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Memorandum

To: Jon Ahlness, Steve Dewar

From: Cheryl Feigum; Mark Jacobson

Subject: Indirect Wetland Impacts at the Mine Site

Date: June 2, 2008

Project: 23/69/-862-008-002

c: John Borovsky, Jim Scott, Stuart Arkley, ERM

The purpose of this memorandum is to evaluate the potential for future indirect hydrologic impacts to the wetlands within the mine site. A drawdown analysis for the bedrock and surficial deposits was completed (RS 22 Appendix B Draft 03, yet to be released) summarizing the predicted impacts to water levels at the PolyMet mine site associated with dewatering during mining operations. The models presented in the drawdown analysis indicated that extensive drawdown of the surficial water table across the site was possible. It appears that two assumptions in the model contributed to an overestimation of drawdown: 1) using a single layer to simulate the surficial deposits (RS22 Appendix B Draft-02, page 9; to be superseded by Draft-03); and 2) basing the hydraulic conductivity value for this layer on the results of a field study where the well screen was placed in the soil layer with the highest transmissivity potential (RS22 Draft-02, page 5; to be superseded by Draft-03).

The hydrology of the wetlands at the site has been very stable over time as shown in the well study, which has been conducted at the site since 2005 and will continue throughout the project. A number of factors contribute to this stable hydrology including: 1) the lack of continuity between the bedrock and surficial aquifers; 2) the variability of the hydraulic conductivities within the soil layers causing perched water tables; 3) the very slow lateral groundwater flow that sustains the down gradient wetlands with a continual supply of groundwater over time; 4) the recharging uplands slowly providing local groundwater discharge to the wetlands over time; 5) the minimal slopes across most of the mine site; and 6) the high water-holding capacity of the soils.

This memorandum utilizes information from soil boring logs, well data from on-site studies, and information from previous RS documents and other literature. A review of detailed and local site information was completed to evaluate whether the hydrology changes on the mine site will cause surficial drawdowns that may indirectly impact the hydrology of wetlands on the mine site. The final conclusion of this memorandum is that the development of this mining project should not cause an indirect hydrologic impact to the wetlands that will remain after closure. The wetland well monitoring study will continue throughout the life of the project to provide additional information regarding the hydrologic stability of the wetlands.

Background Information

The mine site, which encompasses approximately 3,300 acres, is located in the headwaters of the St. Louis River Watershed #3, approximately 6 miles south of Babbitt, Minnesota. The Partridge River, a tributary to the St. Louis River, is located on the north, east and south sides of the mine site (Figure 1). The headwaters of the Partridge River are comprised of Hundred Mile Swamp along with mine dewatering discharge from the Peter Mitchell Pit (operated by Northshore Mining Company), which is located less than one mile north of the site.

Drainage Divides

A surface water drainage divide is generally oriented from southwest to northeast near the north boundary of the site (Figure 1; RS44 Draft-02, page 7). The majority of the site (80 percent) drains south through wetland complexes to the Partridge River. The remaining 20 percent of the site drains north to Hundred Mile Swamp and the Partridge River, or northeast to the Partridge River. Figure 2 shows the location of wetlands in the area.

The surficial groundwater drainage divides generally correspond with the surface water drainage divides (RS22 Appendix B Draft-02, page 5). Bedrock outcrops cause changes in the local flow patterns (Siegel and Ericson, 1980[1]). The direction of the regional groundwater flow across the site is similar to the surface water flow direction with a northwest to southeast flow pattern across the mine site (RS 22 Draft-02, Attachment I, page 2). The groundwater flow paths are generally very short on the site with recharge areas (uplands) located very close to the discharge areas (wetlands).

Groundwater flow within the bedrock is generally believed to be to the south-southeast (RS 22 Appendix B Draft-02, page 5; to be superseded by Draft-03). Since the bedrock is essentially impermeable (Siegel and Ericson, 1980), groundwater flow within the bedrock is through fractures or other secondary porosity features (RS 22 Appendix B Draft-02, page 5; to be superseded by Draft-03). After the pits are

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[1] Siegel, D.I. and D.W. Ericson. 1980. Hydrology and water quality of the copper-nickel study region, Northeastern

constructed at the mine site, water flow on the bedrock surface south of the pits would be directed away (south) from the pits (Figure 3). The exception would be at the pit edges where seepage may occur from the soil or the bedrock surface towards the pit which may dewater the edges of the adjacent wetlands. However, as evidenced at other mining sites, the impacted area of the wetland should be limited to a small area adjacent to the pit, with no evidence of hydrologic impacts to the majority of the wetland (Barr, *Wetland Hydrology Study Work Plan*, June 24, 2005, page 3).

Soils

The soils on the site have formed in coarse-textured till which overlays a denser till and bedrock (U.S. Forest Service, Soil Map Descriptions, *Superior National Forest Ecological Classification System*). Because the dense underlying till acts as an aquitard that restricts downward water flow, most of the organic and mineral soils in the depressional areas of the site have perched water tables. In addition, the water table slope across the site is generally less that 1 percent with the lowest gradients found across Hundred Mile Swamp and the highest gradients found between wells 2 and 12, near the Partridge River (Figure 4; RS 44, pages 7 and 10). These low water table gradients result in large, relatively flat areas of either mineral or organic soils with perched water tables.

Wetlands with large areas of deep organic soils are typically mapped as the Rifle and Greenwood series (Dr. David Grigal, University of Minnesota, Licensed Professional Soil Scientist). The official soil description for these organic soil profiles describes fibric peat at the surface overlying a sapric peat (muck) and/or mineral soil (NRCS, 2004[2]). Mineral soil textures included in the Rifle or Greenwood series include silty clay, sand with silt, or fine sand. Wetlands with mineral hydric soil series are mapped as the Babbitt-Bugcreek complex, which is a mineral complex with textures ranging from extremely stony to stony sandy loam (Dr. David Grigal, University of Minnesota, Licensed Professional Soil Scientist; NRCS, 2004). These mineral soil wetlands are typically located at a slightly higher elevation than the large peatland complexes and are the transitional areas between the peatlands and the uplands.

The soil texture of upland areas are loams intermixed with gravels, stones and sand (RS 44, page 7). These upland soils typically have high infiltration rates with little runoff. Soil series include Wahlsten,

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Minnesota. U.S. Geological Survey, Water-Resources Investigations, 80-739.
[2] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: "http://soils.usda.gov/technical/classification/osd/index.html" [Accessed 10 February 2004]. USDA-NRCS, Lincoln, NE.

Eaglesnest, Eveleth and Conic (Dr. David Grigal, University of Minnesota, Licensed Professional Soil Scientist; NRCS, 2004) which are moderately-well to well drained soils that formed in a loamy parent material with underlying dense glacial till. These soil series are usually found on bedrock-controlled uplands.

An overburden characterization study was conducted in 2008 which provided boring logs for upland and wetland points across the site (Figure 5; Barr, *Overburden Soil Boring Logs - Draft*, January 2008). The surface horizons of the five wetland profiles included varying depths of fibric and hemic peat (0 to 9 ft in depth) overlying mineral soil (Figure 4). The mineral soil textures in the profiles included clay with sand, silt, sand, gravel, silty sand (or sandy loam), silty gravel and gravelly silt. The depth to bedrock in the wetland profiles ranged from 11 to 33 feet, with depth to bedrock at the upland points ranging from 2 to 22 feet. The soil borings completed in the uplands (Figure 4) are characterized by mineral soil with textures including silty sand, sand with gravel, sand with silt, and sandy lean clay with gravel. Other geotechnical studies of the surficial deposits indicate the presence of silty sand, clay and organic soils across the mine site (RS02 Draft-02, page 6).

Hydrology

According to Siegel and Ericson (1980) there is minimal, insignificant interaction between the surficial aquifer, which supports the wetlands, and the deep bedrock aquifer because the bedrock has such low permeability. Figure 4 identifies the moisture content throughout the soil profiles from the soil surface to the bedrock surface (Barr, *Overburden Soil Boring Logs - Draft*, January 2008). The moisture content was field described as dry, moist or wet. The moisture content changes throughout each soil profile, indicating the surficial aquifer is not always continuous from the soil surface to the bedrock surface. For example, Boring RS-06A describes the soil as moist at a depth of 0 to 4.75 feet, but dry at a depth of 5.75 to 10 feet and moist to wet below a clay layer (bedrock is at 21 feet). In contrast, Boring RS-04 describes wet, silty sand to a depth of 25 feet with a one-foot layer of dry, gravel with silt and sand lying on top of the bedrock surface.

Because of the lack of interaction between the surficial and bedrock aquifers, the hydrology of the wetlands at the site is primarily supported by direct precipitation with some variable surficial groundwater component from the uplands. Net precipitation (precipitation minus evapotranspiration) is positive for the Partridge River watershed since evapotranspiration is low, which is typical for northern Minnesota due to the cooler climates and a shorter growing season. The average net precipitation for the existing conditions at the mine site is 11.3 inches/year, as calculated using the Partridge River streamflow data (RS24, page 14).

Organic and mineral soils at the mine site are typically perched over the dense till or a local sandy-textured surficial aquifer resulting in perched wetlands. The primary method for water to move across the landscape towards the Partridge River is either by lateral flow that is either on the surface or within the subsurface soil. Surface flow laterally across the wetland complexes is negligible because of the flat slopes and surface roughness. The wetlands on the site receive minimal surficial runoff from the upland areas because the soil texture allows rapid infiltration. As previously described, the uplands are primarily contributing groundwater to the wetlands by local flow paths, rather than by surface runoff. Wetlands are supported primarily by direct precipitation with local groundwater flow providing a more variable component which is typical of northern Minnesota, with a cold climate and a short growing season, where evapotranspiration is considerably less than compared to warmer climates that have longer growing seasons (RS 44, page 8).

Lateral flow within the soils is typically very slow. Fibric peat at the surface allows infiltration of surficial water; however, the more highly decomposed sapric peat has greatly reduced lateral and vertical hydraulic conductivity compared to the fibric peat (Schlotzhauer and Price, 1999[3]). Therefore, water tends to stay perched and stored within the large peat complexes which typically exhibit only subtle variations in the water tables over time. The silty sand or clay that typically underlies the organic soil has low hydraulic conductivity and therefore is a contributing factor that helps maintain the hydrology of the wetlands. The silty sands are sands mixed with clay and silt that are not permeable enough to be used as drainage sands (RS 02 Draft-02, page 6). Hydraulic conductivities in this field investigation were on the low end of the range for silty sand, while the other soil materials were within the range of expected hydraulic conductivities.

