Water Quality Impacts of Burying Livestock Mortalities

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Introduction

Mortality losses are a normal part of livestock and poultry production. Producers may have losses due to disease, accidents, or inter-animal competition. It is the responsibility of the producer to dispose of these mortalities in an acceptable manner. Livestock and poultry producing regions in Canada and many other industrialized countries have put into place regulations governing acceptable disposal methods for these on-farm mortalities. In Ontario, the Dead Animal Disposal Act outlines three legal disposal methods for dead cattle, swine, sheep, goats, and horses:

a) pickup by a provincially licensed collector;

b) composting under 60 cm (2 feet) of organic substrate, such as sawdust or straw; and

c) burying under 60 cm (2 feet) of soil and away from all waterways (Koebel 2001).

Using the services of a provincially licensed collector seems to be the preferred method of disposal in Ontario. However, some regions of the province, particularly the northwest, do not have access to the services of a licensed collector. Recently, we have seen a withdrawal or reduction of these services in other areas due to concerns over the spread of livestock diseases in rendered animal products (i.e. Bovine Spongiform Encephalopathy). In those cases where a licensed collector is not available, producers must rely on either composting or burial.

Composting offers a smart solution to carcass disposal problems. The finished compost can be used as a nutrient-rich organic soil amendment. However, composting not only requires a proper facility, but also a certain amount of ongoing monitoring and care. In addition, larger animals such as cattle are more difficult to compost. This leaves many time-constrained producers with burial as their only viable option.

Buried livestock mortalities undergo a decomposition process. During this process, nutrients, pathogens, and other components of the animal carcass are released into the environment. As these substances enter the surrounding soil, they may be broken down, transformed, lost to the air, or otherwise immobilized so that they pose no environmental threat. However, there is a possibility that some constituents may eventually contaminate soil, groundwater, and surface water. It is unlikely that a single carcass could cause major contamination. However, in light of the trend toward large-scale livestock production practices, there is concern over the numbers of mortalities that could be buried.

Objectives

In light of the trends in the livestock industry and the potential for negative impacts on the environment, a few questions concerning the burial of mortalities have arisen. Are current regulations and guidelines regarding livestock mortality disposal (and burial) meeting the needs of today's producers? Are the regulations meeting the needs of the environment? This report is an attempt to examine the current state of knowledge in the area of livestock carcass burial and the potential for water quality impacts. Specific objectives are:

1. Determine the current state of knowledge of water quality (and other environmental) impacts of livestock mortality burial.
2. Recommend what, if any, new information is needed, relevant to the needs of Ontario livestock producers.

3. Prepare updated recommendations, if needed, for farmers who want to bury livestock mortalities.

Numbers of Mortalities

As mentioned earlier, mortality losses are a normal part of livestock and poultry production. There is variability in the numbers of these losses from one farm to another and across livestock species. Table 1 contains estimates of these mortality losses for Ontario farms. These numbers put into perspective the scope of the issue. The greatest mass of mortalities is in the form of chickens - laying hens and broilers. Cattle represent the next greatest mass, followed by swine and turkeys.

Table 1: Total Species Numbers, Estimated Average Mortality Rates and Weights For Different Livestock and Poultry Species in Ontario

Type of Livestock or Poultry	Total Species Numbers in Ontario	Average Mortality Rate†	Average Weight kg (lbs)†	Approximate Annual Mass of Mortalities in Ontario (t)
Cattle	2,160,000*	3.6%	341 (750)	26,516
Horses, Ponies	83,337**	3.6%	341 (750)	1,023
Sheep	280,000*	6.2%	24.7 (77.4)	429
Goats	62,310**	6.2%	24.7 (77.4)	95
Swine	3,714,700*	6.3%	70 (153)	16,382
Chickens	199,876,000*	7.1%	2.5 (5.8)	35,478
Turkeys	8,422,000*	6.7%	11.1 (24.4)	6,263
Bison	3,755**	1.6%	359 (791)	22
Elk	5,902**	2.5%	188 (414)	28
Ranched Deer	14,464**	2.8%	68 (149)	28
Mink	84,800***	4.5%	2 (4)	8
Foxes	560***	7.5%	7 (16)	0.3
			Total mass (t)	**86,272.3**

*Ontario Ministry of Agriculture and Food, 2003.
**Statistics Canada, 2002.
***Statistics Canada, 2003.
†Morris, J., Koebel, G., 2003.

