

FINAL REPORT

**GUIDELINES FOR THE
UTILIZATION OF PULP AND
PAPER MILL BIOSOLIDS ON
AGRICULTURAL LANDS**

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1.0 INTRODUCTION

Pulp and paper mills in Ontario generate approximately 350,000 dry metric tonnes of pulp and paper mill biosolids (PPMB) annually. In Ontario, as in most jurisdictions across North America, the majority of PPMB are managed by landfilling at private facilities or by combustion. Pulp and paper mill biosolids are also sent to municipal landfills and increasingly greater amounts are being managed by land application on agricultural, silvicultural and land reclamation sites.

Pulp and paper mill biosolids are the solid residues from the treatment of wastewater from pulping, papermaking and paper recycling operations. These materials are primarily composed of organic matter and contain some macro- and micro-nutrients that are beneficial to land application programs. PPMB are also relatively free of potential contaminants and pose a limited risk to the environment when applied in a controlled, well managed operation.

Because of the beneficial properties of PPMB, they should be considered as a potential resource to be utilized and not wasted. The advantages of using PPMB in a land application program include the following:

- increased productivity for agricultural crops
- improved soil quality through the addition of organic matter
- improved soil structure
- reduced reliance on commercial fertilizers and herbicides
- reduced reliance on landfill disposal
- economic development (ie., job creation)

Agricultural applications of PPMB represent beneficial opportunities for farmers, mill operators and local communities from environmental, agricultural and economic perspectives, including the reduction of Ontario's reliance on landfill disposal.

1.1 PURPOSE

The purpose of these guidelines is to establish a set of recommended standards and management practices specific to the use of PPMB on agricultural land in Ontario. Agricultural utilization of PPMB must be conducted in a controlled manner and must increase crop production, improve soil conditions, or provide some other agricultural benefit. These guidelines have been developed for the specific physical, chemical and biological characteristics of PPMB, and are not intended to apply to other residuals such as dewatered biosolids from municipal sewage treatment works.

These guidelines are intended to assist mill operators, biosolids managers, farmers, consultants, and Ministry of Environment staff in the design, approval, implementation and monitoring of PPMB use on agricultural land in Ontario. The guidelines have been developed on the basis of the best scientific information available at this time. With ongoing research, it is anticipated that the understanding of the use of pulp and paper mill biosolids in agricultural applications will improve. Therefore, it is intended that these guidelines be reviewed and revised as additional research information becomes available and experience with these materials increases.

1.2 SCOPE

The scope of these guidelines is limited to consideration of primary, secondary and combined (primary plus secondary) biosolids from pulp and paper mill wastewater treatment systems, and biosolids from de-inking processes. These guidelines do not consider other solid residues from pulp and paper mills (eg., lime rejects, wood waste, bark, etc.). Some of these residues, such as wood wastes, although designated as wastes, meet the criteria for exemption from the requirements of Part V of the *Environmental Protection Act* and Ontario Regulation 347.

These guidelines are also limited to the use of PPMB in agricultural applications. Guidelines for the application of PPMB on silviculture and land reclamation sites have been prepared by the Ontario Forest Industries Association (OFIA) and are included in a separate document (OFIA, 1999).

Additional technical information related to the physical, chemical and biological characteristics of PPMB and their beneficial use on agricultural land is included in the Technical Annex, which accompanies this Guideline document.

The guidelines reflect considerations in the following areas:

- land productivity (soil quality, vegetation growth)
- protection of human and animal health
- protection of environmental quality

To be sustainable, an application program must provide benefits to the soil and vegetation on the land that the residuals are being applied to, and must not degrade the physical environment. The fundamental approach taken in developing these guidelines is that an application program should be designed to optimize the benefits to the soil and vegetation, rather than to maximize the disposal of unwanted solid residues. If PPMB are to be viewed as a valuable resource, the resource must be used wisely and in an environmentally sustainable manner.

1.3 LEGISLATIVE FRAMEWORK

In Ontario, PPMB are regulated as “processed organic wastes” in accordance with Ontario Regulation 347, made under the *Environmental Protection Act (EPA)*. The biosolids can be utilized at “organic soil conditioning sites”, which require approval under section 27 (Part V) of the EPA as waste disposal sites. The specific definitions in the regulation are as follows:

“processed organic waste” means waste that is predominantly organic in composition and has been treated by aerobic or anaerobic digestion, or other means of stabilization, and includes sewage residue from sewage works that are subject to the provisions of the Ontario Water Resources Act;

“organic soil conditioning” means the incorporation of processed organic waste in the soil to improve its characteristics for crop or ground cover growth;

Standards for the location, maintenance and operation of organic soil conditioning sites, as specified in Section 15 of Ontario Regulation 347, are as follows:

15. The following are prescribed as standards for the location, maintenance and operation of an organic soil conditioning site:

- 1. The site shall be so located that it is an adequate distance from any watercourse, as determined by the land slope, to prevent direct surface drainage to the watercourse.*
- 2. The site shall be at least 300 feet from the nearest individual dwelling.*
- 3. The site shall be at least 1,500 feet from any area of residential development.*
- 4. The site shall be so located that the maximum level of the ground water table at the site is at a sufficient distance below the surface to prevent the impairment of ground water in aquifers as determined by the permeability of the soil.*
- 5. The site shall be at least 300 feet from any water wells.*
- 6. No processed organic waste shall be applied to the site during any period in which conditions are such that surface runoff is likely to occur taking into account land slope, soil permeability and the climatic conditions of the area.*
- 7. The site shall be established only on land that is, or is intended to be, used for pasture, fallow or the growing of forage crops,*
 - i. during the current growing season, or*
 - ii. where application of the processed organic waste is made sometime after the current growing season, to the end of the subsequent growing season.*

8. *Berms and dykes of low permeability shall be constructed on the site where necessary to isolate the site and effectively prevent the egress of contaminants. R.R.O. 1990, Reg. 347, s. 15.*

Prior to the use of an organic soil conditioning site, a Certificate of Approval (C of A) must be issued by the Ontario Ministry of Environment (MOE) upon application by a proponent and review of the application and supporting technical information by the MOE. The C of A usually contains specific conditions applicable to the site and its environs.

Processed organic wastes must be transported from the generator's facility to the land application site by a hauler who holds a valid Organic Waste Management System Certificate for the specific waste materials. These certificates are issued by the MOE under the provisions of the EPA.

Guidance regarding the characterization of biosolids (including sewage biosolids and other organic wastes), the assessment of receiving sites, and site operations is provided in the document entitled, *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land*, which was issued in March 1996 by the MOE and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Pulp and paper mill biosolids are considered as "other wastes" in the document.

In June 2001, the Government of Ontario introduced a new bill intended to set and enforce standards related to nutrient management on farms. The enabling legislation, entitled the *Nutrient Management Act 2001*, would provide the authority for regulations governing all land-applied materials containing nutrients related to agriculture, including livestock manure, commercial fertilizer, municipal sewage biosolids, septage, and pulp and paper mill biosolids. At the time of preparation of this Guideline document, the standards related to pulp and paper

mill biosolids had not yet been prepared. Consequently, it is intended that these Guidelines will form a basis for further consultation between the MOE, OMAFRA, the forest products industry and other stakeholders during the development of the new nutrient management standards.

An extensive knowledge base has been acquired for the utilization of PPMB in agricultural land applications, and the approval of organic soil conditioning sites for agricultural usage has now become fairly routine in Ontario and other jurisdictions. Considerable research and development effort has been expended by many forestry products companies regarding the use of PPMB in agricultural applications. The results of these studies clearly demonstrate that well-managed land application programs using PPMB provide an environmentally beneficial and economic approach to residual management, and provide farmers with a source of organic matter and plant nutrients for improved soil health and crop production.

2.0 BENEFICIAL USE OF PULP AND PAPER MILL BIOSOLIDS ON AGRICULTURAL SITES

2.1 AGRICULTURAL PRODUCTIVITY PRINCIPLES

Producing high, consistent crop yields at an optimal profit without creating adverse environmental affects is the basic objective of the agricultural industry in Ontario. This requires considerable attention to many issues such as soil management, crop rotation and residual management, nutrient management, as well as insect and weed control. Soil and nutrient management form the basis of sustainable agricultural productivity, and also impact most directly on the input costs of production, including fertilizer, fuel, labour, and equipment.

Cultivation (plowing, discing, harrowing etc.) and surface erosion of agricultural soils have led, over time, to the loss of organic matter, soil erosion, and resulting difficulties in maintaining productivity. Nearly all soils used for agriculture in the province would be more

productive if they contained more organic matter, with two exceptions being organic or poorly drained soils. Therefore, all suitable available organic matter sources should be used to increase or maintain the productivity of Ontario soils.

Fertilizers are a very significant and costly requirement for the growth of most farm crops. Optimum production depends on the plants obtaining the correct amount of nutrients at the right time in their growth cycle. Commercial fertilizer and lime applied to agricultural cropland in Ontario is estimated to cost farmers almost \$360 million annually (Best Management Practices, Nutrient Management Planning, 1998). Therefore, less costly nutrient sources are in demand. Organic-based nutrient sources, such as pulp and paper mill biosolids, serve to provide an appropriate form of organic matter and fertilizer for soil and crop management.

2.2 BENEFICIAL CHARACTERISTICS OF PULP AND PAPER MILL BIOSOLIDS

It has been clearly demonstrated that, when properly managed, the application of PPMB to agricultural land can provide benefits through improved crop production and soil health without adverse effects on the environment. Pulp and paper mill biosolids are rich in organic matter and contain moderate levels of nutrients suitable for plant fertilization, such as nitrogen, phosphorus, potassium and micro-nutrients. The materials also have the potential to improve soil properties, such as the organic matter content, structure, water retention capacity, erosion control, and support for microbial populations. Organic additions to soils, such as with pulp and paper mill biosolids, can make the soils more porous leading to easier penetration of air, water and plant roots.

Primary clarifier fibre and other residuals with high C:N ratios are also effective as mulches for weed and erosion control. As described in the following sections, PPMB may also contribute macro-, and micro-nutrients at levels that can provide long-term benefits to soil and plant productivity.

Pulp and paper mill biosolids can be produced and/or processed in the forms and quantities that are amenable to transportation, storage, and application at agricultural sites. The PPMB can be dewatered and/or blended with other materials to a relatively high solids content (from 25-30% and greater), which make them suitable for conventional or easily modified haulage and agricultural spreading technologies.

