Directive 050

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Drilling Waste Management

Contents

1 Introduction

1.1 Purpose of This Directive

The Alberta Energy Regulator (AER) *Directive 050: Drilling Waste Management* sets out the requirements for the treatment and disposal of **drilling waste** generated in Alberta. Drilling waste is the mud and cuttings generated while

- drilling a well (including oil sands exploration, geothermal, and brine-hosted mineral) or
- directional drilling for pipeline construction.

The purpose of this directive is to

- provide the **licensee** of a well or pipeline with methods to manage drilling waste that protect the **environment** and are harmonized with other waste management practices,
- enable the restoration of drilling waste sites to **equivalent land capability**, and
- ensure drilling waste management practices meet AER requirements and environmental outcomes through monitoring and reporting.

The **soil endpoints** for the drilling waste land disposal methods are aligned with the latest edition of the Government of Alberta's *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*. Although this leads to better reclamation outcomes for land used for drilling waste disposal, industry is encouraged to develop alternatives to land disposal in support of the Alberta *Beneficial Use of Waste* study, which supports

- disposing of waste to land when there are agronomic benefits,
- developing technology to improve waste recycling and reuse options, and
- reducing the amount of waste for disposal (including land disposal).

In this directive, defined terms are shown in boldface on first use, and the definitions are provided in appendix 1. Abbreviations used in this directive are listed in appendix 2.

1.2 AER Requirements

In this directive, the term "must" indicates a requirement whereas terms such as "should," "recommends," and "expects" indicate a recommended practice.

If a requirement applies at both the application stage and later in a development's life cycle, the requirement may refer to both the applicant and the licensee.

Each AER requirement that is unique to this directive is numbered.

Information on compliance and enforcement can be found on the AER website.

1.3 Jurisdictional Overview

Under the *Environmental Protection and Enhancement Act* (*EPEA*) and its regulations, Alberta Environment and Protected Areas (AEPA) is responsible for developing soil and **groundwater** quality and remediation guidelines, setting policy for the application of risk assessments, and developing and maintaining reclamation requirements for lands designated as "specified lands" in *EPEA*.

The AER is responsible for issuing reclamation certificates for specified lands where energy resource activities have taken place. For lands not designated as specified lands, reclamation requirements are established by the department or agency managing the land on behalf of the provincial or federal Crown.

Under the *Oil and Gas Conservation Act*, *Oil and Gas Conservation Rules*, *Geothermal Resource Development Rules*, and *Brine-Hosted Mineral Resource Development Rules,* the AER is responsible for developing and maintaining requirements for managing **oilfield waste,** including drilling waste, and ensuring that waste is stored, treated, and disposed of as per AER requirements. Thus, the AER must align its waste management requirements with provincial soil quality and remediation guidelines and with reclamation requirements. If the AEPA develops new soil quality guidelines or updates the existing soil remediation guidelines, the revised guidelines will supersede the guidelines in section 3 of this directive.

1.4 What's New in This Edition

The drilling waste management requirements in this directive apply to brine-hosted mineral developments.

1.5 Landowner, Department, or Agency Consent

A well site and pipeline right-of-way require a written agreement to access the land from the **landowner** or from the department or agency managing the land on behalf of the provincial or federal Crown (e.g., a surface lease or disposition under the *Public Lands Act*). In the case of private land, where landowner consent is not obtained, a right-of-entry order from the Land and Property Rights Tribunal is required.

Except for the burial of **cement returns**, additional landowner, department, or agency consent is not required to manage drilling waste on the well site on which it was generated. Landowner, department, or agency consent is not required to manage directional drilling waste from pipeline construction on the pipeline's right-of-way once the right-of-way surface has been disturbed because of other construction activities (e.g., **topsoil** has been removed, right-of-way is under construction, or disturbance from pipeline work).

1) The licensee must obtain written consent (agreement) from the landowner, department, or agency to

   a) manage drilling waste from pipeline construction on the associated pipeline right-of-way once the right-of-way surface has been restored and is being used by the landowner, department, or agency (also applies to **landspraying**, **landspraying while drilling**, and **pump-off** of drilling waste onto a restored pipeline right-of-way);

   b) manage drilling waste outside the well site or pipeline right-of-way boundaries using the landspray, landspray while drilling, disposal onto forested public lands, or pump-off method;

   c) store, mix-bury-cover, landspread, or use an alternative method (e.g., land treat or biodegrade in a contained system) for treating drilling waste on a remote site from the well site or pipeline right-of-way; and

   d) for private land only, place cement returns in pits on a well site or remote site when the combined area of one or more pits exceeds four square metres (m^2).

2) Licensees must provide a copy of a document called *Information for Landowners on Consent for the Disposal, Treatment, or Storage of Drilling Wastes* to the owners of any land on which licensees plan to manage drilling waste (includes well sites, remotes sites, and disturbed pipeline rights-of-way).

The *Information for Landowners on Consent for the Disposal, Treatment, or Storage of Drilling Wastes* document and frequently asked questions on drilling waste management are found on the AER website at www.aer.ca under Rules and Directives > Directives > *Directive 050*.

Before consenting to have the drilling waste applied to their land, some landowners, departments, or agencies may impose conditions in addition to the requirements set out this directive. The decision regarding monitoring of additional conditions is between the licensee generating the drilling waste and the landowner, department, or agency.

Table 1 specifies the consent required for each land type.

Table 1. Consent by land type

Land type	Consent (landowner, department, agency)
Private land	Landowner. Typically, a written agreement that the licensee will draft with the landowner
Public lands	AER (through the disposition and approval process under the *Public Lands Act*)
First Nations lands	Indian Oil and Gas Canada (IOGC) or Indian and Northern Affairs Canada (Alberta Region) must provide approval for the disposal of drilling waste on First Nation Indian Reserves; IOGC will facilitate the necessary approvals
Métis settlement lands	Affected settlement council
Canadian Forces Base Suffield (wholly owned federal lands)	Department of National Defence (through consent from the base commander)
Canadian Forces Base—Area Support Unit, Wainwright (mix of federally owned and leased provincial lands)	Department of National Defence (through consent from the base commander) and AEPA
Cold Lake Air Weapons Range (leased provincial lands)	Department of National Defence (through consent from the wing commander) and AEPA
Canadian Forces Base Cold Lake (wholly owned federal lands)	Department of National Defence (through consent from the wing commander)

1.6 Reclamation Obligations for Sites Used to Manage Drilling Waste

The methods to store, mix-bury-cover, or landspread drilling waste require extensive management and involve significant land disturbance, requiring the affected sites to be reclaimed. If these methods are used on the well site, the affected area will typically be reclaimed when the well site is reclaimed. If a remote site is used to manage drilling waste, licensees are responsible for reclaiming the remote site to equivalent land capability.

Sites defined as “specified lands” in *EPEA* are subject to the legislated reclamation certification process. For sites not defined as “specified lands,” the reclamation process is through the department or agency identified in table 1.

Landspray, landspray while drilling, and pump-off drilling waste methods typically occur outside the well site or pipeline right-of-way boundaries and involve limited land disturbance. Hence, sites used to manage drilling waste by these methods are not required to undergo the reclamation process.

The disposal onto forested public lands method is limited by the AER to certain types of dispositions issued under the *Public Lands Act* (see section 8).

2 Overview of Drilling Waste Management Methods

The methods set out in this directive address one-time disposal or management techniques for managing drilling waste generated from a well, a licensee drilling program, or waste from pipeline directional drilling.

Each management method shown in figure 1 has its specific requirements and limitations, which along with the characteristics of the drilling waste, needs to be considered when selecting a method.

Directive 058 provides requirements for sending drilling waste to approved waste management facilities or using mobile thermal treatment units to manage drilling waste.

Alteration of a drilling waste management method set out in this directive or using a method not prescribed in this directive, such as biodegradation or subsurface, requires prior approval from the AER (see section 15).

3) Licensees may not use mix-bury-cover or landspread to manage drilling waste from **hydrocarbon-based mud systems** unless the waste has undergone biodegradation.

4) Drilling waste disposal on a pipeline right-of-way is limited to drilling waste generated from the construction of that pipeline right-of-way.

5) If the site has previously been used for disposal, licensees must only proceed with the mix-bury-cover and landspread disposal if

   a) disposal occurs on an area of the site not previously used for drilling waste disposal, and all mix-bury-cover or landspread requirements are met; and

   b) the use of the site for drilling waste management or multiple disposals does not exceed five years, and any reuse of a **storage system** has followed the requirements set out in section 6.6.

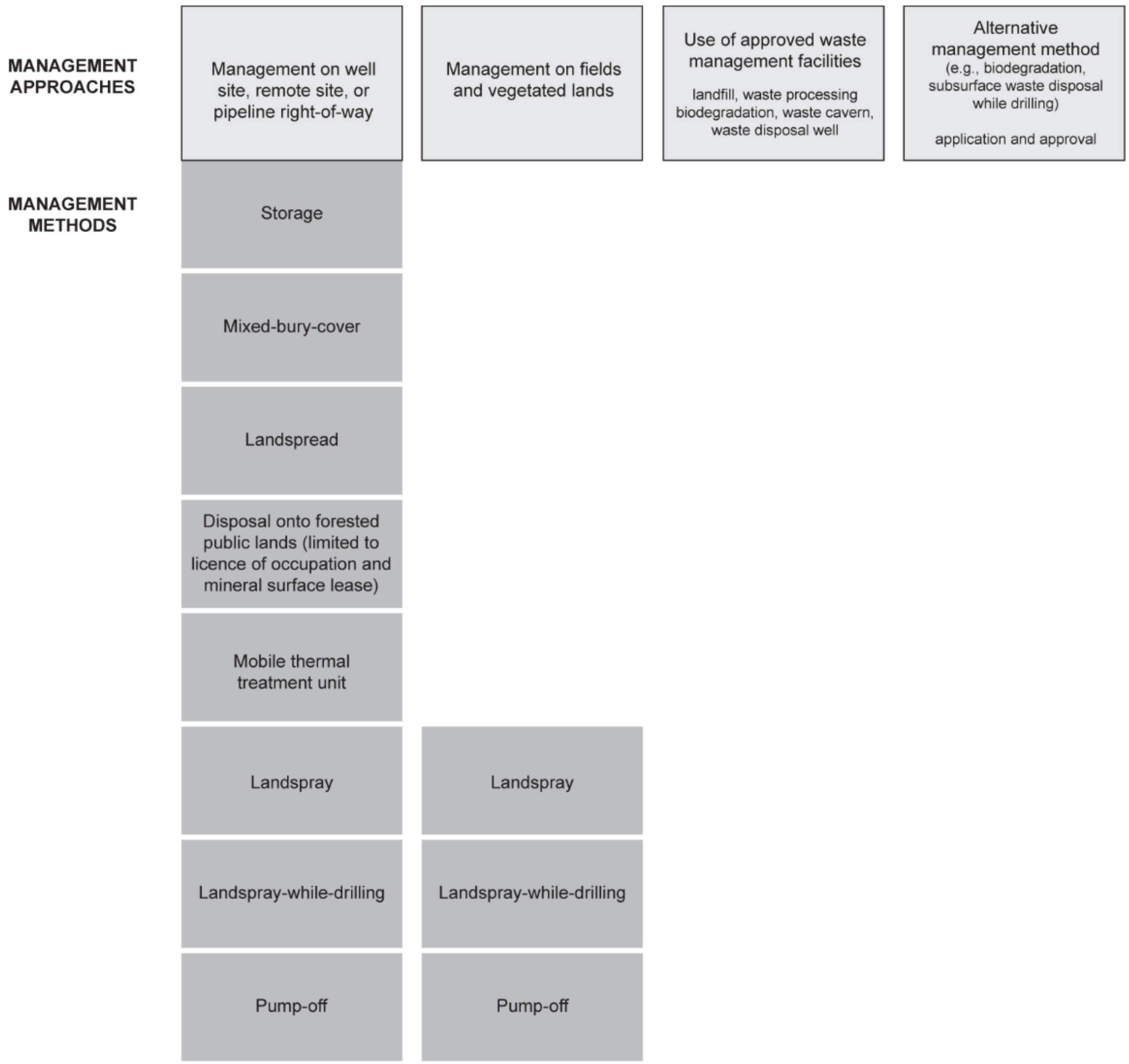

Figure 1. Drilling waste management approaches and methods

3 Assessment for Sites Used to Manage Drilling Waste

Assessment of receiving soils is necessary to determine the suitability of the specific disposal method.

