

**Quantification Protocol for Mechanical Sludge Utilization Projects
Related to Agricultural Land Application**

**Supplemental Information and
Technical Background Document**

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1.0 Analysis of Mechanical Pulp Sludge Disposal Practices in Canada

The environmental data presented was collected by the Forest Products Association of Canada (FPAC) from Canadian pulp and paper mills. Every two years FPAC collects data from Canadian pulp and paper companies in order to produce an environmental report that promotes the industry's efforts towards sustainability. The data presented is sorted using a unique mill identifier called the FPAC number. Mill names and locations have been removed to protect confidentiality of the data. The data presented in this analysis is from the reporting years 2003 and 2007 and is only from the mills classified as, Bleached Chemi-Thermomechanical (BCTMP), Deinked Newsprint (DNWS), Deinked Tissue – Fine Papers (DTF), Mechanical (MECH), Non-Integrated other (NIO), Non-Integrated Fine or Lightweight (NIF), Recycled boxboard (RBOX), and Recycled Containerboard (RCTR). Mills classified as, Bleached Kraft Integrated (BKI), Bleached Kraft Other (BKO), Bleached Kraft Pulp (BKP), Semi-chemical (SC), Sulphite Dissolving (SULD), Sulphite Papergrade (SULP) and Unbleached Kraft (UK1) were not included in the analysis due to the differences in the sludge that is produced as a result of the pulping process.

Alberta Newsprint Company (ANC) (MECH), Millar Western Forest Products-Whitecourt Pulp Division (Millar) (BCTMP), and Slave Lake Pulp (SLP) (BCTMP) operate mechanical and bleached chemi-termomechanical pulp mills in Alberta. Historically in Alberta, common industry practice for sludge disposal was drying and incinerating either in an olivine burner or beehive burner, and landfilling. In an effort to reduce their environmental footprint, economic costs, and enhance local agricultural crop productivity ANC, Millar, and SLP initiated the effort required to get the *Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land* approved through Alberta Environment. These guidelines were approved in 1999 at which time the mill operators began to apply a portion of their sludge to local agricultural land (See Section 3.5 – Adjusted Baseline for quantities and timelines).

Sludge was being disposed of by Canadian pulp mills in 2003 by landfilling, incineration, energy production, landspreading, compost, and other beneficial uses (Table 1). In 2003, less than half of the pulp mills in Canada were practicing some amount of land application and only 33% of mechanical pulp sludge produced was being disposed of by land application (Figure 1 and 2 and Table 2). When Alberta's three mechanical pulp mills are removed from the analysis the percentage of sludge land application in Canada drops to 29%, where as Alberta pulp mills were practicing 90% land application in 2003 (Tables 2 and 3). Figures 3 and 4 and Table 6 demonstrate that land application was not the most common disposal option for Canadian pulp mills in 2003, as the majority of mills were landfilling at least a portion of their sludge.

Table 1. Primary and Secondary Water Treatment Sludge and Process Sludge and Waste Disposal Options for Canadian Pulp Mills in 2003.

FPAC Number	Bone Dry (t)	Energy (t)	Land spread (t)	Compost (t)	Other Beneficial Use (t)	Incinerated (t)	Landfill (t)
104	12,320					10,349	1,971
302	16,655			5,829		10,826	
303	3,800	380	1,900				1,520
304	1,200				1,200		
306	180						180
401	62,764		57,115	5,021			628
402	58,186	1,513	4,829	51,611	233		
404	45,756		45,756				
406	1,356		814	542			
411	53,992	28,400					25,592
417	3,055		794	2,138			122
418	21,465		644				20,821
420	25,725		10,804				14,920
428	11,554	11,011					543
429	12,033		10,372	1,661			
431	1,134			1,134			
433	10,646	9,251		1,395			
434	3,845		3,545		285		15
436	34,561		16,589	6,912	11,059		
436	12,378	3,466		8,912			
437	8,845				3,538		5,307
438	480						480
438	10,003		7,452	2,551			
440	1,012						1,012
440	749						749
443	67,257					67,257	
444	32,000			1,280	28,160		2,560
445	25,525		6,636				18,889
447	2,115			1,580			535
451	236				236		
453	5,816		3,885	1,931			
454	37,997		2,280		35,717		
460	678			678			
461	3,987		2,711				1,276
462	22,500		6,750				15,750
464	11,036		4,415			5,960	662
466	25,869		595				25,274
467	865		861				4
477	1,461						1,461
501	15,317				15,317		
502	10,469						10,469
503	37,800		37,800				
505	4,178						4,178
508	2,883						2,883
518	5,668		2,834	2,834			
531	1,898				1,898		
536	28,794						28,794
537	63,500		20,320				43,180
540	30,596	18,664					11,932
541	9,912		9,912				
542	200				200		
543	10,860						10,860
Millar	23,691	1,421	22,270				
ANC	18,920		14,171	189			4,560
SLP	20,646		20,646				
901	3,537						3,537
914	6,220	2,301					3,919
918	2,798			2,798			
924	1,340				1,340		
927	19,661		8,061			2,792	8,808
953	9,000				9,000		
980	14,017						14,017

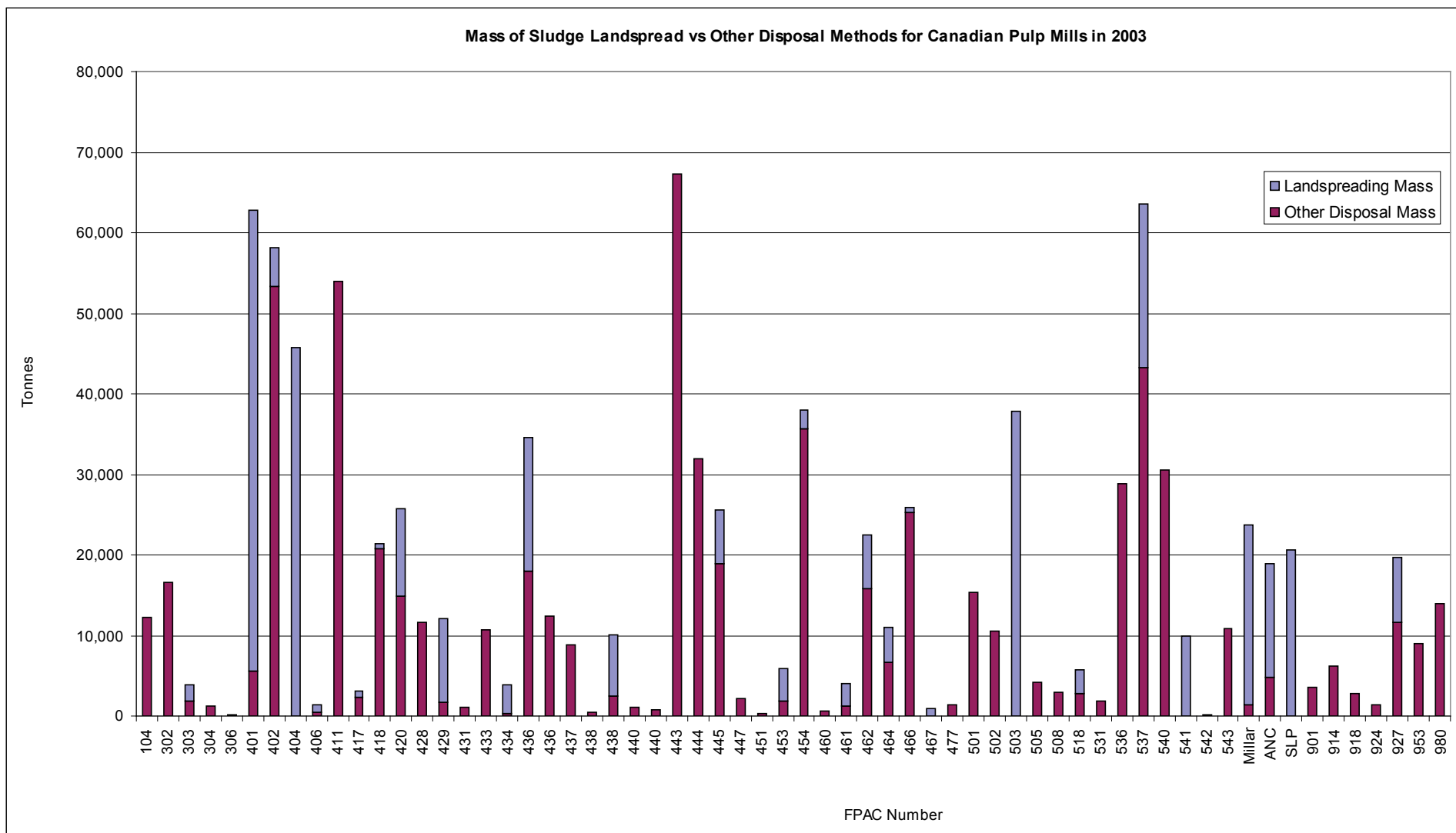


Figure 1. Comparison of the quantity of sludge land spread vs other disposal options for Canadian mechanical pulp mills in 2003.