Environmental Impacts of Livestock Mortality Burial

There has been very little research done in the area of environmental impacts of livestock mortality burial. An exhaustive search of published information turned up only a small number of studies. (Note: the search was limited to reports written in English, or those with English abstracts.) This lack of scientific information has been confirmed by Tom Glanville, one of the few researchers to study the issue (Glanville 2003). Research has been mainly focussed on poultry mortality pits and their effects on the surrounding environment. However, we should expect to see more interest as concerns with Foot and Mouth Disease and Bovine Spongiform Encephalopathy persist.

Following are summaries of the few reports that have been written on the subject:

1. In a presentation to the American Society of Agricultural Engineers (ASAE), Glanville (2000) reported on the impact of livestock burial on shallow groundwater quality. He noted that proper disposal of livestock mortalities can be more difficult than manure management because animal carcasses are not easily stored for long periods of time and cannot be spread on cropland. Biosecurity and environmental impacts must be considered when disposing of livestock mortalities. In order to study the characteristic types, concentrations, and duration of release of contaminants from on-farm burial, the Iowa Department of Natural Resources (IDNR) funded two case studies.

The first case study examined two 1.8 m deep pits containing 28,400 kg of turkey carcasses that had been buried one year prior to the beginning of the study. The site was located in poorly drained soil with moderately-slow permeability. The seasonal high water table could be found at depths of 0.3 to 0.9 m. Twelve monitoring wells were used to define contaminant movement and background water quality. Groundwater samples were collected monthly for a period of 15 months, and again at 20 months and 40 months.

Case study number two sampled two 1.2 m deep trenches spaced 2.4 m apart in well-drained, moderately permeable soil. At this site the seasonal high water table could be found at a depth greater than 1.8 m. This site was specially constructed at the Iowa State University Agricultural Engineering research farm. Each trench was loaded with six 11.3 - 13.6 kg swine carcasses spaced evenly along the trench bottom. The mass of carcasses in each trench was considered a reasonable loading rate according to IDNR rules. One of the trenches was lined with PVC sheeting and ten centimetres of pea gravel. A PVC pipe was buried vertically at one end of the trench and outfitted with a sump pump so that monthly samples of leachate could be obtained. The leachate was measured to examine the mass, concentration, and duration of decay products. Eight monitoring wells were placed around the trenches to monitor groundwater.

Elevated levels of Biochemical Oxygen Demand (BOD), Ammonia-Nitrogen (NH_4-N), Total Dissolved Solids (TDS), and Chloride (Cl) were commonly found within or very near the burial trenches. Although chloride concentrations were generally lower than the other contaminants, elevated chloride levels are generally the best indicator of burial-related groundwater contamination. Localized contamination may persist for a decade or more in wet soil with a high seasonal water table and low groundwater flow velocity. Even in lightly loaded burial trenches constructed in well drained soil, complete decay may take two years or more. Neither of these experiments showed burial-related contamination more than a metre or two from the pits. In cases where groundwater velocities are higher, or where vertical groundwater movement occurs, leachate from burial sites may pose a higher

contamination risk to groundwater.

2. The microbiology of graves is a relatively unknown subject. Hopkins et al (2000) were able to use a forensic experiment involving the burial of pigs to gain knowledge in this area. This experiment was originally meant to supply information on the decomposition of human bodies. However, the use of pig carcasses provided a useful study into the decomposition of livestock mortalities. Three pig carcasses (four to five months of age) were buried within three hours of death, under ten centimetres of clay-based soil in a hornbeam dominated woodland in late December. At 430 days (roughly 14 months) after burial, soil samples were taken from each of the graves and control samples were collected one metre from each grave. At this time, it was noted that the pigs' bodies had lost their integrity and the graves contained mixtures of decaying remains and soil. The results of this experiment showed elevated ammonium concentrations, biomass, and respiratory activity, which all indicate that decomposition was still taking place at the time of sampling.

3. Myers (1998) looked at the impact of poultry mortality pits on groundwater quality in Georgia. There were a number of methods allowed for carcass disposal in Georgia. Burial was the most common method of disposal, but farmers required a permit for their disposal pit and were subject to regular checks of the pits. The covered pits used for disposal were dug into the ground but left unlined, so leachate from the decomposing carcasses could travel through the soil. The leachate could contain nitrates, microbes, and other potential water contaminants. Four areas were chosen to be sampled, one in clay soil and the others in sand soil. Older mortality pits were sampled using electromagnetic survey, water quality monitoring, lysimeters and test wells. Results of the leaching study were not available at the time the 1998 report was published. However, the final report should be available soon (Myers 2003).