3.1 Soil Endpoint Requirements

Tables 2, 3, and 5 set out the salt, hydrocarbon, and metal endpoints for soils that have received drilling waste. The AER has adopted these endpoints from the latest edition of *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*.

6) If the Government of Alberta develops new soil quality guidelines or updates its existing soil remediation guidelines, licensees must adjust the endpoints set out in tables 2, 3, and 5 accordingly.

Licensees wishing to use alternative soil endpoint criteria are required to apply to the AER as per the process described in section 15.

3.2 Soil Salinity Endpoint Requirements

The criteria set out in table 2 identify suitable soil horizon and rating categories for each drilling waste disposal method and acceptable initial soil and final soil-waste salinity endpoints. See appendix 3 for calculations, correction factors, and soil-waste lab mixes that can help meet the salinity endpoints.

7) Licensees must sample the receiving soil of the **disposal area** at the soil horizon and depth appropriate for the disposal method and analyze it to verify that the background soil **electrical conductivity** (EC) and **sodium adsorption ratio** (SAR) values are within the initial salinity criteria specified in table 2.

8) For each disposal method and applicable soil horizon and depth, licensees must ensure the soil-waste mix does not exceed the soil salinity endpoints in table 2.

Table 2. Soil salinity endpoints

Disposal method	**Receiving soil horizon, category[a], and limiting initial salinity criteria**	**Electrical conductivity (EC) changes from background soil conditions (dS/m)**	**Sodium adsorption ratio (SAR) changes from background soil conditions**	**Maximum sodium (Na) and nitrogen[b] (N) loading (kg/ha) and maximum [N] concentration (mg/kg)**	**Post-disposal soil sampling triggers**
Pump-off	Topsoil[c] Good category EC <2 dS/m SAR <4	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil EC, but not to exceed an EC[d] of 2 dS/m	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil SAR, but not to exceed a SAR of 4	Na 250 N 25	Waste EC >5 dS/m N loading rate >20 kg/ha Na loading rate >150 kg/ha
Disposal onto forested public lands	Topsoil Good category EC <2 dS/m SAR <4	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil EC, but not to exceed an EC[d] of 2 dS/m	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil SAR, but not to exceed a SAR of 4	Na 250 N 25	Waste EC >8 dS/m N loading rate >20 kg/ha Na loading rate >150 kg/ha
Landspray, landspray while drilling	Topsoil Good category EC <2 dS/m SAR <4	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil EC, but not to exceed an EC[d] of 2 dS/m	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil SAR, but not to exceed a SAR of 4	Na 250 N 25	Waste EC >10 dS/m N loading rate >20 kg/ha Na loading rate >150 kg/ha
Landspread	Subsoil[e] to 1 m Good category EC <3 dS/m SAR <4	Soil-waste mix limited to a maximum increase of 2 units beyond background soil EC, but not to exceed an EC of 3 dS/m	Soil-waste mix limited to a maximum increase of 3 units beyond background soil SAR, but not to exceed a SAR of 6	Na not applicable N 400	Landspread only, waste EC >8 dS/m or N loading rate >300 kg/ha
Landspread	Subsoil to 1 m Fair category EC of 3 to 5 dS/m SAR of 4 to 8	Soil-waste mix limited to a maximum increase of 1 unit beyond background soil EC	Soil-waste mix limited to a maximum increase of 2 units beyond background soil SAR	Na not applicable N 400	Landspread only, waste EC >8 dS/m or N loading rate >300 kg/ha

Disposal method	Receiving soil horizon, category[a], and limiting initial salinity criteria	Electrical conductivity (EC) changes from background soil conditions (dS/m)	Sodium adsorption ratio (SAR) changes from background soil conditions	Maximum sodium (Na) and nitrogen[b] (N) loading (kg/ha) and maximum [N] concentration (mg/kg)	Post-disposal soil sampling triggers
Mix-bury-cover	Subsoil between 1 and 1.5 m Good or fair category EC ≤5 SAR ≤8	Soil-waste mix limited to a maximum increase of 2 units beyond background soil EC	Soil-waste mix limited to a maximum increase of 4 units beyond background soil SAR	Na not applicable [N] coarse soil[f] = 10 mg/kg or [N] fine soil[g] = 40 mg/kg	Waste EC >10 dS/m or [Na] >3000 mg/L or [N] (wet weight) for coarse soil disposal ≥6 mg/kg or fine soil disposal ≥120 mg/kg
Mix-bury-cover	Subsoil 1.5 m and deeper Good, fair, poor, or unsuitable category	Soil-waste mix limited to a maximum increase of 3 units beyond background soil EC	Soil-waste mix limited to a maximum increase of 6 units beyond background soil SAR	Na not applicable [N] coarse soil[f] = 10 mg/kg or [N] fine soil[g] = 40 mg/kg	Waste EC >10 dS/m or [Na] >3000 mg/L or [N] (wet weight) for coarse soil disposal ≥6 mg/kg or fine soil disposal ≥120 mg/kg

Exercise caution when applying saline waste to hay and pastureland where salt-sensitive plant species are growing. Salt-sensitive species include red clover, alsike clover, alfalfa, and timothy. The potential for damage to vegetation is especially high when the soil is dry. Use extreme caution when conducting disposals on no-till fields in the spring before seeding.

dS/m = decisiemens per metre

[a] Receiving soil categories are defined in accordance with Alberta Environment's *Salt Contamination Assessment and Remediation Guidelines* (2001).

[b] Total mineral nitrogen (i.e., ammonium-nitrogen, nitrate-nitrogen, and nitrite-nitrogen) and the loading rate must be prorated to the total area of land used for disposal.

[c] Topsoil is the uppermost soil layer consisting of the L, F, H, O, or A horizons or the depth of tillage, whichever is greater.

[d] Some plant species will be sensitive to salinity levels below 2 dS/m (e.g., flax, clover, beans, some wheat varieties, peas, some garden crops, and some forest species). Drilling waste disposal must not cause adverse effects to these species.

[e] Subsoil is the layer of soil directly below the topsoil. It consists of the B and C horizons and extends to bedrock. For salinity management, three depths are recognized: top of the subsoil to a depth of 1 m; subsoil from >1 to 1.5 m; and subsoil at a depth >1.5 m.

[f] Coarse soils have a median grain size >75 microns.

[g] Fine soils have a median grain size ≤75 microns.

3.3 Soil Hydrocarbon Endpoint Requirements

Table 3 sets out the hydrocarbon soil quality endpoints for soils receiving drilling waste. Endpoints are identified for coarse- and fine-grained soils for three different land uses: natural area, agricultural, and residential-parkland. See appendix 4 for guidance on predicting hydrocarbon concentrations in soil-waste mixes.

9) Licensees must prevent soils receiving drilling waste from exceeding the hydrocarbon endpoints set out in table 3 and the concentrations in table 4.

Table 3. Soil hydrocarbon endpoints (dry weight) by land use

	Natural area land use		Agricultural land use		Residential-parkland land use	
Hydrocarbon fraction	Fine soil[a] (mg/kg)	Coarse soil[b] (mg/kg)	Fine soil (mg/kg)	Coarse soil (mg/kg)	Fine soil (mg/kg)	Coarse soil (mg/kg)
F1 (C6–C10, excluding BTEX)[c]	210	210	210	24	210	24
F2 (>C10–C16)	150	150	150	130	150	130
F3 (>C16–C34)	1 300	300	1 300	300	1 300	300
F4 (>C34)	5 600	2 800	5 600	2 800	5 600	2 800
Benzene	0.046	0.078	0.046	0.015	0.046	0.015
Toluene	0.52	0.12	0.52	0.12	0.52	0.12
Ethylbenzene	0.073	0.14	0.073	0.14	0.073	0.14
Xylene	0.99	1.9	0.99	1.9	0.99	1.9

[a] Fine soils have a median grain size ≤75 microns.

[b] Coarse soils have a median grain size >75 microns.

[c] BTEX = benzene, toluene, ethyl benzene, and xylene

Table 4. Hydrocarbon concentration in drilling waste

		Concentration of hydrocarbon fraction in drilling waste (wet and dry weight in mg/kg) correlated to specific gravity (SG) of drilling waste[a]							
Waste SG	Parameter	F1	F2	F3	F4	Benzene	Toluene	Ethyl-benzene	Xylenes
1.1	Wet wt.	104	565	1 304	12 169	0.07	0.52	0.32	4.3
	Dry wt.	714	3 870	8 930	83 345	0.45	3.57	2.20	29
1.2	Wet wt.	99	535	1 235	11 529	0.06	0.49	0.30	4.1
	Dry wt.	369	2 000	4 615	43 072	0.23	1.85	1.10	15
1.3	Wet wt.	94	510	1 177	10 989	0.06	0.47	0.29	3.9
	Dry wt.	254	1 377	3 177	29 648	0.16	1.27	0.77	10.5
1.4	Wet wt.	90	489	1 128	10 525	0.06	0.45	0.27	3.7
	Dry wt.	197	1 065	2 457	22 936	0.12	0.98	0.60	8.1
1.5	Wet wt.	87	470	1 085	10 123	0.05	0.43	0.26	3.6
	Dry wt.	162	878	2 026	18 909	0.10	0.81	0.49	6.7
1.6	Wet wt.	84	454	1 047	9 771	0.05	0.42	0.25	3.5
	Dry wt.	139	753	1 738	16 224	0.09	0.70	0.42	5.7
1.7	Wet wt.	81	439	1 014	9 461	0.05	0.41	0.25	3.3
	Dry wt.	123	664	1 533	14 306	0.08	0.61	0.37	5.1

		Concentration of hydrocarbon fraction in drilling waste (wet and dry weight in mg/kg) correlated to specific gravity (SG) of drilling waste[a]							
1.8	Wet wt.	79	426	984	9 185	0.05	0.39	0.24	3.2
	Dry wt.	110	597	1 379	12 868	0.07	0.55	0.34	4.5
1.9	Wet wt.	77	415	958	8 939	0.05	0.38	0.23	3.2
	Dry wt.	101	546	1 259	11 749	0.06	0.50	0.31	4.2
2.0	Wet wt.	75	405	934	8 716	0.05	0.37	0.23	3.1
	Dry wt.	93	504	1 163	10 854	0.06	0.47	0.28	3.8
2.1	Wet wt.	73	395	912	8 516	0.05	0.36	0.22	3.0
	Dry wt.	87	470	1 085	10 122	0.05	0.43	0.26	3.6
2.2	Wet wt.	71	387	893	8 333	0.04	0.36	0.22	2.9
	Dry wt.	82	442	1 019	9 512	0.05	0.41	0.25	3.4
2.3	Wet wt.	70	379	875	8 166	0.04	0.35	0.21	2.9
	Dry wt.	77	418	964	8 996	0.05	0.39	0.23	3.2
2.4	Wet wt.	69	372	859	8 013	0.04	0.34	0.21	2.8
	Dry wt.	73	397	916	8 553	0.05	0.37	0.22	3.0
2.5	Wet wt.	67	366	843	7 873	0.04	0.34	0.21	2.8
	Dry wt.	70	379	875	8 170	0.04	0.35	0.21	2.9

[a] Calculated using *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*, a soil-waste mix ratio of 3:1, and a soil dry bulk density of 1540 kg/m^3.

