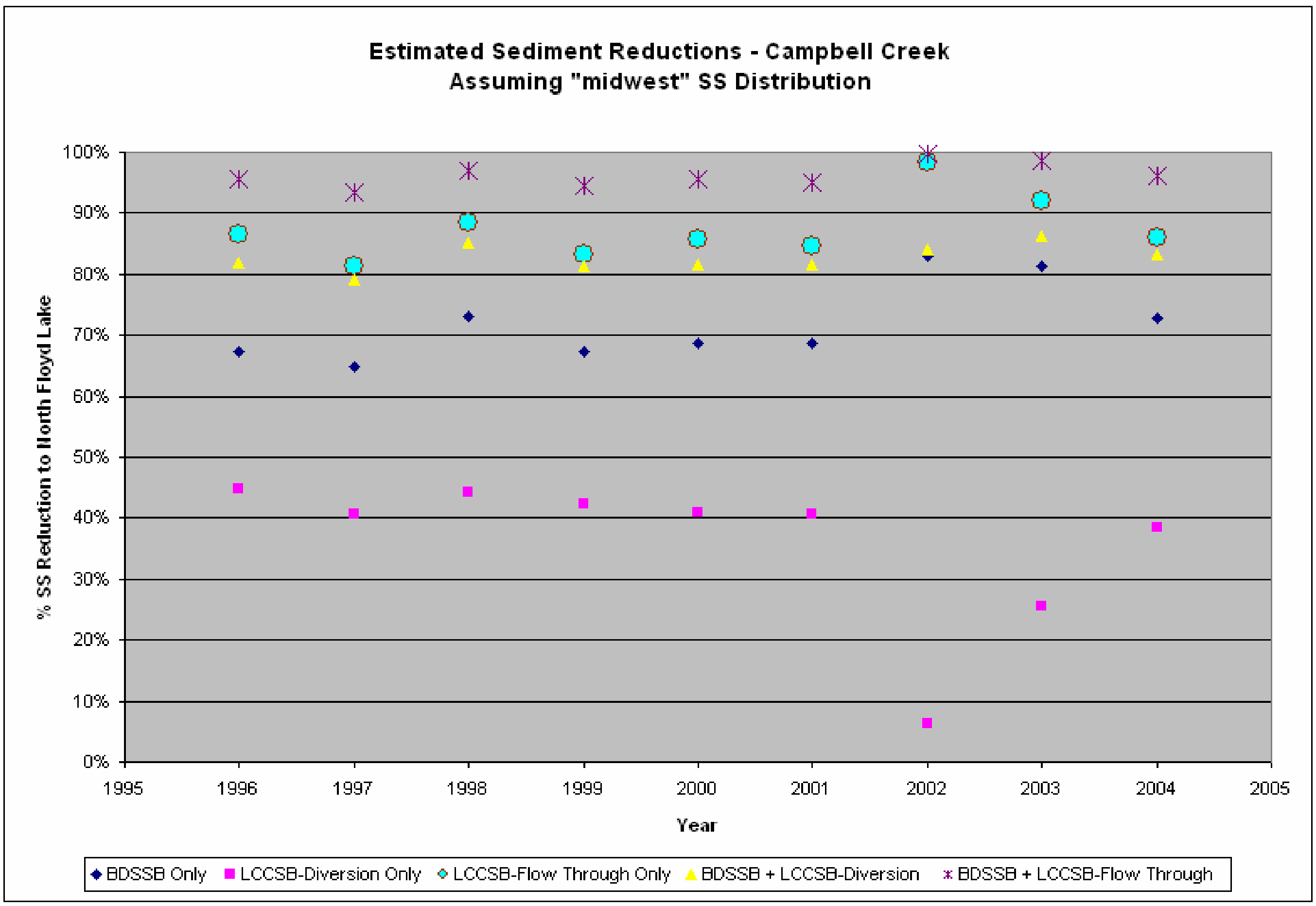

Table 20C - Sediment Trapping Efficiencies by Scenario - Low Suspended Sediment Distribution

Scenario:	Estimated % SS Reduced by Year by Scenario (**Low SS Distribution**)									
	1996	1997	1998	1999	2000	2001	2002	2003	2004	**Average**
1. BDSSB Only	17%	18%	23%	17%	20%	20%	39%	36%	25%	**24%**
2. LCCSB-Diversion Only	20%	16%	22%	17%	20%	18%	6%	16%	18%	**17%**
3. BDSSB+LCCSB-Diversion	34%	31%	40%	31%	36%	35%	42%	46%	39%	**37%**
4. LCCSB-Flow Through Only	39%	31%	45%	34%	41%	37%	89%	59%	40%	**46%**
5. BDSSB+LCCSB-Flow Through	50%	44%	57%	45%	53%	50%	93%	74%	55%	**58%**

Figure 32C - Sedimentation Estimates Assuming Low Solids Particle Size Distribution