4. Ritter et al (1988) examined the impact of dead bird disposal on groundwater quality. They monitored groundwater quality around six disposal pits in Delaware. Producers in Delaware were using open-bottomed pits for their day-to-day mortality disposal. These pits are not strictly the same as burial pits, though there are some similarities. Most of these pits were located in sandy soils with high seasonal water tables. The potential for pollution of groundwater is high with this method of disposal. After selecting the sites, two to three monitoring wells were placed around each pit to a depth of 4.5 metres. Ammonia concentrations were high in two of the wells. Three of the disposal pits caused an increase in ammonia concentrations in the groundwater. Total dissolved solids concentrations were high in all monitoring wells for most dates. Bacterial contamination of groundwater by the disposal pits was low.

5. In a related study, Ritter and Chirnside (1995) looked at the impact of dead bird disposal pits on groundwater quality on the Delmarva Peninsula. They reported these additional discoveries:

- nitrogen is a greater problem than bacterial contamination,
- serious contamination may occur if large numbers of birds are added to the pit,
- abandoned disposal pits should be pumped out and filled with soil to minimize their impact on groundwater quality,
- subsurface disposal of dead birds should be regulated,

- only certain types of disposal pits (i.e. concrete tanks) should be allowed, and
- permits should be issued for disposal sites meeting minimum standards (i.e. dealing with soil-type, water table depth, etc.).

6. Crane (1997) discussed the potential environmental impacts of the disposal of livestock carcasses in the United Kingdom. This paper did not report on a research project - rather it was a discussion of existing practices. Crane concluded that all animal carcasses have the potential to cause environmental damage. Pets and animals from commercial sites were disposed of as controlled waste, and were therefore subject to the stringent Waste Management Licensing Regulations. However, agricultural waste, including carcasses, was not considered "controlled waste" and was not subject to stringent regulations. The acceptable methods for animal carcass disposal were by: a treatment/processing plant, burning, or burial.

According to guidelines: carcasses should be buried deep enough so that carnivorous animals cannot dig them up, and the carcasses should be buried in a type of ground that prevents water table contamination. Carcasses can also be buried at a licensed or unlicensed landfill site. The advantage of a licensed site is that the issue of groundwater protection has been addressed in the licensing process. The Ministry of Agriculture, Fisheries, and Food (MAFF) Code of Practice for carcass disposal advised contacting the Environment Agency if unsure of the suitability of a burial site. It also included guidelines governing distances to water tables, drinking water, etc. However, the guidelines did not address the issue of the monitoring of burials. According to this report, it is unlikely that carcass burial has resulted in any major groundwater contamination. The greatest risks are related to the chemical products of decomposition. However, there is no evidence that significant harm has occurred due to burials. While individual carcass burial is not a cause for concern, as carcass numbers increase so does the need for site assessment.

Environmental Impacts of Human Burial

Because so little information was available on burial of livestock mortalities, a review of studies on human burial was carried out. There has been a limited amount of scientific research regarding water quality impacts of human burial. Most of the work has been done in recent years.

Decomposition of the Body - Processes

Human bodies undergo the same processes of decomposition as animal carcasses. As previously stated, nutrients, pathogens and other components of the body are released into the environment during the process.

A body's decomposition is directly related to soil condition and above-ground temperature. As depth increases, decomposition rates are slowed. As above-ground temperature increases, decomposition increases (Spongberg and Becks 2000). Although the source of contamination is finite (at some point in time the body will have completely broken down), the length of time that organic matter is released into the environment is dependent on a number of factors. Body size, temperature, and precipitation can all affect the decomposition rate (Spongberg and Becks 2000).

The decay of a human body can also be influenced by: a) the features of the remains, b) the

funereal aspects of the interment, c) whether or not the body is in a coffin, d) the hydrogeological setting, e) the soil characteristics, and f) the cemetery's burial management practices (Dent 2000). The most rapid decay is expected in sandy soils, due to their high permeability and the maintenance of aerobic conditions. In his study, Dent used indicators such as electrical conductivity, pH, total forms of organic and inorganic nitrogen, orthophosphate, chloride, total organic carbon, and sulfate to help define the decay of interred corpses. Dent also identified a number of microbiological indicators that may be present in the immediate area of the remains. Examples of these indicators include fecal coliform, *E. coli*, faecal streptococci, and *Pseudomonas aeruginosa*.