3.4 Soil Metal Endpoint Requirements

Table 5 sets out the metal soil quality endpoints for soils receiving drilling waste. Licensees are expected to review the **drilling mud** additives that will be used in their drilling mud system to determine if barite is present.

10) The use of barite in the drilling mud system will determine which of the following analytical methods the licensee must use:

    a) If barite is used, use the barium fusion inductively coupled plasma analysis method to determine the barite concentration.

    b) If barite is not used, use the total digest method to determine the total barium concentration.

Where the soil-waste mix is expected to exceed the total barium value, licensees can follow AEPA's *Soil Remediation Guidelines for Barite: Environmental Health and Human Health* to determine if the barite guidelines can be used at a particular site. See appendix 5 for guidance predicting metal concentrations in drilling waste and soil-waste mixes.

11) Licensees must prevent soils receiving drilling waste from exceeding the metal endpoints set out in table 5 and the concentrations in tables 6 and 7.

Table 5. Soil metal endpoints – guideline values (dry weight)

	Guideline value (mg/kg except boron)		
Metal	**Agricultural land use**	**Natural area land use**	**Residential/parkland land use**
Antimony	20	20	20
Arsenic (inorganic)	17	17	17
Barium	750	750	500
Barite-barium[1]	10 000	10 000	10 000
Beryllium	5	5	5
Boron (mg/L saturated paste extract)	3.3	3.3	3.3
Cadmium	1.4	3.8	10
Chromium (total)	64	64	64
Chromium (hexavalent)	0.4	0.4	0.4
Cobalt	20	20	20
Copper	63	63	63
Lead	70	70	140
Mercury (inorganic)	6.6	12	6.6
Molybdenum	4	4	4
Nickel	45	45	45
Selenium	1	1	1
Silver	20	20	20
Thallium	1	1	1
Tin	5	5	5
Uranium[a]	23	33	23
Vanadium	130	130	130
Zinc	250	250	250

[a] Alberta Environment's *Soil Remediation Guidelines for Barite: Environmental Health and Human Health* (2009) must be followed to determine if the site qualifies as a barite site. If it does not, then the 750 mg/kg total barium value applies.

Table 6. Metal concentration in drilling waste

		Concentration of metal in drilling waste (wet and dry weight in mg/kg) correlated to specific gravity (SG) of drilling waste[a]																				
Waste SG[b]	Para-meter	Antimony	Arsenic	Barium	Barite-Ba	Beryllium	Cadmium	Chromium (total)	Chromium (hexavalent)	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel[4]	Selenium	Silver	Thallium	Tin	Uranium	Vanadium	Zinc
1.1	Wet wt.	86	49	2 500	43 000	20	5.2	200	1.7	53	210	260	29	14	103	2.7	86	3.6	16	92	450	843
	Dry wt.	592	333	17 147	292 482	140	35.9	1 358	11.8	365	1 415	1 796	196	99	707	18.3	587	24.6	109	627	3 064	5 773
1.2	Wet wt.	82	47	2 400	40 500	19	5.0	190	1.6	52	200	250	27	14	101	2.6	81	3.4	15	87	430	806
	Dry wt.	306	175	8 948	151 241	73	18.7	711	6.1	193	739	933	101	51	376	9.6	303	12.8	57	325	1 597	3 012
1.3	Wet wt.	78	45	2 304	39 000	19	4.8	180	1.6	50	190	240	26	13	98	2.5	77	3.3	15	83	410	775
	Dry wt.	211	122	6 216	104 161	50	12.9	495	4.2	135	514	645	70	36	266	6.8	209	8.9	40	224	1 108	2 091
1.4	Wet wt.	75	44	2 200	37 000	18	4.6	180	1.5	49	180	230	25	13	97	2.4	74	3.2	14	80	400	748
	Dry wt.	163	96	4 849	80 621	39	10.0	388	3.3	106	401	501	54	28	210	5.3	162	6.9	31	174	864	1 631
1.5	Wet wt.	72	43	2 200	36 000	17	4.4	170	1.4	48	180	220	24	12	95	2.4	71	3.1	14	77	380	725
	Dry wt.	134	80	4 029	66 496	32	8.3	323	2.7	89	333	415	44	23	177	4.5	133	5.7	26	144	717	1 355
1.6	Wet wt.	69	42	2 100	34 000	17	4.3	170	1.4	47	170	220	23	12	94	2.3	69	3.0	13	74	370	705
	Dry wt.	115	70	3 483	57 080	28	7.2	280	2.3	78	288	358	38	20	155	3.9	114	4.9	22	124	619	1 171
1.7	Wet wt.	67	41	2 000	33 000	16	4.2	170	1.3	46	170	210	22	12	92	2.3	67	2.9	13	72	360	687
	Dry wt.	102	62	3 092	50 355	24	6.3	249	2.0	69	256	317	34	18	140	3.5	101	4.4	20	109	549	1 039
1.8	Wet wt.	65	40	2 000	32 000	16	4.1	160	1.3	45	170	200	22	11	91	2.3	65	2.8	13	70	360	671
	Dry wt.	91	57	2 800	45 310	22	5.7	226	1.8	63	232	286	30	16	128	3.2	91	3.9	18	99	497	940
1.9	Wet wt.	64	40	2 000	31 000	15	4.0	160	1.3	44	160	200	21	11	90	2.2	63	2.8	13	69	350	657
	Dry wt.	84	52	2 572	41 387	20	5.2	208	1.7	58	213	262	28	15	119	2.9	83	3.6	17	90	456	864
2.0	Wet wt.	62	39	1 900	31 000	15	3.9	160	1.2	44	160	200	20	11	89	2.2	62	2.7	12	67	340	644
	Dry wt.	77	49	2 390	38 248	19	4.9	193	1.5	55	198	243	25	13	111	2.7	77	3.4	15	83	423	802
2.1	Wet wt.	61	39	1 900	30 000	15	3.8	150	1.2	43	160	190	20	11	88	2.2	60	2.6	12	66	330	633
	Dry wt.	72	46	2 241	35 680	17	4.5	182	1.4	51	186	227	24	13	105	2.6	72	3.1	14	78	397	752
2.2	Wet wt.	59	38	1 900	29 000	14	3.7	150	1.2	43	150	190	20	10	88	2.1	59	2.6	12	64	330	622
	Dry wt.	68	43	2 116	33 540	16	4.3	172	1.4	49	176	214	22	12	100	2.4	67	3.0	14	73	375	710
2.3	Wet wt.	58	38	1 800	29 000	14	3.7	150	1.2	42	150	180	19	10	87	2.1	58	2.6	12	63	320	613
	Dry wt.	64	41	2 011	31 729	15	4.1	164	1.3	47	167	203	21	11	96	2.3	64	2.8	13	69	356	675
2.4	Wet wt.	57	37	1 800	28 000	14	3.6	150	1.1	42	150	180	19	10	86	2.1	57	2.5	12	62	320	604
	Dry wt.	61	40	1 921	30 177	15	3.9	156	1.2	45	160	193	20	11	92	2.2	60	2.7	12	66	340	645
2.5	Wet wt.	56	37	1 800	28 000	14	3.6	150	1.1	41	150	180	19	10	86	2.1	56	2.5	11	61	310	596
	Dry wt.	58	38	1 846	28 832	14	3.7	150	1.2	43	153	185	19	10	89	2.2	58	2.6	12	63	326	618
Background metal value used		0.12	6	180	180	0.3	0.2	19	0.002[c]	8	16	10	0.03	0.7	22	0.4	0.3	0.18	1.4	2	28	58

[a] Calculated using Alberta-specific metal background values (except Canadian Council of Ministers of the Environment's *Soil Quality Guidelines for the Protection of Environmental and Human Health* used for uranium), *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*, a soil-waste mix ratio of 3:1, and a soil dry bulk density of 1540 kg/m^3.

[b] See appendix 6 for information on specific gravity.

[c] Median value used for background.

Table 7. Boron concentration in drilling waste

Waste specific gravity	Boron in waste filtrate[a] (mg/L)	Boron in waste saturated paste[b] (mg/L)
1.1	8	40
1.2	9	20
1.3	10	14
1.4	11	11
1.5	13	9
1.6	14	8
1.7	16	7
1.8	18	6
1.9	22	6
2.0	25	5
2.1	31	5
2.2	39	5
2.3	51	4
2.4	73	4
2.5	125	4

Boron in saturated paste extract correlated to specific gravity of drilling waste.

[a] Calculated using Alberta-specific metal background values, *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*, a soil-to-waste mix ratio of 3:1, and a soil dry bulk density of 1540 kg/m^3.

[b] Background boron value used: 0.1.

3.5 Receiving Soil Assessment and Disclosure of Exceedance of Soil Endpoint Requirements

The application of drilling waste onto or into soil requires assessment of the receiving soil conditions at the disposal location and the soil-waste mixing depth for the specific disposal method. Post-disposal sampling requirements are set out in the section specific to each disposal method.

See section 5 for field-screening requirements to determine initial soil salinity and suitability for receipt of drilling waste.

12) When assessing receiving soil conditions, licensees must ensure each sampling site is representative of

    a) the landscape within the proposed disposal area and of the most sensitive part of the landscape (e.g., convergent foot slopes and toe slopes are usually the most sensitive parts of the landscape and may have naturally higher levels of sodium and sulphate or may have concentrated parameters from previous drilling waste disposals) and

b) any previous drilling waste disposals within the disposal area.

13) For landspray, landspray while drilling, and disposal onto forested lands, licensees must collect samples for assessing pre- and post-disposal (where applicable) soil conditions as follows:

a) Select one sampling site for every four hectares (ha) of a disposal area.

b) Ensure each sampling site is a circular area with a 10 m radius and a centre precisely located and documented by GPS using the Universal Transverse Mercator (UTM) coordinate system, including bearing and distance in metres from a fixed point.

c) At a minimum, collect one **composite sample** from the 0 to 10 centimetres (cm) soil depth increment from each sampling site. Take the sample from the soil profile beneath the leaf litter layer if present. Each composite sample must comprise five subsamples.