2.2.1 Opportunities for the Beneficial Use of PPMB

The opportunities for the use of PPMB in agricultural activities lie primarily in their ability to supply organic matter and nutrients to the soil and plants. Some examples of the various functions of PPMB at application sites include the following:

Plant Growth and Productivity

- better root penetration
- better air supply to roots
- better moisture supply
- supply of nutrients, with some in slow release, organic form
- pH adjustment

Soil Improvement

- increased organic matter
- improved water infiltration and retention capacity
- improved soil structure
- improved erosion control
- improved storage and cycling of nutrients
- increased cation exchange capacity
- support for a diverse microbial community

2.3 PLANT NUTRIENTS OF POTENTIAL BENEFIT AND ELEMENTS OF POTENTIAL CONCERN

Pulp and paper mill biosolids include a wide range of products with varying characteristics and composition. Detailed descriptions of the parameters of interest for agricultural applications, as well as those parameters that could be of potential concern to the environment or plant growth, are presented in the accompanying Technical Annex.

Secondary and combined pulp and paper mill biosolids, in addition to organic matter, usually contain significant concentrations of fertilizer equivalent nitrogen, phosphorus and potassium as well as other macro and micronutrients, all of which are beneficial for land application. Primary clarifier fibre and other similar residuals are usually low in nitrogen, phosphorus, potassium and other macro and micronutrients. They do contain valuable amounts of organic matter of benefit for land application. However, because of their high organic carbon to nitrogen ratio (C:N ratio), extra fertilizer equivalent nitrogen is usually required to prevent crop deficiency during the early stages of organic matter decomposition.

A brief summary of the plant nutrients and elements of potential concern is provided in Table 1.

Table 1: Summary of Nutrients and Elements of Potential Concern

Parameter	Important Characteristics
Organic Carbon	A measure of organic matter; enhances soil quality
pH	Affects solubility and plant availability of nutrients and metals
Nitrogen	Macronutrient*; Potential for leaching to groundwater
C:N Ratio (Organic carbon:Nitrogen)	Soil fertility; ability to mineralize organic matter; affects nitrogen availability
Phosphorus	Macronutrient; Potential for runoff to surface water
Potassium	Macronutrient
Calcium	Macronutrient often associated with soil pH
Magnesium	Macronutrient
Sulfur	Macronutrient
Sodium	Can cause soil salinity or poor soil structure
Arsenic	Potential toxin to plants & animals
Boron	Micronutrient; narrow range between plant deficiency and toxicity
Copper, Zinc & Nickel	Micronutrients; also potential toxins to plants & animals
Molybdenum	Micronutrient; also a potential toxin to plants & animals
Cadmium, Mercury & Lead	Potential toxins to plants & animals
Chromium	Required by animals, also a potential toxin to plants & animals
Manganese	Micronutrient; also a potential toxin to plants in acid soils
Aluminum	Potential plant toxin in acid soils and to other organisms in water
Trace Organic Chemicals	Potential leaching to surface and groundwater

**Nutrients are defined as elements required by plants for growth and reproduction. Healthy vegetative plants may contain 0.2% of some macronutrients to 4.0 % of others and from 0.02 mg/kg (ppm) of some micronutrients to 300 mg/kg of others.*

Pulp and paper mill process waters are usually treated separately from sewage wastes, and are therefore free from contamination by human and animal pathogens. As is described further in the accompanying Technical Annex, pulp and paper mill biosolids typically do not represent a source of pathogens to human or animal receptors. Therefore, there is little risk for disease transmission from agricultural land applications, either with or without incorporation of the materials. Consequently, in these guidelines, there are no pathogen-related restrictions on the use of the pulp and paper mill biosolids known to be free of human and animal sewage wastes.



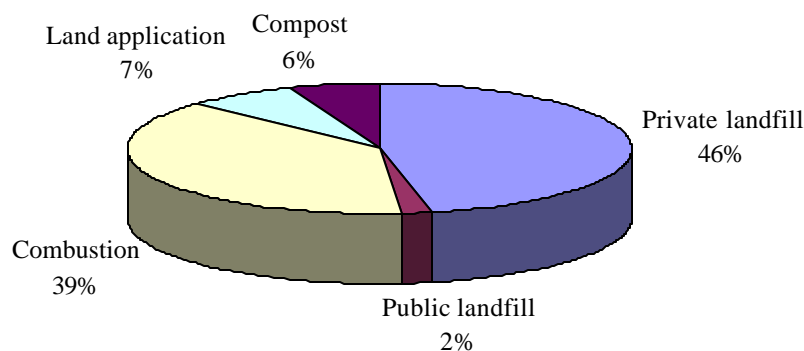
2.4 ALTERNATIVE MANAGEMENT PRACTICES

Pulp and paper mills in Ontario (35 mills in total) generate approximately 350,000 dry tonnes of PPMB annually, which represents 20% of the estimated annual PPMB generation of 1.7 million dry tonnes in Canada (OFIA, 1996; Reid, 1997). From information gathered in two 1996 surveys, the approximate distribution of PPMB generated in Ontario is estimated to be as follows:

- Primary 25 – 45 %
- Secondary 16 % (the OFIA survey did not distinguish secondary biosolids)
- Combined 29 – 71 %
- De-inking 4 – 10 %

The majority of PPMB generated in Ontario are disposed at landfills (primarily privately-owned, with a small percentage sent to public sites), or by combustion as fuel in boilers at the mill sites. A small proportion of the biosolids are land applied; however, the percentage of land application appears to be increasing from year to year as the practice becomes more widely accepted. Recent data from 55 Canadian forestry product mills (Reid, 1997) indicate the distribution of selected management options for biosolids as shown below in Figure 1.

Figure 1: Selected PPMB Management Options in Canada (1996)



The data for Canada are believed to be fairly representative of Ontario conditions, except that the amounts of PPMB being land applied may be slightly higher, and the proportion being combusted may be smaller than the national average. The ultimate usage of the composted material is not described in the referenced report; however, it is assumed that the material will be land applied.

The reliance on landfilling as the predominant means of biosolids management reflects a continued perception of biosolids as unwanted residues that require disposal, rather than materials with intrinsic value to agricultural production. Certainly, the economics of land application versus landfill disposal play a critical role in the selection of residue management options. For example, in Northern Ontario the transportation distance (and hence haulage costs) from the mill to suitable agricultural land may be prohibitive to sustain an agricultural land application program. However, in many situations in Ontario it has been demonstrated that land applications of biosolids to agricultural sites can be economically viable and environmentally sustainable when properly managed.

Pulp and paper mill biosolids can be applied to agricultural land and mixed with the soil, applied and left on the soil surface as a mulch, or mixed with soil or other media as potting mixtures for horticultural plants. Secondary and combined PPMB are frequently more desirable to mix with the soil because of the nitrogen which these materials usually supply. Primary PPMB is likely to be more desirable for mulching at higher rates of application because of its greater stability and low concentration of nutrients, but it can also be used to mix with the soil.

Organic materials are in demand for use as rooting and potting media to grow horticultural plants such as ornamental shrubs and landscaping plants for the commercial nursery industry. Various forms of pulp and paper mill biosolids have the potential for use as an appreciable portion of the media. Recent studies of PPMB used as a rooting medium amendment for deciduous landscape shrub cuttings indicated optimum amounts of biosolids ranging from 30% to 60% by volume (Chong et al, 1998).

3.0 APPLICATION CRITERIA FOR AGRICULTURAL SITES

The application of PPMB to agricultural sites must provide benefits to soil quality and plant growth, without causing adverse effects to human and animal health, and the environment. The purpose of this section is to provide appropriate criteria for PPMB applications to agricultural sites in order to achieve these objectives. A brief overview of the general principles is presented first, followed by recommended application rates and management practices. A summary of the recommended criteria for receiving soils and biosolids is presented in Table 5, which is found at the end of Section 3.3.

3.1 GENERAL PRINCIPLES

To be acceptable for application to agricultural land, any organic or inorganic residual must be of benefit. In the case of pulp and paper mill biosolids, the benefit would normally come from the organic matter content and plant nutrients.

In terms of the supply of nutrients, the biosolid should be applied at an agronomic rate that is required to provide optimum plant growth. For secondary or combined pulp and paper mill biosolids, the limiting nutrient will be nitrogen in most situations. In other words, the material applied must not supply more fertilizer equivalent nitrogen than the crop to be grown requires. The crop requirements must therefore be measured, which is usually done by a soil analysis. Where livestock manure, green manure, or off-farm wastes are applied, commercial fertilizer applications should be reduced by amounts equalling the amounts of fertilizer equivalent nutrients applied in the alternative sources of nutrients. The development and implementation of nutrient management plans on farms receiving pulp and paper mill biosolids is critical to the long-term sustainability of the programs (see Section 4.2 for more guidance on the development of nutrient management plans).

3.2 RECEIVING SOIL CRITERIA

The following criteria apply to soils to be used for agricultural crop production that are to receive pulp and paper mill biosolids.

Soil pH

- Pulp and paper mill biosolids with metal contents exceeding the concentrations specified on Column 3 of Table 3 should not be applied to soils with a pH value below 6.0

Traditionally, sewage biosolids have not been allowed on agricultural land with a soil pH of less than 6.0 because most heavy metals are much more soluble and plant available at low soil pH. For many field crops, it is recommended that soil pH be maintained at a level near 6.0 or higher for crop production. Agricultural soils are commonly limed in order to sustain these pH levels. The optimum range for many crops is above 6.0. However, some crops require or tolerate lower pH values. For example, corn grows well at pH values as low as 5.6 and blueberries need pH values between 4.3 and 4.8.

Changes in soil pH can affect nutrient availability to crops and metal solubility. In order to limit metal availability, pulp and paper mill biosolids with metal concentrations exceeding those specified in Column 3 of Table 3 should not be applied to soils with pH values below 6.0. However, if all the metal concentrations in PPMB are less than those in Column 3 of Table 3, soil pH should not be a factor affecting the acceptability of the soil to receive PPMB.

It is noted that this recommended guideline is somewhat less stringent than the soil pH criteria specified in the current MOE/OMAFRA Biosolids Guidelines (MOE/OMAFRA, March 1996) by providing for the application of certain PPMB to soils with pH less than 6.0. In doing so, the criteria recognizes the specific characteristics of certain PPMB that contain very low concentrations of metals. It is important to note that regardless of the PPMB being utilized, the metal criteria and maximum metal accumulations in soil specified elsewhere in these guidelines should be adhered to.

Heavy metals

- Pulp and paper mill biosolids with metal concentrations greater than Column 2 of Table 3 should not be applied to agricultural soils. Pulp and paper mill biosolids with metal concentrations greater than Column 3 of Table 3 should not be applied to soils with mean metal contents greater than those listed in Column 3 of Table 2.

Metals such as copper, molybdenum and zinc are required in small quantities by plants for proper growth and development, and cobalt, chromium and selenium are required by animals. However, at higher concentrations, these and the other metals listed in Tables 2 and 3 can be toxic to plants and animals. The levels at which different metals become toxic may vary from site to site, and are not firmly established. Therefore, in order to prevent any toxic effects, the concentrations of metals in the soil must be maintained at acceptable levels to provide a wide margin of safety, based on current scientific evidence. The metals concentrations presented in Column 3 of Table 2 have been established as the maximum acceptable metals concentrations in soil receiving biosolids containing significant concentrations of metals (ie., concentrations above those listed in Column 3 of Table 3).

