

**PHOSPHORUS EXPORT FROM BUNGO CREEK
CASS COUNTY, MINNESOTA**

**By The Whitefish Area Property Owners Association
P.O. Box 342 Crosslake MN 56442
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INTRODUCTION AND BACKGROUND

The Whitefish Area Property Owners Association (WAPOA) conducted a PHOSPHORUS LOADING STUDY FOR THE WHITEFISH CHAIN RESERVOIR of 14 lakes in 2000 and 2001 to determine the amount of phosphorus entering and leaving the chain and the quantity of phosphorus accumulating in the deep basins of the chain. This study was conducted because water quality measurements dating to 1985 had shown decreasing water quality, and in order to plan remedial action, quantitative measures of the three main sources of phosphorus was necessary. One of the conclusions of this study was that 75 per cent (29,335 lbs/year) of the phosphorus entering the system came from the nine feeding streams. One of the streams, the Pine River, contributed 53 percent (15,664 lbs/yr) of the stream input and 40 percent (39,261 lbs/yr) of the phosphorus from all sources, streams, septics and precipitation). The input from precipitation was 15.4 percent of all phosphorus sources and the input from septics was 9.9 percent of all sources. Clearly the most significant phosphorus import is from the streams and specifically the Pine River. The result of this conclusion was a plan resulting in a report entitled a PINE RIVER PHOSPHORUS EXPORT STUDY was conceived to quantitatively determine the concentration of phosphorus and discharge of feeder streams to the main stem of the Pine River during 2002 and 2003.

Twelve sampling sites along the Pine River were identified to determine the concentration and quantity of phosphorus exported from the feeder streams so that the major exporting streams could be identified and possible remedial action developed. This investigation was conducted and funded through a grant from the Crow Wing County Water Plan via the Pine River Watershed Protection Foundation (PRWPF). The North Fork of the Pine passes through forested land and was not expected to be a major factor in exporting phosphorus. The South Fork, however, passes through agricultural lands and has the majority of the feeder streams. Therefore, the majority of the sampling sites were along the South Fork of the Pine. Bungo Creek, feeding the South Fork, led all feeder streams with an average monthly total phosphorus (TP) concentration of 109 micrograms per liter (ug/L) and a yearly phosphorus export of 10,379 lbs.

Dabill/Brittan Creek followed with an average monthly TP concentration of 78 ug/L and a yearly phosphorus export of 1,936 lbs. Even though the TP concentration was relatively high, the low flow rate resulted in a low yearly phosphorus export.

Since the PINE RIVER PHOSPHORUS EXPORT STUDY did not provide enough localization of phosphorus export sources along Bungo Creek, a study of phosphorus export on the creek was conducted under the sponsorship of the Whitefish Area Property Owners Association, and is the focus of this report.

DATA COLLECTION METHODS

Stream cross section profiles were measured at the time of sample collection. Culvert cross sectional areas were calculated from culvert diameter, top of culvert to water distance and top of culvert to bottom distance (+/- 0.1 ft). Sedimentation depth at the

bottom of culverts was obtained by subtracting the top of culvert to bottom distance from the culvert diameter. A nonograph for calculations of "Volume in Partially Filled Pipes" from Global Water Instrumentation, Inc. was then used to calculate water cross sectional area in the culverts. The two bridge stream profiles were measured at horizontal intervals of 1 foot and depths to ± 0.1 feet. Location C had a very undulating bottom, the contour of which changed from month to month making the depth measurements difficult. The major flow channel also changed monthly. The one foot interval x depth products were added to produce the cross sectional area. The cross section measurement and area calculation at this location is likely the largest single source of measurement error. The fact that our conclusions are based on the assumption that one measurement is typical for at least 30 days can also introduce significant errors, which could exceed 20 percent.