14) When post-disposal sampling is required, licensees must sample the soil-waste mix within 60 days of the disposal and analyze it to verify that the endpoints specified in tables 2, 3, and 5 and the concentrations in tables 4, 6, and 7 have not been exceeded. The post-disposal sampling and analysis must include

a) lab analysis of the samples (i.e., field screening is not acceptable) as per section 5 and

b) an assessment of soil particle size using discrete samples (not composite) of the soil or soil-waste mix to analyze for hydrocarbon fractions set out in table 3.

15) If the post-disposal or cement pit sample results exceed any of the soil endpoints in tables 2, 3, or 5, then licensees must email the AER at Directive050@aer.ca and provide a PDF notification disclosing the exceedance as a noncompliance event. The notice of disclosure must describe the situation (i.e., the type of disposal and drilling waste and the soil endpoints that are exceeded) and include a plan to remedy the exceedance (i.e., reduce the exceedance to acceptable levels).

The AER will return incomplete notifications to the licensee and will consider the start of any activity associated with the notification as a noncompliance.

3.6 Drilling Waste Disposal Setbacks

16) For the landspray, landspray while drilling, disposal onto forested public lands, and pump-off disposal methods, licensees must ensure disposal does not occur within

a) 10 m of a road ditch or property line,

b) 50 m of a water well,

c) 100 m of a water body, or

d) 50 m of a water body if

i) the water body is upgradient of the storage system or

ii) the landscape creates a physical barrier that prevents the drilling waste from migrating towards the water body.

17) For mix-bury-cover and landspread disposal methods, licensees must ensure disposal does not occur within 10 m of an on-site rig water well.

4 Drilling Waste Assessment

4.1 General Drilling Waste Sampling and Assessment

Appropriate sample collection, preservation, and storage are essential to acquiring useful data to assess drilling waste and determining suitable disposal methods.

4.2 Drilling Waste Sampling Requirements

18) Where a **storage system** has an area less than or equal to 500 m^2, licensees must obtain a representative composite drilling waste sample comprising equal amounts of five subsamples.

19) Where a storage system has an area greater than 500 m^2, licensees must obtain a representative composite drilling waste sample comprising equal amounts of one subsample for every 100 m^2 to a maximum of ten subsamples.

20) Samples must be taken at least 1 m from the edge of the storage system.

21) If the suction and discharge points of a storage system are identifiable, licensees must ensure one subsample is taken at each point.

22) If the fluid (i.e., **clear liquids**) or **solid** phases of the drilling waste are managed separately, licensees must obtain a representative composite drilling waste sample for each phase.

23) Licensees must ensure subsamples are collected from the entire depth of each phase and keep any hydrocarbon layer in the sample if the hydrocarbon is not being removed from the drilling waste before disposal.

24) If the fluid and solid phases of the drilling waste are jointly managed, licensees must take each subsample comprising the representative composite drilling waste samples from the entire depth of each phase at one time (i.e., not made up of individually sampled phases).

25) Licensees must identify on a sketch of the storage system the locations and depths of the subsamples taken to obtain the representative composite drilling waste sample.

26) Licensees must divide the representative composite drilling waste sample into containers for the analysis and provide the data to support the method used to manage the drilling waste.

27) If the drilling waste management method starts 30 days to 6 months after the original sampling date, licensees must determine the pH, EC, and SAR of the drilling waste using field-screening methods in section 5 to ensure the parameters are consistent with the original analysis.

28) If the drilling waste management method does not start within six months of the original sampling date, licensees must resample and analyze the drilling waste.

29) Immediately before implementing the waste management method, licensees must inspect the drilling waste storage system to determine if materials have been added to the drilling waste.

30) If field-screening tests or an inspection indicate that materials may have been added to the drilling waste since the original sampling date, licensees must resample and analyze the drilling waste.

31) Licensees must sample the drilling waste by taking either

a) a **total waste** (fluids and solids) sample if both phases are being managed by mix-bury-cover or landspread or

b) a solids sample if only the solid phase is being managed by mix-bury-cover or landspread.

4.3 Drilling Waste Assessment and Toxicity Requirements

32) Licensees must ensure analyses for EC, SAR (sodium, calcium, magnesium), and forms of nitrogen (including ammonium-nitrogen [NH_3-N], nitrate-nitrogen [NO_3-N], and nitrite-nitrogen [NO_2-N]) are done

a) in **oversaturated drilling waste samples** using as-received filtrate; clarified filtrate generated by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent;

b) in undersaturated drilling waste samples using a saturated paste extract.

33) Licensees must conduct metal and hydrocarbon content analyses on the as-received drilling waste samples. Screening methods can be used to determine hydrocarbon content in drilling waste samples. However, hydrocarbon content in soils and soil-waste mixtures must be determined using the procedures and methods referenced in the latest edition of *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*.

34) Licensees must use the luminescent bacteria toxicity test to evaluate drilling waste toxicity. The pass threshold for a drilling waste to be considered nontoxic is 75 per cent for an **EC50(15)** (i.e., a drilling waste aqueous concentration that halves the initial light output of luminescent bacteria after 15 minutes must be 75 per cent or higher). See appendix 6 for reference methods and procedures for toxicity testing using luminescent bacteria.

35) If the EC50(15) value of the toxicity test is less than 75 per cent, licensees must have a lab treat the drilling waste sample with coarse activated carbon (charcoal) and test the charcoal-treated sample for toxicity using luminescent bacteria (see appendix 6 for more information).

36) If the charcoal-treated drilling waste passes the toxicity test (EC50[15] ≥75 per cent), licensees must then test for hydrocarbon content (**BTEX** [benzene, toluene, ethyl benzene, and xylene] and **hydrocarbon fractions F1 to F4**). If analysis identifies the presence of hydrocarbons and they are the likely source of toxicity, the disposal may only proceed once all relevant criteria for the disposal method are met. Charcoal treatment is to be done by lab analysis before land disposal.

37) For drilling waste with an original EC50(15) value or charcoal-treated EC50(15) value less than 75 per cent (indicating toxicants), licensees must

a) gather more data to determine the cause of toxicity before proceeding with disposal or

b) send the drilling waste to an **approved waste management facility** or use an alternative method approved by the AER.

Toxicity unattributable to hydrocarbon content indicates the need to treat and retest drilling waste before disposal. Toxicological information should be reviewed for all **additive**s and **mud products** used to formulate the drilling mud; where information about an additive or product is unknown, its contribution to toxicity cannot be dismissed. Operating practices at the well site should be reviewed to determine whether other circumstances could have caused toxicity to develop (e.g., adding camp sewage or rig waste, such as chain oil, pipe dope, or rig wash, to the storage system).

38) If in-field treatments are conducted (e.g., **pH** adjustment) to reduce drilling waste toxicity, licensees must resample and retest the drilling waste to determine if it meets the toxicity requirements. Additional lab testing may be required to determine whether field treatment methods will reduce toxicity. Figure 2 shows the decision-making process described in this section.

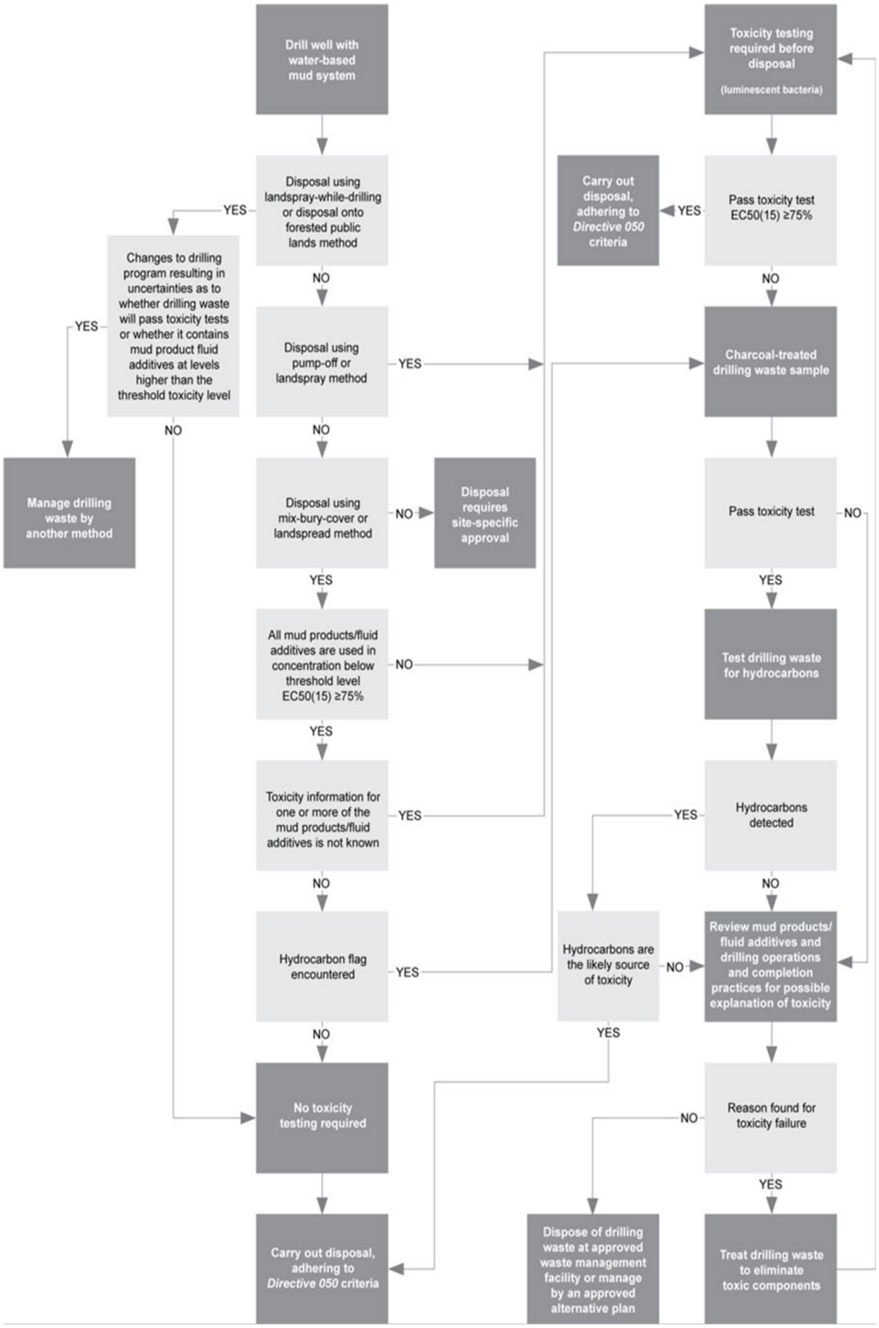

Figure 2. Drilling waste toxicity assessment decision tree

39) If the waste is treated, licensees must resample and reanalyze the waste to determine the applicability of the disposal method.

40) For pipeline drilling activities, licensees must evaluate the toxicity of additives and products used in the drilling mud system to verify that all are used in concentrations below the accepted pass threshold for the luminescent bacteria toxicity test (EC50[15] ≥75 per cent). Drilling mud systems composed solely of nonsaline water or nonsaline water and **bentonite** do not require toxicity evaluations.

41) The mechanism used to evaluate the toxicity of the system must be addressed in the licensee's disposal management plan submitted for approval under this directive.

42) If terrestrial toxicity testing is used (see appendix 6) to establish a threshold toxicity level for an additive or mud product, the licensee must provide information showing that luminescent bacteria toxicity testing is not a suitable method for the additive or mud product.