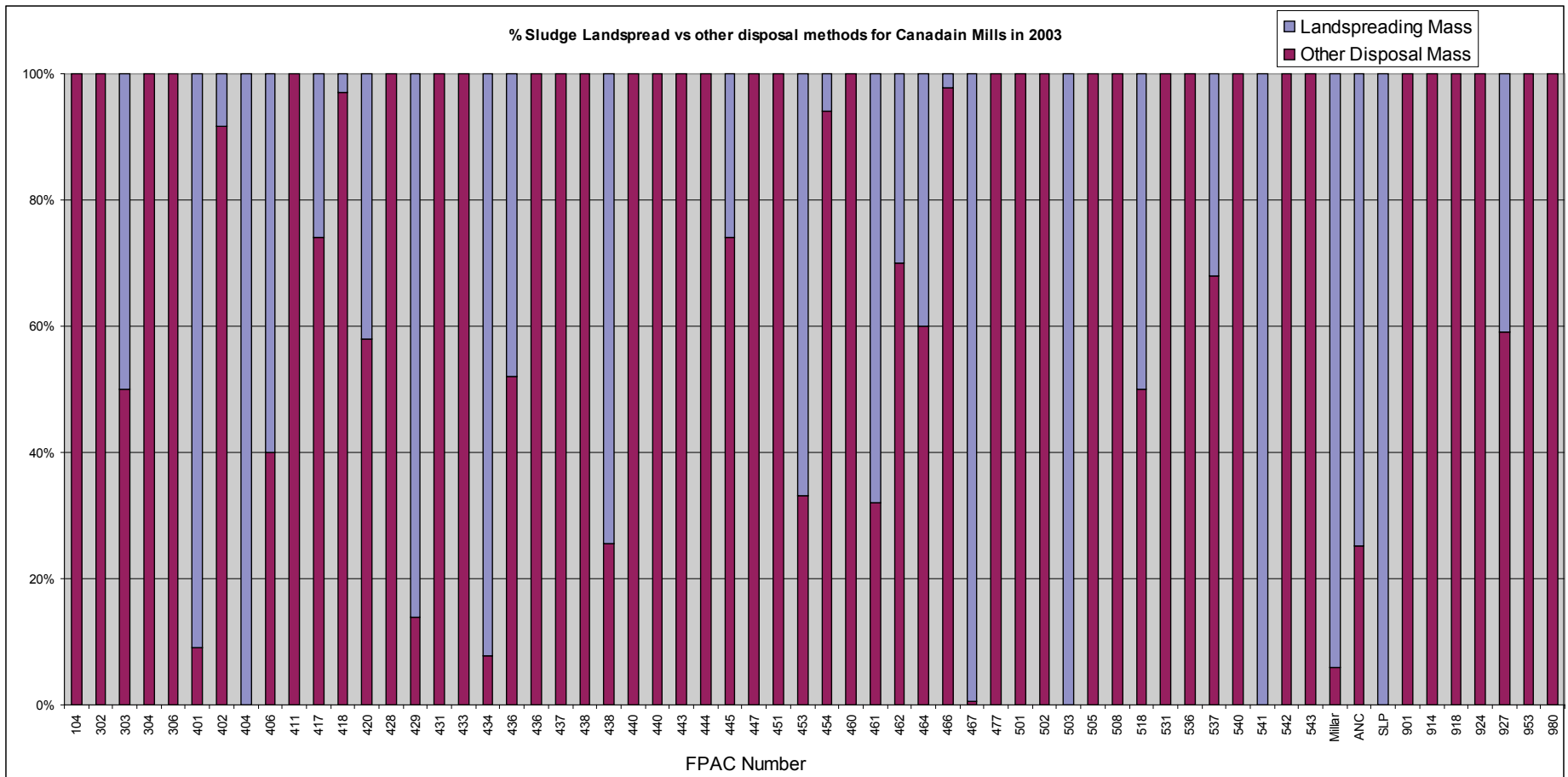


Figure 2. Comparison of the quantity of sludge land spread vs other disposal options for Canadian mechanical pulp mills in 2003 expressed as a percent of the total amount of sludge produced.

Table 2. Amount of sludge produced vs amount of sludge land spread for Canadian Mills in 2003.

FPAC #	Bone Dry (BDT)	Landsread (BDT)	Applied '03 Produced '03
104	12,320	0	0%
302	16,655	0	0%
303	3,800	1,900	50%
304	1,200	0	0%
306	180	0	0%
401	62,764	57,115	91%
402	58,186	4,829	8%
404	45,756	45,756	100%
406	1,356	814	60%
411	53,992	0	0%
417	3,055	794	26%
418	21,465	644	3%
420	25,725	10,804	42%
428	11,554	0	0%
429	12,033	10,372	86%
431	1,134	0	0%
433	10,646	0	0%
434	3,845	3,545	92%
436	34,561	16,589	48%
436	12,378	0	0%
437	8,845	0	0%
438	480	0	0%
438	10,003	7,452	75%
440	1,012	0	0%
440	749	0	0%
443	67,257	0	0%
444	32,000	0	0%
445	25,525	6,636	26%
447	2,115	0	0%
451	236	0	0%
453	5,816	3,885	67%
454	37,997	2,280	6%

FPAC #	Bone Dry (BDT)	Landsread (BDT)	Applied '03 Produced '03
460	678	0	0%
461	3,987	2,711	68%
462	22,500	6,750	30%
464	11,036	4,415	40%
466	25,869	595	2%
467	865	861	100%
477	1,461	0	0%
501	15,317	0	0%
502	10,469	0	0%
503	37,800	37,800	100%
505	4,178	0	0%
508	2,883	0	0%
518	5,668	2,834	50%
531	1,898	0	0%
536	28,794	0	0%
537	63,500	20,320	32%
540	30,596	0	0%
541	9,912	9,912	100%
542	200	0	0%
543	10,860	0	0%
Millar	23,691	22,270	94%
ANC	18,920	14,171	75%
SLP	20,646	20,646	100%
901	3,537	0	0%
914	6,220	0	0%
918	2,798	0	0%
924	1,340	0	0%
927	19,661	8,061	41%
953	9,000	0	0%
980	14,017	0	0%
SUM	992,940	324,762	33%

SUM (w/out AB Mills)		
	929,683	267,676
		29%

Table 3. Amount of sludge produced vs amount of sludge land spread for Alberta Mills in 2003.

Alberta Mills	Bone Dry (BDT)	Landsread (BDT)	Applied '03 Produced '03
Millar	23,691	22,270	94%
ANC	18,920	14,171	75%
SLP	20,646	20,646	100%
SUM	63,257	57,087	90%

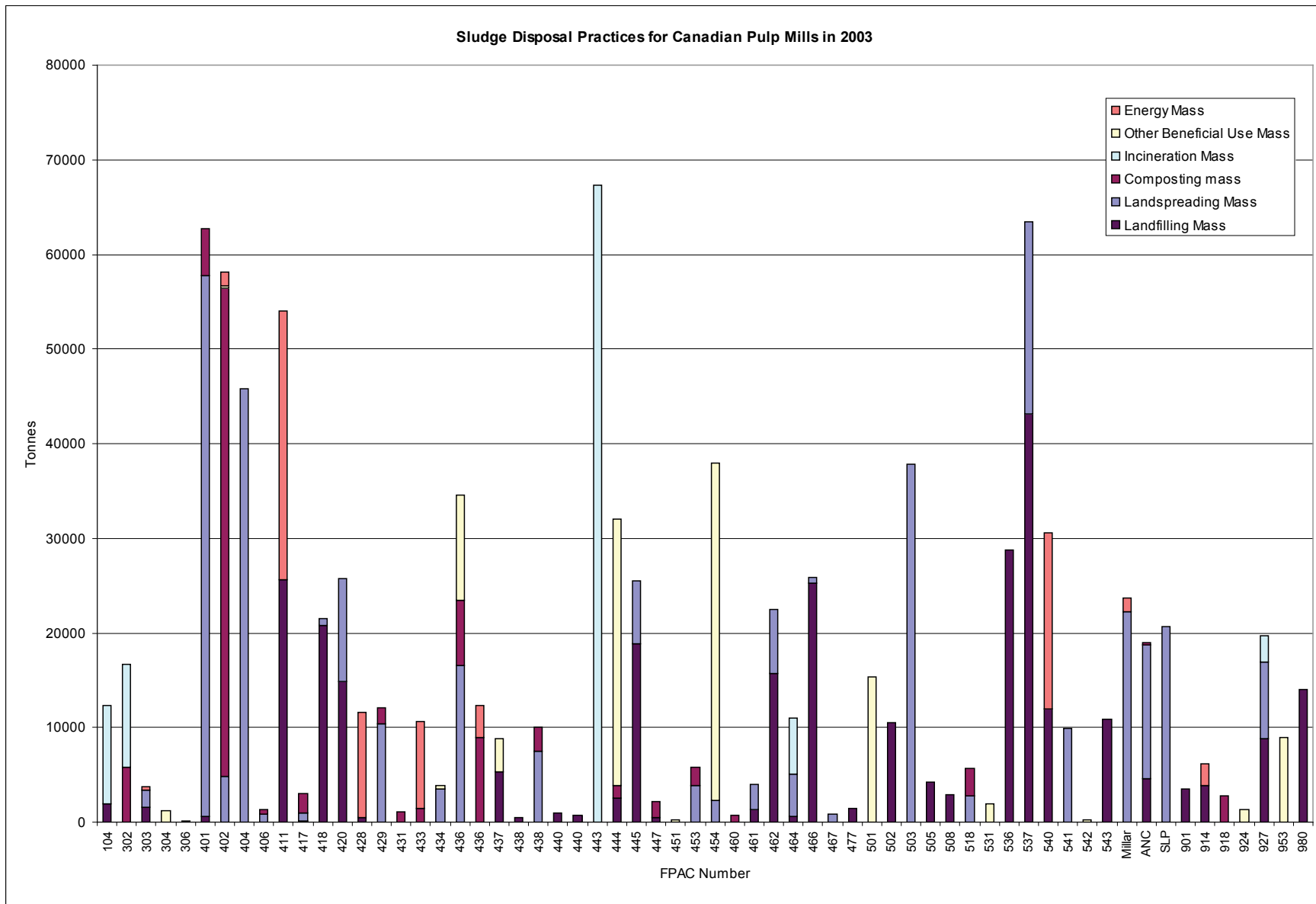


Figure 3. Comparison of the quantity of sludge per disposal method for Canadian mechanical pulp mills in 2003.