Flow velocity was measured at two thirds of the water depth with a Marsh McBurney Flow meter, model 201D on loan from the Crosslake Army Corps of Engineers. Total phosphorus water grab samples were collected in 250 mL sample bottles (acid washed by the analytical laboratory) after rinsing three times in a central location of the stream flow. The samples were identified, stored on ice and shipped the same day via UPS to ERA Laboratories in Duluth, Minnesota. Total phosphorus analysis was conducted in accordance with EPA method 365.2 with a minimum detection level of 2 ug/L. Three field duplicates run during the course of the work varied from accepted values by an average of 6.3 percent.

Data input sheets were developed for the required field measurements to insure consistency and to insure that no measurements were overlooked. The data sheet forms with actual data are shown in Table 3.

Monthly precipitation data are shown on Table 1. In addition the amount of precipitation (in.) that occurred in the 24 hours prior to sampling is shown. Long-term average precipitation for Cass County is 27.7 inches versus the 31.0 inches reported. The data are from the Minnesota Climatology Office, DNR Waters for Bungo Township.

BUNGO CREEK PHOSPHORUS EXPORT STUDY – CONCLUSIONS

In order to obtain a quantitative assessment of where and how much phosphorus entered the creek, the stream was sampled for phosphorus concentration and discharge at approximately one-mile intervals from the headwaters (Location A) to near where Bungo empties into the South Fork of the Pine (Location F). The measurements were made about monthly from May 2004 through May 2005 except for the period when the creek was iced over. Bungo Creek drops about 100 feet in elevation as it meanders over private land approximately six miles from its origin at the easterly edge of the Foothills State Forest (Bungo Township, Section 33) to its mouth near Cass County Highway 2 (Section 1) where it joins the South Fork of the Pine. Six sample locations (Figure 1) were selected along the six miles to determine where the, previously identified, high concentrations of phosphorus were introduced. The sites were selected at approximately

one-mile intervals where the creek crossed roads or other accessible locations. GPS locations and elevations are shown in Table 2.

The greatest phosphorus concentration increase between monitoring sites was found where the creek crossed 36th Street (Location C). The greatest discharge (flow volume) and hence the greatest phosphorus mass increase also occurred at this location. This location drains Bungo Township Section 23, which is approximately 1/3 agricultural, and 2/3 deciduous trees, brush and wetland. (The Township Section numbers are shown in Figure 1) An aerial photo of this section from the Farm Service Agency of the U S Department of Agriculture is presented in Figure 2. Notable is the relatively high flow volume at Location C, which was not evident at upstream locations and therefore, must come from surface water springs in Township Section 23. In addition, examination of the photograph shows that the upper reaches of the creek and its branches flow through wetland surrounded by trees and brush with no obvious agricultural impact.

Of concern is that the data show that the average annual total phosphorus concentrations for all six sites were greater than 56 ug/L and ranged up to a high annual average of 87 ug/L. This is in general agreement with the earlier Pine River Export study where the average annual total phosphorus exported from Bungo Creek to the South Fork of the Pine was reported to be 93 ug/L. These concentrations are all well above the expected level for streams in the Northern Lakes and Forests ecoregion which is 30 to 50 ug/l. Summary data for all six monitoring sites are shown in Table 1.

The most upstream monitoring site (Location A) which had low flow (<0.6 cubic ft./sec.) on only four occasions had an average concentration of 57 ug/L. for four sample periods. Moving downstream, the two feeder streams at 40th Street (Location B) had virtually no flow at any time and did not contribute significant phosphorus. Virtually no water flow was evident where the creek passes under 56th avenue (upstream of Location C) and therefore was not monitored. Location C is the next downstream location (at 36th Street) had the highest average concentration and greatest concentration increase from the next upstream location of all sites at 87 ug/L and 30 ug/L respectively. Clearly the majority of the phosphorus in Bungo Creek and subsequently, the Pine River enters the creek between Locations A and B and Location C.

RECOMMENDATIONS

Since we now know that the major source of phosphorus-laden creek water comes from Section 23, the next step is to have a professional geohydrologist locate the source of surfacing ground water and determine its phosphorus content. It is possible that what appears phosphorus-laden ground water could be picking up phosphorus from an agricultural activity some distance away. If the phosphorus content of the surfacing ground water does not exceed 30 ug/L further investigation must be made to locate the phosphorus source.