4.4 Generic Mud System Requirements

To mitigate uncertainties about metal content and toxicity of mud additives or products, licensees can develop a generic mud system, analyze it, and use the results to determine the suitability of landspray, landspray while drilling, and disposal onto forested public lands.

Using a generic mud system does not allow licensees to forgo field screening to assess the suitability of a drilling waste management method.

43) Licensees must

a) develop a lab-tested generic mud system that mimics the mud formulation that will be used for the drilling program (must contain the highest concentration of individual mud products and additives used), and

b) lab test the mud system for metals listed in table 5, toxicity (luminescent bacteria), and salinity in table 2 (EC, SAR, Na, NH_3-N, NO_3-N, NO_2-N) before use.

44) Licensees may proceed with disposal using landspray, landspray while drilling, and disposal onto forested public lands if the generic mud system

a) passes the luminescent bacteria toxicity test,

b) contains metal concentrations that do not exceed the soil metal endpoints in table 5, and

c) does not exceed the salinity endpoints set out in table 2.

45) Licensees must re-evaluate using landspray, landspray while drilling, or disposal onto forested public lands if drilling operations result in changes to the drilling mud waste composition (i.e., an increase in the concentration of additives or mud products, addition of new additives or mud products, or encountering a **hydrocarbon flag**). Licensees may continue using these methods if the change in waste composition meets the requirements specific to the method.

46) Licensees must monitor changes to the generic mud system by sampling and testing drilling waste for toxicity and metals from

a) 5 per cent of the wells drilled for the drilling program or

b) from at least two wells for a small drilling program where 5 per cent would be less than two wells.

Disposal may proceed before the sampling results are received if all other requirements for the landspray, landspray while drilling, or disposal onto forested public lands method are met.

47) If drilling waste sampling identifies a metal content exceeding the values in tables 6 or 7 or a toxicity threshold failure, licensees must sample the disposal area (drilling soil-waste mix) and analyze the samples to determine compliance with endpoints set out in tables 2, 3, and 5.

48) If sampling the disposal area identifies an exceedance of the endpoints in tables 2, 3, or 5, licensees must re-evaluate the continued use of landspray, landspray while drilling, and disposal onto forested public lands as suitable disposal methods for the remainder of the drilling program. See section 3.5 for disclosure of soil endpoint exceedance.

4.5 Drilling Waste Containing Radioactive Isotopes Requirements

Radioactive isotopes are sometimes added to drilling mud systems as tracers and will be present in the drilling waste.

The disposal of radioactive isotopes is regulated by the Canadian Nuclear Safety Commission (CNSC) as per the *Nuclear Substances and Radiation Devices Regulations*, which falls under the *Nuclear Safety Control Act*. Under section 5.1 of the regulations,

> a person may, without a licence, abandon or dispose of a radioactive nuclear substance if the activity or the activity concentration of the substance does not exceed its exemption quantity, conditional clearance level, or unconditional clearance level.

Drilling waste containing radioactive isotopes are subject to the CNSC regulations, so only waste with concentrations less than the prescribed quantities can be land applied following the methods outlined in this directive.

49) When land-applying drilling waste containing radioactive isotopes following a method in this directive, licensees must

a) ensure the concentration of the radioactive isotope used is documented and kept in the well or pipeline file, including any conversion factors used to demonstrate that the resulting concentration in the drilling waste is below the prescribed limits, and

b) disclose to relevant landowners that drilling waste disposed of on their land contains radioactive isotopes.

For information on control and disposal of recirculated radioactive contaminated sand from fracturing, see *Directive 058*.

5 Analytical Method and Field-Screening Requirements

Technical advances may render analysis methods obsolete. Consequently, this directive does not include a complete list of analytical protocols. For more information, see appendix 8 for references on analytical methods.

Figure 3 shows the field verification process.

50) To assess drilling waste, soils, and soil-waste mixes, licensees must refer to recognized and published analytical methods by accredited laboratories with quality assurance and quality control (QA/QC) programs in place.

51) Licensees must limit the use of field-screening test methods to assess

a) the suitability of soils to receive drilling waste,

b) the suitability of drilling waste for landspray while drilling and disposal onto forested public lands,

c) the minor treatment of drilling waste in the field (e.g., pH adjustment), and

d) the suitability for disposal of pipeline drilling waste composed solely of bentonite and nonsaline water.

52) Licensees may only use field-screening test methods to assess pH, EC, SAR (magnesium, sodium, calcium), nitrogen (NH_3-N, NO_3-N, NO_2-N), and hydrocarbons (i.e., BTEX and F1 to F4 fractions).

53) When choosing a field-screening test method, licensees must ensure

a) the detection range of the chosen method is appropriate for the characteristics of the waste or receiving soils being measured, and

b) the detection limit of the test encompasses the criteria the sample is being evaluated against (e.g., for receiving soils that must have an EC below two decisiemens per metre (dS/m), the method chosen to analyze the receiving soil sample must have a detection range below and above 2 dS/m).

54) Licensees must ensure all field-screening programs are supported by an ongoing quality assurance and quality control (QA/QC) program that includes the following:

a) training of field personnel on methods and instrumentation

b) equipment and instrument calibration and maintenance programs

c) documented standard operating procedures

d) verification of data quality objectives (e.g., lab truthing, use of duplicates and blanks, use of analytical methods in the correct range)

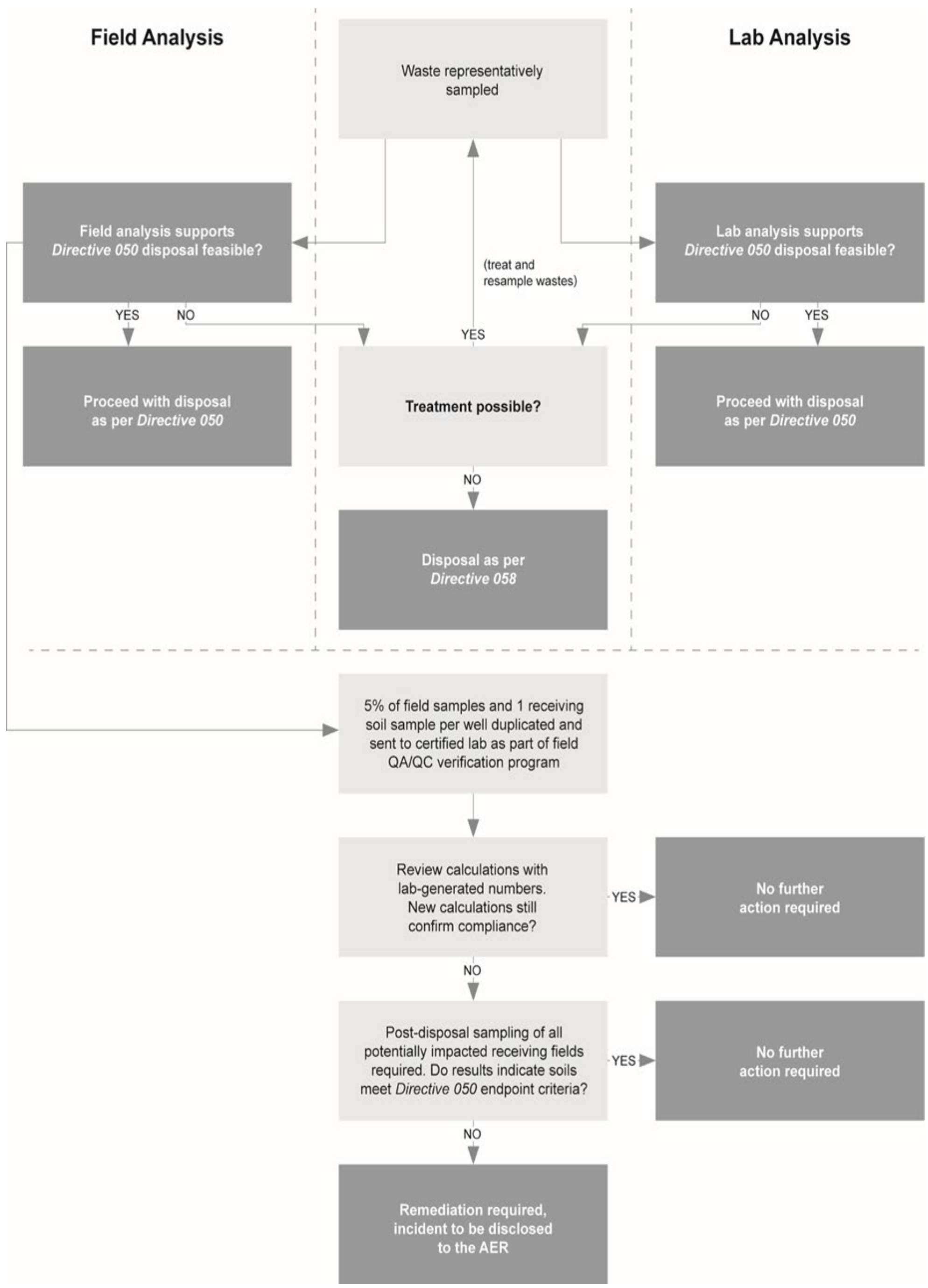

Figure 3. Field QA/QC verification program

55) Licensees must lab verify 5 per cent of field measurements and one receiving soil sample per well, and

   a) if any of the lab results are higher than the field results, recalculate the loading rates or spread rates using the lab results, or

   b) if the recalculated loading or spread rates exceed the section 3 soil endpoints, sample the receiving field (soil-waste mixture) after deposition of waste.

See section 3.5 for disclosure of soil endpoint exceedance.

6 Storage of Drilling Waste

Drilling waste can be stored on the well site or pipeline right-of-way where it was generated or at a remote site. Typical systems used to store drilling waste include the following:

- earthen excavations called sumps
- earthen-bermed structures built on grade
- aboveground **tanks**, bins, sumps lined with a synthetic liner, or other storage systems approved by the AER

See section 6.7 for storage system setback requirements.

6.1 General Drilling Waste Storage Requirements

56) Licensees must only put drilling waste into a storage system. It is prohibited to mix camp sewage or other oilfield waste (e.g., produced fluids, completion fluids, workover fluids, or spill material) with the drilling waste. It may be appropriate to direct rig washwater to a storage system provided only water-based drilling waste are stored in it and only nonsaline water is used to wash the rig; this activity needs to be considered when assessing the drilling waste as it could be a source of toxicity. If wishing to conduct other drilling waste treatment activities in a storage system, licensees must obtain written AER approval as set out in section 15 before implementing the treatment activity.

57) Licensees must only use a storage system to store drilling waste. Licensees may treat drilling waste in a storage system to adjust pH, facilitate solids and liquids separation, or reduce drilling waste toxicity.

58) Licensees must ensure drilling waste storage areas are kept clean. The drilling waste may not create or constitute a safety hazard, nuisance, or adversely affect air, soil, surface water, or groundwater.

59) Licensees must secure the storage system or remote site so that it is not a hazard to the public or wildlife (i.e., implement measures to prevent access).

60) Licensees must ensure only wells and pipelines for which they are the licensee contribute drilling waste to their storage system or remote site.

61) Licensees must ensure waste from directional drilling for pipeline construction and waste from drilling oil, gas, geothermal, or brine-hosted mineral wells are stored and disposed of separately.

62) Licensees must locate the storage system or implement measures (e.g., site contouring, berms) to prevent surface water from entering or exiting the storage system. Precipitation landing within the storage system must be managed as drilling waste.