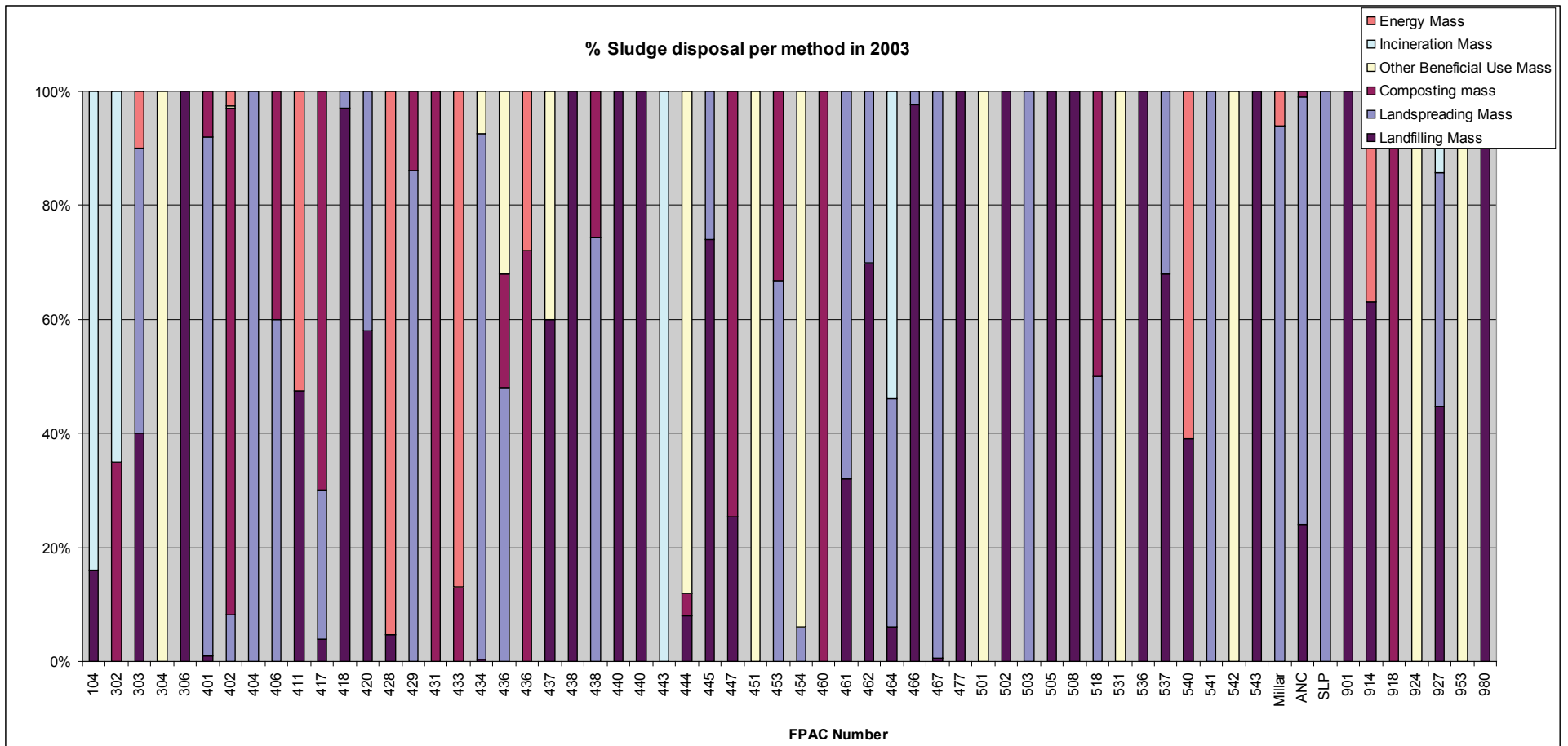


Figure 4. Comparison of the quantity of sludge per disposal method for Canadian mechanical pulp mills in 2003 expressed as a percent of the total amount of sludge produced.

Similar trends can be observed in the 2007 data (Table 4). Less than half of the 38 pulp mills in Canada used for the analysis were practicing land application and only 27% of mechanical pulp sludge produced was being disposed of by land application (Figure 5 and 6 and Table 5). When Alberta's three mechanical pulp mills are removed from the analysis the percentage of sludge land application in Canada drops to 21%, where as Alberta pulp mills were practicing 93% land application in 2007 (Table 5). Figures 7 and 8 and Table 6 demonstrate that land application was the third most common disposal option for Canadian pulp mills in 2007 (excluding Alberta Mills), as the majority of mills were using at least a portion of their sludge for energy production.

Table 2. Primary and Secondary Water Treatment Sludge Disposal Options for Canadian Mills in 2007.

FPAC #	effluent	energy	land	compost	other	incinerated	landfill	energy	land	compost	other	incinerated	landfill
	sludge (t/yr)				beneficial						beneficial		
		%	%	%	%	%	%	t/yr	t/yr	t/yr	t/yr	t/yr	t/yr
466	21,177	0	0	0	0	0	100	0	0	0	0	0	21,177
Millar	22,000	5	95	0	0	0	0	1,100	20,900	0	0	0	0
SLP	24,165	0	100	0	0	0	0	0	24,165	0	0	0	0
ANC	16,746	0	81	0	0	0	20	0	13,481	0	0	0	3,265
927	11,000	0	72	0	0	0	28	0	7,920	0	0	0	3,080
928	3,900	100	0	0	0	0	0	3,900	0	0	0	0	0
980	13,551	0	58	0	0	0	42	0	7,860	0	0	0	5,691
443	37,329	83	0	0	0	0	17	30,983	0	0	0	0	6,346
537	69,832	0	5	0	0	0	95	0	3,492	0	0	0	66,340
953	25,874	0	100	0	0	0	0	0	25,874	0	0	0	0
454	34,467	54	28	15	0	0	3	18,612	9,651	5,170	0	0	1,034
101	15,477	100	0	0	0	0	0	15,477	0	0	0	0	0
104	11,545	97	0	0	0	0	3	11,199	0	0	0	0	346
202	10,219	97	0	0	0	0	4	9,861	0	0	0	0	358
209	10,887	0	0	100	0	0	0	0	0	10,887	0	0	0
302	6,796	78	0	22	0	0	0	5,301	0	1,495	0	0	0
304	26,628	95	0	0	5	0	0	25,297	0	0	1,331	0	0
401	41,916	0	91	9	0	0	0	0	38,144	3,772	0	0	0
402	31,845	55	25	20	0	0	0	17,515	7,961	6,369	0	0	0
406	1,306	0	86	14	0	0	0	0	1,119	187	0	0	0
410	57,679	100	0	0	0	0	0	57,679	0	0	0	0	0
430	38,526	75	0	0	0	0	25	28,894	0	0	0	0	9,631
433	11,030	64	0	36	0	0	0	7,059	0	3,971	0	0	0
436	12,837	100	0	0	0	0	0	12,837	0	0	0	0	0
438	11,491	0	77	23	0	0	0	0	8,848	2,643	0	0	0
445	35,834	0	14	0	0	0	86	0	5,017	0	0	0	30,817
456	9,821	100	0	0	0	0	0	9,821	0	0	0	0	0
464	12,683	40	49	0	0	0	11	5,088	6,155	0	0	0	1,440
503	8,039	0	100	0	0	0	0	0	8,039	0	0	0	0
540	19,026	77	0	0	0	0	23	14,707	0	0	0	0	4,319
601	17,002	100	0	0	0	0	0	17,002	0	0	0	0	0
914	7,639	45	0	0	0	0	55	3,438	0	0	0	0	4,201
916	10,260	100	0	0	0	0	0	10,260	0	0	0	0	0
440	527	0	0	100	0	0	0	0	0	527	0	0	0
460	608	60	0	40	0	0	0	365	0	243	0	0	0
467	1,581	0	100	0	0	0	0	0	1,581	0	0	0	0
531	240	0	0	100	0	0	0	0	0	240	0	0	0
417	24,345	39	20	0	41	0	0	9,568	4,747	73	9,933	0	24

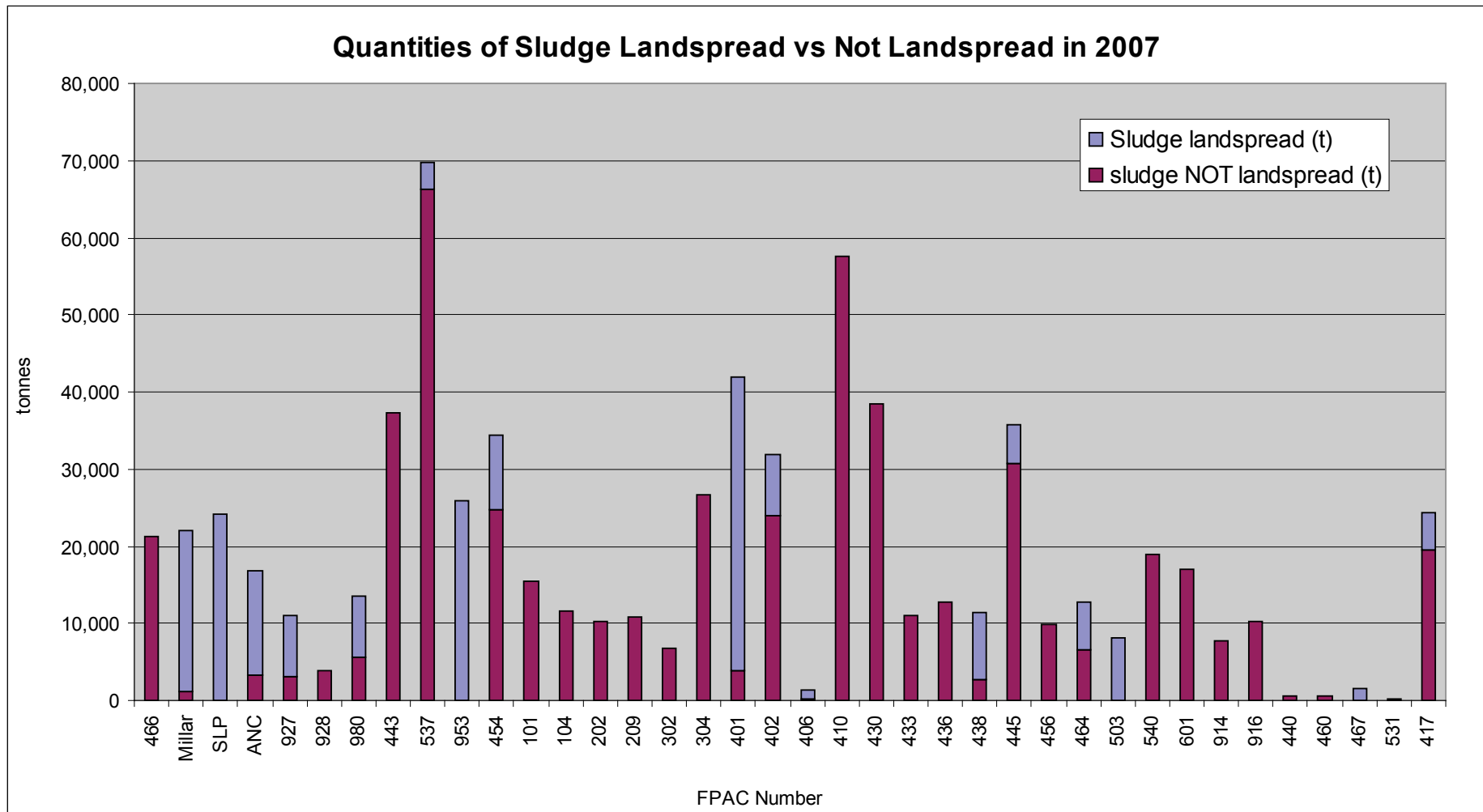


Figure 5. Comparison of the quantity of sludge land spread vs other disposal options for Canadian mechanical pulp mills in 2007.