As part of the Wetland Hydrology Monitoring Study at the mine site, manual and recording wells have been installed with water tables monitored in the wells between 2005 and 2007 (Figure 6). Recording wells 4M and 12M are located within the Hundred Mile Swamp with extensive deep organic soil deposits, large watersheds with little flowthrough from upstream watersheds, and relatively flat gradients. The data from these wills indicates very stable hydrology with limited direct response to precipitation events with

[3] Schlotzhauer, S.M. and J.S. Price. 1999. Soil water flow dynamics in a managed cutover peat field, Quebec: field and laboratory investigations. Water Resources Research, 35(12):3675-3683.

the water table slowly increasing followed by a slow drawdown of the water table (RS 44, page 9). This slow response in the water level indicates that minimal groundwater is flowing away from the wetlands; therefore, in these wetlands the hydrology remains stable over time.

In contrast, recording wells 1M and 7M are located in areas with shallow organic deposits over mineral soil. These areas are generally smaller watersheds with considerable flowthrough from upstream watersheds because of the steeper gradients between the watersheds. The data from these wells typically show a quicker response to precipitation to precipitation events, with rapid water table increases as well as rapid drawdown of the water table (RS 44, page 9). This rapid response in the water level indicates that groundwater is flowing away from the wetlands; therefore, in these wetlands the hydrology fluctuates over time.

Within soil profile, sand or gravel layers may be found between silty or clay textured soil layers. Sands and gravels typically have large pore spaces that allow rapid subsurface lateral groundwater flow. However, these sand/gravel layers typically have fine textured soil (silt and clay) within their pore spaces which will decrease porosity, and therefore reduce the hydraulic conductivity and the lateral groundwater flow (Freeze and Cherry, 1979[4]). In addition, these sand/gravel layers are usually discontinuous, typically resulting in a reduction of lateral groundwater flow. As a result of the slow lateral groundwater flow, water will remain stored in the wetlands and the storage component of the wetlands should exhibit minimal changes over the year.

The large wetland complexes are characterized by organic soils with a saturated hydrologic regime. Typically, the water table is at or near the soil surface most of the year, with little to no inundation. The majority (greater than 97 percent) of these wetlands on the site are Types 2, 6, 7 and 8 which are saturated, but not typically inundated (RS 14 Addendum 01, Table 1). The remaining 3 percent of wetlands do not commonly occur in the landscape and are typically impounded artificially as a result of beaver dams, roads or railroads (RS 14 Draft-02, page 14). These wetlands are classified as Types 3 (shallow marsh), 4 (deep marsh) and 5 (shallow open water) which are typically inundated throughout the year with 0.5 to 10 feet of water (RS 14 Draft-02, page 9).

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[4] Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Watersheds

The contributing watershed areas will change during the project with the development of pits, stockpiles, ditches, roads and other infrastructure. Table 1 compares the area of the watersheds and the area of wetlands found within each watershed during the three stages of the project: 1) pre-mining; 2) during mining; and 3) after closure. Throughout the project, the total area of the watersheds will remain constant at 7,311 acres (Table 1); however during the project, the drainage divides will be altered and consequently the number and size of the watersheds will change.

Pre-mining, 24 watersheds represent the existing, relatively undisturbed conditions at the site (Figure 7; Table 1). Table 1 identifies the acreage for each of the 24 watersheds, or tributary areas, and the total acres of wetlands in each watershed. The tributary area was considered to include only the area within the watershed. The watersheds range in size from 17.2 acres (PM 09) to 1,097 acres (Main 01). There is a total of 7,311 acres within the 24 watersheds with 3,751 acres of wetlands; this results in about 51 percent of the area covered by wetlands. The amount of wetland in the watersheds ranged from 13 to 76 percent (Table 1).

During the project and after closure, there will be 22 watersheds and the size of the watersheds will change (Figure 8; Table 1). Figure 8 shows that watershed PM 04 will increase in size from 189.5 acres to 1,633 acres because it will incorporate watersheds PM 01 and PM 06, as well as portions of watersheds Main 01, Main 05, and Main 06. As a result, the amount of water contributed by the watershed to support the hydrology of the wetlands will also change.

Table 1 identifies the size of each watershed, which is considered to be the contributing watershed area for the wetlands within that watershed. However, as the project develops, portions of each watershed will no longer contribute to the wetlands. The resulting area of the watershed that actually contributes water to the wetlands is the "effective contribution area". For example, during pre-mining conditions watershed PM 13 is 107 acres in size which is considered to be the contributing watershed. During mining, the watershed size will be reduced to 78 acres. However, because ditches will intercept surface water runoff from the stockpiles, the "effective contribution area" will be reduced to less than 78 acres. After closure, the ditches will be removed and the "effective contribution area" should be 78 acres. The "effective contribution area" for each of the watersheds will change as the project develops and structures are added or removed.

In order to understand the distribution of water to the wetlands and how it may affect the hydrology of the wetlands, a comparison was made (Table 1) between the hydrologic regimes for the existing condition and future conditions (during the project and after closure). To make this comparison, the acreage of the watersheds and wetlands were determined using GIS. These acreages were used in the following formulas to obtain the values as demonstrated using watershed PM 13 (values in **bold font** are shown on Table 1):

Calculation 1 -The ratio of tributary acres to wetland acre was calculated for the existing and future conditions.

Ratio of tributary acres to wetland acres = 107.7 acres of watershed / 37.3 acres of wetland

= 2.9 acres of watershed : 1 wetland acre

= 2.9 : 1

= **2.9**

Calculation 2 - The net precipitation rate (11.3 in/yr) is the same throughout the project (RS 24, page 16). The rate was applied to each watershed to convert the ratio to an equivalent flow (or equivalent average contributing net precipitation), expressed as acre-feet/year (ac-ft/yr) per acre of wetland.

Equivalent flow = ((2.9 acres of watershed)*(11.3 in/yr)) per wetland acre

= 32.8 ac-in/yr per wetland acre

= ((32.8 ac-in/yr) * (1 ft / 12 in)) per wetland acre

= **2.7 ac-ft/yr** per wetland acre

Evaluation of Select Watersheds

Figure 9 identifies the wetlands that will remain throughout the future conditions, including during the project and after closure. The potential indirect hydrologic impact to these wetlands was evaluated by grouping watersheds in select areas of the site, including: 1) Hundred Mile Swamp; 2) watershed PM 04; 3) Northeast Area watersheds; and 4) Southwest Area watersheds. These groups of watersheds were selected because they contain the wetlands that are to be maintained throughout the project and after closure. Therefore, by evaluating the hydrologic contribution from the watersheds, the future condition of the wetlands can also be evaluated for potential indirect hydrologic impacts.

The following sections compare the existing and future watershed contribution to the wetlands and the potential for indirect hydrological impacts to the wetlands. Tables 1, 2 and 3 show the watershed acres, wetland acres, percentage of wetlands in the watershed, ratio of watershed acres per wetland acre, and equivalent flow per wetland acre (expressed as ac-ft/yr) for the existing and future conditions.

Hundred Mile Swamp

Three watersheds (Main 01, Main 05, Main 07a) represent Hundred Mile Swamp (Figure 7). These three watersheds were considered as a group because they contain more wetland on a percentage-basis than all of the other watersheds (Table 1). The total watershed area is 1,790 acres with 1,321 acres of wetlands. Under existing conditions, 70 to 76 percent of the watershed areas were identified as wetland. The average watershed area per wetland area ratio is 1.4:1 (watershed acres per wetland acre). The equivalent flow for the Hundred Mile Swamp watersheds is 1.3 ac-ft/yr per wetland acre.

Under future conditions, portions of these watersheds will be incorporated into watershed PM 04. The area of the watersheds will decrease to 1,462 acres. Wetlands will cover 83 percent of these watersheds (Figure 9) with an average watershed area per wetland area ratio of 1.2:1 (Table 1). The northern boundary of the project will be located along the southern boundary of watersheds Main 01, Main 05, and Main 07a (Figure 8). Therefore, the watershed area will be the same acreage as the “effective contribution area”. The equivalent flow for the Hundred Mile Swamp watersheds will be 1.2 ac-ft/yr per wetland acre, which represents a decrease of about 6 percent from the existing conditions.

Wells located in these three watersheds (wells 4, 4a, 4M, 5 and 10; Figure 6) fluctuated an average of less than 0.8 feet (10 inches) over the three-year well monitoring period (Table 2). Therefore, a decrease of 0.1 ac-ft/yr is within the range of fluctuation for the wells in these watersheds (Table 2). The Hundred Mile Swamp is a large contiguous area of forested wetland with organic soils, with the hydrology primarily supported by precipitation. The hydrology is stable with limited fluctuations in the water table. Based on the characteristics of these wetlands, indirect hydrologic impacts are not likely in this area. The well study will continue throughout the project to evaluate if there are changes in the wetland hydrology.

Watershed PM 04

During the project, the existing 24 watersheds (Figure 7) will be reduced to 22 watersheds (Figure 9). Two watersheds (PM 01 and PM 06), along with portions of 11 other watersheds, will be incorporated into watershed PM 04 as a result of the project. These watershed boundary changes will result in watershed PM 04 encompassing 1,633 acres within the project area. The project will eventually cover over 86 percent of this 1,633-acrea watershed, with 28 percent of the watershed covered by pits.

Under existing conditions, the total watershed area of PM 04, 01, and 06 is 1,003 acres (Table 1). There are 539 acres of wetlands, or about 55 percent, within the 1,003-acre area. The average watershed area per wetland area ratio is 1.9:1 (watershed acres per wetland acre). The equivalent flow for the three watersheds is 1.8 ac-ft/yr per wetland acre.

Under future conditions, the "effective contribution area" will be used in the calculations rather than the watershed area. The pits are omitted from the "effective contribution area" since the water level will be within the bedrock and will not discharge into the watershed (RS 52, pages 3-2 and 3-3; RS 52, Figure 3-11). In addition, the ditches around the stockpiles to the north of the west pit will not be removed after closure, so water will continue to be diverted away from the watershed (Figure 8).

Within watershed PM 04, there are three larger groups of wetlands (A, B, and C) with different "effective contribution areas" (Figure 10). Table 3 identifies the approximate acreage of the "effective contribution area" and the acreage of wetlands within each area. For the three areas, the average watershed area per wetland area ratio is 1.8:1 (watershed acres per wetland acre). The average equivalent flow for the three areas is 1.7 ac-ft/yr per wetland acre.

Wells located in these wetlands (wells 2, 3, 11, 17, 18, and 19; Figure 6) fluctuated an average of less than 1 foot (12 inches) over the three-year well monitoring period (Table 2). Within the three areas (A, B, and C), the equivalent flow remains the same value as during existing conditions. Therefore, indirect hydrologic impacts are not likely in these areas. The well study will continue throughout the project to evaluate if there are changes in the wetland hydrology.