According to Hopkins et al (2000), future studies should look at the extent to which soil conditions affect the decomposition of human bodies. They also felt that studies to improve the understanding of the processes earlier in decay need to be done. There are still questions which further research into the topic may answer.

Potential Contaminants

The abundance of corpses in cemetery soil provides an obvious source of organic contamination (Spongberg and Becks 2000). Fluids from decomposing bodies in graveyards can leak into underlying groundwater if non-leakproof caskets are used. The areas most vulnerable to this type of contamination are those with a high water table, and those with high rainfall. There have been historical cases of contamination from cemeteries, such as a higher incidence of typhoid fever in people living near cemeteries in Berlin from 1863-1867. In Paris, water from sources near cemeteries often had a "sweetish taste and infected odour", especially during hot weather (Bouwer 1978).

Pacheco et al (1991) examined the water table below three different cemeteries and found the presence of proteolytic and lipolytic bacteria. These bacteria are related to the process of decomposition, and as such should not be found in any elevated quantity in the water table. According to the study, the water samples had a "nauseating smell", considered to be an indicator of contamination by corpses. As a result of this study, the water tables in all of the cemeteries were considered unsatisfactory from a bacteriological point of view. The group chose to do this study because of the potential environmental impacts. There was a risk of contamination of groundwater by microorganisms that proliferate during the process of decomposition of corpses and the later use of this water by the population. The group's main concerns centred around the exposed water table and its susceptibility to biological contamination. In addition, they were concerned that this water was used by the low-income population who drew their water from shallow sources.

Cemeteries may also be a source of inorganic contamination. Potential contaminants include: arsenic, mercury, formaldehyde, varnishes, sealers, preservatives, lead, zinc, copper and steel. Some of these have been and are used in embalming. Others are components of wood or metal coffins. With the idea that anything that has been buried can cause contamination, Spongberg and Becks (1999) performed a study to obtain preliminary findings on what happens to products of burial. The cemetery used in this study was located in Northwestern Ohio and contained about 14,610 graves, ranging in age from the mid 1800's to 1999. Soil samples were analysed for metal contaminants. Sampling was concentrated around rows of older plots. The results were compared with samples from soil cores located off cemetery property. Overall, the levels of adsorbed metal concentrations were found to be low, except for arsenic. The study showed that certain metals associated with burial practices may accumulate at depth in cemeteries. The authors recommended that additional research be done to

expand the pool of knowledge on this subject (Spongberg and Becks 1999).

As a result of public concern that burial preservatives may be a significant source of groundwater contamination, Chan et al (1992) began researching this topic. Two literature reviews were carried out but no literature on this subject could be found. This appeared to be the first study of its kind done in North America. The results of a survey done in Ontario regarding burial practices found that 90% of bodies were embalmed before being placed into a casket. The study concluded that cemeteries were not a significant contributing source of formaldehyde to groundwater (Chan et al 1992).

Although the decay of a human body can be profiled using many different organic indicators, the decay plume is better characterized inorganically (Dent 2000). Organic or inorganic, human burial is the source of many environmental contaminants. Through the decomposition process, many potential contaminants are released into the soil over a period of time. It is apparent from the research that the extent of this problem has not been fully explored.

Transport Through Soil

Bio-oxidation of the protein, fat, and carbohydrate found in the average human corpse, has been estimated to take 10 years at a burial depth of 2.5 metres in sandy soil under Dutch climatic conditions (Bouwer 1978). Schraps (1972) found that shallow groundwater samples taken in a cemetery showed contamination in the immediate vicinity of the graves, but that this contamination rapidly attenuated with distance (as reported by Bouwer 1978).

Pacheco et al (1991) found that differences in the water table depth and lithology of each site accounted for differences in the primary bacteria found. In this case the bacteria found were related to the process of decomposition. This led the researchers to conclude that cemeteries are a potential risk to groundwater which can become a real risk if previous geological and hydrogeological studies are not consulted when building a cemetery. The bacteriological quality of the groundwater depends on the soil type and the depth to the water table.

Spongberg and Becks (2000) studied an active cemetery which dated back to the 1800's. The soil was a silty loam and the seasonal high water table was at a depth of 0.3 to 1.0 m. Thirty soil samples were collected over a two-year period. The depressed soil surface above the graves indicated that decay had occurred. The study found possible relationships between organic matter in the soil and nearby grave sites. This study did not address the question of off-site contaminant migration, though the authors felt that the fine texture of the soil may prevent migration of the compounds off-site.