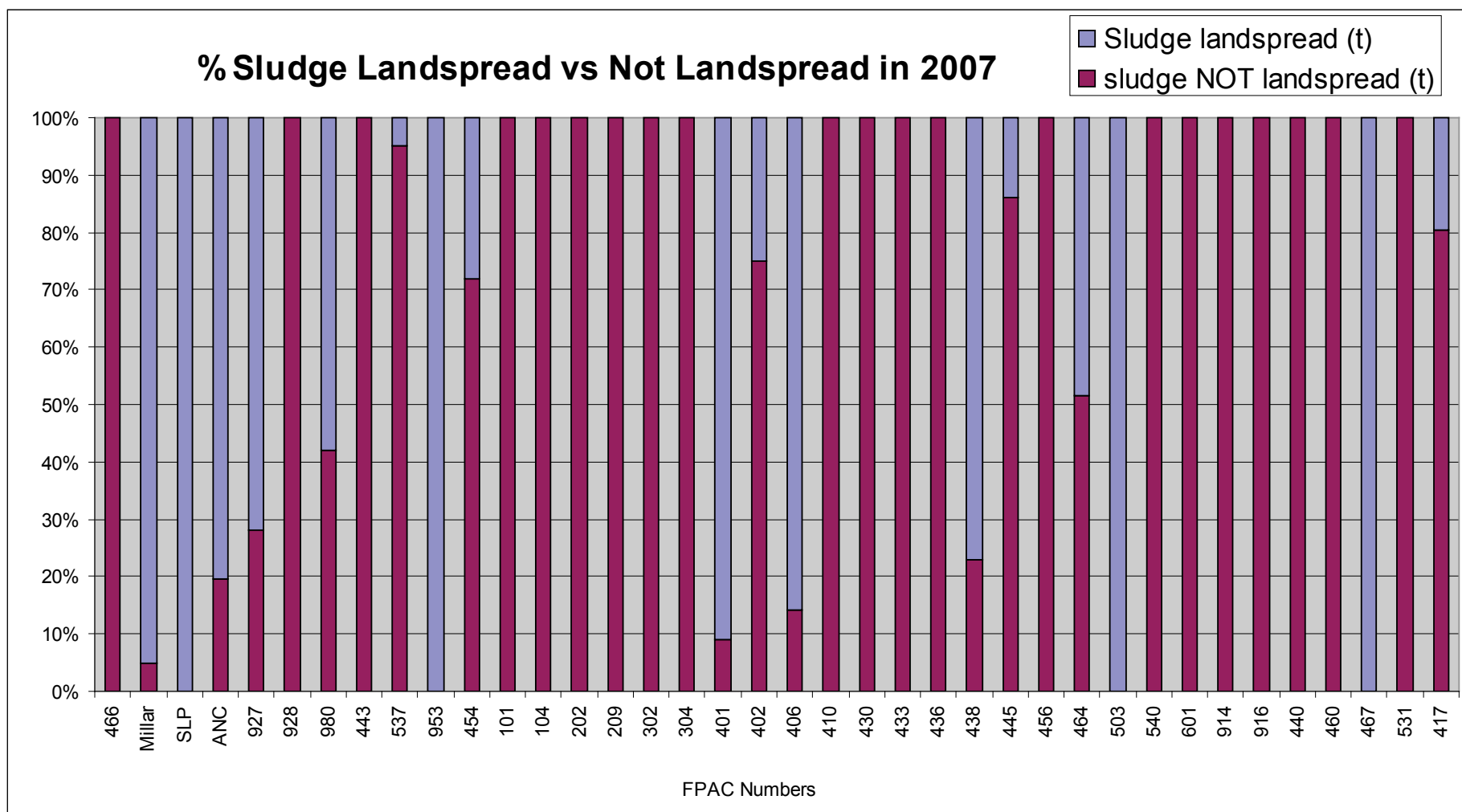


Figure 6. Comparison of the quantity of sludge land spread vs other disposal options for Canadian mechanical pulp mills in 2007 expressed as a percent of the total amount of sludge produced.

Table 5. Amount of sludge produced vs amount of sludge land spread for Canadian And Alberta pulp mills in 2007.

FPAC #	Bone Dry (BDT)	Landsread (BDT)	Applied '07 Produced '07
466	21,177	0	0%
Millar	22,000	20,900	95%
SLP	24,165	24,165	100%
ANC	16,746	13,481	81%
927	11,000	7,920	72%
928	3,900	0	0%
980	13,551	7,860	58%
443	37,329	0	0%
537	69,832	3,492	5%
953	25,874	25,874	100%
454	34,467	9,651	28%
101	15,477	0	0%
104	11,545	0	0%
202	10,219	0	0%
209	10,887	0	0%
302	6,796	0	0%
304	26,628	0	0%
401	41,916	38,144	91%
402	31,845	7,961	25%
406	1,306	1,119	86%
410	57,679	0	0%
430	38,526	0	0%
433	11,030	0	0%
436	12,837	0	0%
438	11,491	8,848	77%
445	35,834	5,017	14%
456	9,821	0	0%
464	12,683	6,155	49%
503	8,039	8,039	100%
540	19,026	0	0%
601	17,002	0	0%
914	7,639	0	0%
916	10,260	0	0%
440	527	0	0%
460	608	0	0%
467	1,581	1,581	100%
531	240	0	0%
417	24,345	4,747	20%
SUM	715,827	194,953	27%
SUM (w/out Alberta Mills)			
	652,916	136,407	21%

Alberta Mills	Bone Dry (BDT)	Landsread (BDT)	Applied '03 Produced '03
Millar	22,000	20,900	95%
ANC	16,746	13,481	81%
SLP	24,165	24,165	100%
SUM	62,911	58,546	93%

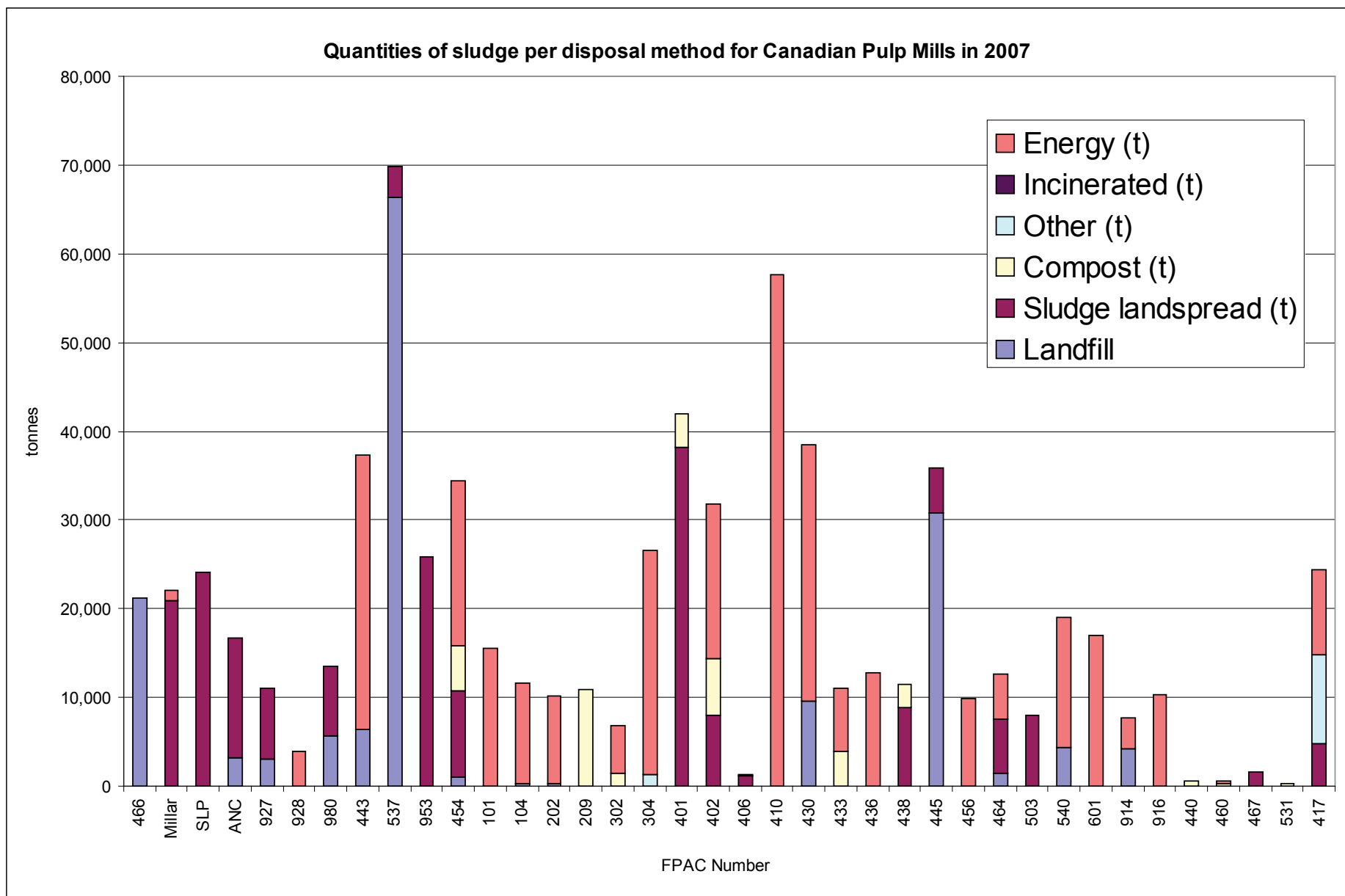


Figure 7. Comparison of the quantity of sludge per disposal method for Canadian mechanical pulp mills in 2007.