At this point it appears that the major phosphorus source in Bungo Creek is not a direct agriculture impact, which means that we must continue to search for the actual source

DISCUSSION OF RESULTS

Water Resource

It can be noted from Table 1 that there was virtually no flow from June through October for Locations A and B. The fact that there was flow at Location C, when there was no flow at Locations A and B indicates that there was ground water surfacing somewhere upstream of Location C in section 23. This plus the high concentration of phosphorus (30 to 176 ug/L) suggests that the surfacing ground water is rich in phosphorus or that the surfaced water flushes phosphorus from land surfaces upstream from location C.

In a perfect world one would expect a sequential increase in phosphorus, discharge and mass as the stream flows to lower elevations. The data do not support this expectation but instead demonstrates a generally increasing trend. One partial explanation is that beaver dams were observed downstream of Location E in May 2004 and upstream of Location E in October 2004. There may have been other blockages along the stream course, which were not observed but could have further skewed discharge and mass data. High levels of precipitation, particularly in July and September, would be expected to drive discharge and possibly flashy increases in phosphorus concentration. There is some indication that this is true, but the data are certainly not consistent.

The total mass of phosphorus exported by Bungo Creek at Location F, into the Pine River, for the eight measurements is 4761 lbs., which is half the 10,379 lbs reported in the previously cited report – PHOSPHORUS EXPORT FROM THE PINE RIVER. The exported mass was calculated using the flow weighted average formula as follows:

$$T = QC 0.16376$$

Where

T = Amount of phosphorus per month in pounds

Q = Average discharge rate in cubic feet per second

C = Total phosphorus concentration in micrograms per liter

Land Resource

The raw data for all locations and sample dates are presented in Table 3. These data are organized alphabetically, and then chronologically, for culverts and bridges. The Bungo Sub - Watershed land use is presented in Figure 3. The watershed data came from The National Wetland Inventory (1996) based on Circular 39. This inventory is useful in helping to understand the types of land cover around the creek. The Phosphorus Export Coefficient for the terrestrial area of 11,803 acres in the sub – watershed is calculated as follows: $4761 \text{ lbs (8 measurements)} \times \{4761 + (4761 \times 4/12)\} / 11,803 \text{ acres} = 0.538 \text{ lbs/acre/year}$. The 4/12 factor adds four months to the estimated export for a yearly number. The 0.538 coefficient is in the most likely range for rural/agricultural land use and may be compared with the 1.06 value previously reported in the Pine River Export report.

CREDITS

Our thanks to the Whitefish Area Property Owners Association for sponsoring and funding this project.

Thanks to Mr. John Sumption, Cass County Environmental Services, for providing the Arc View map used to describe Bungo Creek Locations.

Special thanks to Mr. Edward Feiler, DNR Waters for providing the Bungo Sub Watershed Figure which shows land use in the watershed.

Thanks to Mr. Ray Nelson, Army Corps of Engineers at Crosslake, for the use of a water velocity measuring instrument.

Thanks to the proofreaders for correcting my mistakes: D. Carlson, S. Lucas, R. Meyer, K. Rezanka and J. Sumption