Bastionon et al (2000) studied a cemetery in Brazil to investigate the groundwater contamination by the leachate from the corpse decomposition. The cemetery site was located at the top of a hill, on an area of irregular bedrock and fault zones. An unconfined aquifer that contained areas of both high and low permeability was located beneath the cemetery. The water table was very high, and in some places there were corpses lying in groundwater. Geophysical testing methods (e.g. electrical resistivity, ground-penetrating radar) were used. The results of this testing suggested the presence of contaminants, which was confirmed by groundwater samples obtained from observation wells. Analysis of the samples showed chemical and bacteriological contamination of the unconfined aquifer.

Existing Recommendations

A study cited by Bouwer (1978) recommended that the water table in cemeteries be at least 2.5 metres deep, with the grave depth being 1.8 metres. In medium-textured soils, this should be enough to protect groundwater. However, burial should be avoided in very permeable soils (sand, gravel), very fine soils (due to anaerobic conditions), and above fractured or cavernous bedrock. Each cemetery must be considered individually. Generalizations about groundwater contamination by cemeteries cannot be made (Bouwer 1978).

Ministry of Environment (MOE) guidelines state that concrete vaults (containing caskets) must be placed at least 0.5 metres above the highest water table. The guidelines also recommend graves be at least 30 metres from any drinking water sources. At the time of their report, there were no drinking water standards for formaldehyde in Canada (Chan et al 1992).

Spongberg and Becks (1999, 2000) reported that the United States has set up regulations for cemeteries in order to protect public health and the environment. They also recommended further research into the topic of potential environmental impacts of human burial in order to better understand the topic.

Current Regulations and Guidelines

Most regions of North America and Europe have outlined acceptable burial practices regarding livestock mortalities. These take the form of either guidelines or regulations. Table 2 contains a summary of the key burial practice guidelines and regulations from Canada, the United States, the European Union, and New Zealand. A more detailed listing of these may be found in the Appendix.

It is interesting to explore the sources of these regulations and guidelines to find if they were backed up by research findings. There is no evidence that any of the standards were based on research involving livestock mortalities, or on human cemetery research. For example, when Goltz (2003) spoke to his peers regarding New Brunswick's regulations, he found that the province only had one regulation regarding livestock mortality disposal. He was unable to find the information source that was the basis of this regulation. It appears that most regulations and guidelines were based on established properties of contaminant movement through soil.

Table 2: Comparison of Key Livestock Mortality Burial Practice Guidelines and Regulations for Canada, The United States, The European Union, and New Zealand.

Jurisdiction	Minimum Earth Cover	Minimum Distance from Pit Bottom to Groundwater	Minimum Distance to Watercourse	Minimum Distance to Well	Maximum Weight/Pit	Guidelines vs. Regulations
Ontario	60 cm	--	--	--	--	Both
British Columbia	1 m	1.2 m	30 m	120 m	700 kg	Both
Alberta	1 m	1 m	100 m	100 m	2500 kg	Regulations
Saskatchewan	0.6 m	1 m	90 m	90 m	--	Guidelines
Manitoba	1 m	--	100 m	100 m	--	Regulations
New Brunswick	--	--	--	--	--	--
Prince Edward Island	0.6 m	--	61 m	304.8 m	--	Guidelines
Newfoundland and Labrador	0.6 m	1.4 m	30 m	90 m	700 kg	Regulations
USDA	--	96.5 cm	100 m	--	--	Guidelines
California	1.2-1.9 m	1.5 m	30.5 m	30.5 m	--	Guidelines
Georgia	0.9 m	0.9 m	--	--	--	Regulations
Idaho	0.9 m	--	91.4 m	61 m	--	Regulations
Kentucky	1.2 m	--	30.5 m	--	--	Regulations
Michigan	0.6 m	--	61 m	--	918 kg/ha	Regulations
Minnesota	--	1.5 m	--	--	907.2 kg	Both
Ohio	1.2 m	--	--	--	--	Guidelines
Oregon	1.2 m	--	402.3 m	--	--	Regulations
Wyoming	0.6 m	--	--	--	--	Regulations
European Union*	--	--	--	--	--	--
New Zealand	--	--	100 m	--	--	Guidelines

Note: The double dash (–) is used when the jurisdiction's regulations and/or guidelines do not cover the topic.

* The European Union has effectively banned burial of livestock mortalities, except in remote areas and under strict regulation by the competent authority.