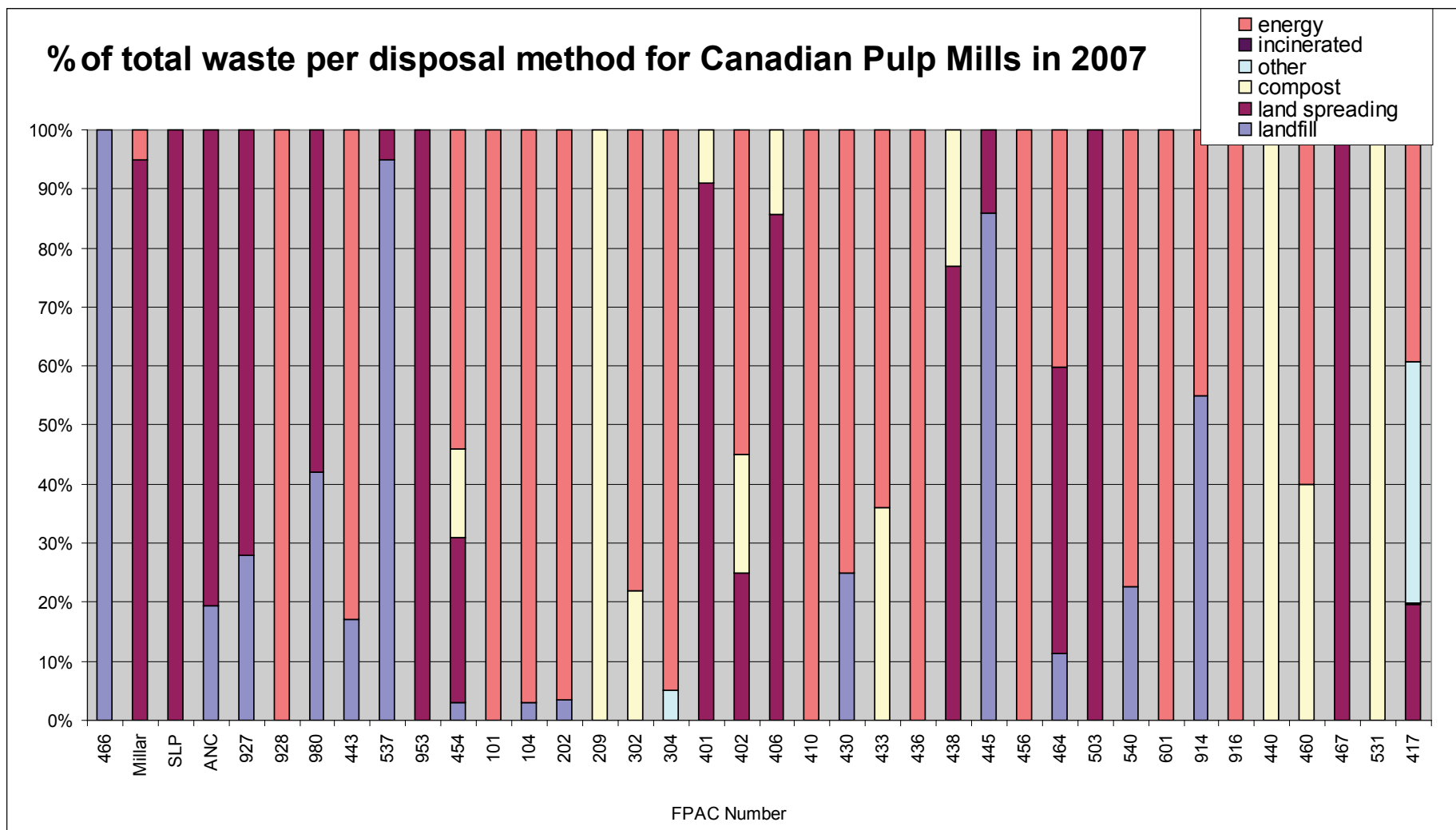


Figure 8. Comparison of the quantity of sludge per disposal method for Canadian mechanical pulp mills in 2007 expressed as a percent of the total amount of sludge produced.

Table 6. Quantity of sludge disposal as a percent of sludge produced in 2003 and 2007 for Canadian Pulp Mills.

Sludge Disposal Methods for Canadian Mills in 2003								
	Bone Dry Sludge Produced (BDT)	Energy (BDT)	Landspread (BDT)	Landspread (BDT) w/out AB Mills	Composting (BDT)	Other Beneficial Use (BDT)	Incineration (BDT)	Landfill (BDT)
Total BDT for Canadian Mills in 2003	992,940	76,407	324,762	267,676	98,996	108,182	97,183	287,409
% of sludge disposed (Disposal Method (BDT) /Produced (BDT)	-	8%	33%	29%	10%	11%	10%	29%
Sludge Disposal Methods for Canadian Mills in 2007								
	Bone Dry Sludge Produced (BDT)	Energy (BDT)	Landspread (BDT)	Landspread (BDT) w/out AB Mills	Composting (BDT)	Other Beneficial Use (BDT)	Incineration (BDT)	Landfill (BDT)
Total BDT for Canadian Mills in 2007	715,827	315,962	194,953	136,407	35,577	11,264	0	158,071
% of sludge disposed (Disposal Method (BDT) /Produced (BDT)	-	44%	27%	21%	5%	2%	0%	22%

2.0 Economic Analysis of Alternative Disposal Options for Alberta Mills

Alberta Newsprint Company

Costs are based on Bone Dry Tonnes (BDT)

Landfilling - \$23.42/BDT @ 30% solids

Landspreading - 26.88/BDT @ 30% solids

Slave Lake Pulp

Costs are based on BDT

Landspreading - \$50.76/BDT @ 18.7% solids or \$9.49/wet tonne

Gas Drying - \$83.50/BDT @ 22% solids or \$18.39/wet tonne based on average gas input of 2.77 GJ/wet tonne @ 2008 year end gas price of \$6.64/GJ to increase dryness from 22% to 40/50% for incineration

Biomass to Energy - (\$3/tonne) @ 25% - 30% solids to ship to DAPP Power for incineration (limited quantities trialled in 2009)

Incineration - < 1 year payback on \$1MM capital installation to increase sludge solids from 20% to 40% solids for onsite incineration (minimal ongoing cost)

Cost differential between Biomass to Energy and Landspreading is \$12.49/wet tonne.

Millar Western Pulp

Costs are based on Wet Tonnes

Hauling to the Chickadee burner - \$4.19/tonne

Landspreading (2007/2008) - \$6.23/tonne

Extra cost associated with landspreading is \$2.04/tonne compared to incineration at Chickadee.

3.0 Technical Background

3.1 Development of the Discount Factor

The 0.55 discount factor for use in the simple quantification approach was determined based on the following:

Monitoring and quantification procedures prescribed for the simple quantification approach are designed to err on the conservative side in order to not over-estimate GHG emission reductions. A 50% discount factor applied to the carbon value of the simple quantification approach (Section 2.5.1.2) aims to account for the variability in bulk density and soil organic carbon content estimations. The organic carbon values provided in Table A1 for the Ap horizon vary by 70% and the bulk density values vary by 40%. The midpoint between the ranges in variation in organic matter content and bulk density is 55% and was chosen to represent the variation. As a result the discount factor was set at 0.55.

The discount factor could be decreased if appropriate historical documentation of actual measurement data could be presented to reassure verifiers that the variability in bulk density and organic carbon contents are less than the conservative values used for developing this discount factor.

3.2 Nitrous Oxide Quantifications – Land Application

Nitrous oxide (N₂O) is produced naturally in soils through the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N₂). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in the soil (IPCC 2006). The following methodology estimates N₂O emissions using human-induced net N additions to soils (e.g., synthetic or organic fertilizers, pulp sludge). The emissions of N₂O that result from anthropogenic N inputs or N mineralization occur through both a direct pathway (i.e., directly from the soils to which the N is added/released), and through two indirect pathways: i) following volatilization of NH₃ and NO_x from managed soils and the subsequent redeposition of these gases and their products NH₄⁺ and NO₃⁻ to soils and waters; and ii) after leaching and runoff of N, mainly as NO₃⁻ from managed pathways.

The Tier 1 IPCC (2006) methodologies were used to quantify the direct and indirect N₂O emissions from the project and baseline condition, for the purpose of determining if it is acceptable to exclude N₂O emissions from the quantifications using the most conservative approach. The Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions, or management practices. For simplicity, N from crop residues was omitted from these quantifications due to the variability in farming practices and crop types within the region, however the addition of this step would not increase the overall emission enough to change the results.

$$N_{20-N} = (N_{20\text{direct-N}} + N_{20\text{indirect-N}}) * (44 \text{ t} \cdot \text{mol N}_{20} / 28 \text{ t} \cdot \text{mol N}_2)$$

Where:

$$N_{20\text{direct-N}} = [F_{SN} + F_{ON}] * EF_1$$

F_{SN} = annual amount of synthetic fertilizer N applied to soil, kg N yr⁻¹
 F_{ON} = annual amount of pulp sludge N applied to soil, kg N yr⁻¹
 EF_1 = emission factor for N₂O emissions from N inputs, (0.01 kg N₂O-N (kg N input)⁻¹)

$$N_2O_{\text{indirect-N}} = N_2O_{\text{ATD-N}} + N_2O_{\text{L-N}}$$

Where:

$$N_2O_{\text{ATD-N}} = [F_{SN} * \text{Frac}_{\text{GASF}}] + [F_{ON} * \text{Frac}_{\text{GASM}}] * EF_4$$

$N_2O_{\text{ATD-N}}$ = annual amount of N₂O-N produced from atmospheric deposition of N volatilized from managed soils kg N₂O-N yr⁻¹

F_{SN} = annual amount of synthetic fertilizer N applied to soil, kg N yr⁻¹

F_{ON} = annual amount of pulp sludge N applied to soil, kg N yr⁻¹

$\text{Frac}_{\text{GASF}}$ = fraction of synthetic fertilizer N that volatilizes as NH₃ and NO_x, (0.10 kg N volatilized (kg N applied)⁻¹)

$\text{Frac}_{\text{GASM}}$ = fraction of pulp sludge N that volatilizes as NH₃ and NO_x (0.20 kg N volatilized (kg N applied)⁻¹)

EF_4 = emission factor for N₂O emissions from atmospheric deposition of N on soils and water surfaces (0.01 kg N-N₂O (kg NH₃-N + NO_x-N volatilized)⁻¹)

$$N_2O_{\text{L-N}} = (F_{SN} + F_{ON} + F_{SOM}) * \text{Frac}_{\text{LEACH}} * EF_5$$

$N_2O_{\text{L-N}}$ = annual amount of N₂O-N produced from leaching and runoff of N additions to managed soils, kg N yr⁻¹

$\text{Frac}_{\text{LEACH}}$ = fraction of all N added to/mineralized in managed soils that is lost through leaching and runoff, (0.30 kg N (kg N additions)⁻¹)

EF_5 = emission factor for N₂O emissions from N leaching and runoff, (0.0075 kg N₂O-N (kg N leached)⁻¹).