Pulp and paper mill biosolids with lower concentrations of heavy metals (ie., concentrations below those listed in Column 3 of Table 3) may be applied provided application rates do not result in metal applications exceeding those in Table 2, Columns 4 and 5.

Table 2: Criteria for Metal Content in Soils

1	2	3	4	5
Metal	Mean Metal Content in Uncontaminated Ontario Soils (mg/kg)	Maximum Permissible Metal Content in Soils Receiving PPMB (mg/kg)	Maximum Permissible Metal Addition to Uncontaminated Soil (kg/ha)	Maximum Permissible Metal Application per 5 years (kg/ha)
Arsenic	7	14	14	1.4
Cadmium	0.8	1.6	1.6	0.27
Chromium	15	120	210	23.3
Cobalt	5	20	30	2.7
Copper	25	100	150	13.6
Lead	15	60	90	9
Mercury	0.1	0.5	0.8	0.09
Molybdenum	2	4	4	0.8
Nickel	16	32	32	3.56
Selenium	0.4	1.6	2.4	0.27
Zinc	55	220	330	33

Note: From Table 2 of the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land (MOE/OMAFRA, 1996).

Organic soils

- Pulp and paper mill biosolids should be applied to mineral soils, not to organic soils.

The primary benefit of PPMB applications to agricultural land is the organic matter these materials supply. Organic matter in soils helps cement the soil particles together into porous aggregate making them more resistant to erosion, and easier to penetrate by plant roots, water and air. Organic soils, which are defined as soils of a minimum of 0.4 metres thickness consisting of 17% or more organic carbon content (approximately 30% organic matter) will not benefit from the addition of organic matter provided by PPMB.

Table 3: Criteria for Metal Content in Biosolids

1	2	3
	Maximum Permissible Metal Concentration	
Metal	Present Requirement - (mg/kg of solids)	Long Term Targets - (mg/kg of solids)
Arsenic	170	35
Cadmium	34	4
Cobalt	340	77
Chromium	2,800	530
Copper	1,700	380
Mercury	11	1.4
Molybdenum	94	1.2
Nickel	420	80
Lead	1,100	220
Selenium	34	6
Zinc	4,200	840
Boron	Boron does not provide long term pollution concerns like the metals listed above but it is toxic to plants at lower concentrations than any of the metals listed. The maximum boron application in biosolids is one kilogram per hectare per year.	

Note: From Table 1 of the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land, (MOE/OMAFRA,1996).

Phosphorus

- In soils with an Olsen sodium bicarbonate extractable phosphorus concentration greater than 60 mg/L, the application of pulp and paper mill biosolids should be assessed on a site-specific basis, and should be restricted to a phosphorus application of 20 kg fertilizer equivalent P₂O₅ per hectare per year.

Phosphorus is an important plant nutrient, and PPMB, particularly secondary and combined biosolids (which often contain total phosphorus concentrations of 2000 mg/kg or greater) can supply plant available phosphorus to soils. Primary biosolids generally contain much lower concentrations of total P (200 mg/kg or less).

Historically, phosphorus was naturally deficient for crop production in most Ontario soils. It is still required on most farms and is expensive to buy. However, an increasing portion of intensively farmed soils have received sufficient phosphorus from fertilizer and manure that they will need no phosphorus additions for a number of years of cropping.

High concentrations of extractable phosphorus in the surface soils can lead to nutrient loadings in surface water due to runoff and erosion. This can lead to excessive plant growth in aquatic environments, which impacts the availability of oxygen for fish and other aquatic animals. Phosphorus is generally tightly bound to soil particles, and is lost from agricultural soils primarily through erosion. Soil concentrations of extractable phosphorus higher than 60 mg/L do not provide additional benefits to plant growth, and may result in impacts to surface water quality. Therefore, the above guideline provides an acceptable balance between beneficial use and potential environmental impact.

Where high phosphorus soils do occur (ie., soils with an Olsen sodium bicarbonate extractable phosphorus concentration greater than 60 mg/L), applications of PPMB should be assessed on a site-specific basis regarding the amount of fertilizer equivalent phosphate that

will be supplied by the biosolid. Additions of PPMB should be restricted to a phosphorus application of 20 kg fertilizer equivalent P_2O_5 per hectare per year, which is considered to be a conservative estimate of crop removal of phosphorus.

The current Ontario Field Crop Recommendations assume that 40% of the total P in a nutrient source is available as fertilizer equivalent P_2O_5 . However, aluminum or iron in the pulp and paper mill biosolids may reduce the availability of P. Therefore, 40% availability of P is likely a conservative overestimation of fertilizer equivalent P_2O_5 in pulp and paper mill biosolids.

With any application, the fertilizer equivalent PPMB phosphate should be subtracted from the amount of fertilizer phosphate that would be recommended for the plants if PPMB were not applied.

3.3 BIOSOLIDS CRITERIA AND APPLICATION RATES

The main benefits of PPMB application to agricultural land are usually the organic matter and plant nutrients that are supplied. Most agricultural soils in Ontario can benefit from increases in organic matter content.

In research trials, quite high rates of PPMB have been applied to soils (e.g., 60 dry tonnes/ha as reported in Curnoe and Velema, 2000) without detrimental effects to plant growth, provided an appropriate balance of carbon and nitrogen was maintained. One of the more extreme examples of this is in nursery pot trials where shrubs grew as well or better where the potting mixture consisted of one-third PPMB than where it contained lesser amounts (Chong and Cline, 1993). It is clear that quite high rates of PPMB may be applied without negative effects on plant growth. However, the application rates must be controlled in order to properly balance the nutrient requirements of the crop to be grown.

Pulp and paper mill biosolids produced in Ontario vary markedly in nutrient content, with most primary biosolids being very low in nitrogen and most other nutrients, and most secondary and combined biosolids being higher.

The following criteria apply to the pulp and paper mill biosolids to be used for agricultural land applications.

Nitrogen

- Pulp and paper mill biosolids should be applied to agricultural lands at an application rate of fertilizer equivalent nitrogen that is required to provide optimum plant growth. All other nitrogen sources used on the agricultural land should be accounted for in the determination of the PPMB application rate.
- Specific biosolids and soil testing should be conducted to determine the appropriate rate of PPMB application for the site.

Provided the permitted heavy metal, boron and sodium concentrations are not exceeded in the PPMB applications, it can be expected that nitrogen will be the most critical factor controlling the application rate. Primary biosolids contain very small quantities of nitrogen, typically 0.3 % or less by dry weight, and possess C:N ratios well above 100:1. Combined primary and secondary biosolids generally contain from 0.5 to 5 % nitrogen (on a dry weight basis), with C:N ratios ranging between 20:1 and 100:1.

Most of the nitrogen in PPMB is present in organic forms that are not readily available to plants. Microorganisms in the soil and biosolids are largely responsible for organic matter decomposition and the transformation of the organic forms of nitrogen to the mineralized forms of ammonium (NH_4^+) and nitrate (NO_3^-), which are plant available. The rate of decomposition of organic matter is maximized when carbon and nitrogen are present in a C:N ratio less than 30:1.

For biosolids with C:N ratios of 30:1 or less, the fertilizer equivalent nitrogen in the year of application will equal the ammonium plus nitrate nitrogen plus a fraction (commonly 20 to 30%) of the organic nitrogen, calculated as follows:

$$N_f = [\text{NH}_4^+] + [\text{NO}_3^-] + \text{Min.Rate} * [N_{\text{org}}]$$

$$\text{where } N_{\text{org}} = [N_t] - ([\text{NH}_4^+] + [\text{NO}_3^-])$$

N_f - fertilizer equivalent nitrogen

NH_4^+ - ammonium nitrogen

NO_3^- - nitrate nitrogen

Min.Rate - yearly mineralization rate of organic nitrogen

N_{org} - organic nitrogen

N_t - total nitrogen

PPMB's with C:N ratios of 30:1 or less would include most of the secondary and combined biosolids. The amount of PPMB to be applied in a particular situation (ie., in dry tonnes/ha) will depend on the fertilizer equivalent nitrogen content of the biosolids and the annual plant nitrogen requirement. These requirements should apply whether the biosolids are incorporated into the soil or applied as a surface treatment.

For biosolids with C:N ratios of greater than 30:1, the fertilizer equivalent nitrogen will be negative. That means that additional nitrogen will need to be added to the soil, or to the biosolids, in addition to what would otherwise be recommended for the crop. This extra nitrogen will be the amount needed to bring the C:N ratio down to 30:1 and is required by the soil organisms during the early stages of organic matter decomposition.

In some agricultural situations, it may be desirable to apply and incorporate low nitrogen PPMB, with a C:N ratio in excess of 30:1 into the soil as a source of organic matter. Alternatively, the material may function as a "sponge" to temporarily immobilise excess available nitrogen from nutrient sources in the upper soil horizons. In the context of these guidelines, this category of PPMB function is likely to include only primary biosolids (primary



clarifier fibre). Where there is established or new plant growth requiring available N, nitrogen must then be added to the PPMB application to bring the C:N ratio down to 30:1 in order to prevent nitrogen immobilization and nutrient deficiency in the plants.

Where high C:N ratio PPMB are applied to the soil and left on the surface as a mulch for weed and erosion control or moisture retention, the breakdown of the material will occur over several years. The nitrogen requirement for breakdown will be spread over that period, with a gradual decrease in the C:N ratio as the material degrades.

Experience with high C:N ratio biosolids in mulching applications has shown that the materials are highly effective for weed control with no negative growth response as long as the plant cuttings and roots have adequate contact with the natural soil. Some studies have used blended PPMB applications in mulch layers to ensure that there is adequate nitrogen for decomposition.

In all instances, the rate and timing of PPMB application, with or without supplemental nitrogen application, should be tailored to the specific crop requirements based on an understanding of the PPMB and soil characteristics. Crop demands for nitrogen are generally highest during the period of most rapid vegetative growth.

Residual nitrogen from organic nitrogen sources applied in previous years applications should be accounted for in the analysis of plant requirements. This accounting can be done most effectively by soil nitrogen tests. Also, other nitrogen sources, including livestock manure, cover crops, crop residuals and commercial fertilizer must be managed along with the pulp and paper mill biosolids applications.

One exception to the above guidelines is for legumes such as soybeans, alfalfa, trefoil and clovers which do not require fertilizer nitrogen but will use it to replace nitrogen otherwise fixed by bacteria in nodules on their roots. Up to 100 kg fertilizer equivalent nitrogen/hectare per year could be applied for these legume crops. As noted above, any residual nitrogen from previous



applications of organic nitrogen sources should be included in the calculation of how much additional N can be applied to legume crops. This application of fertilizer nitrogen to legumes is not an efficient use of the nitrogen but at the rate described above would not be expected to significantly increase the potential for leaching of nitrate-nitrogen to the groundwater. The specified rate is based on experience with pulp and paper mill biosolids and other residuals used on agricultural land in Ontario.