Summary

Mortality losses are a normal part of livestock and poultry production. One option for disposal of these mortalities is burial. Buried livestock mortalities undergo a decomposition process, during which nutrients, pathogens, and other components of the animal carcass are released into the environment. This report examines the current state of knowledge in the area of livestock carcass burial and the potential for water quality impacts. Main findings:

- Very little research has been done on this topic. Most of the existing research focusses on poultry mortality pits.
- Burial of livestock mortalities is not a common practice. Most producers prefer to use the services of a licensed collector.
- The potential for contamination exists when livestock mortalities are buried. Both organic and inorganic substances are released during decomposition.
- Elevated levels of Biochemical Oxygen Demand (BOD), Ammonium-Nitrogen (NH_4-N), Total Dissolved Solids (TDS), and Chloride (Cl) have been found within or very near burial trenches. Elevated chloride levels are generally the best indicator of burial-related groundwater contamination. It is uncommon to find burial-related contamination more than a metre or two from the source.
- There is currently no evidence of environmental problems being caused by livestock mortality burial. Existing studies point to limited movement of contaminants from livestock mortalities.
- Many jurisdictions have regulations or guidelines to protect the environment from any negative impacts caused by contamination from buried livestock mortalities.
- The potential for pollution of groundwater is high around dead bird disposal pits. High concentrations of ammonia and total dissolved solids have been measured in nearby groundwater. Bacterial contamination of the groundwater is less of a problem.
- Human bodies undergo the same decomposition processes as animal carcasses. Their decomposition is related to soil condition, temperature, body size, precipitation, etc.
- Organic and inorganic contamination of local water tables by human cemeteries has been documented around the world. The level of contamination seems to be related to the hydrogeological characteristics of the cemetery location. Some areas show contamination in the immediate vicinity of the graves, where others show more widespread contamination.

Recommendations

Due to the lack of research in this area, any studies on the effects of livestock mortality burial will be useful to producers, scientists, and policy makers. Possible topics include:

- Measurement of the relative impacts of different types of contaminants, including: nutrients, pathogens, antibiotics (e.g. sulfa drugs), etc.
- Movement of contaminants from buried large animals (e.g. cattle).
- Movement of contaminants through different textures of soils.
- Development of burial options (or restrictions) for tile-drained land.

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Appendix

Canadian Livestock Mortality Burial Regulations and Guidelines

Province	Regulations or Guidelines	Specifics	Source
British Columbia (B.C.)	**Both**	▸ **mortalities disposed of on farm where died (regulation)** ▸ **disposal done so as not to cause pollution (regulation)** ▸ **burial pit located >30 m from domestic water intake (regulation)** ▸ **burial pit located >120 m from any water well (guideline)** ▸ **burial pit constructed to prevent escape of pollution-causing waste (regulation)** ▸ **burial pit constructed so that bottom is >1.2 m above seasonal high water (guideline)** ▸ **carcass is covered (regulation) with >1 m earth (guideline)** ▸ **<700 kg animals in each pit (guideline)** ▸ **multiple sites should be staggered over farm or ranch (guideline)**	**(B.C. Ministry of Agriculture and Food, 1999)** **(Province of British Columbia, 1992) (regulations)**

Alberta	**Regulations**	▸ **mortalities must be disposed of within 48 hours of death** ▸ **weight of animals in burial pit must not exceed 2500 kg** ▸ **pit must be >100 m from wells and other domestic water intakes, streams, creeks, ponds, springs, and high water marks of lakes** ▸ **pit must be >25 m from edge of coulee, major cut, or embankment** ▸ **pit must be >100 m from any residences** ▸ **pit must be >100 m from any livestock facilities including pastures, owned or leased by another person** ▸ **pit must be >300 m from a primary highway, >100 m from a secondary highway, >50 m from any other road allowance** ▸ **pit must be covered with >1 m of compacted soil OR** ▸ **pit must be covered by a wooden or metal lid to exclude scavengers, and quicklime must be applied to mortality** ▸ **bottom of pit must be >1 m above seasonal high water table**	**(Province of Alberta, 2002)**
Saskatchewan	**Guidelines**	▸ **bottom of pit should be >1 m above any "water bearing formation"** ▸ **pits should not be dug in areas prone to flooding** ▸ **locate burial pits in medium to fine-textured soils** ▸ **pit should be >90 m from any watercourses, bodies of water, or wells** ▸ **carcass should be covered with >0.6 m of soil** ▸ **carcass should be disposed of within 48 hours of death**	**(Government of Saskatchewan, 2000)**