Table 1
Bungo Creek

TP, Volume and Mass Comparisons

| Location | Total Phosphorus (ug/L) | | | | | | | | TOTAL | Average |
|----------------------------------|-------------------------|-----------------|-----------------|-----------------|------------------|-----------------|------------------|----------------|-------|---------|
| | May 5/19/04 | June 6/22/04 | July 7/30/04 | Aug. 8/30/04 | Sept. 9/27/04 | Oct. 11/2/04 | April 3/31/05 | May 5/20/05 | | |
| A. Bungo @ 60th Avenue. | 49 | | 64 | | | | 90 | 23 | 226 | 57 |
| B. @ 40th Street | 37 | | | | | | 77 | | 114 | 57 |
| C. @ 36th Street | 40 | 99 | 176 | 120 | 61 | 30 | 111 | 59 | 696 | 87 |
| D. @ Bungo Creek Ln. | 43 | 86 | 114 | 94 | 67 | 38 | 122 | 50 | 614 | 77 |
| E. @ 50th Ave S.W. | 43 | 75 | 90 | 100 | 73 | 38 | 122 | 43 | 584 | 73 |
| F. @ 48th Avenue | 52 | 94 | 106 | 82 | 67 | 42 | 134 | 51 | 628 | 79 |
| Discharge (cu. ft./sec.) | | | | | | | | | | |
| A. Bungo @ 60th Avenue | 0.2 | | 0.2 | | | | 0.6 | 0.1 | 1.1 | 1 |
| B. @ 40th Steet. | 0.1 | | | | | | 0.2 | | 0.3 | 0 |
| C. @ 36th Street | 16 | 2 | 4 | 1 | 18 | 12 | 48 | 18 | 103 | 13 |
| D. @ Bungo Creek Ln. | 3 | 2 | 5 | 2 | 6 | 4 | 30 | 12 | 64 | 8 |
| E. @ 50th Ave. S.W. | 16 | 2 | 3 | 1 | 7 | 14 | 86 | 5 | 134 | 17 |
| F. @ 48th Avenue | | 0.7 | 1 | 0.7 | 7 | 2.5 | 5 | 3 | 22 | 3 |
| Phosphorus Mass (lbs/mo.) | | | | | | | | | | |
| A. Bungo @ 60th Avenue | 2 | | 2 | | | | 8 | 1 | 13 | 3 |
| B. @ 40th Street | 1 | | | | | | 3 | | 4 | 2 |
| C. @ 36th Street | 64 | 34 | 110 | 4 | 96 | 59 | 843 | 175 | 1385 | 173 |
| D. @ Bungo Creek Ln. | 21 | 23 | 86 | 28 | 71 | 28 | 590 | 100 | 947 | 118 |
| E. @ 50th Ave. S.W. | 112 | 23 | 43 | 16 | 85 | 85 | 1711 | 34 | 2110 | 264 |
| F. @ 48th Avenue | 21 | 10 | 22 | 9 | 78 | 11 | 123 | 28 | 302 | 38 |
| TOTAL | | | | | | | | | 4761 | 598 |
| Precipitation (in./mo.) | | | | | | | | | | |
| Bungo Township | 3.32 | 2.70 | 6.23 | 1.87 | 8.02 | 2.24 | 2.43 | 4.17 | 31.0 | 3.9 |
| Days between Samples | 31 | 34 | 38 | 31 | 28 | 36 | 149 | 50 | | |
| Precip. 24 hrs. prior to sample | 0 | 0 | 0.76 | 0.03 | 0 | 0 | 0 | 0.83 | | |
| Beaver Dam Blockage | | | | | | | - No Flow | | | |
| Surface Spring Water Addition | | | | | | | | | | |

Table 2
 Bungo Creek Sampling Locations and Elevations

| LOCATION | LATITUDE | LONGITUDE | REF.ELEV. (ft.) | ADJUSTMENT | ACT. ELEV (ft.) | ELEV. DROP (ft.) |
|------------------------|---------------|---------------|-----------------|------------|-----------------|------------------|
| A. Bungo @ 60th Avenue | 46 deg.39.614 | 94 deg.35.881 | 1434 | -2.1 | 1431.9 | 0 |
| B @ 40th Street | 46 39.618 | 94 34.122 | 1432 | -2.6 | 1429.4 | 2.5 |
| C. @ 36th Street | 46 40.475 | 94 34.043 | 1396 | -7.0 | 1389.0 | 42.9 |
| D. @ Bungo Creek Ln. | 46 41.590 | 94 33.264 | 1361 | -6.8 | 1354.2 | 75.2 |
| E. @ 50th Ave. SW | 46 42.555 | 94 32.707 | 1327 | -2.0 | 1325.0 | 106.9 |
| F. @ 48th Avenue | 46 42.940 | 94 32.149 | 1326 | -4.0 | 1322.0 | 109.9 |