63) Licensees must maintain a minimum **freeboard** of 0.5 m for all storage systems. The storage system design capacity must account for seasonal precipitation rates and the volume of the expected drilling waste.

64) Within 18 months of **rig release** of the first well that contributed drilling waste to the storage system or within 12 months of the first receipt of pipeline drilling waste, licensees must do the following:

   a) Remove the drilling waste from the storage system and manage it following the requirements of this directive.

   b) Physically close the storage system. Physical closure includes dismantling the storage system, decontaminating (if needed) the area beneath and surrounding it, and any applicable backfilling and contouring of the area used for the storage system. The objective is to close the storage system for restoration to equivalent land capability.

6.2 Sump Construction Requirements

65) Licensee must only construct sumps on a site with appropriate deposits of **clayey** soils (i.e., meets the criteria set out in requirement 66(b)) below that are free of hydraulic defects, such as gravel lenses, silt lenses, sand lenses, cracks, fissures, and root channels. If the soils do not meet the criteria set out in requirement 66(b), the sump must have a synthetic liner that meets the requirements of *Directive 055: Storage Requirements for the Upstream Petroleum Industry*.

66) Unless using a tank, bin, or sump with synthetic liner at the site, the licensee must engage a qualified person to conduct a site investigation to delineate the in situ clayey deposits at the site. The site investigation must include the following:

   a) At least three boreholes arranged in an approximate equilateral triangle to establish the orientation of any significant geological plane. Sufficient lithology data (borehole) to confirm that the deposit of appropriate clayey material extends a minimum of 1 m beyond the horizontal and vertical dimensions of the sump.

b) Take representative soil samples from the coarsest material within the planned sump area and from within the area extending 1 m beyond the boundary of the planned sump area. Each of the three core samples must be analyzed in a lab to confirm that the clay deposit has the following characteristics:

i) greater than 50 per cent fines (defined as dry weight percentage passing a no. 200 sieve)

ii) equal to or greater than 28 per cent clay (i.e., 0.002 millimetres [mm] or less as determined by the hydrometer method)

c) The lab analysis required in (b) for sumps of 100 m^2 or less can be reduced to one sample if the three cores from the boreholes required in (a) are similar in texture (i.e., hand texture method) and appearance, indicating limited variability for the characteristics set out in (b). This exception does not apply to sites with multiple sumps.

67) Before constructing the sump, licensees must prepare the site following typical well site and soil conservation practices. When constructing the sump, determine whether naturally saline subsoils are being excavated and keep them separate from nonsaline soil so that they can be placed at a depth during final reclamation to enable site restoration to equivalent land capability.

6.3 Pipeline Drilling Storage Requirements

68) While drilling, licensees must store drilling muds and waste at the entry and exit pits of the drilling activity. The following are acceptable storage systems:

a) earthen pits constructed in clayey soils that contain at least 20 per cent clay and 50 per cent fines, extending at least 1 m beyond the bottom and sides of the pit

b) tanks, conductor barrels, or lined earthen pits

c) earthen pits not meeting the criteria specified in (a) if the drilling mud waste released into the pit is immediately and continually removed during drilling and stored as per this directive

69) Immediately on completion of drilling, licensees must remove the drilling waste from the pits and manage it as per this directive, then backfill and reclaim the pits.

6.4 Remote Site Requirements

A remote site is used to store drilling waste or cement returns (see appendix 1).

Licensees intending to recycle or reuse drilling waste to drill a subsequent well can temporarily store the drilling waste on the subsequent well site without designating it a remote site provided the subsequent well site holds an AER well licence, the drilling waste is stored in aboveground tanks, and the storage duration does not exceed three months as per *Directive 055*.

70) If the remote site is on a site other than a licensed well site, licensees must obtain a written agreement from the landowner or department agency managing the land on behalf of the provincial or federal Crown (e.g., a surface lease or disposition under the *Public Lands Act*).

71) If the storage system is on a site other than a licensed well site, licensees must have signage at the site entrance identifying the legal subdivision (LSD), the licensee, the well licence, or pipeline licence and line number to which the site is linked, and a 24-hour emergency phone number. Remote sites with multiple sumps and contributing wells or pipelines constructed after May 1, 2022, must have signage at each sump used to store drilling waste. The signage must indicate the type of drilling waste stored in the sump and the licence number of the first well or pipeline that contributed to that sump. Signage is required to be updated where a sump is reused.

72) For liability tracking purposes, licensees must link the well or pipeline licence that generated the drilling waste to the remote site. Where more than one well or pipeline contributes drilling waste to the remote site, licensees must link the well or pipeline licence that first contributed drilling waste to the remote site.

73) A remote site must not be used for more than five years from rig release of the first well that contributed drilling waste to the storage system or from the first receipt of pipeline drilling waste. Licensees wishing to extend the use of the remote site beyond five years are required to apply as per the process described in section 15.

6.5 Earthen-Bermed Storage System Requirements

74) Licensees must only use earthen-bermed storage systems

a) to store nonhydrocarbon-based **drilling waste solids** (e.g., cuttings) intended for disposal by landspread, mix-bury-cover, or at an approved waste management facility; and

b) on a well site or remote site that has been prepared following typical well site and soil conservation practices (i.e., topsoil removed and conserved).

75) Licensees must assess the shallow **subsoils** of the area on which the earthen-bermed storage system will be constructed and verify the subsoils are of limited **permeability**. The assessment must be conducted by a qualified person and consist of at least three subsoil samples taken from the area on which the bermed storage system will be constructed. Each sample must be analyzed to confirm that for a minimum depth of 30 cm the soil forming the base of the system has

   a) greater than 50 per cent fines (defined as dry weight percentage passing a no. 200 sieve) and

   b) greater than 20 per cent clay (i.e., 0.002 mm or less as determined by the hydrometer method).

76) Licensees must construct the **berms** with clayey soil meeting the characteristics set out in requirement 75 above. The berms must be of sufficient capacity, but at least 15 cm high, to contain any generated leachate and prevent the flow of surface water into the storage system.

6.6 Reuse of a Storage System Requirements

77) Licensees must not reuse an earthen-bermed storage system.

78) Licensees wishing to reuse a storage system (other than an earthen-bermed storage system) for another drilling program must verify its integrity before reuse.

79) Licensees must notify the AER at least 30 days before the intended day of reuse. Send an email notification to Directive050@aer.ca and include the following information:

   a) the location of the site on which the storage system is located and, if on a well site, the licence number for the well

   b) a description of the method used to verify the integrity of the storage system and determine its appropriateness for reuse

   c) a description of any additional construction work done to prepare the storage system for reuse

   d) verification that the landowner, department, or agency has agreed to the reuse of the storage system

   e) a commitment to meet the requirements set out in sections 6.1, 6.2, and 6.4

   f) the number of previous drilling programs for which the storage system has been used and the age of the system, including the licence number of the first well or pipeline that contributed drilling waste to the storage system

g) verification that the site, overall, has not been used to store drilling waste for a period that exceeds five years

The AER will return incomplete notifications to the licensee and will consider the start of any activity associated with the notification as a noncompliance.

6.7 Storage System Setbacks

Storage systems are setback from features such as water bodies and water wells to prevent drilling waste from migrating into these features.

80) Licensees must ensure the exterior walls of the storage system are at least

a) 20 m from an on-site rig water well,

b) 50 m from any off-site water well,

c) 100 m from a water body, or

d) 50 m of a water body if

i) the water body is upgradient of the storage system or

ii) the landscape creates a physical barrier that prevents the drilling waste from migrating towards the water body.

6.8 Storage of Hydrocarbon-Based Drilling Waste Requirements

81) Licensees must store liquid hydrocarbon-based drilling waste in tanks. Suitable solids storage options that prevent solids from contact with the ground include

a) lining the sump or earthen-bermed storage system with a synthetic liner as per *Directive 055* or

b) containing the drilling waste solids in tanks or other storage vessels as per *Directive 055*.

7 Management of Cement Returns

7.1 Introduction

In some situations, cement returns are not isolated from the drilling waste and get placed in the sump and are managed with the solids using the mix-bury-cover method. This practice is acceptable provided all the requirements for mix-bury-cover are met.

During the storage of cement returns, water may collect within the storage system. Licensees may use the pump-off method to remove the collected water given that all requirements under section 9 are followed.

7.2 Requirements

82) Licensees must use one of the following options to manage cement returns that have been isolated from the drilling waste:

a) Allow the isolated cement returns to harden in aboveground synthetically lined walled storage systems (AWSS), which are often called cement rings. The following requirements must be met when using AWSS to store cement returns:

i) The AWSS capacity must not exceed 50 cubic metres (m^3).

ii) The synthetic liner must be at least 12 mil thick with properties (i.e., density, tensile strength, elongation, tear resistance, and puncture resistance) suitable for the intended use, be chemically resistant to the compounds used to formulate the cement, and be rated for the temperatures encountered (i.e., the temperature of the cement returns and the ambient temperatures). The manufacturer’s liner specifications must be documented.

iii) The wall system must be engineered to withstand the hydraulic pressure of the stored contents at full capacity.

iv) The liner must cover the ground floor of the walled system, extend up the wall and be fastened onto the outside of the wall.

v) The system used to fasten the liner must secure the liner to the wall system and must not damage the liner.

vi) The storage duration must not exceed one year; the cement returns must be removed within the one-year timeframe, and the AWSS dismantled.

vii) The removed, hardened cement returns must be broken into pieces no larger than 0.5 m^3 and placed into pits meeting requirement (c) below or managed as per requirements (d) or (e) below.

viii) The liners must not be reused and must be managed as oilfield waste as per *Directive 058*.

b) Allow the isolated cement returns to harden in aboveground portable rigid structures that will adequately contain the cement returns and prevent releases into the environment. The following requirements must be met when using portable structures for storage of cement returns:

i) The structures must be able to withstand the hydrostatic pressure of the stored contents at full capacity.

ii) The storage duration must not exceed one year; the cement returns must be removed within the one-year timeframe, and the portable structure dismantled.

iii) The removed, hardened cement returns must be broken into pieces no larger than 0.5 m^3 and placed into pits meeting requirement (c) below or managed as per requirements (d) or (e) below.

c) Place the isolated cement returns into a segregated pit (or pits) on the originating well site or associated remote site. Allow the cement to harden, break the cement into pieces no larger than 0.5 m^3, and cover with at least 1 m of clean fill. The following requirements must be met when using segregated pits for storage of cement returns:

i) The pits must not be constructed in the water table.

ii) The area of one pit or combined area of more than one pit on one well site, multiwell site, or remote site must not exceed 100 m^2.

iii) Despite requirement (c)(ii) above, if the wells that generated the cement returns are part of an oil sands development, and the well site, multiwell site, or remote site used to store the cement returns is on public lands, then the area of each temporary storage pit must not exceed 900 m^2 and the combined area of all temporary storage pits must not exceed 2700 m^2 (e.g., 3 pits × 900 m^2 each). For the final disposal of cement returns, the total final disposal area must not exceed 900 m^2.

iv) Measures must be implemented to prevent the public or wildlife from entering the pits.

v) The cement returns must be buried or removed within 18 months of the rig release date of the first well that contributed cement returns to the pits.

vi) The buried cement returns must not interfere with subsurface water flow and the objective to restore the site to equivalent land capability.

vii) During the well site or remote site reclamation process, the licensee must disclose the presence of buried cement returns.

viii) Any unhardened cement returns must be removed for disposal at an approved waste management facility as per the timeline stated in requirement (c)(v) above.

ix) The licensee must conduct representative soil sampling of the pit walls and base after the unhardened cement returns have been removed except in the circumstances outlined in requirement (c)(xi) below.

x) The licensee is required to follow section 3.5 regarding soil exceedance notifications for any soil exceedance beyond the endpoints stated in tables 2, 3, and 5 unless alternative endpoint criteria have been approved under section 15.

xi) Representative soil sampling is not required after unhardened cement returns have been removed from a sump meeting the requirements of 66(c) above or from an earthen pit lined with a synthetic liner (see *Directive 055* for synthetic liner specifications).

d) Place cement returns that are either isolated from drilling waste or removed from a cement return storage pit into cells that are part of an approved landfill. Landfills on AER-regulated upstream petroleum sites are subject to the application and approval process set out in *Directive 058.* All other landfills in Alberta are subject to the application and approval process prescribed by *EPEA*.