F_{SOM} = annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr⁻¹

Note: $F_{SOM} = \sum_{LU} [(\Delta C_{\text{Mineral, LU}} * 1/R) * 1000]$, where = average loss of soil carbon for each land use (LU) type, in tonnes C, 1/R = C:N ratio of soil organic matter. This factor involves specific information regarding soil organic carbon stock changes, stock change factors for management regimes and organic carbon additions, and the land area of the stratum being estimated. All land in the stratum requires common biophysical conditions (i.e., climate and soil type) and management history over the inventory time period. Although, this information is variable and site specific, based on initial quantifications it is not expected to significantly increase the quantity of N₂O emissions and can therefore be considered negligible and immaterial to these quantifications.

Using this approach to quantify N₂O emissions it was determined that the overall emissions from nitrous oxide were less than 5% of the overall emissions quantified in the project and thus were immaterial and excluded from the quantifications. See the example quantification below.

Table 7. Assumptions for Example Quantification:

Fertilizer	Sludge Parameters	Trucking	Receiving Soil Properties		
			Depth	Db (kg/m3)	% Carbon
Application Rate = 50 kg N /ha (Applied 5 times over 5 year credit period)	Carbon Content = 45% Nitrogen Content = 2%	Haul Distance = 100 km			
	Application Rate = 50 t/ha (Applied 1 time over 5 year credit period)	35 t Truck Capacity	0-15 cm	0.9	3.29
		33.6 L/100km	15-30 cm	1.35	1.06

BASELINE N₂O-N =

$$\begin{aligned}
 & [F_{SN} * EF_1] + [F_{SN} * \text{Frac}_{GASF} * EF_4] + [F_{SN} * \text{Frac}_{LEACH} * EF_5] * 44/28 \\
 & = [50 \text{ kg N/ha} * 0.01 \text{ kg N}_2\text{O-N (kg N input)}^{-1}] + [50 \text{ kg N/ha} * 0.10 \text{ kg N volatilized (kg N applied)}^{-1} \\
 & * 0.01 \text{ kg N-N}_2\text{O (kg NH}_3\text{-N + NO}_x\text{-N volatilized)}^{-1}] + [50 \text{ kg N/ha} * 0.30 \text{ kg N (kg N additions)}^{-1} * \\
 & 0.0075 \text{ kg N}_2\text{O-N (kg N leached)}^{-1}] \\
 & = (0.5 \text{ kg N}_2\text{O-N} + 0.05 \text{ kg N}_2\text{O -N} + 0.1125 \text{ kg N}_2\text{O-N}) * 44/28 \\
 & = 0.6625 \text{ kg N}_2\text{O-N} * 44/28 \\
 & \text{Baseline N}_2\text{O emissions} = 1.04 \text{ kg N}_2\text{O ha}^{-1} \text{ yr}^{-1} \\
 & 1.04 \text{ kg N}_2\text{O ha}^{-1} \text{ yr}^{-1} * 310 \text{ kg CO}_{2e} / 1 \text{ kg N}_2\text{O} * (1 \text{ t} / 1000 \text{ kg}) * 5 \text{ applications over 5 year credit} \\
 & \text{period} = 1.61 \text{ t CO}_{2e} / \text{ha}
 \end{aligned}$$

PROJECT N₂O-N =

$$\begin{aligned}
 & [F_{ON} * EF_1] + [F_{ON} * \text{Frac}_{GASM} * EF_4] + [F_{ON} * \text{Frac}_{LEACH} * EF_5] * 44/28 \\
 & = [1000 \text{ kg N/ha} * 0.01 \text{ kg N}_2\text{O-N (kg N input)}^{-1}] + [1000 \text{ kg N/ha} * 0.20 \text{ kg N volatilized (kg N} \\
 & \text{applied)}^{-1} * 0.01 \text{ kg N-N}_2\text{O (kg NH}_3\text{-N + NO}_x\text{-N volatilized)}^{-1}] + [1000 \text{ kg N/ha} * 0.30 \text{ kg N (kg N} \\
 & \text{additions)}^{-1} * 0.0075 \text{ kg N}_2\text{O-N (kg N leached)}^{-1}] \\
 & = (10 \text{ kg N}_2\text{O-N} + 2 \text{ kg N}_2\text{O -N} + 2.25 \text{ kg N}_2\text{O-N}) * 44/28 \\
 & = 14.25 \text{ kg N}_2\text{O-N} * 44/28 \\
 & \text{Project N}_2\text{O emissions} = 22.39 \text{ kg N}_2\text{O ha}^{-1} \text{ yr}^{-1} \\
 & 22.39 \text{ kg N}_2\text{O ha}^{-1} \text{ yr}^{-1} * 310 \text{ kg CO}_{2e} / 1 \text{ kg N}_2\text{O} * (1 \text{ t} / 1000 \text{ kg}) * 1 \text{ application over 5 year credit} \\
 & \text{period} = 6.94 \text{ t CO}_{2e} / \text{ha}
 \end{aligned}$$

Overall N₂O Emissions = (Baseline N₂O-N) – (Project N₂O-N)

$$= 1.61 \text{ t CO}_{2e} / \text{ha} - 6.94 \text{ t CO}_{2e} / \text{ha} = - 5.33 \text{ t CO}_{2e} / \text{ha}$$

Table B-2. Project and Baseline Emissions Associated with Mechanical Pulp Sludge Land Application over a 5 year period (without applying the discount factor)

Table 8. Baseline and Project Emissions.

		t CO_{2e} / 50 t/ha application	
		Landfill	Incineration
Baseline	B9 Landfill Operations	78	-
	B11 Flash dryer	-	72
	B12 Incineration	-	117
	B2 Sludge Transportation	0.044	-
	B23 Fertilizer N₂O	1.61	1.61
	B17 SOC Reservoir	-201	-201
	Σ Emissions Baseline	-121.96	-10.34
Project	P17 SOC Reservoir	-279	-279
	P23 Sludge N₂O	6.94	6.94
	P2 Sludge Transportation	0.44	0.44
	Σ Emissions Project	-271.62	-271.62
Baseline - Project		149.66	261.28

Since the overall N₂O emissions using the conservative Tier 1 IPCC (2006) methodologies are less than 5% of the total emissions for the project ($[5.28 \text{ t CO}_{2e} / \text{ha}] / [149.66 \text{ t CO}_{2e} / \text{ha}] * 100\% = 3.5\%$) the emissions can be excluded from the quantification.

3.3 Methane Gas Quantifications – Land Application

B₀ values

The maximum methane-producing capacity of the sludge (B₀) has not been specifically determined. The theoretical default value for B₀ of wastewater is 0.25 kg CH₄/kg BOD (IPCC 1996). Other sludges from kraft pulp mills have been tested and it was determined that the methane producing capacity ranged between 0.1 and 0.25 m³ CH₄/kg volatile solids (Felske and Jenson, Personal Communication 2009).

MCFs

Methane conversion factors (MCFs) are determined for a specific waste management system and represent the degree to which B₀ is achieved. The amount of methane generated by a specific waste management system is affected by the extent of anaerobic conditions present, the temperature of the system, and the retention time of organic material in the system. No MCFs specifically apply to pulp sludge however default methane conversion factors (MCFs) are provided in IPCC (2006) guidelines for different manure management systems and by annual average temperatures. MCF values are determined by temperature and manure management systems. The mean annual temperature of the Parkland region in Alberta is less than 10°C and the closest manure management system to land application of pulp sludge would be Pasture/Range/Paddock where the manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed. The MCF under these conditions is 1%. Since the sludge is incorporated the MCF is likely higher than 1%

(Table 10.17, V4:Ch10, IPCC 2006), therefore to ensure conservativeness a MCF of 5% was applied to the pulp sludge.

Table 9. Characteristics of Mechanical Pulp Sludge.

Total %C (Volatile Solids)	B ₀	MCF	Application Rate
45%	0.25 m ³ CH ₄ /kg VS	5%	50 t/ha

The potential amount of methane that could be produced under the right conditions from transportation, storage and land application of sludge can thus be calculated.

Using a conservative approach:

$$\begin{aligned}
 &50 \text{ t/ha} * 1000 \text{ kg/t} * 45\% \text{ VS} \\
 &= 22\,500 \text{ kg VS/ha} \\
 &22\,500 \text{ kg VS/ha} * 0.25 \text{ m}^3 \text{ CH}_4/\text{kg VS} * 5\% \\
 &= 218.25 \text{ m}^3 \text{ CH}_4/\text{ha} \\
 &218.25 \text{ m}^3 \text{ CH}_4/\text{ha} * 0.00068 \text{ t/m}^3 * 21 \text{ CO}_{2e} \\
 &= \mathbf{4.02 \text{ t CO}_{2e}/\text{ha}}
 \end{aligned}$$

This indicates that even if 5% of the maximum methane-producing capacity of the sludge was emitted the amount would be immaterial in terms of the overall emission reductions ($[4.02 \text{ t CO}_{2e}/\text{ha}] / [149.66 \text{ t CO}_{2e} / \text{ha}] * 100\% = 2.7\%$) and thus methane emissions can be excluded from the overall quantification.