East-Central Watersheds

Wetlands are oriented in a northeast-to-southwest direction within watersheds Main 07e, PM 11, and PM 18 in the east-central portion of the mine site (Figure 9). These three watersheds were considered as a group because they include the contiguous area of wetlands. The wetlands form one large complex with their hydrology primarily supported by direct precipitation along with local groundwater flow from the adjacent upland areas. The existing condition of the upland soils and vegetation allow rapid infiltration with minimal runoff. This provides a slow release of water to the wetland complex over time, rather than a large amount of runoff flowing into the wetlands over a very short time.

Under existing conditions, the total watershed area of Main 07e, PM 11, and PM 18 is about 970 acres (Table 3). There are 440 acres of wetlands, or about 45 percent, within the 970-acre area. The average watershed area per wetland area ratio is 2.2:1 (watershed acres per wetland acre). The equivalent flow for the three watersheds is 2.1 ac-ft/yr per wetland acre.

Under future conditions, the "effective contribution area" will be used in the calculations rather than the watershed area. During operation of the mine, the stockpiles will vary in size and vegetative cover type (RS 22, Section 3.2). After closure the stockpiles will be capped with a layer of soil that allows infiltration and vegetative growth. There will be a system of ditches around the stockpiles that will divert surface water away from the wetlands. Upon closure, most of these ditches will be removed and the stockpile areas will act as contributing tributary areas for the wetlands (RS 22, Section 5.1.1). The three watersheds have different "effective contribution areas" during the life of the project (Table 3). Table 3 identifies the approximate acreage of the "effective contribution area" and the acreage of wetlands within each area.

During the project, the "effective contribution area" for the three watersheds is nearly 590 acres (Table 3). There are about 290 acres of wetlands, or about 49 percent, within the 590-acre area. The area is reduced compared to the closure area since the project will temporarily remove stockpile areas from the "effective contribution area". The average watershed area per wetland area ratio is 2.1:1 (watershed acres per wetland acre). The average equivalent flow for the three areas is 1.9 ac-ft/yr per wetland acre.

After closure, the "effective contribution area" for the three watersheds is over 750 acres (Figure 11; Table 3). There are about 290 acres of wetlands, or about 38 percent, within the 770-acre area. The area increases compared to the area during the project since the stockpiles will become part of the "effective contribution area" during closure. The average watershed area per wetland area ratio is 2.6:1 (watershed acres per wetland acre). The average equivalent flow for the three areas is 2.5 ac-ft/yr per wetland acre.

Wells located in these wetlands (wells 14 and 16; Figure 6) fluctuated an average of 0.8 feet (9 inches) over the three-year well monitoring period (Table 2). Therefore, a fluctuation of 0.6 ac-ft/yr is within the range of fluctuation for the wells in these wetlands and indirect hydrologic impacts are not likely in these areas. The well study will continue throughout the project to evaluate if there are changes in the wetland hydrology.

Conclusions

The hydrology for the wetlands in the mine site is primarily dependent up on precipitation and local groundwater flow. Wetlands generally have a perched surficial water table and no interaction with the bedrock aquifer. For each wetland, the amount of precipitation and runoff will influence the rate of evapotranspiration; however runoff from the uplands to the wetlands is negligible. The recharging uplands provide a slow discharge of local groundwater to the wetlands over very long time periods.

The storage component of the wetlands will not change since the soils in the undisturbed areas will not be altered. The change in the hydrology of the wetlands would be primarily influenced by the net precipitation (precipitation minus evapotranspiration) which varies with the change in size of the watersheds and wetlands from existing to post-closure conditions. In addition, some of the local groundwater flow paths may be altered in tributary areas where stockpiles or roads comprise a portion of the watershed.

A number of factors contribute to the stable hydrology of the wetlands on the site including: 1) the lack of continuity between the bedrock and surficial aquifers; 2) the variability of the hydraulic conductivities within the soil layers causing perched water tables; 3) the very slow lateral groundwater flow that sustains the down gradient wetlands with a continual supply of groundwater over time; 4) the recharging uplands slowly providing local groundwater discharge to the wetlands over time; 5) the minimal slopes across most of the mine site; and 6) the high water-holding capacity of the soils.

The change in the ratio of the watershed area to wetland area, and the equivalent flow (ac-ft/yr per wetland acre), falls within the range of natural variability observed during the well study between 2005 and 2007. Based on the well study, the majority of the wetlands on the site are dependent on precipitation and local groundwater flow to maintain their hydrology. This is evidenced by the minimal water table fluctuation (bounce) that occurs in most of the wells on the site. The large wetland complexes have a very stable hydrologic regime even with periods of extreme precipitation and drought.

The development of this mining project should not cause an indirect hydrologic impact to the wetlands that will remain after closure. To evaluate changes in hydrology throughout the project, the 2008 plan for the well study has been revised to install additional wells in some areas where the change from existing to post-closure conditions is the greatest (Figure 12). Continued monitoring at the site will provide information about the potential hydrologic impacts to wetlands.

Tables

Table 1

CHARACTERISTICS OF SELECTED WATERSHEDS
PolyMet Mining
Hoyt Lakes, MN

Watershed Name	Pre-Mining (Existing) Conditions					Conditions during the Mining Project						Closure Conditions				
	Watershed Total Area (acres)	Wetland Area (acres)	Wetland Area (%)	Tributary Acres per Wetland Acre	Equivalent Flow (ac-ft/yr)	Watershed Total Area (acres)	Wetland Area (acres)	Wetland Area (%)	Tributary Acres per Wetland Acre	Equivalent Flow (ac-ft/yr)	% change from existing conditions	Watershed Total Area (acres)	Wetland Area (acres)	Wetland Area (%)	Tributary Acres per Wetland Acre	Equivalent Flow (ac-ft/yr)
Main01	1097.0	820.7	74.8%	1.3	1.3	865.0	720.6	83.3%	1.2	1.1	-10%	865.0	720.6	83.3%	1.2	1.1
Main05	228.6	173.6	76.0%	1.3	1.2	132.8	125.7	94.6%	1.1	0.9	-20%	132.8	125.7	94.6%	1.1	1.0
Main06	127.7	70.0	54.9%	1.8	1.7	43.8	41.6	94.9%	1.1	0.9	-42%	43.8	41.6	94.9%	1.1	1.0
Main07a	464.0	326.4	70.3%	1.4	1.3	464.0	326.4	70.3%	1.4	1.2	0%	464.0	326.4	70.3%	1.4	1.3
Main07b	474.0	243.2	51.3%	1.9	1.8	478.8	241.9	50.5%	2.0	1.6	2%	478.8	241.9	50.5%	2.0	1.9
Main07e	417.6	205.6	49.2%	2.0	1.9	465.2	182.0	39.1%	2.6	2.1	26%	465.2	182.0	39.1%	2.6	2.4
Main09	147.8	67.5	45.7%	2.2	2.1	147.8	66.9	45.2%	2.2	1.8	1%	147.8	66.9	45.2%	2.2	2.1
Main10	584.4	252.3	43.2%	2.3	2.2	571.8	251.6	44.0%	2.3	1.9	-2%	571.8	251.6	44.0%	2.3	2.1
Main11	232.0	97.1	41.9%	2.4	2.2	232.0	97.1	41.9%	2.4	2.0	0%	232.0	97.1	41.9%	2.4	2.2
Main12	691.7	277.1	40.1%	2.5	2.4	691.7	274.5	39.7%	2.5	2.1	1%	691.7	274.5	39.7%	2.5	2.4
Main13	546.1	228.2	41.8%	2.4	2.3	546.1	228.2	41.8%	2.4	2.0	0%	546.1	228.2	41.8%	2.4	2.3
PM01 [1]	662.9	393.3	59.3%	1.7	1.6	NA[1]	NA1	NA[1]	NA[1]	NA[2]	NA[4]	NA[1]	NA[1]	NA[1]	NA[1]	NA[2]
PM02	90.6	22.7	25.1%	4.0	3.8	84.9	18.1	21.3%	4.7	4.4	18%	84.9	18.1	21.3%	4.7	4.4
PM03	22.2	7.2	32.3%	3.1	2.9	22.2	6.8	30.8%	3.3	3.1	5%	22.2	6.8	30.8%	3.3	3.1
PM04	189.5	89.6	47.3%	2.1	2.0	1633.0	115.1	7.0%	14.2	13.4	570%	1633.0	48.1	2.9%	34.0	32.0
PM06 [1]	150.5	56.0	37.2%	2.7	2.5	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]
PM07	145.2	32.9	22.7%	4.4	4.2	123.4	1.7	1.4%	NA[2]	NA[2]	NA[2]	123.4	0.0	0.0%	NA[2]	NA[2]
PM08	210.1	92.5	44.0%	2.3	2.1	180.5	41.9	23.2%	4.3	4.1	90%	180.5	0.2	0.1%	NA[2]	NA[2]
PM09	17.2	2.3	13.2%	7.6	7.2	17.2	0.0	0.0%	NA[2]	NA[3]	NA[5]	17.2	0.0	0.0%	NA[2]	NA[2]
PM10	106.5	32.4	30.4%	3.3	3.1	119.1	33.0	27.8%	3.6	3.4	10%	119.1	33.0	27.8%	3.6	3.4
PM11	343.7	141.6	41.2%	2.4	2.3	190.3	63.6	33.4%	3.0	2.8	23%	190.3	63.6	33.4%	3.0	2.8
PM12	59.7	19.2	32.1%	3.1	2.9	31.1	0.4	1.3%	NA[2]	NA[3]	NA[5]	31.1	0.4	NA[2]	NA[3]	NA[4]
PM13	107.7	37.3	34.6%	2.9	2.7	77.6	11.1	14.3%	7.0	6.6	142%	77.6	11.1	14.3%	7.0	6.6
Wetlegs1	194.6	62.9	32.3%	3.1	2.9	193.0	59.4	30.8%	3.3	3.1	5%	193.0	59.4	30.8%	3.3	3.1
TOTAL	7311.2	3751.5	51.3%	1.9	1.8	7311.2	2907.5	39.8%	2.5	2.4	29%	7311.2	2797.1	38.3%	2.6	2.5

[1] Watersheds PM01 and PM06 are incorporated into other watersheds as a result of mining activity and do not exist after closure

[2] Wetland area is approximately zero; ratios of total area to wetland area are unrealistic