Phosphorus

- For pulp and paper mill biosolids applications where the annual loading will result in less than 20 kg applied fertilizer equivalent phosphorus per hectare each year and the crop is to be harvested, PPMB can be applied to agricultural sites regardless of the soil phosphorus concentration.

As noted in Section 3.2 above, some pulp and paper mill biosolids can supply valuable amounts of fertilizer equivalent phosphorus to the soil. On many agricultural fields, this replaces some of the annual requirement for expensive fertilizer. According to these Guidelines, pulp and paper mill biosolids may not be applied to soils with Olsen sodium bicarbonate extractable phosphorus concentrations greater than 60 mg/L if the annual loading will result in more than 20 kg applied fertilizer equivalent phosphorus per hectare.

Primary biosolids are usually low in phosphorus, whereas secondary and combined biosolids are appreciably higher. Where the annual application will result in less than 20 kg applied fertilizer equivalent phosphorus per hectare each year and the crop is to be harvested, thereby removing the phosphorus, there is no appreciable risk of increasing the soil phosphorus levels above acceptable limits. Therefore, these materials should be acceptable for application regardless of the soil phosphorus concentrations. The value of 20 kg/ha of fertilizer equivalent phosphorus represents a conservative estimate of the annual crop removal of P.

Potassium

- The quantity of fertilizer equivalent potassium added from pulp and paper mill biosolids applications should be used to reduce the amount of other potassium sources required for optimum plant growth.

Potassium fertilizers are needed for crop production on an appreciable portion of Ontario soils. Secondary or combined pulp and paper mill biosolids can provide fertilizer equivalent potassium which should be used to reduce the amount of other fertilizer sources required. Primary pulp and paper mill biosolids can be expected to be low in potassium.

Heavy metals

- The concentrations of heavy metals in pulp and paper mill biosolids used in agricultural programs must not exceed the concentration limits specified in Column 2 of Table 3.

All biosolids, plants and animals contain some heavy metals. However, most PPMB have metal concentrations that are lower than the concentrations listed in Column 3 of Table 3. These are the long-term targets for heavy metals identified in the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA; March, 1996). In some PPMB, such as those from mills that produce newsprint using de-inked fibre, concentrations of such metals as copper have been observed above the long-term targets. The metals originate from colour inks and pigments from the recycled paper feedstock.

Pulp and paper mill biosolids with any one or more metal concentrations greater than specified in Column 2 of Table 3 must not be applied to land. Also, pulp and paper mill biosolids with acceptable metal concentrations (ie., below the concentrations listed in Column 2 of Table 3) must not be applied to soils which have concentrations of metals greater than those listed in Column 3 of Table 2. The soil metal concentrations in Column 3 of Table 2 have been established as the maximum acceptable concentrations in soil receiving biosolids containing significant concentrations of metals (ie., concentrations above those listed in Column 3 of Table 3).



Pulp and paper mill biosolids with lower concentrations of heavy metals (ie., concentrations below those listed in Column 3 of Table 3) may be applied provided application rates do not result in metal applications exceeding those in Table 2, Columns 4 and 5.

Boron

- Pulp and paper mill biosolids should not be applied at rates supplying more than 0.5 kilogram of plant available (hot water soluble) boron per hectare per year for boron intolerant crops, and 1 kilogram per year for boron tolerant crops.

Boron is required by plants and is commonly deficient for certain crops on a number of Ontario soils. It has an unusually narrow range between the concentrations required by some common crops such as turnips, and toxic concentrations for others such as beans. It is not required by animals and is not commonly a serious water pollutant. Excessive boron applied to Ontario soils (unlike the heavy metals) tends to dissipate in a few years due to leaching and precipitation to less soluble forms.

The current Ontario guidelines state that biosolids should not be applied at rates supplying more than one kilogram of boron per hectare per year for boron intolerant (most) crops. For boron tolerant crops such as alfalfa, turnips, cabbage, cauliflower and broccoli, the application limit is 2 kg of boron per hectare per year.

In the case of PPMB, much of the boron present in the material is not expected to be plant available. The PPMB guidelines are intended to be specific to the plant available fraction of boron. Therefore, it is recommended that the limits should be 0.5 kilogram of hot water soluble boron per hectare per year for boron intolerant crops and 1 kilogram per hectare per year for boron tolerant crops.

Aluminum and Manganese

- An assessment of the aluminum and manganese concentrations and loading rates should be completed for pulp and papermill biosolids to be applied on agricultural land with a soil pH less than 5.5.

Aluminum and manganese are metals with limited solubility in neutral, well-drained soils, although the total concentration of aluminum in soils may range from 0.5 to 10 % and of manganese from 50 to 2000 mg/kg. Neither of these elements are of concern for land application to agricultural soils with pH values above 5.5 because of their low solubility. High soluble aluminum and/or manganese concentrations do occur in soils with pH values below about 5.4, and can be toxic to all but the acid-loving crops such as blueberries. Manganese is also more soluble where the oxygen supply is limited such as in poorly drained soils. Manganese is deficient for soybeans and cereals on a number of Ontario soils, but aluminum is not required by plants or animals.

Manganese concentrations in pulp and paper mill biosolids need only be considered for application to soils of pH 5.5 or less because of its increased solubility and availability at lower pH.

Sodium, Calcium & Magnesium

- Sodium additions to agricultural soil from pulp and paper mill biosolids should not exceed the limits specified in Table 4.

Sodium is not required by plants and excessive sodium in soils can contribute to high salt levels that are toxic to plants. High sodium levels, relative to calcium and magnesium concentrations, can result in rapid and almost irreversible deterioration of soil structure. Much of the sodium in pulp and paper mill effluent and biosolids is soluble, and along with other soluble salts some will be removed from wastewater treatment solids during dewatering.



Calcium and magnesium are contained in pulp and paper mill biosolids required by plants. These elements also help to maintain soil pH.

Table 4: Sodium Additions to Soils

Soil Texture	Maximum Annual Sodium Addition (kg/ha/yr)
Sands, loamy sands & sandy loams	200
Loams, clay loams & clays	500

Note: From Table 3 of the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land (MOE/OMAFRA, 1996).

Trace Organic Compounds

- The PCDD/PCDF (polychlorinated dibenzo-p-dioxin / polychlorinated dibenzofuran) level of pulp and paper mill biosolids should not exceed 27 parts per trillion (ppt) I-TEQ (International Toxicity Equivalent factor).
- The PCDD/PCDF level of the receiving soil should not exceed 10 ppt I-TEQ.

Possible sources of organic chemical compounds in pulp and paper mill biosolids include background concentrations naturally occurring in wood fibre and waste paper feedstock materials, derivation as a result of chemical reactions during the manufacturing process, and wastewater treatment chemicals and processes.

Trace organic compounds in PPMB are not detectable or found at very low concentrations. At such levels, trace organic compounds are not expected to pose any environmental impact from the utilization of PPMB. In fact, most organic contaminants of

concern to health and the environment, including PCB's, phenolics, dioxins and furans, and halogenated hydrocarbons are not detected or are found at low levels in pulp and paper mill biosolids. A detailed review and evaluation of the scientific literature on organic contaminants in pulp and paper mill biosolids was completed by Water Technology International Corporation in 1996 (WTI, 1996). The review found that volatile organic compounds and PAH's in PPMB were generally found at concentrations less than 2 mg/kg (dry weight), and that extractable organics such as phenolics and phthalates were generally found at concentrations less than 5 to 15 mg/kg (dry weight). Polychlorinated biphenyls (PCB's) ranged from 0.01 to 6.81 mg/kg (dry weight).

The levels of dioxins and furans in pulp and paper mill biosolids are much less than those found in everyday materials such as plastic packaging and household dust (WTI, 1996). The available data indicate that PCDD/PCDF concentrations in pulp and paper mill biosolids are generally less than 14 ppt I-TEQ (dry weight) and have decreased since 1994 as mills have switched to elemental chlorine free bleaching. Current PCDD/PCDF levels in pulp and paper mill biosolids that are not derived from chlorine-based bleaching are generally less than 5 ppt I-TEQ (dry weight).

The MOE has reported a background value of 7 ppt I-TEQ in Ontario soils (MOE, 1997). The criteria of 27 ppt I-TEQ for PCDD/PCDF specified in the box above is used by the State of Maine (*Chapter 419, Agronomic Utilization of Residuals*) as the allowable concentration for residuals that do not require any additional restrictions related to dioxins and furans. The soil criteria specified in the box above (10 ppt I-TEQ) is used by the MOE for allowable dioxin and furan concentrations of solid residuals applied to land.

Trace levels of surfactants have been found in pulp and paper mill biosolids, originating from industrial cleaning and de-inking operations, as well as from the wastewater treatment processes. The concentrations of these compounds are at very low levels, and current scientific evidence indicates that application of biosolids containing surfactants to agricultural land does not pose a significant risk to health and the environment. A recent project involving a detailed review of the scientific literature conducted on behalf of the Water Environment Association of Ontario (Webber et al, 2000) concluded that common domestic and industrial surfactants such as linear alkylbenzene sulfonates (LAS), as well as alkylphenols and their metabolites including 4-nonylphenol, did not require further research with regard to their potential impacts from biosolids applications. The surfactants were found to degrade rapidly in agricultural soils, and did not persist in the environment under aerobic conditions.