Manitoba	**Regulations**	▸ **disposal may not cause pollution to the surface water, groundwater, or soil** ▸ **mortalities must be covered with >1 m of soil** ▸ **disposal site must be >100 m from watercourses, sinkholes, springs, or wells** ▸ **disposal site must be constructed to prevent escape of any decomposition products that could contaminate water or soil** ▸ **if mortality cannot be disposed of within 48 hours of death, it must be kept frozen or refrigerated in a secure location**	**(Province of Manitoba, 1998)**
Ontario	**Both**	▸ **mortality must be disposed of within 48 hours of its discovery (regulation)** ▸ **must be buried beneath >60 cm of earth (regulation)** ▸ **select burial sites in areas of low environmental risk and away from all waterways, wells, and where water collects (guideline)** ▸ **learn more about provincial regulations and guidelines regarding disposal (guideline)**	• **(Province of Ontario, 1990)** • **(Koebel, 2001)**
New Brunswick (N.B.)	**Regulation**	▸ **carcass shall be removed and disposed of within 24 hours**	**(Goltz, 2003)**
Prince Edward Island (P.E.I.)	**Guidelines**	▸ **disposal site must be >300 m from any drinking water well (may be less with permission from Dept. of Environmental Resources, but never closer than 150 m)** ▸ **disposal site must be >60 m from any freshwater stream, estuary, pond, or coastal area** ▸ **disposal site must be >30 m from any public right-of-way** ▸ **all buried poultry and livestock must be covered by >0.6 m earth**	**(Province of Prince Edward Island, 1998)**

Newfoundland and Labrador	**Regulations**	▸ **burial it must be >90 m from any domestic water supply** ▸ **pit must be >30 m from any other surface water** ▸ **bottom of burial pit must be >1.4 m above the high water table** ▸ **pit must allow for 0.6 m earth cover** ▸ **each pit may hold a maximum of 700 kg** ▸ **carcasses must be covered with quicklime to speed up decomposition, deter scavengers, and prevent insect infestations** ▸ **carcasses must be disposed of within 48 hours of death, or properly stored until disposal is possible**	**(Hookey,)**

American Livestock Mortality Burial Regulations and Guidelines

State	Regulations or Guidelines	Specifics	Source
United States Department of Agriculture (USDA)	**Guidelines**	▸ dead animals should be disposed of so as not to pollute surface water, groundwater, or create public health concerns ▸ burial area should be >100 m away from any houses or watercourses ▸ bottom of pit should be >38 inches above the water table ▸ pit should be dug in heavy soil with low permeability and good stability ▸ avoid areas that slope towards watercourses ▸ cover the carcass with quicklime to reduce soil pH before covering with earth ▸ bury mortalities deep below the surface of the ground **Note: Some states already prohibit burial except in extreme circumstances. Other states are in the process of phasing out burial.**	**(USDA, 2000)**
California	**Guidelines**	**This is a summary from a number of counties (not exhaustive):** ▸ mortality should be buried within 24 - 48 hours after death ▸ each animal should be buried in a separate pit, except in emergency ▸ should be buried under 4-6 feet of compacted soil in an area not likely to be disturbed ▸ should be >25 feet from property lines, major cuts, and embankments ▸ should be >100 feet from streams, creeks, ponds, high water marks of lakes, water wells, and springs ▸ should be >5 feet from groundwater ▸ should be >100 feet from dwellings, and >25 feet from other structures ▸ should be >0.25 miles from parks, roads, and highways	**(Horney, 2002)**
Georgia	**Regulations**	▸ disposal of dead animals must be done within 24 hours of death or discovery ▸ must be buried >3 feet below ground level ▸ must have > 3 feet of earth covering the carcass ▸ must not contaminate groundwater or surface water	**(State of Georgia, 1978)**