Watersheds that are part of Hundred Mile Swamp

Table 2

WETLAND MONITORING WELLS
PolyMet Mining
Hoyt Lakes, MN

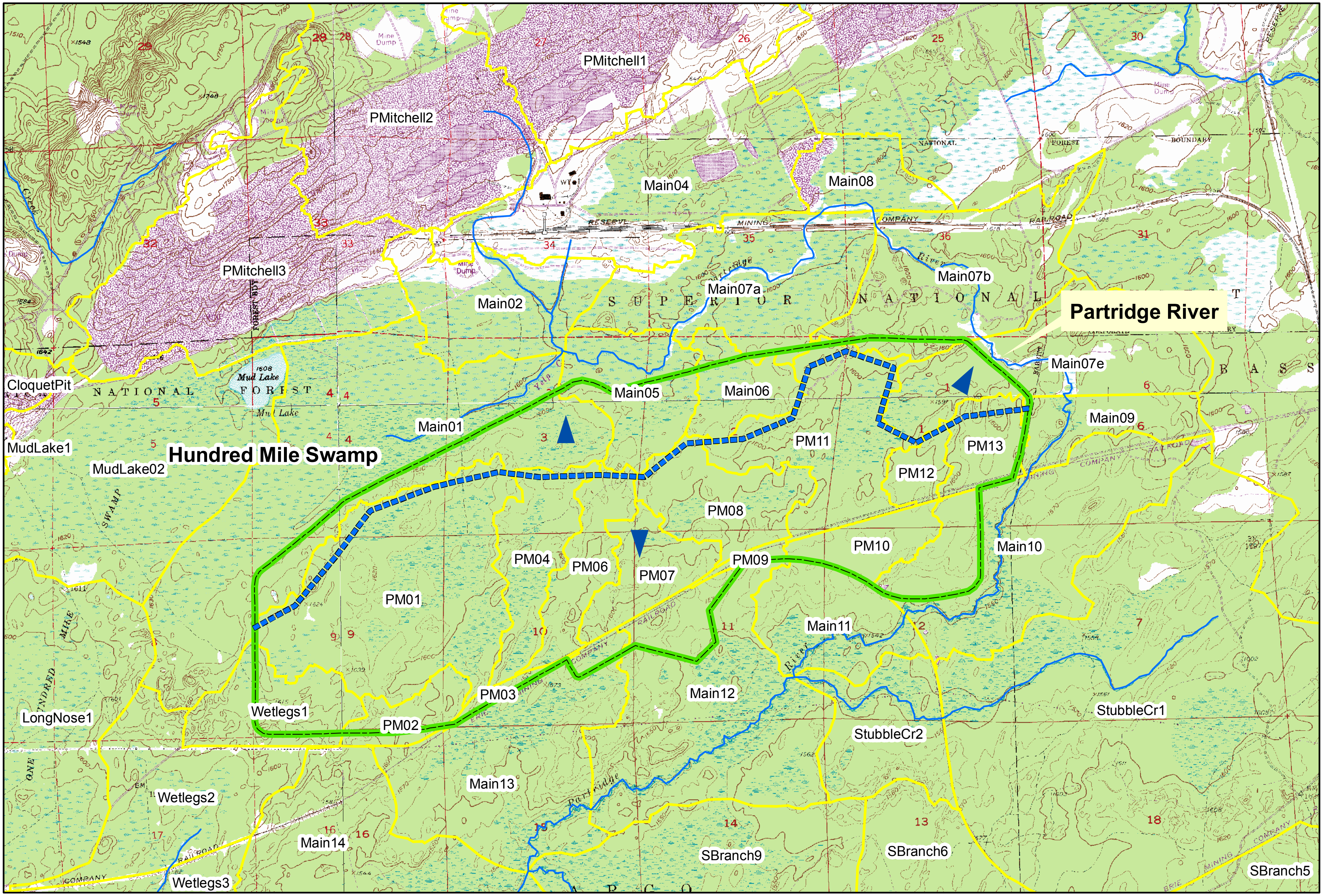
Well No.	Monitoring Year 2005 Water level range (ft)	2005 (in)	2006 Water level range (ft)	2006 (in)	2007 Water level range (ft)	2007 (in)	Location of Well Watershed Pre-mining	During Project and After Closure
1	0.17	2.00	1.60	19.25	1.96	23.50	PM 07	PM 07
1M	0.27	3.25	2.67	32.00	1.99	23.90	PM 07	PM 07
2	0.46	5.50	0.90	10.75	1.38	16.50	MAIN 06	MAIN 07
3	0.08	1.00	0.71	8.50	1.13	13.50	PM 01	PM 04
4	0.25	3.00	0.67	8.00	0.92	11.00	MAIN 01	MAIN 01
4M	0.08	1.00	0.00	0.00	1.40	16.85	MAIN 01	MAIN 01
4A	0.10	1.25	0.65	7.75	1.17	14.00	MAIN 01	MAIN 01
5	0.33	4.00	0.56	6.75	0.83	10.00	MAIN 01	MAIN 01
6	0.42	5.00	1.27	15.25	2.69	32.25	WETLEGS 1	WETLEGS 1
7	0.19	2.25	1.19	14.25	1.56	18.75	MAIN 13	MAIN 13
7M	0.13	1.50	0.00	0.00	1.15	13.80	MAIN 13	MAIN 13
8	0.35	4.25	0.90	10.75	2.65	31.75	MAIN 12	MAIN 12
9	0.19	2.25	0.75	9.00	1.96	23.50	PM 10	PM 11
10	0.90	10.75	0.75	9.00	1.60	19.25	MAIN 05	MAIN 06
11	0.42	5.00	0.88	10.50	1.10	13.25	MAIN 05	PM 04
12	0.38	4.50	0.96	11.50	1.25	15.00	MAIN 06	MAIN 06
12M	0.00	0.00	0.60	7.25	3.92	47.00	MAIN 06	MAIN 06
13	0.67	8.00	0.44	5.25	1.58	19.00	MAIN 7b	MAIN 7b
14	0.90	10.75	1.00	12.00	1.54	18.50	MAIN 7e	MAIN 7e
15	0.21	2.47	0.73	8.75	1.52	18.25	MAIN 09	MAIN 10
16	0.44	5.25	0.71	8.50	1.40	16.75	PM 11	PM 11
17	0.17	2.00	0.85	10.25	1.17	14.00	PM 01	PM 04
18	1.17	14.00	1.00	12.00	2.00	24.00	MAIN 01	PM 04
19	0.39	4.68	1.33	16.00	2.64	31.68	PM 01	PM 04

Table 3

Select Watersheds
PolyMet Mining.
Hoyt Lakes, MN

Condition	Watershed	"Effective Contribution Area" (ac)	Wetlands (ac)	Tributary Acres per Wetland Acre	Equivalent Flow (ac-ft/yr)
Future	**PM04 A**	110.55	47.03	2.4	2.2
	PM04 B	153	53.91	2.8	2.7
	PM04 C	95.13	81.74	1.2	1.1
	total	358.68	182.68	2.0	1.8
Existing conditions	**PM 07e**	417.60	205.60	2.0	1.9
	PM 11	343.70	141.60	2.4	2.3
	PM 08	210.10	92.50	2.3	2.1
	total	971.4	439.7	2.2	2.1
During conditions	**PM 07e**	395.8	182	2.2	2.0
	PM 11	76.58	63.6	1.2	1.1
	PM 08	104.3	41.9	2.5	2.3
	total	576.68	287.5	2.0	1.9
Future conditions	**PM 07e**	465.54	182	2.6	2.4
	PM 11	131.58	63.6	2.1	1.9
	PM 08	155.3	41.9	3.7	3.5
	total	752.42	287.5	2.6	2.5

Figures



Mine Site
Watersheds
Partridge River
Surface Water Drainage Divide
Surface Water Flow Direction

0 2,000 4,000 8,000 Feet

Figure 1

LOCATION MAP
PolyMet Mining
Hoyt Lakes, Minnesota

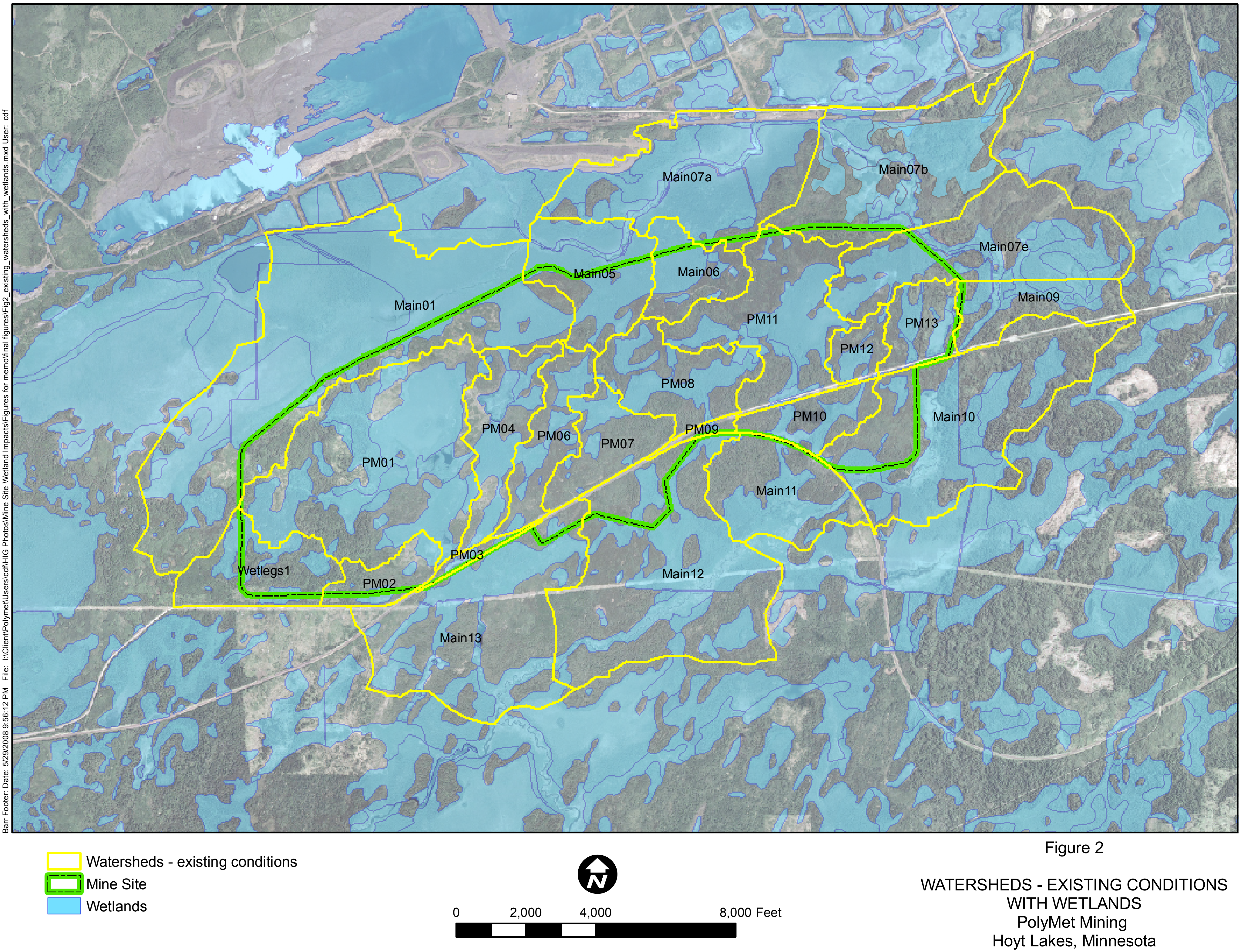


Figure 2

WATERSHEDS - EXISTING CONDITIONS
WITH WETLANDS
PolyMet Mining
Hoyt Lakes, Minnesota