3.4 SOC Reversal Quantifications

To increase the assurance that an offset has been created, the proponent must address the chance that a change in practice might occur during the credit period that could result in the release of carbon removed by applying a reversal using a reversal factor set out in the protocol. Previous work has assumed that the effect of reversing a practice change on soil organic carbon (SOC) is of the same magnitude but is the negative value of the effect of practice change (McConkey et al. 2007).

The a requirement is to quantify not only the impact of not storing any new carbon in the current year, but also the impact of losing previously sequestered carbon due to a change in management practice. The principle of equal but opposite effects must also be applied to previously stored carbon. As such, the amount of previously stored carbon that would be lost by practicing Full-Till for one year would be equal to the amount of carbon gained from practicing No-Till for one year, assuming that the previous practice in the project was No-Till.

In order to calculate the reversal coefficients for SOC change, one must first calculate the net coefficients for positive tillage change. This is done by using the raw 5 year linear SOC coefficients from Table 10, to represent the number of years in the credit period and the area (ha) being treated.

Table 10. Effective Raw Linear Coefficients used to predict soil organic carbon change from tillage practice change for Specified Years after Practice Change.

Region	Tillage System Change	5 yr (Mg C ha ⁻¹ yr ⁻¹)	5 yr (Mg CO ₂ ha ⁻¹ yr ⁻¹)	10 yr (Mg C ha ⁻¹ yr ⁻¹)	10 yr (Mg CO ₂ ha ⁻¹ yr ⁻¹)
Parkland	FT to NT	0.17	0.63	0.16	0.59
	NT to FT	-0.17	-0.63	-0.16	-0.59

Total Reversal Coefficient

(5 year Credit Period) = Yrs * ha * 0.63 Mg CO_{2e} ha⁻¹ yr⁻¹

(8 to 10 year Credit Period) = Yrs * ha * 0.59 Mg CO_{2e} ha⁻¹ yr⁻¹

Example:

Area of field treated = 100 ha

Credit Period = 5 years

Total Reversal Coefficient = 5 yr * 100 ha * 0.63 Mg CO_{2e} ha⁻¹ yr⁻¹
= 320 Mg CO_{2e}

3.5 Adjusted Baseline

Historically in Alberta mechanical pulp sludge was a discarded by-product produced during the production of pulp and paper. Common industry practice for sludge disposal was drying and incinerating either in an olivine burner or beehive burner, and landfilling. The *Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land* (Alberta Environmental Protection 1999) were approved in 1999, around which time the mill operators began to apply a portion of their sludge to local agricultural land. Historical sludge disposal practices for ANC, SLP and Millar are provided in Table 11 and Figure 9, Table 12 and Figure 10, and Table 13 and Figure 11, respectively.

Table 11. Alberta Newsprint Company Historical Sludge Disposal Practices.

Year	Produced (BDT)	Land Applied (BDT)	Baseline Disposal (BDT)
1992	25,000	0	25,000
1993	25,000	0	25,000
1994	22,700	1,900	20,800
1995	16,600	3,600	13,000
1996	13,769	8,909	4,860
1997	15,423	10,530	4,893
1998	15,607	12,305	3,302
1999	15,789	10,669	5,120
2000	18,354	12,136	6,218
2001	20,441	11,987	8,454
2002	19,955	10,545	9,410
2003	20,369	14,166	6,203
2004	24,870	15,419	9,451
2005	16,792	7,351	9,441
2006	20,016	11,722	8,294
2007			
2008			

Table 12. Slave Lake Pulp Historical Sludge Disposal Practices.

Year	Produced (BDT)	Land Applied (BDT)	Baseline Disposal (BDT)
1992	17,674	0	17,674
1993	18,059	6,000	12,059
1994	18,545	0	18,545
1995	17,203	0	17,203
1996	11,353	0	11,353
1997	22,144	914	21,230
1998	20,310	0	20,310
1999	25,394	0	25,394
2000	20,075	5,590	14,485
2001	14,499	13,596	903
2002	18,472	18,472	0
2003	20,646	20,646	0
2004	25,219	25,219	0
2005	23,419	23,410	9
2006	20,352	20,352	0
2007	21,228	21,228	0
2008	23,012	23,012	0

**Table 13. Millar Western Forest Products
Historical Sludge Disposal Practices.**

Year	Produced (BDT)	Land Applied (BDT)	Baseline Disposal (BDT)
1992	14,725	0	14,725
1993	14,725	0	14,725
1994	14,725	0	14,725
1995	15,151	0	15,151
1996	11,778	5,786	5,992
1997	11,430	6,905	4,525
1998	15,655	12,613	3,042
1999	15,205	11,208	3,997
2000	22,647	20,792	1,855
2001	18,757	18,187	570
2002	20,442	18,040	2,402
2003	25,647	23,911	1,736
2004	25,645	24,067	1,578
2005	25,074	23,942	1,132
2006	23,592	22,467	1,125
2007	22,713	22,713	0
2008	19,112	19,112	0

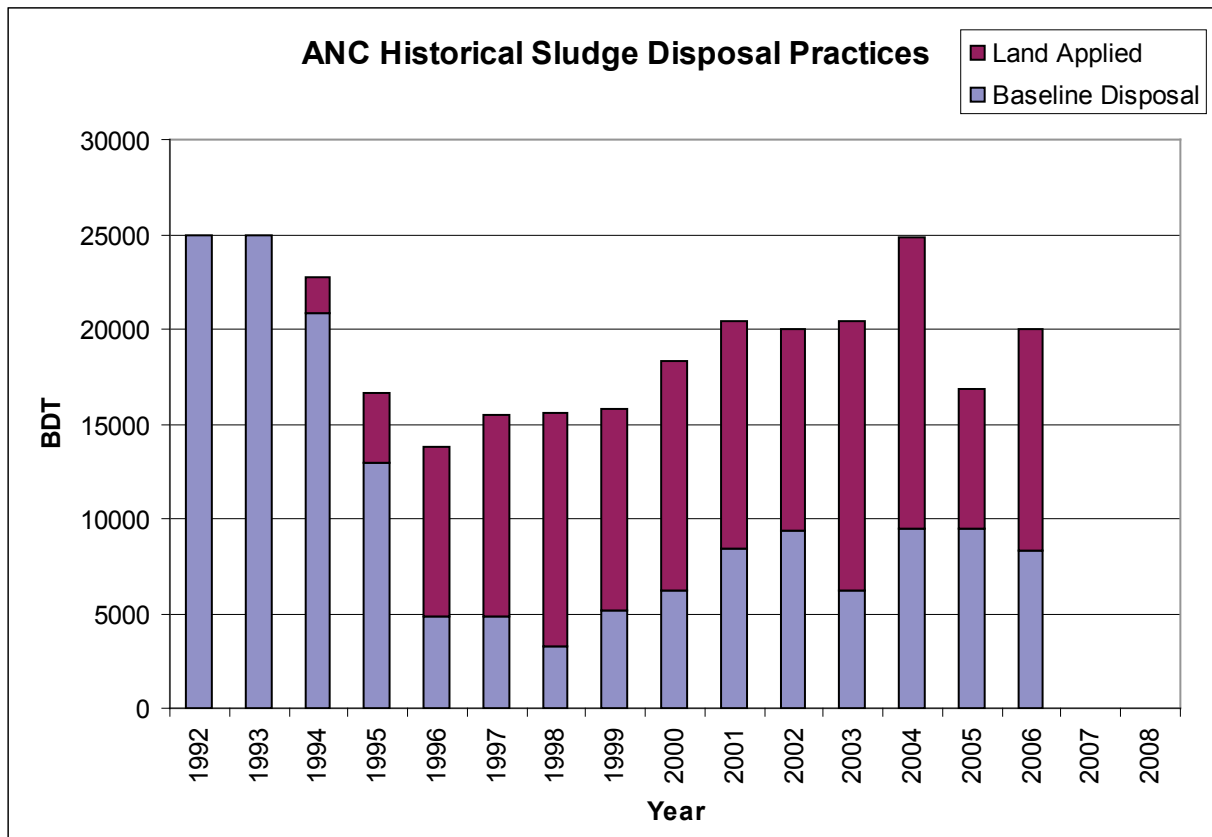


Figure 9. Alberta Newsprint Company Historical Sludge Disposal Practices.

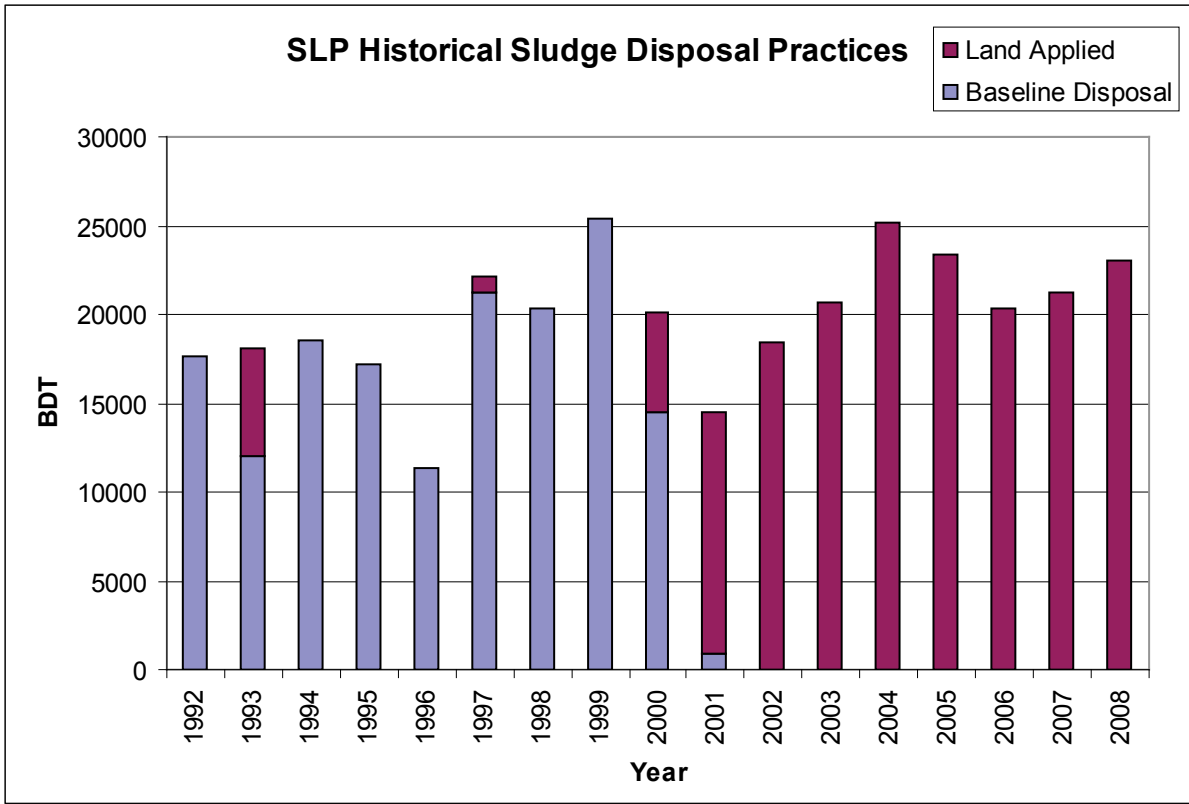


Figure 10. Slave Lake Pulp Historical Sludge Disposal Practices.