Table 5: Summary of Receiving Soil & Biosolids Criteria

<p><u>Receiving Soil Criteria</u></p> <ul style="list-style-type: none"> • Soil pH • Heavy Metals • Organic Soils • Phosphorus 	<p>Pulp and paper mill biosolids with metal contents exceeding the concentrations specified on Column 3 of Table 3 should not be applied to soils with a pH value below 6.0.</p> <p>Pulp and paper mill biosolids with metal concentrations greater than Column 2 of Table 3 should not be applied to agricultural soils. Pulp and paper mill biosolids with metal concentrations greater than Column 3 of Table 3 should not be applied to soils with mean metal contents greater than those listed in Column 3 of Table 2.</p> <p>Pulp and paper mill biosolids should be applied to mineral soils, not to organic soils.</p> <p>In soils with an Olsen sodium bicarbonate extractable phosphorus concentration greater than 60 mg/L, the application of pulp and paper mill biosolids should be restricted to a phosphorus application of 20 kg fertilizer equivalent P₂O₅ per hectare per year.</p>
<p><u>Biosolids Criteria</u></p> <ul style="list-style-type: none"> • Nitrogen • Phosphorus • Potassium • Heavy Metals • Boron • Aluminum & Manganese • Sodium, Calcium & Magnesium • Trace Organic Compounds 	<p>Pulp and paper mill biosolids should be applied to agricultural lands at an application rate of fertilizer equivalent nitrogen that is required to provide optimum plant growth. All other nitrogen sources used on the agricultural land should be accounted for in the determination of the PPMB application rate. Specific biosolids and soil testing should be conducted to determine the appropriate rate of PPMB application for the site.</p> <p>For pulp and paper mill biosolids applications where the annual loading will result in less than 20 kg applied fertilizer equivalent phosphorus per hectare each year and the crop is to be harvested, PPMB can be applied to agricultural sites regardless of the soil phosphorus concentration. Fertilizer phosphorus applications should be reduced by an amount equivalent to that applied from the pulp and paper mill biosolids.</p> <p>The quantity of fertilizer equivalent potassium added from pulp and paper mill biosolids applications should be used to reduce the amount of other potassium sources required for optimum plant growth.</p> <p>The concentrations of heavy metals in pulp and paper mill biosolids used in agricultural programs should not exceed the concentration limits specified in Column 2 of Table 3.</p> <p>Pulp and paper mill biosolids should not be applied at rates supplying more than 0.5 kilogram of plant available (hot water soluble) boron per hectare per year for boron intolerant crops, and 1 kilogram per year for boron tolerant crops.</p> <p>An assessment of the aluminum and manganese concentrations and loading rates should be completed for pulp and papermill biosolids to be applied on agricultural land with a soil pH less than 5.5.</p> <p>Sodium additions to agricultural soil from pulp and paper mill biosolids should not exceed the limits specified in Table 4.</p> <p>The PCDD/PCDF level of pulp and paper mill biosolids should not exceed 27 ppt I-TEQ. The PCDD/PCDF level of the receiving soil should not exceed 10 ppt I-TEQ.</p>

3.4 TIMING OF APPLICATIONS

3.4.1 Low Nutrient PPMB's (C:N ratios greater than 30:1)

Because of their higher C:N ratios, usually accompanied by low phosphorus content relative to other residuals, these materials are more suitable than low C:N materials for use as mulches and for leaving on the soil surface without serious risk of nutrient runoff that will impact surface water or groundwater. The timing of application is therefore more flexible than for materials with higher nutrient content. In general, application of mulches is acceptable at any time of the year provided there is less than 15 cm of snow on the ground where it is to be applied, and when the soil is dry enough to prevent serious soil compaction during application.

When left on the soil surface, pulp and paper mill biosolids provide excellent protection of the soil against erosion. Fall or winter application can take advantage of this to protect the soil against erosion during early spring and be incorporated, if desired, during spring seedbed preparation. Where this is done, the extra nitrogen required to balance the C:N ratio of the biosolids to less than 30:1 should be applied in the spring. In areas where the soil frequently freezes before snow comes, application on frozen ground in the winter has the advantage of practically eliminating the risk of soil compaction during spreading in addition to the reduction in early spring erosion.

Where high C:N ratio PPMB's are to be incorporated into the soil, they can also be applied at any time the soil is dry enough to prevent serious compaction, and may be incorporated when the soil is dry enough to cultivate. Late summer or fall application and incorporation of these materials may help to immobilize any excess nitrogen, which is frequently present on cultivated lands at this time of year.

For high C:N materials that are incorporated into the soil where crops requiring available N are to be seeded or planted, nitrogen must then be added to the PPMB application to bring the C:N ratio down to 30:1 in order to prevent nitrogen immobilization and nutrient deficiency in the plants. The exact amount of nitrogen required cannot be calculated exactly due to differences in PPMB and climatic effects; therefore, a specific agronomic assessment will be required. The assessment should involve soil nitrogen testing to determine the amount of available fertilizer N and the amount of supplemental N required to match the crop requirements. For fall or winter applications on land to be used for spring seeded or planted crops, any supplemental nitrogen that is required with high C:N ratio materials to assist in decomposition should be applied the spring following application to minimize the potential for nutrient leaching and runoff.

3.4.2 Moderate to High Nutrient PPMB's (C:N ratios less than 30:1)

These products, including secondary and combined PPMB's, can be applied and either left on the soil surface or incorporated. However, higher nutrient, lower C:N ratio materials are less suitable for using as surface mulches because in these applications they may supply more nitrogen than is required by the crop, thereby increasing the potential for nitrogen leaching, and because they can be expected to decompose at a greater rate, and therefore not last as long as high C:N materials.

Generally, the rates of application will be limited by the material's fertilizer equivalent nitrogen concentrations and the nitrogen requirements of the crop to be grown. Spring and early summer applications are preferred to make the best possible use of the nitrogen and to minimize nutrient losses. Late summer or early fall application of these materials is best suited to crops that need some fall nitrogen such as winter wheat. The sites should be dry enough at the time of application to prevent serious soil compaction.

Because a very significant proportion of the total nitrogen found in pulp and paper mill biosolids is in the organic form, the risk of nutrient runoff from winter applications is greatly reduced. The problems of nitrogen loss in surface runoff and leaching to groundwater are primarily related to nitrogen in its more soluble, inorganic forms including ammonium and nitrate (Henry et al., 1999). Organic nitrogen must first be mineralized to an inorganic form before it is readily mobile in the environment. The low mineralization rate of organic nitrogen during winter conditions will limit the conversion of organic N to the inorganic forms. Therefore, during winter applications, the pulp and paper mill biosolids applied to land will be low in fertilizer equivalent nitrogen content.

Both high and low C:N ratio materials can be used for potting media depending on the proportions and types of other materials in the mix. A specific assessment of the biosolid materials and the type of vegetation to be grown should be carried out.

3.5 SITE CRITERIA

In addition to the above criteria, which are intended to ensure appropriate application rates for PPMB applications to agricultural land, the following guidelines are provided for site assessment purposes. This assessment will minimize the risk of environmental impact to surface water, groundwater, wells and neighbouring properties.

3.5.1 SEPARATION DISTANCES

Separation distances from the application area to potential receptors are required to reduce nuisance impacts and to prevent contamination of surface water and groundwater supplies. The required separation distances are presented in Tables 6 and 7. Reductions from these separation distances may be permitted on a case-by-case basis, depending on site-specific circumstances and the type of biosolids to be applied.



Separation from Surface Watercourses

- A minimum horizontal separation distance between the PPMB land application site and a surface watercourse should be maintained as specified in Table 6.

For the purposes of these guidelines, a surface watercourse is defined as a natural or established watercourse or an open municipal drain along which water flows on a continuous or intermittent basis. In addition, ponds, lakes, springs, wetlands, and points of direct access (such as catch basins for drainage tiles or municipal drains) should be treated as watercourses for purposes of determining separation distances.

The separation distances presented in Table 6 were developed taking into account land slope and soil permeability (MOE / OMAFRA, 1996). The separation distances are intended to be restricted to pulp and paper mill biosolids with total solids contents greater than 25%. The reduced separation distances specified in Column 4 of Table 6 are only appropriate if one or more of the following criteria are met:

Mitigating Criteria for Reduced Separation Distances:

- receiving sites are dry and incorporation is within 24 hours (applicable only to PPMB with C:N ratios less than 30:1);
- there are site features, such as berms, natural ridges, etc., to prevent the direct movement of PPMB to watercourses;
- the receiving site and/or the surrounding watercourses are vegetated in a way that will prevent or inhibit precipitation from washing PPMB residues into watercourses (e.g., vegetated buffer strips).

However, under no circumstances should PPMB be applied or stored within 10 metres of any surface watercourse.

Table 6: Separation Distances between Application Area and Surface Watercourses

1	2	3	4	5
Maximum Sustained Slope	Soil Permeability	Separation Distance for High Nutrient, Low C:N PPMB* (metres)		Separation Distance for Primary PPMB (metres)
		Without Mitigating Criteria	With One or More of Mitigating Criteria	
0 – 3 %	Rapid to Moderately Rapid	50	10	10
	Moderate to Slow	100	20	20
3 – 6 %	Rapid to Moderately Rapid	100	20	20
	Moderate to Slow	200	40	40
6 – 9 %	Rapid to Moderately Rapid	150	Assess on a site-specific basis	30
	Moderate to Slow	Not permitted		50
> 9 %	All permeabilities	Not permitted	Assess on a site-specific basis	50

Notes: * This category includes secondary, combined and de-inking residues.
Soil permeabilities to be determined in accordance with OMAFRA's Drainage Guide for Ontario.
Soil types to be determined from site testing or from County Soil Maps.

The justification for the above separation distances to be used specifically for pulp and paper mill biosolids includes the following:

- When applied uniformly at agronomic rates, there is no substantial physical movement of the biosolids on agricultural fields. The biosolids do not readily erode, they are not easily transported, and are effective as a surface mulch.
- The organic matter and nutrients in pulp and paper mill biosolids (primarily nitrogen and phosphorus) are not readily soluble and are of significantly less risk to nutrient transport than for liquid biosolids or manure.

- Water quality monitoring programs conducted at agricultural sites using pulp and paper mill biosolids where reduced separation distances have been practiced do not indicate any adverse effects in surface watercourses adjacent to the application sites.

In addition to maintaining separation distances from the watercourses described above, the location of the receiving site and the application operations must reflect the following constraints:

- applications to floodplains and other areas that are prone to seasonal or frequent flooding should be avoided;
- applications to low-lying depressions and swales should be avoided when these features are wet;
- PPMB may be applied to areas of depressions and swales that are used for crop production when these features are dry enough to support the application/spreading equipment without operational difficulty and so as to prevent soil compaction. However, moderate to high nitrogen PPMB (i.e. C:N ratio less than 30:1) should not be applied in these areas if there is not a realistic expectation of crop utilization.

Separation from Groundwater

In accordance with Section 15 of Ontario Regulation 347 regarding standards for organic soil conditioning sites, it must be ensured that the maximum level of the groundwater table is at a sufficient distance below the ground surface to prevent impairment of the groundwater in aquifers. The MOE uses a guideline of 0.9 metres from the ground surface to the maximum level of the groundwater table; however, a reduction in this separation distance may be considered, where a site-specific assessment indicates other hydrogeologic conditions, such as the presence of low permeability confining layers, will be sufficient in meeting the MOE's Reasonable Use Guidelines for groundwater management (MOE, 1994a).

Separation from Bedrock

- A minimum soil thickness of 1.5 metres should be present above bedrock on agricultural sites to be used for PPMB applications.

This separation distance is designed to protect groundwater quality from infiltration of soluble parameters in the biosolids, as there is a reduced attenuation capacity in fractured bedrock aquifers relative to unconsolidated deposits. A reduced thickness of soil overlying bedrock may be considered in situations where only primary PPMB's are to be applied.

Separation from Water Supply Wells

- A horizontal separation distance of at least 15 metres should be maintained from the PPMB application area to drilled wells more than 15 metres deep.
- A horizontal separation distance of at least 90 metres should be maintained from the PPMB application area to any other well, including dug wells.