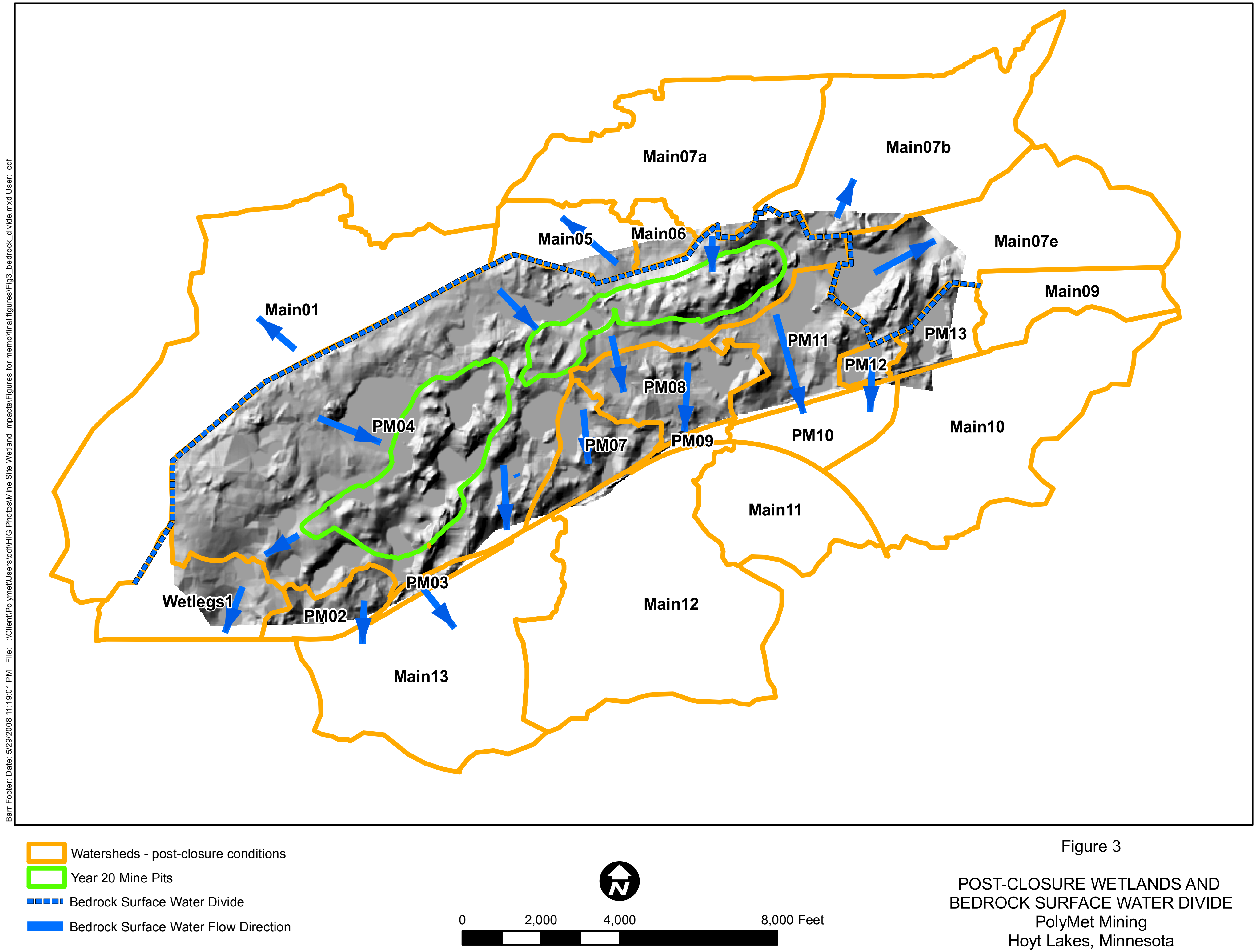


Figure 3

POST-CLOSURE WETLANDS AND BEDROCK SURFACE WATER DIVIDE
PolyMet Mining
Hoyt Lakes, Minnesota

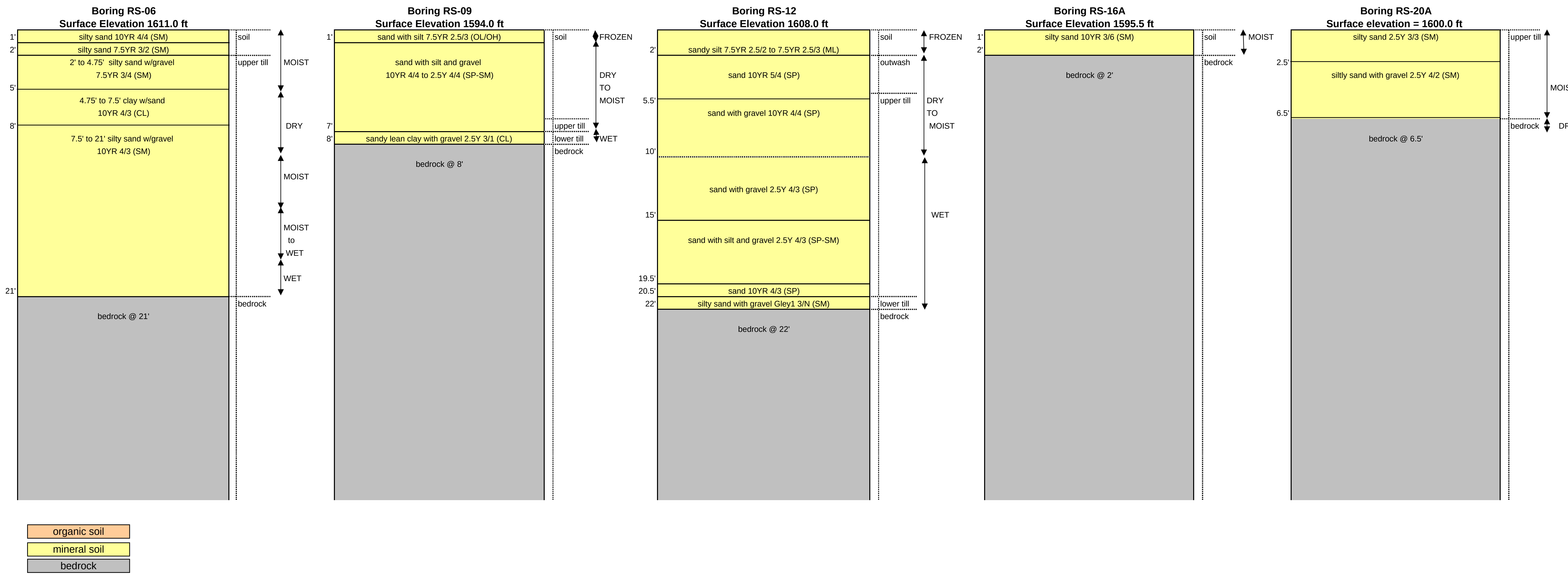


Figure 4

OVERBURDEN CHARACTERIZATION
UPLAND PROFILES
PolyMet Mining Inc.
Hoyt Lakes, MN

I:\Client\Polymet\Users\cdf\HIG Photos\Mine Site Wetland Impacts\indirect wetland impacts - mine site\boring logs mine siteUpland