Cement return storage pits may be reused provided conditions (i)–(vi) in (c) above are met.

e) Apply to the AER for approval of alternatives to manage or recycle cement returns (see section 15).

8 Disposal Onto Forested Public Lands

8.1 Introduction

The requirements set out in this section are limited to the application of drilling waste from nontoxic water-based mud systems onto forested public lands (also known as green areas).

Disposal onto forested public lands (DFPL) is primarily used in the winter when applying **drilling waste fluids** or total waste (slurried solids and fluid) to specific types of dispositions issued under the *Public Lands Act*. This method is particularly suited to disposing of drilling waste from shallow wells and winter-access-only wells while enabling minimum-ground-disturbance (MGD) winter operations. DFPL reduces the need to construct sumps and remove timber to accommodate oil and gas, geothermal, and brine-hosted mineral operations. Although similar to landspray while drilling regarding the applicable type of drilling waste and the opportunity for sumpless drilling, this method allows higher drilling waste application rates.

Application methods include applying the drilling waste at a predetermined rate with a vacuum truck, terragator, or a wagon equipped with a spray bar or deflector. Application with hoses or other similar equipment is not suitable.

This method may be used alone or in combination with other methods such as mix-bury-cover or landspreading on the well site or remote site under a mineral surface lease (MSL).

8.2 Disposal Onto Forested Public Lands Site Receiving Soil Requirements

83) Licensees must only use DFPL on lands for which the AER has issued the following types of dispositions:

a) MSLs, which include well sites, remote sites, and some short access roads

b) licences of occupation (LOCs), which include developed and undeveloped roads

84) Licensees must not dispose of waste in the ditches of a developed LOC (e.g., where a roadbed has been constructed). The AER has identified any disposal on an MSL or LOC as an MGD operation and must be restricted to cleared areas. In addition, under winter MGD (frozen) conditions, lands under a LOC (whether developed or not) must be ploughed to create snow windrows, and the waste must be applied in several passes (without exceeding the disposal limit) between the snow windrows.

85) Licensees must not use DFPL on

a) other accesses, seismic lines, or existing clearings and openings on public lands;

b) areas with a slope greater than 5 per cent;

c) areas where the applied drilling waste could pool, cause erosion, or migrate into lakes or watercourses (e.g., transmitted through ditches, ditched roads, or natural drainage channels); and

d) receiving soils where the depth to the mineral soil horizon is greater than 30 cm or where vegetative indicators (e.g., tamarack, stunted black spruce) indicate unsuitable receiving soils such as open muskeg.

8.3 Disposal Onto Forested Public Lands Disposal Requirements

86) Licensees must sample and analyze the drilling waste (i.e., fluids or total waste) for pH, EC, SAR, Na, and N (if the cumulative amount of N [NH_3-N, NO_3-N, NO_2-N] in additives or products added to the drilling mud or waste system exceeds 100 kg or is unknown) and use the results to calculate spray rates that will prevent the receiving soil from exceeding the salinity endpoints set out in table 2.

87) Licensees must segregate cement returns from the drilling waste and manage them as set out in section 7.

88) If solids and cuttings are separated from the drilling waste, licensees must manage them using a different method (e.g., mix-bury-cover, landspreading) or send them to an approved waste management facility. If the drilling waste was analyzed as a total waste and the volume of the separated solids and cuttings is less than 20 m^3, additional analysis is not required unless further information is needed to meet the requirements of the other disposal method.

89) Licensees must isolate drillstem test fluids and any sections of the mud system contaminated by hydrocarbons and manage them by a different method.

90) Licensees must only use the DFPL disposal method for **water-based drilling mud** systems where the drilling waste (fluids or total waste)

a) has a pH between 6 and 10.5;

b) has an EC that does not exceed 10 dS/m;

c) contains no **visible hydrocarbons**, and no other hydrocarbon flags were encountered while the well was drilled;

d) does not contain cumulative concentrations of metals from mud additives or products that exceed the endpoints set out in table 5 (another disposal option must be used if metal content is unknown); and

e) does not contain any mud additives or products that were used in concentrations above the luminescent bacteria toxicity test pass threshold (EC50[15] ≥75 per cent).

91) Despite the preceding requirements 90(c), (d), and (e), licensees must store, sample, and test the drilling waste before proceeding with DFPL if

a) a hydrocarbon flag was encountered during the drilling of the well (the concentration of each hydrocarbon component [BTEX and F1 to F4 fractions] in the drilling waste must be determined and used to calculate a spray rate such that the concentrations in the soil-waste mix do not exceed the endpoints set out in table 3);

b) additives and mud products were used in concentrations exceeding the luminescent bacteria toxicity test pass threshold (EC50[15] ≥75 per cent) or for which toxicity data are unknown (the drilling waste must be tested for toxicity and found to be nontoxic [see section 4.3 for toxicity assessment requirements]); or

c) the **cumulative concentration** of metals (contributed by all additives and mud products) in the drilling mud system exceeds the endpoints set out in table 5, or if there is not enough information on additives and mud products to determine the metal concentrations in the drilling waste, then the concentration of metals in the drilling waste must be determined and used to calculate spray rates such that the concentrations in the soil-waste mix do not exceed the endpoints set out in table 5.

Licensees can compensate for requirement (b) and (c) above by following the “generic mud system” protocol set out in section 4.5.

92) Licensees must ensure the following when using DFPL:

a) The minimum drilling waste spray rate is at least 10 m^3/ha (i.e., the calculated spray rate for a parameter decreases as the concentration of the parameter in the drilling waste increases).

b) The maximum drilling waste spray rate does not exceed 80 m^3/ha for summer or winter operations.

c) The drilling waste does not clump or pool on the land, migrate off the disposal area, or cause land erosion.

d) The sodium application rate does not exceed 250 kg/ha, and the nitrogen loading rate does not exceed the rates in table 10. Licensees wishing to increase the nitrogen loading rate may refer to appendix 3 for more information and are required to apply to the AER for approval as per the process described in section 15 for alternative management methods.

e) The solids application rate does not exceed six tonnes per hectare (t/ha) when spraying onto vegetated lands, and the DFPL does not smother or stress the vegetation (i.e., clumping or uneven application resulting in vegetation coated with drilling waste).

93) Licensees must mark the spray area before disposal. All stop and start points must be clearly marked (e.g., flags). Markers are to remain in place until the entire disposal operation is complete and then removed.

8.4 Disposal Onto Forested Public Lands Post-Disposal Sampling Requirements

94) Licensees must conduct post-disposal sampling of the soil-waste mix and compare the results to the applicable soil endpoints set out in section 3 if predisposal testing (see section 8.3) resulted in any of the following outcomes:

a) The EC of the drilling waste exceeded 8 dS/m, the nitrogen loading rate exceeded 20 kg/ha, or the sodium loading rate exceeded 150 kg/ha (post-disposal analyses for EC, SAR, Na and N [NH_3-N, NO_3-N, NO_2-N]). If an alternative nitrogen loading rate from table 10 is used, then post-disposal sampling for nitrogen must be completed.

b) The concentrations of metals in the drilling waste exceeded any of those in tables 6 or 7 (post-disposal analysis for metals).

c) A hydrocarbon flag was encountered, and the hydrocarbon concentrations in the drilling waste exceeded the values for any of the parameters in table 4 (post-disposal analyses for BTEX and F1 to F4 hydrocarbon fractions).

9 Pump-off

9.1 Introduction

The pump-off disposal method involves pumping the clear liquid portion of drilling waste onto land (usually vegetated land) using irrigation equipment, such as a big gun, sprinkler, gated pipe, perforated hose, or water or vacuum trucks.

Typically, pump-off is an off-site management option, but this does not preclude pumping off small volumes on the well site that generated the drilling waste or on a remote site provided the drilling waste was stored on the remote site. Small volumes of clear fluids may be pumped onto well site access roads provided these locations are leased or owned by the licensee and landowner, department, or agency written consent has been obtained. Drilling waste from directional drilling can be pumped off onto the associated pipeline right-of-way only. Water collected in cement return storage systems can be disposed of by the pump-off method if it meets the criteria listed below.

9.2 Pump-off Receiving Soil Requirements

95) Licensees must collect samples for assessing pre- and post-disposal (where applicable) soil conditions as follows:

a) Select one sampling site for each hectare of the disposal area.

b) Ensure each sampling site is a circular area with a 10 m radius and a centre precisely located and documented by GPS using the Universal Transverse Mercator (UTM) coordinate system, including bearing and metres from a fixed point.

c) At a minimum, collect one composite sample from the 0 to 10 cm soil depth increment and one from the 10 to 30 cm soil depth increment from each sampling site. Each composite sample must include five subsamples.

Licensees cannot take the result from the composite sample from the 0 to 10 cm soil depth and the result from the composite sample from the 10 to 30 cm soil depth and average them; each composite sample must be assessed separately.

9.3 Pump-off Disposal Requirements

96) Licensees must only use the pump-off disposal method for the portions of water-based drilling waste that qualify as clear liquids (i.e., do not contain any visible hydrocarbons and appear nonturbid when sampled from the discharge point; may be colourless or have natural colour or staining).

97) Licensees must sample and analyze the clear liquids for toxicity, pH, EC, SAR, Na, and N (if any of the additives or products added to the drilling mud system or drilling waste contain any amount of N [NH_3-N, NO_3-N, NO_2-N] or if the N content is unknown) to ensure the liquids meet the following criteria:

a) a pH between 6 and 8.5. If the pH is adjusted, it must be reverified before pumping off. Lab analysis is not required for a pH adjustment of less than two units

b) an EC that does not exceed 10 dS/m

c) pass a luminescent bacteria toxicity test before disposal (see section 4.3). If the initial toxicity assessment fails but passes after being charcoal treated, the fluids must be analyzed for BTEX and F1 to F4 hydrocarbon fractions, and the sum of the results must be less than 100 mg/L for pump-off to proceed

d) the sodium loading rate does not exceed 250 kg/ha, and the nitrogen loading rate does not exceed the rates in table 10. Licensees wishing to increase the nitrogen loading rate may refer to appendix 3 for more information and are required to apply to the AER for approval as per the process described in section 15 for alternative management methods.

98) Licensees must not exceed an application rate of 1000 m^3/ha.