These separation distances are intended to protect water supplies from surface water runoff and potential groundwater impacts related to PPMB applications. Any abandoned water supply wells within these separation distances should be permanently closed following MOE protocol (MOE, 1994b) to prevent any seepage of biosolid residues into the water supply aquifer.

Separation from Residences

- A minimum horizontal separation distance of 90 metres from the PPMB application area to the property boundaries of any individual residence should be maintained.
- A minimum horizontal separation distance of 450 metres from the PPMB application area to the property boundaries of any residential area should be maintained.

The above criteria are specified in Section 15 of Ontario Regulation 347 regarding standards for organic soil conditioning sites. For purposes of this guideline, a residential area is defined as three or more residential lots with common boundaries, and dwellings within 300 metres of each other.

Separation distances from residences are required to mitigate off-site odour and airborne particle impacts. Odours are usually encountered during loading/unloading and spreading operations, and for short periods after spreading. Under certain circumstances, such as the following, the separation distances from the PPMB application areas may be reduced on a case-by-case basis:

- For primary biosolids: the total storage time, on and off-site, is less than 30 days;
- For secondary and combined biosolids: the total storage time on and off-site is less than 10 days, and the materials are to be incorporated into the soil within 24 hours of spreading.

However, the proponent must provide technical justification for any reduction in separation distance before the MOE will make a decision to allow the reduction.

The criteria for separation distance from residences does not apply to the individual residence occupied by the owner, lessor or operator of the agricultural site that is to receive the PPMB application.

Table 7: Separation Distances from Site Features

Site Feature	Separation Distance (metres)	Notes
Water table	0.9	Measured vertically
Bedrock	1.5	Measured vertically
Drilled wells more than 15 metres deep	15	Measured horizontally
All other wells, including dug wells	90	Measured horizontally
Individual residences	90	Measured horizontally
Residential areas	450	Measured horizontally

3.5.2 Land Slope

- The land slope criteria specified in Table 6 should be maintained for PPMB applications to agricultural sites.

Although it is desirable to apply PPMB to relatively flat-lying sites to minimize the risk of runoff into surface watercourses, the solid nature of most PPMB's will serve to reduce this risk even on steeply sloping farm fields. There is considerable experience in Maine with the use of municipal sewage biosolids and PPMB in steeply sloping agricultural terrain, which indicates that the materials can be applied at fertilization rates on such sites with minimal adverse environmental effects. For example, current regulations in the State of Maine (Chapter 419, Department of Environmental Protection, 1999) permit the use of residuals on agricultural sites with slopes up to 15%.

Pulp and paper mill biosolid applications to sites where a continuous slope exceeds 9% can be considered on a case-by-case basis, provided there is adequate protection to adjacent surface watercourses. Use of high fibre, low nutrient PPMB (eg., primary biosolids) left on surface as an erosion control measure may be appropriate in such cases.

4.0 SITE MANAGEMENT AND OPERATIONS GUIDELINES

The following are recommended practices in order to ensure a properly managed PPMB application program on approved agricultural sites, with minimal nuisance impacts to neighbouring properties.

4.1 DEVELOPMENT OF A BIOSOLIDS MANAGEMENT PLAN

A Biosolids Management Plan can help the mill residuals manager establish and achieve the goals and objectives of the biosolids program, and will allow the opportunity to be prepared to take action in the event of foreseeable impacts and/or emergency situations. A typical Biosolids Management Plan would be comprised of two main parts: an initial planning phase and an implementation plan. A summary of the typical components of a Biosolids Management Plan is outlined in Table 8.

Table 8: Biosolids Management Plan Components**Initial Phase:**

- Statement of Goals and Objectives of Program.
- Identify types, quantities and general characteristics of the biosolids to be included in the program.
- List available beneficial use options.
- Identify regulatory requirements:
 - material characteristics
 - haulage & storage requirements
 - processing approval requirements
 - land use approvals
 - monitoring and reporting
- Detailed PPMB characterization
- Site and receiving soil assessment
- Logistical planning
 - biosolids generation (rates, characteristics)
 - storage
 - transport
 - spreading & incorporation
 - climatic variables
 - contractual relationships
- Technical and financial feasibility assessment

Implementation:

- Obtain all necessary approvals and finalize all contracts
- Prepare a communications plan:
 - contractors
 - farmers/landowners
 - regulatory agencies
 - municipalities
 - public information
- Prepare a contingency plan
- Conduct biosolids quality assurance monitoring
- Conduct operational monitoring:
 - agronomic assessments
 - soil sampling
 - water quality monitoring
 - inspection of haulage routes and land application sites
 - inspection, maintenance and calibration of application equipment
- Maintain detailed, accurate records and reports



4.1.1 Initial Phase

The initial phase of planning will identify the types and quantities of residuals to be included in the program and the possible beneficial use options that may be available. At this stage, the plan would also clearly identify the regulatory requirements regarding biosolids material quality, haulage/storage/processing requirements, and land use approvals.

For land application programs, the characteristics of the PPMB will need to be known (ie., physical quality, nutrient concentrations and availability, and potential contaminants), as will the potential suitability of any available agricultural sites. Detailed information requirements for biosolids characterization and site suitability assessments are found in Appendix 2 of the *Ontario Guidelines for Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE/OMAFRA, 1996).

An understanding of the logistics involved in the biosolids program should also be demonstrated in the initial phase of the management plan. This will include information on the rate of biosolids generation, the storage requirements both at the mill and off-site, transportation/spreading/incorporation operations, and the climatic variables that may affect the various elements of the program. Written contracts should be used to clearly define the responsibilities and relationships between the PPMB producer and the different contractors to be used in the program.

Finally, an assessment of the technical and financial feasibility of the biosolids program should be completed at this stage, before going forward with an implementation plan.

4.1.2 Implementation Phase

A carefully prepared implementation plan will assist the mill in addressing the many issues which will arise during the program.

Firstly, it is important that all regulatory approvals are obtained for the production, processing/storage, transportation and land application of the biosolids. This may include several levels of government approvals, from municipal zoning requirements to provincial (and possibly federal) transportation and environmental regulations.

At this stage, all contracts with the various biosolids handlers should be prepared, and the roles and responsibilities clearly understood.

A plan for sampling and monitoring the biosolids to ensure a consistent product quality should be outlined. Details of the recommended PPMB sampling and analysis plan are found in Section 4.3. The results of the biosolids monitoring should be used to confirm the agronomic rate calculations and to ensure compliance with environmental standards.

In addition, a plan for communicating information about the biosolids management program to the various stakeholders should also be prepared. The goal of the plan is to establish a positive perception about the use of the particular mill's PPMB, and to identify potential concerns at an early stage when they can be more easily addressed. The plan may include regular notification to the biosolids applier and farmer regarding biosolids quality, routine communications with the regulatory authority to exchange information about the program, public information newsletters, and/or special events such as site tours and open houses.

Routine operational monitoring will be required to verify the agronomic aspects of the biosolids management program and to ensure compliance with any conditions to Certificates of Approval or other environmental standards. The monitoring program should include regular agronomic assessments based on the PPMB nutrient quality and the farmers' cropping programs, soil testing, sufficient water quality monitoring in adjacent watercourses at representative sites to establish that there are no impacts from the applications, and regular inspections along the haulage routes and at land application sites. Regular inspection, maintenance and calibration of application equipment is also essential.

Accurate record keeping is another important element of a successful biosolids management program, and the implementation plan should include a description of what information should be gathered and retained. Guidelines regarding record keeping and reporting for PPMB management programs are found in Section 4.10 of this document.

Finally, a contingency plan should be prepared describing the measures that need to be taken in the event that problems arise during implementation of the program. Such problems may be the result of operational upsets at the mill wastewater treatment facility, transportation spills, odour complaints, weather conditions, etc. The plan should provide flexibility in the required action, depending on the nature and severity of the problems encountered. Where appropriate, the actions should involve not only the producer of the PPMB, but also the transporter, applicator, farmer, etc. as necessary to address any foreseeable situations.

The following documents provide further detailed information on the development and implementation of a Biosolids Management Plan:

- California Water Environment Association, Manual of Good Practice, Agricultural Land Application of Biosolids, 1998.
- L'association des industries forestières du Québec, Valorisation des résidus des papetières at des scieries, Guide de gestion et de bonnes pratiques; matières résiduelles fertilisantes, 1997 (Version Consultation).

4.2 NUTRIENT MANAGEMENT PLANNING

Excessive concentrations of nutrients such as nitrogen (N) and phosphorus (P) applied to land have the potential to contaminate groundwater and surface water resources, and to negatively impact human and animal health. Nitrate-nitrogen is soluble and mobile, and

can leach below the root zone of crops into the groundwater, where it can become a concern to drinking water quality. Phosphorus tends to bind tightly to soil particles and is much less mobile in the groundwater environment; however, it becomes a concern in surface water where it is a limiting nutrient for aquatic plant growth. Excessive growth of aquatic plants can deplete the availability of oxygen in surface waters, which can affect fish and other aquatic animals. Phosphorus transport to surface water environments is primarily caused by soil erosion, and at very high soil phosphorus concentrations, it can leach into groundwater.

The long-term sustainability of a PPMB Management Program is largely dependent on the careful management of all nutrient sources on the farm application site. Therefore, it is recommended that a Nutrient Management Plan be prepared for all agricultural sites utilizing pulp and paper mill biosolids. The development of such a plan will normally be the responsibility of the farm operator, with input from the PPMB producer, agronomist and/or crop consultant.

The objectives of a Nutrient Management Plan are as follows (from *Nutrient Management Planning*, AAFC/OMAFRA, 1998):

- Achieve optimal crop yields and product quality
- Manage input costs
- Protect soil and water resources

A detailed description and guidelines related to the development of Nutrient Management Plans is beyond the scope of this document. For further information and assistance in developing a plan, the following documents are recommended:

- Ontario Farm Environment Coalition, *Nutrient Management Planning Strategy*, March 1998.

- AAFC/OMAFRA Best Management Practices publications, including *Nutrient Management Planning, Nutrient Management, Livestock and Poultry Waste Management, Soil Management, and Water Management*.
- OMAFRA, *Nutrient Management Workbook 98-027* and *NMAN2000 Computer Program*.
- Washington State Department of Ecology and Northwest Biosolids Management Association, *Managing Nitrogen from Biosolids*, April 1999.
- State of Maine, Department of Environmental Protection, *Nitrogen Loading Rate Calculation Worksheet* (based on Appendix A, Loading Rate Calculations, from Chapter 419: Agronomic Utilization of Residuals).

4.3 ASSESSMENT AND MONITORING PROGRAMS

In order for a PPMB application program to be beneficial to agricultural land, knowledge of the biosolids characteristics, which may vary with time, and the needs of the receiving site, must be obtained. The receiving site should be assessed in terms of the soil characteristics, the past usage and intended future usage, crop requirements, etc. The following guidelines pertain to PPMB characterization and monitoring, and to soil sampling.