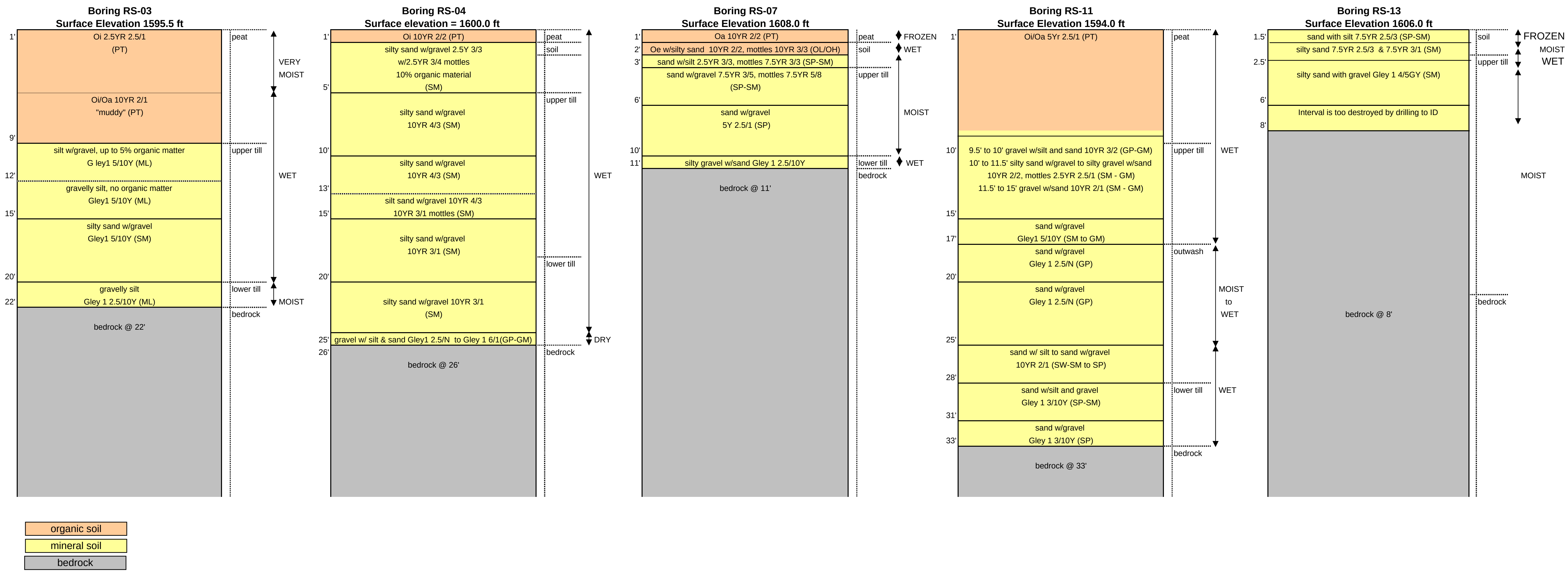
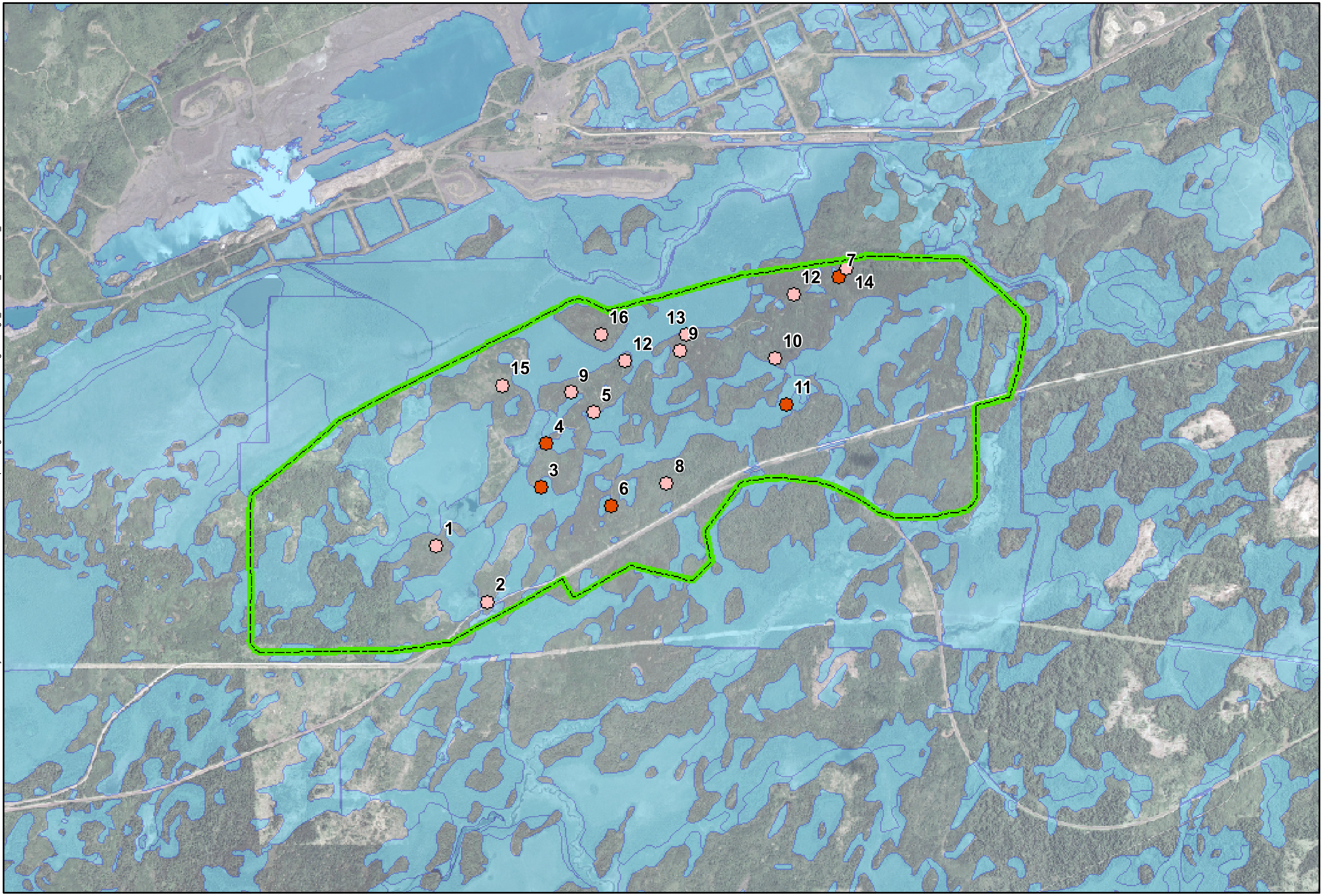


Figure 4

OVERBURDEN CHARACTERIZATION
WETLAND PROFILES
PolyMet Mining
Hoyt Lakes, MN

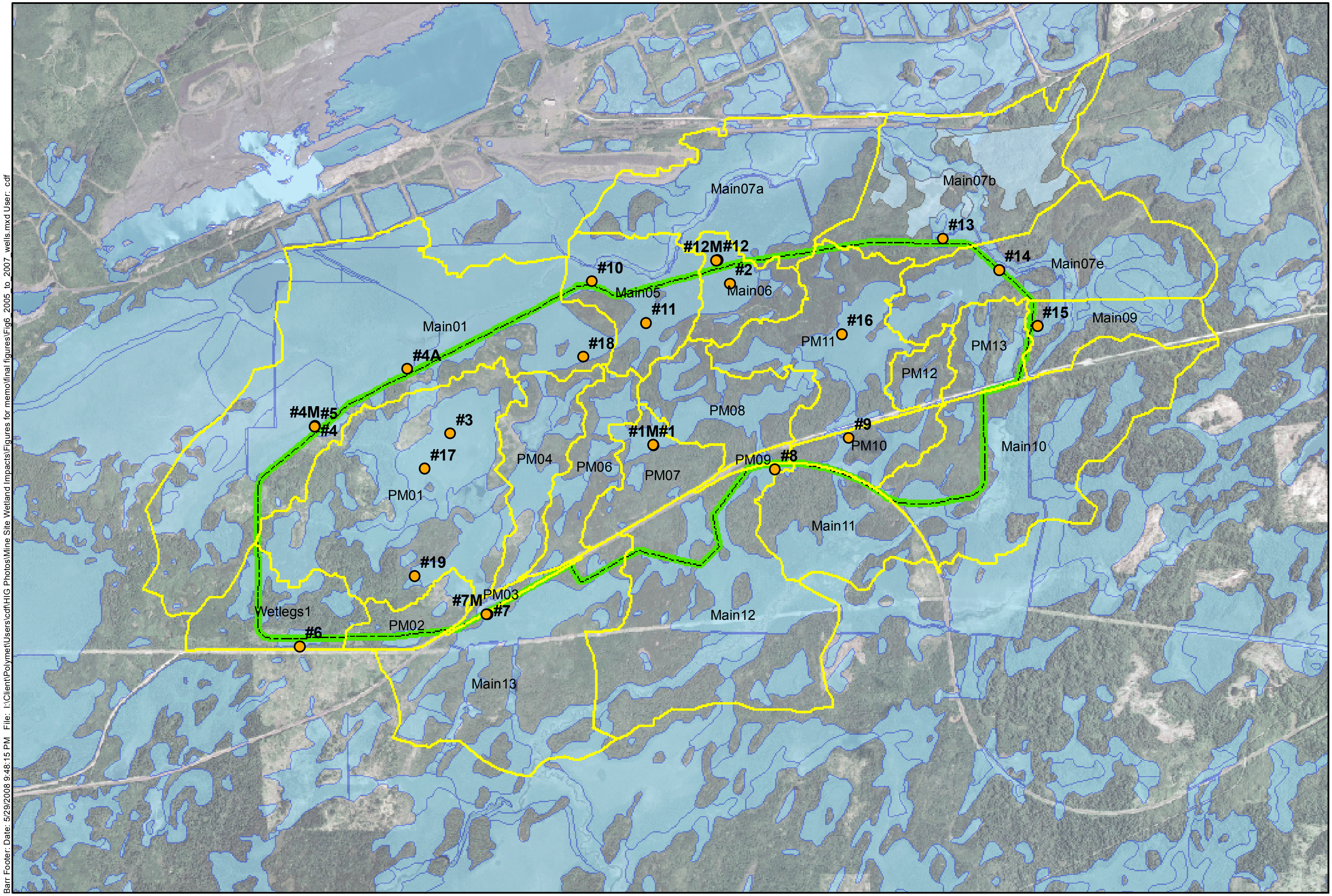


Mine Site
Wetlands
Upland Soil Boring Sites
Wetland Soil Boring Sites

0 2,000 4,000 8,000 Feet

Figure 5

LOCATION OF WETLANDS
AND OVERBURDEN SITES
PolyMet Mining
Hoyt Lakes, Minnesota

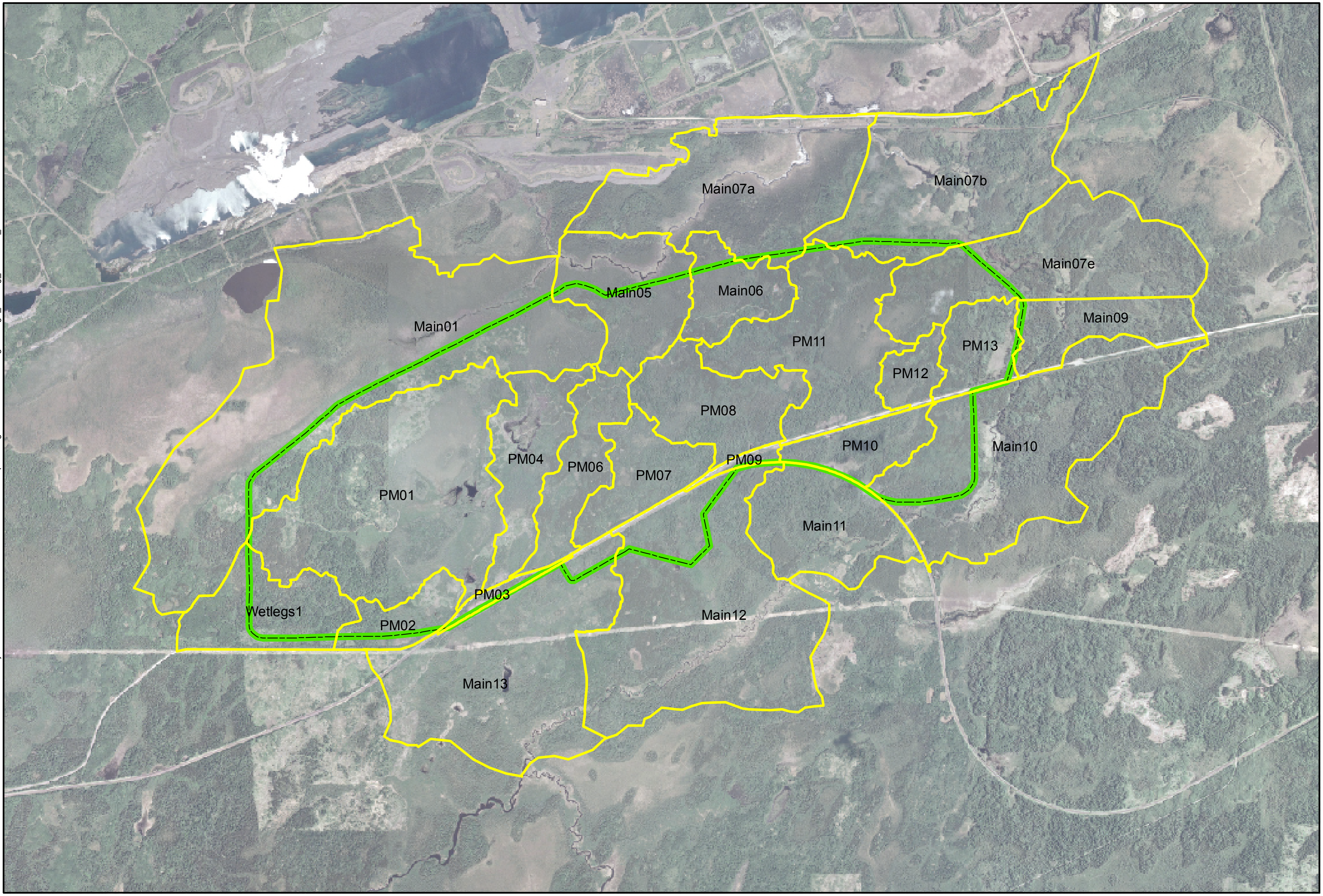


Mine Site
Watersheds - existing conditions
Wetlands
Wetland Monitoring Well Locations in 2007