Idaho	**Regulations**	▸ **dead animals must be disposed of within 72 hours of discovery of death** ▸ **no dead animal can be buried on the land of another without the owner's permission** ▸ **no part of the dead animal may be nearer than 3 feet to the natural surface of the ground (every part of the animal must be covered with >3 feet of earth)** ▸ **must be >300 feet from any wells, surface water intake structures, and public or private drinking water supply lakes or springs** ▸ **must be >300 feet from any existing residences** ▸ **must be >50 feet from property lines** ▸ **must be >100 feet from public roadways** ▸ **must be >200 feet from any body of surface water (river, stream, lake, pond, intermittent stream, sinkhole)** ▸ **burial pit must not be located in areas subject to flooding or with a high water table**	**(State of Idaho,)**
Kentucky	**Regulations**	▸ **mortalities must be disposed of within 48 hours of discovery** ▸ **carcass must be buried at least 4 feet deep** ▸ **must be buried in an area that does not flood** ▸ **must be buried >100 feet from any water source, residence, or highway**	**(National Association of State Departments of Agriculture Research Foundation, 2001)**
Michigan	**Regulations**	▸ **carcass must not come into contact with the waters of the state** ▸ **may not exceed 100 individual graves per acre with the maximum combined weight of animals being 5 tons per acre** ▸ **individual graves must be separated by >2.5 feet** ▸ **graves must be located >200 feet away from any groundwater that is used to supply potable drinking water** ▸ **the owner of the land must authorize placement of the grave** **Regulations specific to common graves:** ▸ **carcasses deposited in a common grave must be covered by >1 foot of soil within 24 hours of death** ▸ **common graves may not stay open for more than 30 days and must receive a final earth covering of >2 feet** ▸ **total carcass weight per common grave is <5000 lbs./acre** ▸ **multiple common graves must be separated by >100 feet**	**(Michigan Department of Agriculture, 1999)**

Minnesota	**Both**	▸ **dispose of carcass within 48 to 72 hours (regulation)** ▸ **carcass must be 5 feet above the seasonal high water table (regulation)** ▸ **carcass must be covered with earth (regulation)** ▸ **sandy areas, gravelly areas, and areas within 10 feet of bedrock should be avoided (regulation)** ▸ **burial is best for small amounts, i.e. <2000 lbs/pit/acre (guideline)** ▸ **do not place in or near lakes, ponds, rivers, streams, wetlands, ditches, or wells (guideline)** ▸ **do not bury in areas subject to flooding (guideline)**	**(Minnesota Board of Animal Health, 2003)**
Ohio	**Guidelines**	▸ **must be buried >4 feet below the ground** ▸ **must be buried within a reasonable time of knowledge of death**	**(Ohio Revised Code, 2003)**
Oregon	**Regulations**	▸ **any dead animal within 0.5 mi of a dwelling or 0.25 mi of a running stream must be removed within 15 hours** ▸ **no part of the animal may be nearer than 4 feet to the natural surface of the ground** ▸ **all parts of the animal must be covered with quicklime and >4 feet of earth**	**(Oregon Revised Statutes, 2001)**
Wyoming	**Regulations**	▸ **must be buried with >2 feet of soil over the carcass** ▸ **the carcass must be buried within 48 hours of death** ▸ **carcasses may not be placed in or near any river, creek, bay, pond, canal, ditch, lake, stream, railroad right-of-way, public or private roadway, highway, street, alley lot, field, meadow, public place, or public ground, or in any other locality, building, or establishment where it may cause the pollution of the purity and usefulness of the waters of any spring, reservoir, stream, irrigation ditch, lake or water supply whether surface or subterranean, which are used as a source of public or domestic water supply, or where the same may become a source of annoyance to any person, or within 0.5 mi of any inhabited dwelling, or within 0.5 mi of any public roadway**	**(State of Wyoming,)**

Foreign Livestock Mortality Burial Regulations and Guidelines

Country	Regulations or Guidelines	Specifics	Source
European Union (Includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom)	**Regulations**	▸ animal by-products (including dead stock) have been divided into three categories (Category 1 being the most infective (incl. TSEs), Category 3 being the least) ▸ on-site burial of Category 2 and 3 materials is permitted in remote areas only (i.e. those areas isolated from rendering facilities) ▸ Category 1 materials may be buried in remote areas if they meet specific criteria and the burial is supervised by a competent authority ▸ mass burials in the case of an outbreak of disease may be allowed if the competent authority deems it the safest alternative ▸ each member state must define what it considers to be a remote area and give reasons for that designation The competent authority: ▸ must ensure that the burial of animal by-products does not endanger human or animal health ▸ must prevent the uncontrolled disposal of animal by-products	**(European Parliament and the Council of the European Union, 2002)**

New Zealand	**Guidelines**	**Offal pits should conform to the following guidelines:** ▸ **should be 100 m from surface water bodies** ▸ **should be 50 m from boundaries** ▸ **must not construct pits in areas where separation distances from groundwater or community drinking water supply zones cannot be maintained** ▸ **limit the size of the offal pit** ▸ **site the pit appropriately so that it does not flood**	**(Environment Canterbury, 2002)**