4.3.1 PPMB Sampling and Analysis

The purpose of conducting PPMB analyses is to ensure that the material is suitable for application and that a uniform and consistent quality material is being used, and to match the application rates to the needs of the receiving site.

It is important that regular monitoring of the PPMB being used in a land application program be undertaken to confirm application rates based on nutrient loading or other factors, estimate supplemental fertilizer requirements, and adjust timing of the applications, if necessary.

Grab samples of the pulp and paper mill biosolids can be collected from the dewatering discharge points, or from storage areas. Samples from a representative number of individual sampling points should be collected using a shovel or trowel and mixed together to yield a single, uniform composite. The composite is then sub-sampled for analysis.

Where the PPMB samples are collected from a large storage pile, care must be taken to collect samples that are representative of the full depth profile and spatial variability within the pile.

The recommended containers and preservation techniques for various classes of analysis are presented in Table 9. Analysis for organic parameters should occur as soon as possible after sample collection.

Table 9: Sample Containers and Storage for PPMB Samples

Parameter Group	Container	Storage Comments
Inorganics & organic carbon	plastic, glass	kept cool (<4°C); out of sunlight; refrigerate for storage.
VOC's	amber glass, preferably VOC vials with teflon-lined lids	kept cool (<4°C); out of sunlight; refrigerate for storage; decant free water, minimize headspace; no contact with plastics.
PAH's and PCDD/PCDF	solvent-rinsed, amber glass, foil or teflon-lined lids	kept cool (<4°C); out of sunlight; refrigerate for storage.
All other organics	solvent-rinsed glass, foil or teflon-lined lids	kept cool (<4°C); out of sunlight; refrigerate for storage; no contact with plastics.

Sampling quality assurance and quality control measures should follow established industry practices, including sampling observations, record-keeping, sample chain of custody documentation, and replicate samples, if warranted. Guidance for field and lab QA/QC protocols is provided in the document, *Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario*, developed by the MOE Standards Development Branch (MOE, 1996).

4.3.2 Frequency of PPMB analysis

The parameters and frequency of analysis for PPMB should be undertaken as outlined in Table 10. These criteria only apply when consistent historical records of all parameters can be established. More frequent analyses would be necessary under the following general conditions and as specifically noted:

- where the analytical data and records show considerable variations of individual parameter values between individual samples, and especially macro-nutrients, nitrogen and phosphorus,
- where changes in feedstocks, manufacturing processes, chemicals or other additives, and effluent treatment processes could result in changes of PPMB properties.

Table 10: Analysis Frequency for Pulp and Paper Mill Biosolids

Parameter	Frequency of Sampling and Analysis
pH	Monthly
Total solids (TS)	Monthly
Organic carbon	Monthly
Total nitrogen	Monthly
Ammonia (NH ₄ + NH ₃ -N)	Monthly
Nitrate (NO ₃ -N)	Monthly
Phosphorus	Monthly
Potassium	Monthly
Chloride (total & soluble)	Monthly
Sulphate (total & soluble)	Monthly
Calcium (total & soluble)	Monthly
Magnesium (total & soluble)	Monthly
Sodium (total & soluble)	Monthly
Arsenic	Quarterly
Cadmium	Quarterly
Chromium	Quarterly
Cobalt	Quarterly
Copper	Quarterly
Lead	Quarterly
Mercury	Quarterly
Molybdenum	Quarterly
Nickel	Quarterly
Selenium	Quarterly
Zinc	Quarterly
Boron	Quarterly
Other metal/elements of potential concern (aluminum, manganese, etc.)	Quarterly
Dioxins/Furans	Yearly
VOC's	Yearly
PCB's	Yearly
Other trace organics	as warranted

4.3.3 Receiving Soil Analyses

Areas proposed for initial and re-applications of PPMB (ie., following a five year Certificate of Approval cycle), should be characterized to determine the suitability of the site to receive PPMB applications. Also, since the application rates must be suited to the plant nutrient requirements, an assessment of the proposed land use and crop rotation should be carried out.

Soil sampling procedures should follow those outlined in the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE/OMAFRA, 1996).

Documentation of the soil sampling should include the following:

- Sampling methods and dates completed, sampling materials, and any special handling procedures;
- Names of companies conducting the sampling and analyses, and the chain of custody records;
- Summary of the laboratory methods, protocols, standards and quality assurance procedures;
- Results and interpretation of soil analyses.

The soil analyses should include the following parameters:

- Soil pH;
- Total organic carbon, total nitrogen, and C:N ratio;
- Organic carbon
- Phosphorus (sodium bicarbonate extractable);
- Exchangeable sodium, calcium, magnesium and other soluble salts, if warranted;
- Metals (arsenic, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium and zinc); and
- Any other specific parameters of interest to the farm site.

Guidelines regarding analytical procedures and method detection limits for soils are provided in Appendix 1 of the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA, 1996).

4.4 HAULAGE FROM GENERATOR TO APPLICATION SITE

The hauler contracted to transport the biosolids from the mill to the application site must hold a valid Organic Waste Management Systems Certificate for the specific materials to be transported. The hauler must be in compliance with all conditions of the Certificate, as well as all other relevant federal and provincial transportation regulations. In addition, the haulage should be conducted in a way that minimizes the negative impacts on the population surrounding the site (noise, dust, odours, leachate).

Documentation of the quantities of PPMB delivered to the site are to be kept by the hauler and provided to the generator. The generator should provide a report of these records to the owner of the application site, at least once annually. The report should provide a summary of the types and quantities of biosolids brought to the site, the application areas and timing, average nutrient content of the biosolids, and any other pertinent information.

The following good management practices are recommended for biosolids haulers (CWEA, 1998):

- Prepare a written transportation management plan.
- Hire and train qualified drivers.
- Maintain vehicles and trailers in a safe operating condition.
- Operate vehicle safely and drive courteously at all times.
- Follow proper loading, tarping and sealing procedures.
- Minimize nuisance potential during transport.

- Keep ignition sources away from/do not physically enter tarped trailer loads of biosolids.
- Carry proper biosolids documentation at all times.
- Clean biosolids and mud from vehicle before entering public roads.
- Unload biosolids only in designated areas at land application sites.
- Practice appropriate health safeguards.

Additional guidelines related to spreading and incorporation are provided in Section 4.7.

4.5 ODOUR CONTROL

Secondary and combined biosolids are biologically active, as a result of the microorganisms from the secondary wastewater treatment systems. Strong odours may be associated with these materials if they become anaerobic during decomposition in storage. The odours are typically generated when the storage piles are disturbed during loading/unloading and spreading operations, and usually dissipate within 1 to 2 days after spreading operations have been completed.

Although primary pulp and paper mill biosolids do not typically generate nuisance odours when normal storage and land application procedures are followed, these materials can also become odourous if stored in piles for an extended period of time, and if the conditions in the storage piles become anaerobic.

The potential nuisance impact of odours can be managed by maintaining the separation distances from residences presented above in Section 3.5.1. Storage piles and loading/unloading operations should be kept as far away from neighbouring residences as practical. Pulp and paper mill biosolids applied to cultivated fields should be incorporated into the soil as soon as practically possible to reduce the odours and minimize the loss of ammonia due to volatilization.

The biosolids manager should also endeavour to communicate with the adjacent landowners to notify them of the spreading activities prior to commencement. Such information as the types of materials to be applied, the spreading and incorporation procedures, schedules, and contact information will help in reducing or avoiding odour complaints at the application sites.

Avoiding activities associated with PPMB when the atmospheric conditions could cause odours to linger and be transported in the direction of sensitive receptors will also assist in minimizing the nuisance impacts.

4.6 BIOSOLIDS STORAGE

Storage of PPMB will be required due to weather conditions, site conditions, scheduling of applications, and other factors that prevent immediate spreading. Research conducted in Quebec, Ontario and Alberta has shown minimal impact to groundwater from storage of PPMB on agricultural sites, both in winter and summer conditions. However, it is important that the storage of biosolids occurs in such a manner that prevents surface water runoff that may result in impacts to watercourses.

Dry biosolids (30% solids or greater, by dry weight) will tend to absorb water in storage, and can usually be stored without need for runoff or leachate controls. Wet biosolids (25% solids or less) have the potential to generate seepage from direct drainage and release of moisture as the solids decompose in storage. It may be necessary to construct control measures, such as berms, swales, ditches, vegetative buffers, etc. to prevent any direct discharge of seepage from the storage piles into surface watercourses. This must be determined on a site-specific basis during the initial appraisal of an application site. Regardless of the solids content, all separation distances specified in Tables 6 and 7 should be maintained from the storage pile.

Adequate capacity for the volume of PPMB to be applied on the site in one year, based on the approved application rate(s), should be available. The quantity of biosolids stored at the site should not exceed the amount to be spread in the next application event, and the duration of biosolids storage at the approved site should not exceed eight months in any one calendar year. Results from research conducted in Alberta have shown that winter stockpiling of pulp and paper mill biosolids does not have a negative impact on soil or biosolids quality (Alberta Environmental Protection, 1998).

Biosolids stockpiles should be made as compact and visually unobtrusive as possible, and should be located in such a manner so as to prevent nuisance odour impacts (eg., if possible, in an area that the prevailing wind direction is not oriented toward sensitive receptors). Access roads to and from the storage area should be maintained passable at all times, with the exception of snow clearing, which can be done on an as-needed basis.

The following specific guidelines should be implemented for pulp and paper mill biosolids storage sites that are to be used for more than 30 consecutive days:

- All of the stockpiled biosolids should be kept within a designated storage area with sufficient capacity to hold the volume of PPMB to be applied on the site in one year, based on the approved application rate.
- If more than one type of PPMB is to be stored at the site, the biosolids should be stockpiled separately, and the piles should be clearly labelled to indicate the different materials.
- The storage site should comply with all setback distances specified in Tables 6 and 7. Setback distances are to be measured from the nearest edge of the storage pile.
- The land slope of the area used for storage should be 3% or less.

- All surface runoff from lands adjacent to the storage site should be controlled or diverted away from the stored biosolids using berms or ditches to prevent contact with the stored materials.
- PPMB should not be stored directly over field tiles and separation distances equivalent to watercourses must be maintained from the storage piles to field tile inlets (i.e., catchbasins).
- Provisions should be made for the control of any leachate or runoff mixed with leachate from the storage of the biosolids. The storage facility should be designed and operated in a manner that does not impact surface water or groundwater on or adjacent to the site. Preferred soil types underlying PPMB storage areas include fine-textured loams and clays to minimize potential impacts to the shallow groundwater; however, the soils must be drained sufficiently to allow access to the storage site in the spring without undue compaction.
- The stored material should not cause a dust or odour nuisance to any adjacent property.
- Access roads to the storage facility should be maintained passable to vehicular traffic at all times (with the exception of snow clearing, which may be required on occasion).