0 2,000 4,000 8,000 Feet

Figure 6

WATERSHEDS - EXISTING CONDITIONS
WITH WETLANDS and WELLS
PolyMet Mining
Hoyt Lakes, Minnesota



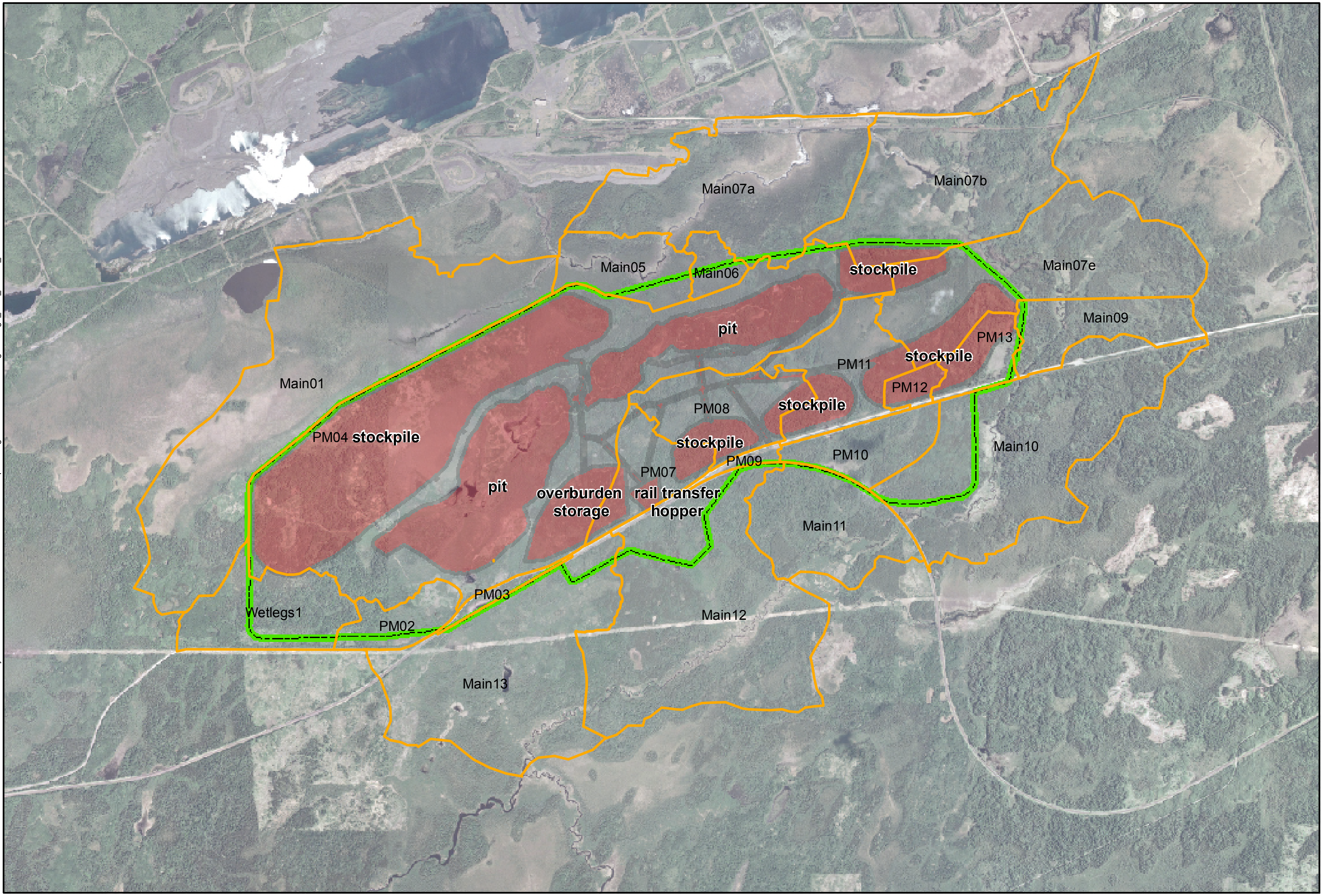
Mine Site

Watersheds - existing conditions

0 2,000 4,000 8,000 Feet

Figure 7

WATERSHEDS - EXISTING CONDITIONS
PolyMet Mining
Hoyt Lakes, Minnesota



Mine Site
Watersheds - after closure
Proposed Project Areas
Wetlands after Closure

0 2,000 4,000 8,000 Feet

Figure 8

WATERSHEDS - AFTER CLOSURE
AND PROJECT AREA
PolyMet Mining
Hoyt Lakes, Minnesota

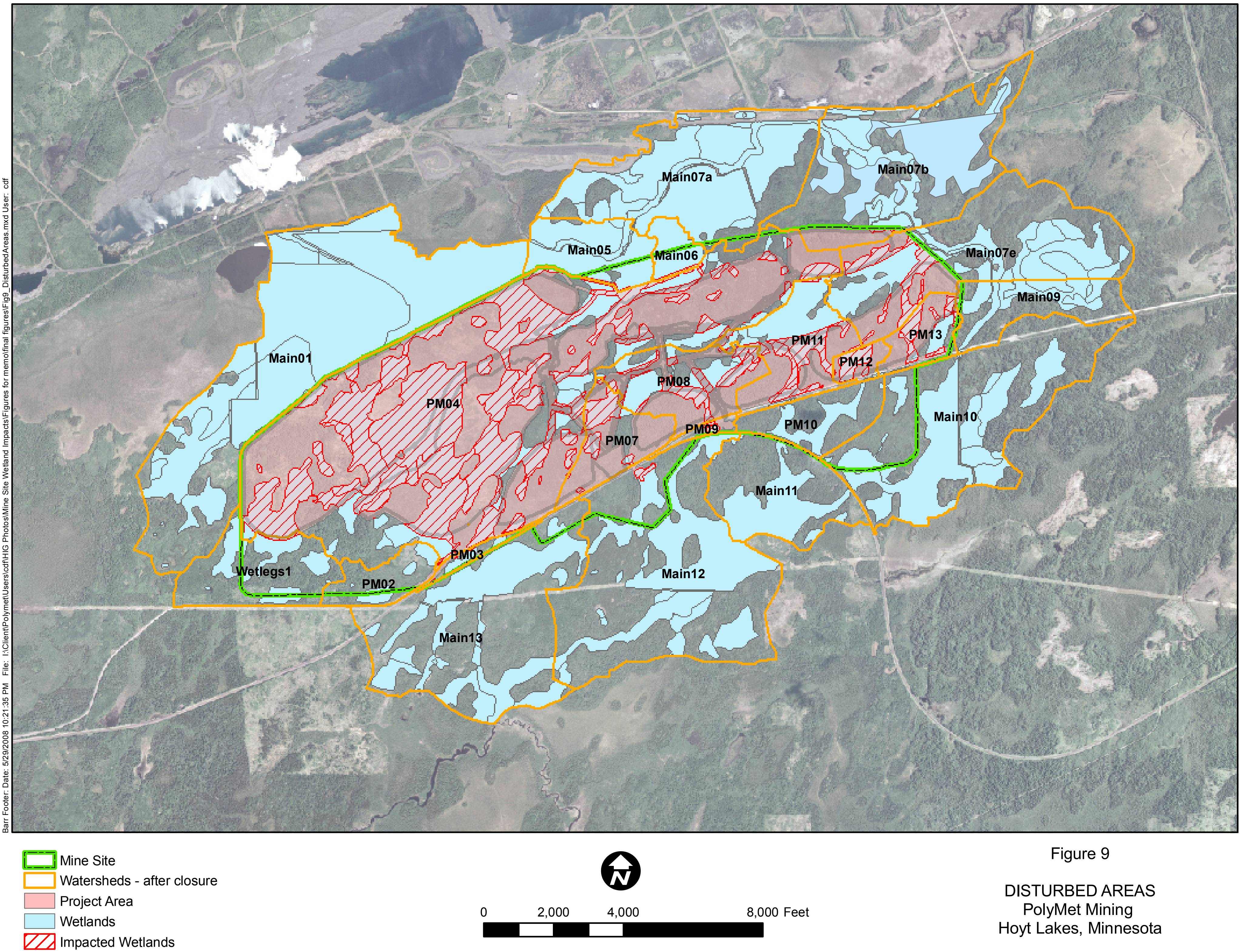
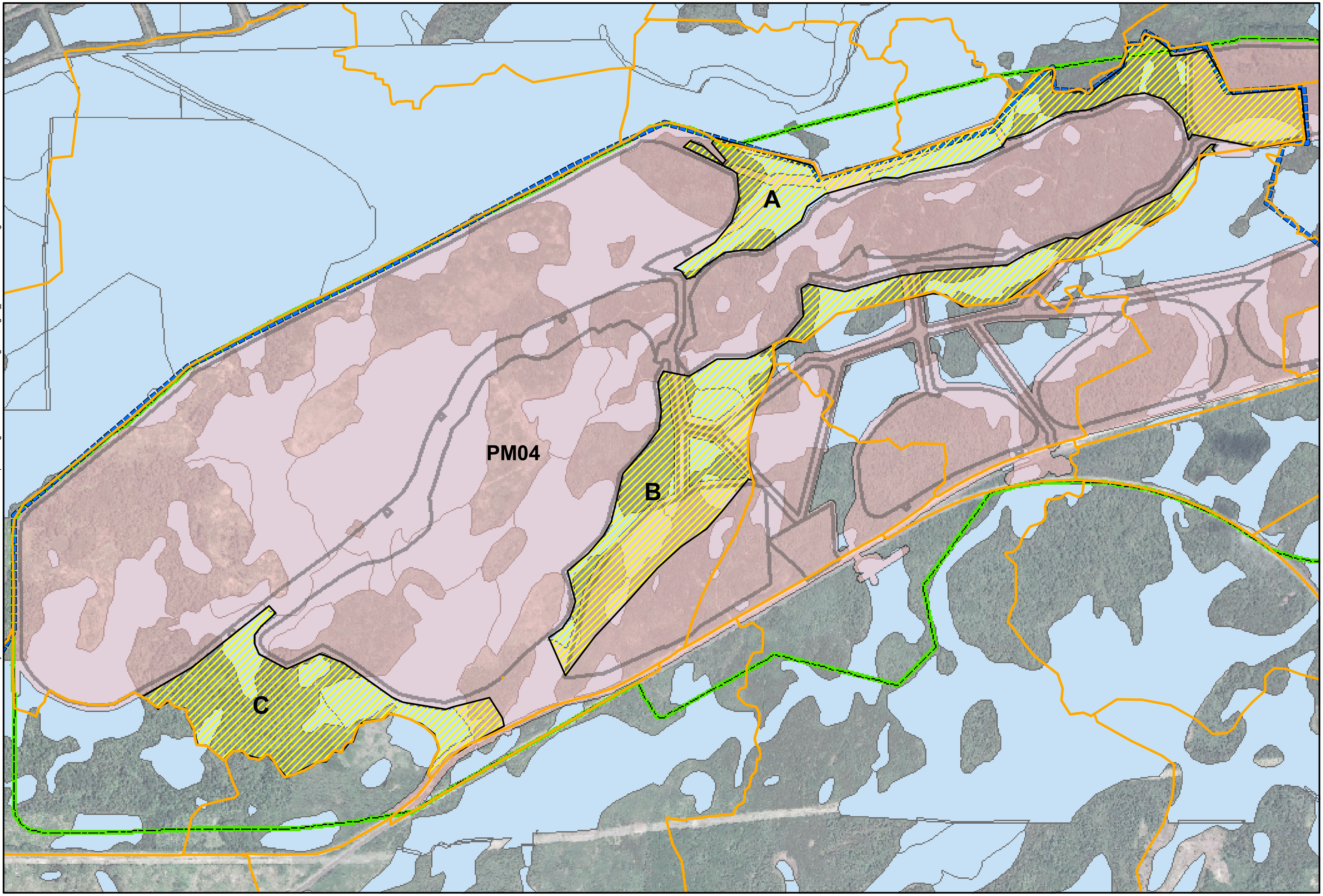