2.5

40.4

32.3

31.7

3

Table 3B

Location C - 36th Street

Bungo Creek Bridge Phosphorus Export

| 1 | A | B | C | D | E | F | G | H | I |
|----|------------------------------------|------------|--------|-------------|----------|-----------|-------------|-------------|-------------|
| 2 | Date | Bridge to | Width. | Ave. Depth. | Area. | Av. Vel. | Volume. | Total Phos. | Mass |
| 3 | | Water. ft. | feet | feet | sq. feet | feet/sec. | cu.ft./sec. | microgms/l. | lbs/mo. |
| 4 | 5/19/04 | 7.0 | 6.0 | 0.7 | 4.2 | 2.34 | 9.8 | 40 | 64.4 |
| 5 | 6/22/04 | 7.0 | 6.0 | 0.5 | 3.0 | 0.69 | 2.1 | 99 | 33.6 |
| 6 | 7/30/04 | 7.1 | 6.0 | 0.7 | 4.2 | 0.91 | 3.8 | 176 | 110 |
| 7 | 8/30/04 | 7.2 | 6.0 | 0.4 | 2.4 | 0.08 | 0.2 | 120 | 3.8 |
| 8 | 9/27/04 | 6.7 | 6.0 | 1.0 | 6.0 | 1.60 | 9.6 | 61 | 95.9 |
| 9 | 11/2/04 | 6.6 | 6.0 | 1.1 | 6.6 | 1.82 | 12.0 | 30 | 59.0 |
| 10 | 3/31/05 | 7.2 | 6.0 | 2.4 | 14.4 | 3.2 | 46.4 | 111 | 843 |
| 11 | 5/20/05 | 8.6 | 6.0 | 1.1 | 6.6 | 2.7 | 18.1 | 59 | 175 |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | Location E - 50th Avenue SW | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | data | data | data | C*D | data | E*F | data | G*H*0.16376 |
| 17 | Date | Bridge to | Width. | Ave. Depth. | Area. | Av. Vel. | Volume. | Total Phos. | Mass |
| 18 | | Water. ft. | feet | feet | sq. feet | feet/sec. | cu.ft./sec. | microgms/l. | lbs/mo. |
| 19 | 5/19/04 | 1.5 | 11.0 | 3.0 | 33.0 | 0.48 | 15.8 | 43 | 112 |
| 20 | 6/22/04 | 1.2 | 11.0 | 2.4 | 26.4 | 0.07 | 1.8 | 75 | 22.7 |
| 21 | 7/30/04 | 2.0 | 11.0 | 1.9 | 20.9 | 0.14 | 2.9 | 90 | 43.1 |
| 22 | 8/30/04 | 2.0 | 11.0 | 1.8 | 19.8 | 0.05 | 1.0 | 100 | 16.2 |
| 23 | 9/27/04 | 2.3 | 11.0 | 1.8 | 19.8 | 0.36 | 7.1 | 73 | 85.2 |
| 24 | 11/2/04 | 2.5 | 11.0 | 1.5 | 16.5 | 0.83 | 13.7 | 38 | 85.2 |
| 25 | 3/31/05 | 0.8 | 11.0 | 3.4 | 37.4 | 2.29 | 85.6 | 122 | 1711 |
| 26 | 5/20/05 | 2.3 | 11.0 | 0.5 | 5.5 | 0.87 | 4.8 | 43 | 33.7 |

Bungo Ck. Br. Phos. Export.