4.7 SPREADING AND INCORPORATION

The long-term success of a PPMB land application program depends largely on the ability of the applier of the biosolids to become a part of the farming operation. This means that proper agricultural equipment and practices must be used when applying the materials.

The nature of spreading and incorporation operations at the application site will depend on the type of PPMB to be applied. Biosolids with 25% solids content or greater can be applied with conventional agricultural spreading equipment. The general guidelines and principles outlined below should be followed:

- PPMB should be applied to the soil in a manner that ensures a uniform, evenly distributed application. The spreading equipment should be calibrated at the beginning of the spreading and re-calibrated at regular intervals in order to respect the planned application rate.
- Operation of the spreading equipment should be conducted in such a way and at times of the year that prevents soil compaction and rutting. The potential for soil compaction depends on the soil type, moisture content and vehicle pressure. Proper soil management procedures should be followed to assess the potential for soil compaction on fields receiving biosolids. Reference should be made to the AAFC/OMAFRA Best Management Practices publication, *Soil Management* (1997) for detailed information on recommended soil management practices. Small tractors (wheeled or tracked), manure spreaders, harrows and discs, and box trailers are ideal equipment for these operations. Some mills have also developed successful operations with large capacity, custom-designed spreading equipment.
- For application of secondary and combined biosolids, incorporation on cultivated fields should be completed in as short a time as possible after spreading to minimize volatilization losses of ammonia, and to control odours. Ideally, incorporation should take place on the same day as spreading occurs. However, this cannot always be achieved due to weather conditions, equipment availability and other factors. In these situations, incorporation within three days is a reasonable time frame.

- Incorporation of pulp and paper mill biosolids is not practical on hay fields, pastures and cultivated fields using conservation tillage or no-till practices. On these fields, it is important that the application be evenly distributed with no large clumps remaining to ensure an even application of nutrients and organic matter.
- Pulp and paper mill biosolids have also been shown to be effective as surface mulches in orchards and vineyards. Immediate incorporation of the materials is not required in these situations, as long as there are no sensitive receptors (potential odours, surface watercourses, etc.) immediately adjacent to the application areas.

4.8 WINTER SPREADING

Experience with PPMB applications on agricultural sites has demonstrated that winter applications can be successfully completed with minimal risk to the environment (Bailey et al., 1995). Winter mulching applications of high C:N ratio PPMB can protect the soil on cultivated fields against erosion during early spring and can be incorporated, if desired, during spring seedbed preparation. Where this is done, the extra nitrogen required to balance the C:N ratio should be applied in the spring.

Application on frozen ground in the winter helps reduce or eliminate the potential for soil compaction during spreading, and ensures that the biosolids are available on the field for incorporation in the early spring.

The primary concerns associated with biosolids applications during winter conditions include the physical movement of residues with surface runoff to watercourses, the dissolution of inorganic nitrogen and subsequent transport in runoff, and the movement of biosolids particles with wind across relatively smooth, frozen or ice-covered ground. However, the characteristics

of pulp and paper mill biosolids are such that these concerns can be mitigated by implementing good management practices. For example, the following characteristics of PPMB make these materials potentially suitable for winter applications:

Dry matter: Pulp and paper mill biosolids generally have total solids contents in excess of 30%, which make the materials suitable for dry handling and spreading, and less susceptible to surface runoff in the winter. A large proportion of the solids content consists of wood fibre, calcium carbonate, clay and other relatively inert materials. Pulp and paper mill biosolids are therefore physically stable and resistant to movement from where they are applied to land.

Organic nitrogen: A very significant proportion of the total nitrogen (N) found in pulp and paper mill biosolids is in the organic form and is not readily mobile in the environment. Typically, 90 to 95% or more of the nitrogen in both primary and combined biosolids is organic N (OFIA/WESA, 1999). The problems of nitrogen loss in surface runoff and leaching to groundwater are primarily related to nitrogen in its more soluble, inorganic forms including ammonium and nitrate (Henry et al., 1999). This reduces the risk of nutrient runoff from winter applications.

Low fertilizer equivalent nitrogen content: The most common forms of inorganic nitrogen used as nutrients by plants are nitrate (NO_3^-) and ammonium (NH_4^+). Organic nitrogen must first be mineralized to an inorganic form before it can be taken up by plants. The concentration of nitrate and ammonium readily available in pulp and paper mill biosolids is generally very low, and the low mineralization rate of organic nitrogen during winter conditions will limit the conversion of organic N to the inorganic forms. Therefore, during winter applications, the pulp and paper mill biosolids applied to land will be low in fertilizer equivalent nitrogen content.

High C:N ratios: Some pulp and paper mill biosolids (eg., primary clarifier fibre and some combined biosolids) have C:N ratios in excess of 30:1. This results in the immobilization of nitrogen as it is utilized for microbial growth, and slower mineralization rates to the inorganic forms of N. For these materials, there is little risk of nutrient loss to surface runoff.



Pathogen content: Pulp and paper mill process waters are usually treated separately from sewage wastes, and are therefore free from contamination by human and animal pathogens. (This requires confirmation by individual mills that wish to use their biosolids in land application programs.) As these materials do not represent a source of pathogens to human or animal receptors, there is no risk for disease transmission from winter land applications, when immediate incorporation is not possible.

The following guidelines are recommended for PPMB applications during winter conditions. The guidelines are based on the best scientific information available at this time. With ongoing research, it is anticipated that the understanding of the use of pulp and paper mill biosolids in agricultural applications will improve. Therefore, it is intended that these guidelines for winter land application of PPMB be reviewed and revised as additional research information becomes available and experience with these materials increases.

- Winter spreading should be reserved for applications that supply a limited amount of fertilizer equivalent nitrogen ($\text{NH}_4^+ + \text{NO}_3^- \text{ N}$) to agricultural land. Materials with low concentrations of fertilizer equivalent nitrogen are preferred for winter application. As a preliminary guideline, it is recommended that winter applications be limited to 20 kg of fertilizer equivalent N/hectares.
- PPMB with solids contents greater than 30% can be applied to frozen and snow-covered ground, where the depth of snow cover is less than 15 cm.
- PPMB with higher moisture contents may be spread on frozen and snow-covered ground (snow cover less than 15 cm), provided the risk of surface runoff is minimal. This may be achieved on relatively flat-lying (ie., less than 3% slope), well-drained sites or sites with established vegetation to reduce runoff.

- The use of agricultural sites with vegetative buffer strips along watercourses and at drainage tile inlets (ie., catchbasins), and around any perennially wet land, are preferred for winter applications.
- Agricultural fields with significant vegetative cover, such as forages, crop residues, or cover crops, are preferred for winter applications of PPMB. However, PPMB applications in winter will also supply erosion protection on cultivated fields.
- The slope of the land surface on the application site in the area of winter spreading should be less than 3%.
- The minimum setback distances from watercourses, etc. specified in Tables 6 and 7 should be adhered to.
- Biosolids should not be applied to ice-covered ground, including low-lying depressions, to avoid movement by wind and runoff.
- Biosolids should not be spread during extended periods of thawing, or when runoff due to rain, freezing rain, wet snow, snowmelt, etc. is expected in the ensuing 48 hours.

4.9 BLENDING WITH OTHER MATERIALS

It is feasible to blend PPMB with other materials that are acceptable for land application, or blend together PPMB's with differing characteristics, to obtain a material with improved opportunities for beneficial use. Some examples of such usage are provided below. Until sufficient experience is obtained for a functional use of a particular PPMB blend, it is

recommended that each situation be addressed on a case-by-case basis. The primary purpose of blending other materials with PPMB must be to provide incremental benefit to the application site, rather than to increase waste disposal quantities.

- Blends of low and high C:N ratio PPMB's may be advantageous as a means of increasing the soil organic matter while controlling the fertilizer nitrogen additions. Higher rates of application will frequently be desirable to more rapidly increase soil organic matter content. Blends of PPMB's may also be effective in reducing the amount of supplemental nitrogen required for low nitrogen, high C:N ratio biosolids.
- The slow release organic nitrogen in PPMB may be effectively co-utilized with high nitrogen materials such as livestock manures and commercial fertilizers to provide a sustained nutrient release over a full growing season, and to increase the organic matter, which provides additional long-term benefits to the soil compared to inorganic fertilization.
- Fall applications of high C:N ratio pulp and paper mill biosolids may be used to immobilize any nitrate-nitrogen remaining in the soil after the cropping season.

A blended mixture consisting of a material that is classified as a waste under Ontario Regulation 347, with other materials that are exempt from the regulation (eg., livestock manure) would result in a mixture that is classified as a waste. Such materials can only be utilized on a site that has been approved under the *Environmental Protection Act* provisions (ie., an organic soil conditioning site), in accordance with any conditions of a Certificate of Approval. Therefore, prior to using a blended material involving PPMB, a comprehensive plan should be developed, including the purpose of the application, characterization of all materials, application rates and techniques, etc. It is also important that the blended materials are thoroughly mixed together to ensure uniform distribution across the application site. Periodic inspections and actual testing may be warranted to verify adequate blending, and to document the mixture characteristics.

4.10 RECORD-KEEPING AND REPORTING

It is important that the person responsible for biosolids management at a pulp and paper mill is knowledgeable of the status of the program at all times. In addition, others involved in the program, including haulers, applicators and farm operators, need to be aware of changes to biosolids quality and any adjustments to crop requirements and application rates. Therefore, the Biosolids Management Plan should include provisions for maintaining records in an organized, easily-understood manner. The following records should be gathered:

PPMB Monitoring:

- Volume of PPMB generated at the mill; on a monthly basis with annual totals.
- Volume of PPMB delivered to off-site locations for storage, processing or utilization; on a monthly basis with annual totals.
- PPMB field sampling records and chain of custody forms.
- Laboratory reports for all PPMB analyses.

Haulage:

- Copy of signed contractual agreement with haulage contractor
- Copy of Organic Waste Management System Certificate of Approval for haulage
- Map showing primary and secondary transportation routes from the mill to each land application site.
- Notes from periodic inspections of transportation routes.

Land Application:

- Names, addresses and telephone numbers of all farm landowners using the mill's land application program.
- Site plan showing the locations and sizes of all fields at each farm.

- Site plan showing the setback locations from all site features.
- Copy of the Certificate of Approval for each farm, along with the application form, supporting documentation and any amendments to the approval.
- Amounts of PPMB applied to each field; on a monthly basis with annual totals.
- Soil testing results.
- Notes from periodic inspections of land application sites.

The PPMB generator should supply the necessary information to the farm operator or their agronomic consultant to allow for an assessment of crop requirements and PPMB application rates within the context of the farm's Nutrient Management Plan. This will include the biosolids monitoring information, the quantity of PPMB delivered to the farm, delivery dates, application and incorporation methods, application rates and any other pertinent information.

Conditions on specific Certificates of Approval for organic soil conditioning sites may also require the holder of the certificate to keep records and prepare an annual summary report for submission to the Ontario Ministry of Environment.