Figure 9

DISTURBED AREAS
PolyMet Mining
Hoyt Lakes, Minnesota



Watersheds
Mine Site
Wetlands
Post-closure Surface Water Divide
Project Area
"Effective Contribution Area"

0 1,000 2,000 4,000 Feet

Figure 10

WATERSHED PM 04
"EFFECTIVE CONTRIBUTION AREAS"
PolyMet Mining
Hoyt Lakes, Minnesota

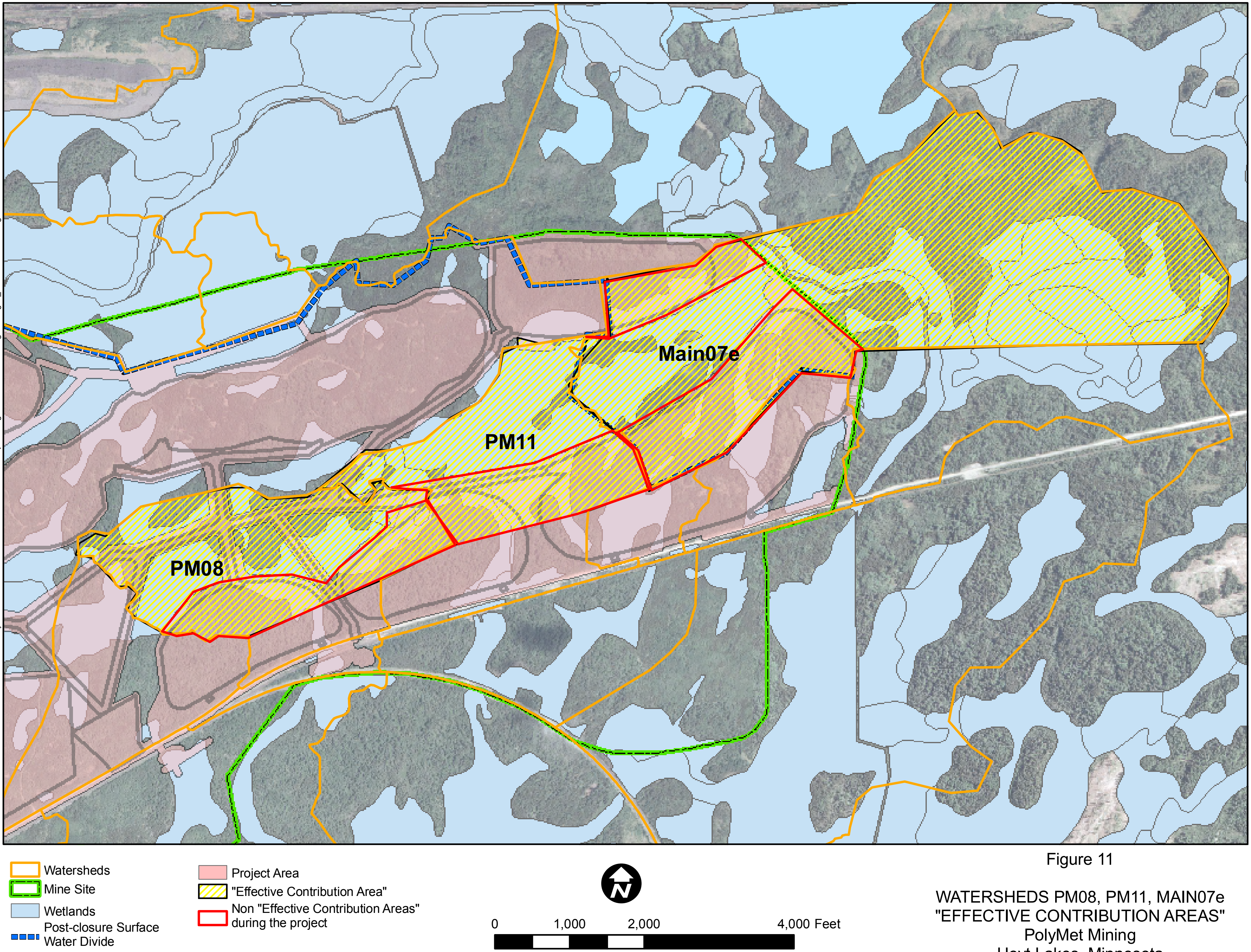
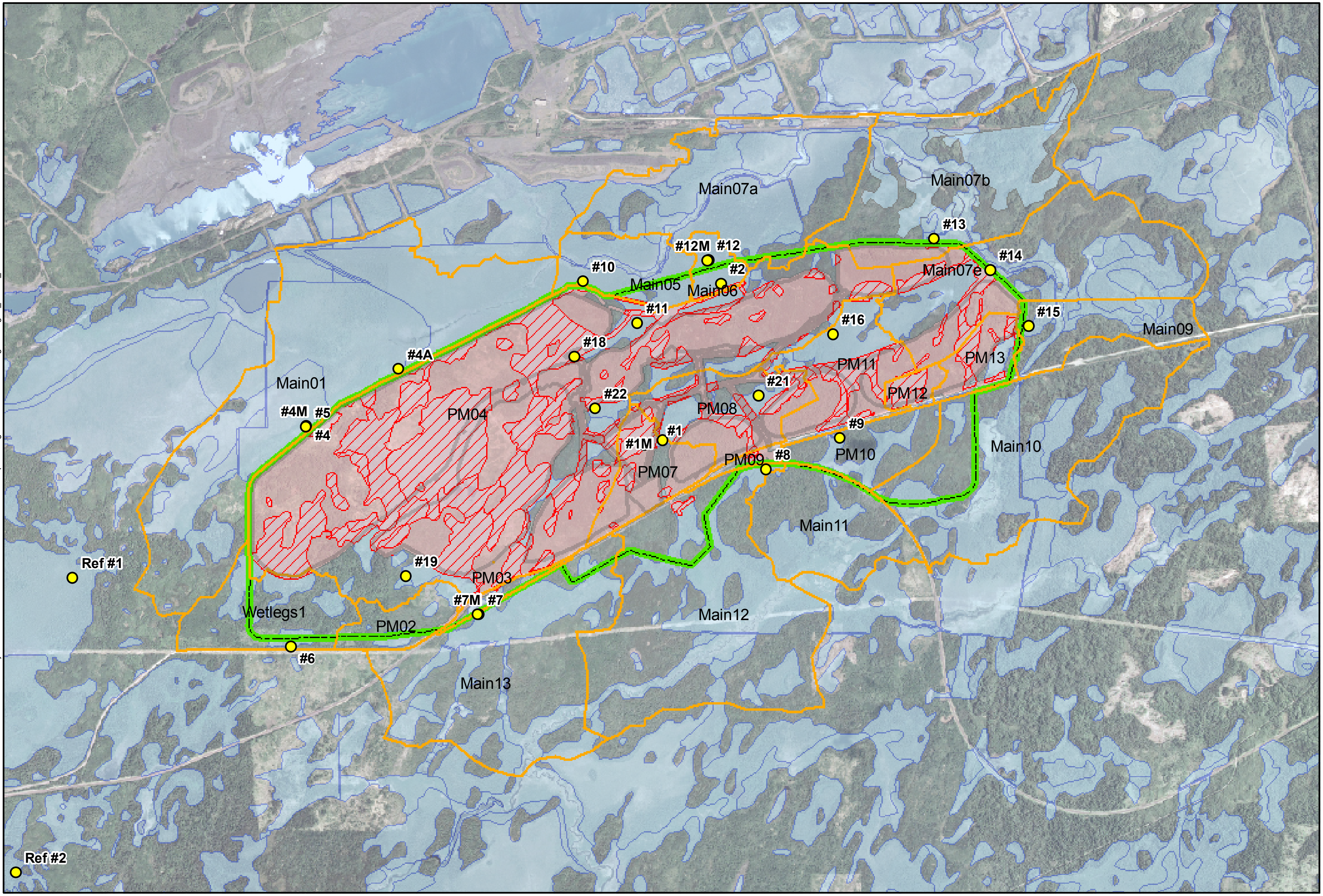


Figure 11

WATERSHEDS PM08, PM11, MAIN07e
"EFFECTIVE CONTRIBUTION AREAS"
PolyMet Mining
Hoyt Lakes, Minnesota



Mine Site
Watersheds
Project Area
Wetlands
Impacted Wetlands
2008 Monitoring Wells

0 2,000 4,000 8,000 Feet

Figure 12

WETLAND MONITORING WELLS IN 2008
PolyMet Mining
Hoyt Lakes, Minnesota