0.75 in. precipitation morning of 7/30/04

0.2 in. precip. 8/29/04

4.5 in. of precip 9/23/04

Bungo Ck.Br. Phos. sheet 1

Figure 1
Bungo Creek Locations

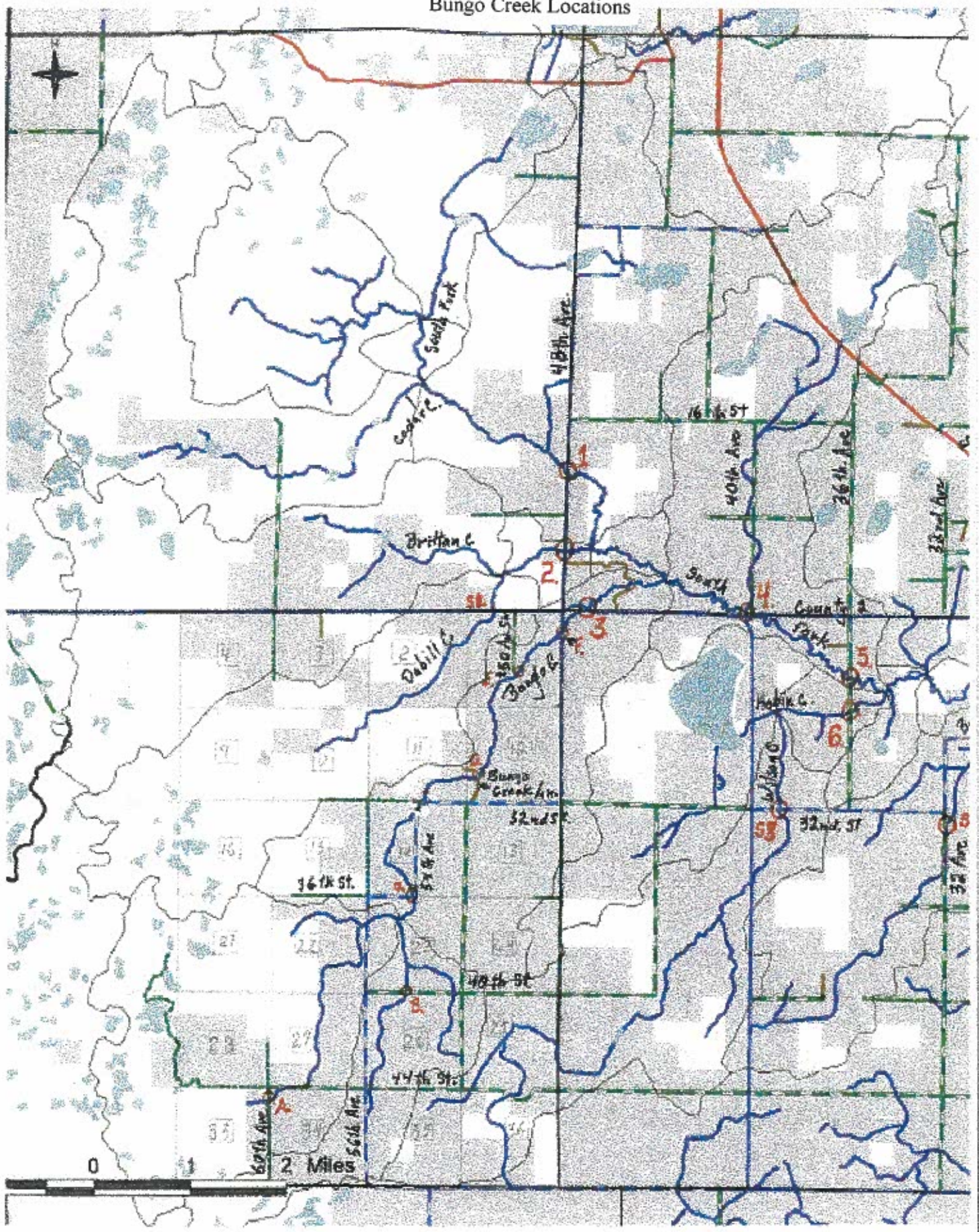
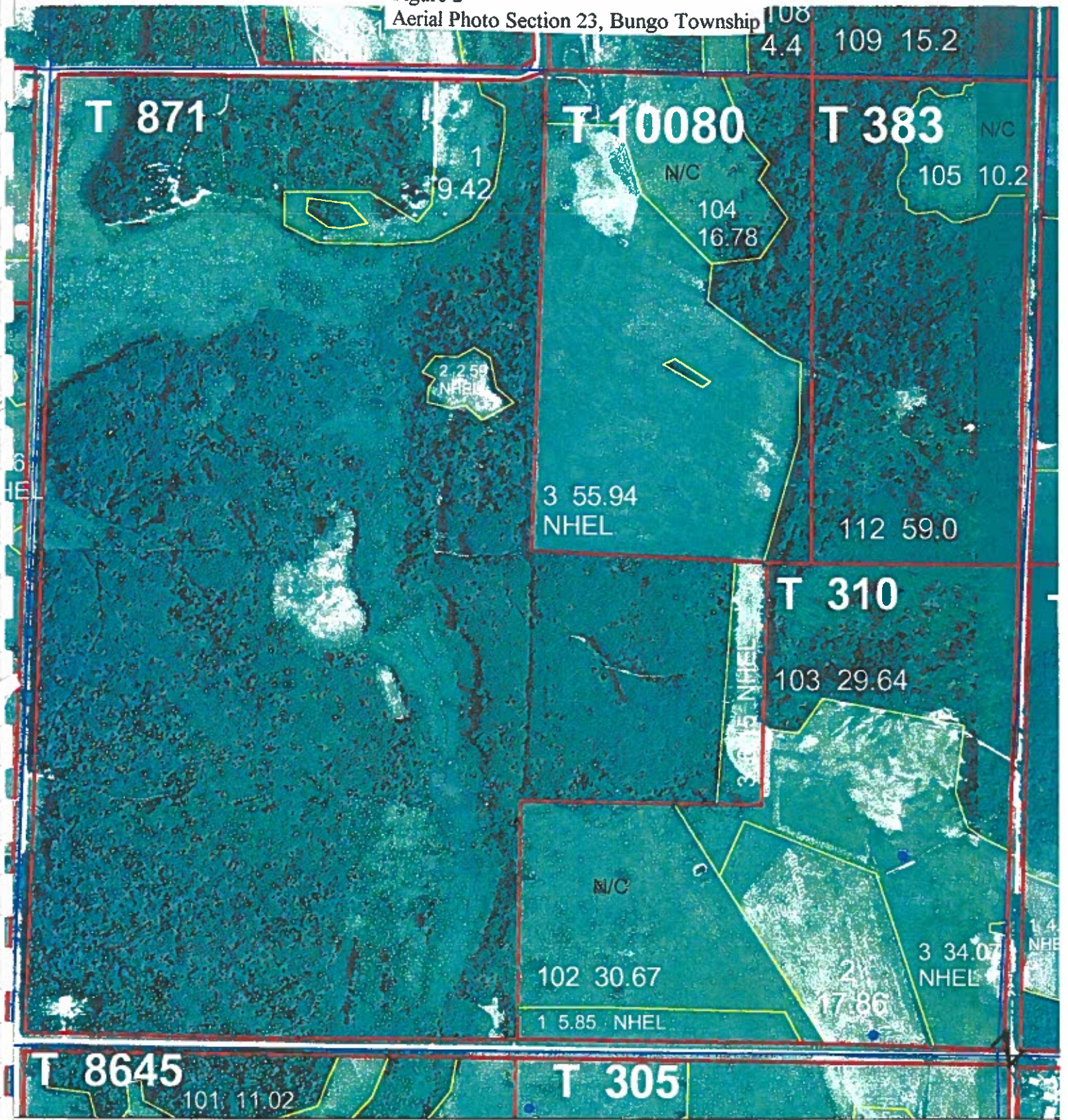


Figure 2
Aerial Photo Section 23, Bungo Township



Bungo 23
137 31
Twp Range

United States Department of Agriculture
Farm Service Agency

Cass County

February 15, 2004

2003 Digital Orthophotography - Not To Scale

- Wetland or FW on Field
- Tract Boundary
- Field or Pasture Boundary
- Section Line



Bungo Creek Sub-Watershed