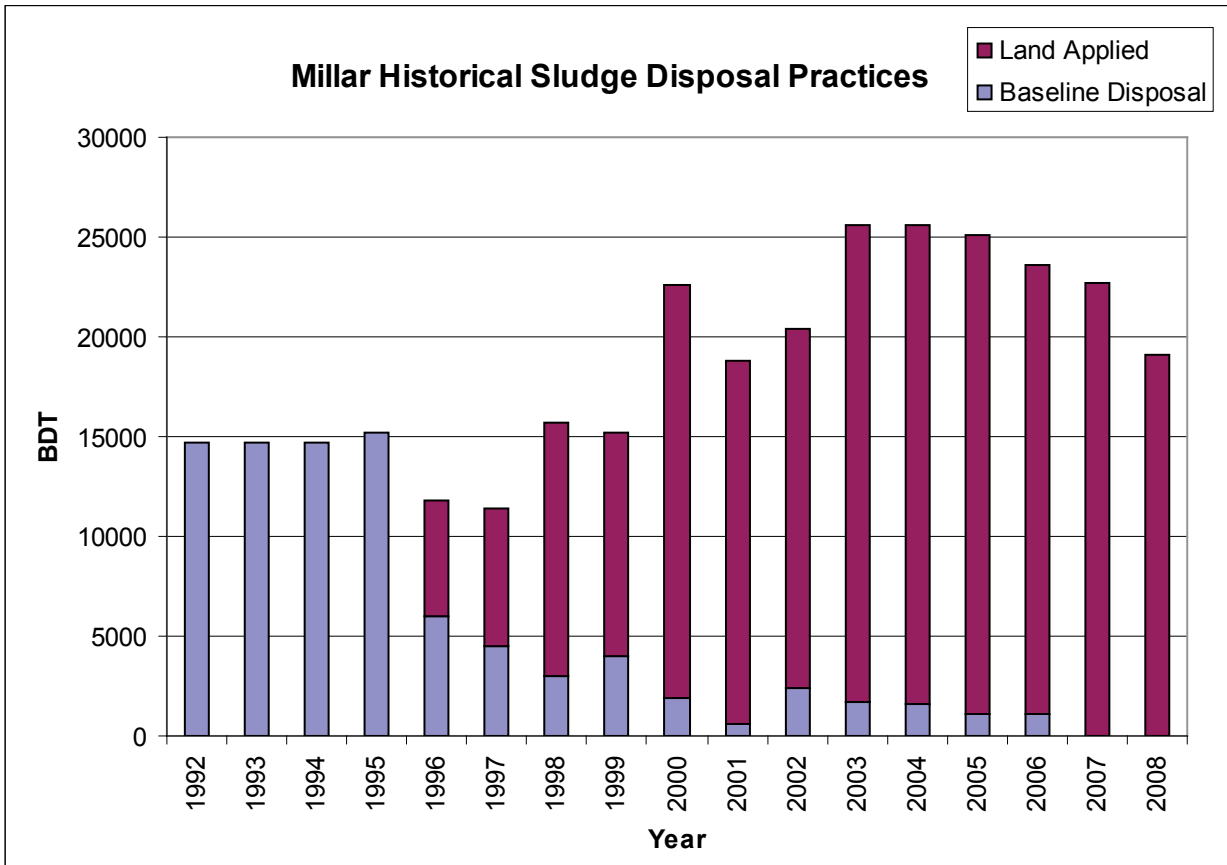


Figure 11. Millar Western Forest Products Historical Sludge Disposal Practices.

Baseline is defined as the most appropriate and best estimate of GHG emissions and removals that would have occurred in the absence of the project. In this protocol the baseline condition is variable due to different sludge disposal methods and land spreading adoption levels during the base period. An adjusted baseline is required to account for industry land spreading adoption levels to ensure GHG emissions and removals that occur during the credit period are beyond business as usual practices.

An adjusted baseline was determined by comparing the total amount of sludge produced to the total amount of sludge applied to agriculture land in Alberta for three mechanical pulp mills from 1996 to 2001 (Table 14 and Figure 12). This value (0.53) represents the amount of land application that would be considered business as usual practice during the time period 1996 to 2001 and therefore is not eligible for carbon offset credits as it would have occurred without the project condition.

Table 14. Amount of sludge produced vs amount of sludge land spread for ANC, SLP and Millar from 1996 to 2001.

Mill	Sludge Produced (Bone Dry t)							Sludge Land Applied (Bone Dry t)							
	1996	1997	1998	1999	2000	2001	96-01	1996	1997	1998	1999	2000	2001	96-01	
ANC	13,769	15,423	15,607	15,789	18,354	20,441	<u>99,383</u>	8,909	10,530	12,305	10,669	12,136	11,987	<u>66,536</u>	
SLP	11,353	22,144	20,310	25,394	20,075	14,499	<u>113,775</u>	0	914	0	0	5,590	13,596	<u>20,100</u>	
Millar	11,778	11,430	15,655	15,205	22,647	18,757	<u>95,472</u>	5,786	6,905	12,613	11,208	20,792	18,187	<u>75,490</u>	
Total Sludge Produced (t)							<u>308,630</u>	Total Sludge Applied (t)							<u>162,126</u>

Sector Adjusted Baseline (1996 - 2001)

$$\text{Adjusted Baseline}_{\text{sector adjusted}} = \frac{\sum \text{total applied}_{1996-2001}}{\sum \text{total produced}_{1996-2001}} = 0.53$$

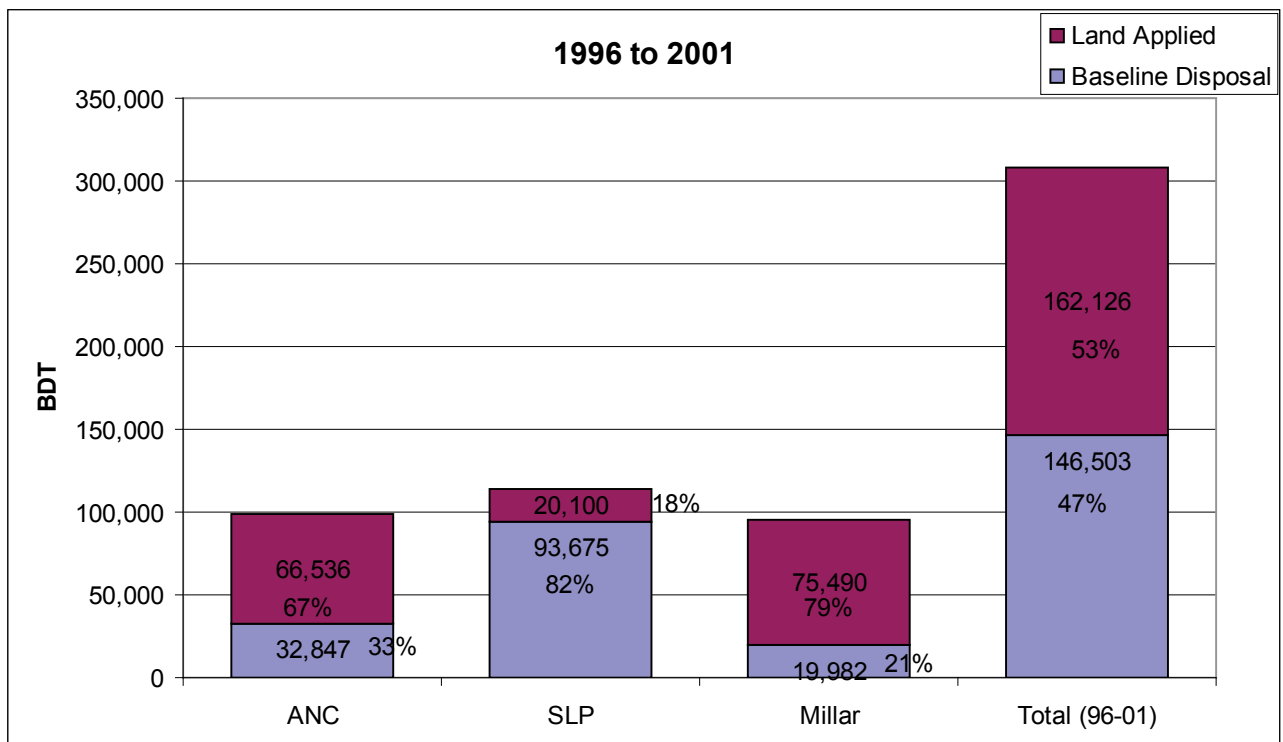


Figure 12. Amount of sludge disposed of by land spreading vs other baseline disposal options (incineration, landfilling) for ANC, SLP and Millar from 1996 to 2001, cumulatively.

3.6 Professional Qualifications

Minimum experience standards for personnel conducting field measurements, sampling and analysis can be determined at the discretion of the professional signing off on the project. A qualified professional consists of any individual belonging to an accredited professional organization or a person with 10 or more years of relevant experience in soils. It is the responsibility of the professional to ensure that an appropriate number of field samples were collected using appropriate methods and handled according to laboratory requirements.

4.0 References

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