99) When using pump-off disposal, licensees must ensure the drilling waste does not clump or pool on the land, migrate off the disposal area, or cause land erosion.

9.4 Pump-off Post-Disposal Sampling Requirements

100) Licensees must conduct post-disposal sampling and compare the results to the applicable soil endpoints set out in section 3 if predisposal testing (see section 9.3) resulted in any of the following outcomes:

a) The EC of the clear liquid exceeded 5 dS/m (post-disposal analyses for EC and SAR).

b) The sodium loading rate exceeded 150 kg/ha (post-disposal analyses for Na and SAR).

c) The nitrogen loading rate exceeded 20 kg/ha (post-disposal analysis for N [NH_3-N, NO_3-N, NO_2-N]). If an alternative nitrogen loading rate from table 10 is used, then post-disposal sampling for nitrogen must be completed.

10 Mix-Bury-Cover

10.1 Introduction

The mix-bury-cover (MBC) disposal method involves mixing nonhydrocarbon-based drilling waste solids or **total waste** with subsoils on the well site, pipeline right-of-way (provided the surface of the right-of-way is disturbed as per section 1.5 and the drilling waste is from the construction of the associated pipeline), or remote site (provided the drilling waste was stored at the remote site).

Typical MBC methods are

- mix waste and subsoil in the sump and cover
- mix waste from the sump and subsoil on the surface, and then put the mixture back in the sump and cover
- bail the waste from the sump onto the lease surface and mix with the subsoil and bury when filling in a cut
- spread the waste on the lease surface and allow it to dry, and then put the waste back into the sump and mix and cover

Licensees can use on-site management techniques (e.g., dewatering systems, shakers, solids control) to pretreat drilling waste before using this method. See section 15 regarding AER approval for use of new technologies or treatment methods.

10.2 Mix-Bury-Cover Receiving Soil Requirements

101) Licensees must conduct MBC disposals within deeper subsoils (i.e., at a depth profile between 1 and 1.5 m or deeper to form a stabilized waste-soil mass below the major rooting zone) on the well site, pipeline right-of-way, or remote site.

102) Licensees must collect samples for assessing pre- and post-disposal (where applicable) soil conditions as follows:

   a) For disposal areas that are 3000 m^2 or less, collect a minimum of one composite sample comprising five subsamples.

   b) For disposal areas that exceed 3000 m^2, divide the area into equal plots that are no larger than 3000 m^2 and collect one composite sample comprised of five subsamples for each plot.

   c) Collect each subsample at the soil profile depth for **incorporation** of the drilling waste (excluding clean fill and cap).

   d) Ensure the soil-waste mix sample is not **diluted** with soil from above or below the mix depth.

103) If the drilling waste contains nitrogen or the nitrogen content is unknown, licensees must determine whether the receiving soil is coarse grained (median **grain size** is greater than 75 microns) or fine grained (median grain size is 75 microns or less).

10.3 Mix-Bury-Cover Disposal Requirements

104) Licensees must have the sample analyzed for the following parameters and use the results to determine the soil-waste mix ratio that will prevent the receiving soil from exceeding the soil endpoints set out in section 3:

a) pH, EC, SAR, and Na

b) nitrogen (N), if the additives or products added to the drilling mud system or drilling waste contain any amount of N (NH_3-N, NO_3-N, NO_2-N) or the N content is unknown

c) metals, if the cumulative concentration of metals in mud additives or products added to the drilling mud system exceeds the endpoints set out in table 5 or metal content of the mud additives or products is unknown

d) hydrocarbons (i.e., BTEX and F1 to F4 hydrocarbon fractions), if a hydrocarbon flag was encountered

e) toxicity, if mud additives or products were used in concentrations above the luminescent bacteria toxicity test pass threshold (EC50[15] ≥75 per cent) or toxicity data are unknown. The sample must pass the toxicity test. For any drilling waste that only passes the toxicity test after being charcoal treated, the disposal may only proceed if hydrocarbons are the likely source of toxicity

105) Licensees must mix the subsoil and drilling waste at a ratio of at least three parts subsoil to one part drilling waste. (See appendix 3 for the lab protocol for mixing drilling waste with receiving soil.) In addition,

a) licensees must use predictive lab mixes to determine the soil-waste mix ratio for drilling waste with an EC of 10 dS/m or more, an Na concentration of 3000 milligrams per litre (mg/L) or greater (in saturated paste extract or filtrate from oversaturated sample); and

b) licensees must not start MBC operations when the predictive lab or **calculated mix ratio**s exceed seven parts soil to one part waste (alternative options include treating and retesting the waste to verify the method's suitability or using a different disposal method).

106) Licensees must not exceed a soil N endpoint (i.e., concentration of N [NH_3-N, NO_3-N, NO_2-N] in the soil-waste mix) of 10 mg/kg for coarse soils (>75 microns) or 40 mg/kg for fine soils (≤75 microns).

107) Licensees must cover the subsoil-waste mixture with at least 1 m of clean fill. The EC and SAR of the clean fill must meet the latest edition of Alberta *Tier 1 Soil and Groundwater Remediation Guidelines* for the applicable soil rating category and depth.

The use of naturally saline subsoils as the fill material may introduce unacceptable levels of salts to the rooting zone and may interfere with the final reclamation process and objective to restore the site to equivalent land capability.

10.4 Mix-Bury-Cover Post-Disposal Sampling Requirements

108) Licensees must conduct post-disposal sampling and compare the results to the applicable soil endpoints set out in section 3 if predisposal testing (see section 10.3) resulted in any of the following outcomes:

a) The EC of the drilling waste exceeded 10 dS/m, or the Na content of the drilling waste exceeded 3000 mg/L in saturated paste extract or filtrate from an oversaturated sample (post-disposal analyses for EC, SAR, and Na).

b) The concentrations of metals in the drilling waste exceeded any of those in tables 6 or 7 (post-disposal analysis for metals).

c) The hydrocarbon concentration in the drilling waste exceeded the values for any of the parameters in table 4(post-disposal analyses for BTEX and F1 to F4 hydrocarbon fractions).

d) If the nitrogen concentration in the drilling waste (wet weight) is 6 mg/kg or more for disposals in coarse soils (>75 microns) or 120 mg/kg or more for disposals in fine soils (≤75 microns), then analyze for N (NH_3-N, NO_3-N, NO_2-N).

11 Landspray and Landspray While Drilling

11.1 Introduction

The landspray and landspray while drilling (LWD) disposal methods involve spraying fluid or total waste onto topsoil and might involve incorporating the waste into the soil. Drilling waste sprayed onto vegetated land is usually not incorporated with soil. Vegetated lands include grasslands, native prairie, and forage lands but not forested public lands. See section 8 for requirements on disposal on forested public lands.

Only drilling waste from water-based drilling mud systems, which are shown to be nontoxic using the luminescent bacteria toxicity test, can be disposed of using landspray while drilling. Disposal is allowed without the need to store the drilling waste (e.g., by sumpless drilling).

11.2 Landspray and Landspray While Drilling Receiving Soil Requirements

109) For landspray and landspray while drilling, licensees must only select land with a slope of less than 5 per cent for summer (unfrozen ground) operations or a slope of less than 3 per cent for winter (frozen and snow covered) operations.

11.3 Landspray and Landspray While Drilling Disposal Requirements

11.3.1 Requirements for Landspray

110) Licensees must contain the drilling waste in a storage system before landspraying and

a) take a fluids sample to determine the suitability of landspraying of the fluids only (solids managed by other means) or

b) take a **total waste sample** to determine the suitability of landspraying the fluid and solid phases together.

111) Licensees must analyze the drilling waste sample for the parameters listed below to determine spray rates that will prevent the receiving soil from exceeding the soil endpoints for salts, hydrocarbons, and metals set out in section 3:

a) pH, EC, SAR, sodium (Na), and toxicity

b) nitrogen (N) if the cumulative amount of N (NH_3-N, NO_3-N, NO_2-N) in additives or products added to the drilling mud or waste system exceeds 100 kg or is unknown

c) metals if cumulative concentrations of metals in mud additives or products added to the drilling mud system exceed the endpoints set out in table 5 or are unknown

d) hydrocarbons if a hydrocarbon flag is present

112) Licensees must ensure

a) the pH of the drilling waste is between 6 and 10.5;

b) the drilling waste passes a toxicity test (for drilling waste that only passes the toxicity test after being charcoal treated, the disposal may only proceed if hydrocarbons are the likely source of toxicity, see section 4.3); and

c) spray rates for winter operations must be determined using calculations for application without soil incorporation.

113) For disposal with incorporation, licensees must ensure drilling waste spray rates are determined by the calculations for soil incorporation and that the drilling waste incorporates into the receiving soil to a maximum depth of 15 cm within 60 days of application. If incorporation does not occur within 60 days of application, licensees must select sites where migration of drilling waste from the application area would not occur within the 60 days

allowed for incorporation and ensure the waste spray rates are determined by the calculations without soil incorporation.

11.3.2 Requirements for Landspray While Drilling

114) Licensees must isolate drillstem test fluids and any sections of the mud system contaminated by hydrocarbons and manage them by a different method.

115) Licensees must sample and analyze the drilling waste for pH, EC, SAR, Na, and N (if the cumulative amount of N [NH_3-N, NO_3-N, NO_2-N] in additives and products added to the drilling mud or waste system exceeds 100 kg or is unknown) and use the results to determine spray rates that will prevent the receiving soil from exceeding the soil endpoints set out in section 3.

116) Licensees must only use the LWD disposal method for water-based drilling mud systems where the resulting drilling waste (fluids or total waste)

a) has a pH between 6 and 10.5;

b) has an EC that does not exceed 16 dS/m;

c) contains no visible hydrocarbons, and no other hydrocarbon flags were encountered while the well was drilled;

d) does not contain cumulative concentrations of metals from mud additives or products that exceed the endpoint values set out in table 5 (otherwise choose a different disposal option if metal content is unknown);

e) does not contain any mud additives or products used in concentrations above the luminescent bacteria toxicity test pass threshold (EC50[15] ≥75 per cent) (otherwise choose a different disposal option if the toxicity of any of the mud additives or products is unknown); and

f) spray rates are determined using calculations for application without soil incorporation.

Licensees can compensate for points (d) and (e) above by following the “generic mud system” protocol as set out in section 4.4.

117) Licensees must separate and handle drilling waste as different sections of the well are drilled (e.g., top, middle, and bottomhole) if changes are made to the drilling mud formulation for the different well sections and it cannot be confirmed that the conditions of requirements 116 and 121 will continue to be met.

118) Licensees must ensure LWD disposal operations occur within 48 hours of rig release. Under extreme weather conditions, drilling waste can be stored in tanks for a maximum of 96 hours after the rig has been released, but the drilling waste must be retested before starting the LWD operations. An alternative management option must be used if this timeline cannot be met.

11.3.3 Requirements Common to Landspray and Landspray While Drilling

119) Licensees must segregate cement returns from the drilling waste and manage them as set out in section 7.

120) If solids and cuttings are separated from the drilling waste, licensees must manage them using a different method (e.g., mix-bury-cover, landspreading) or send them to an approved waste management facility. If the drilling waste was analyzed as a total waste and the volume of the separated solids and cuttings is less than 20 m^3, additional analysis is not required unless further information is needed to meet the requirements of the other disposal method.

121) Licensees must ensure the following:

a) The minimum drilling waste spray rate is not less than 10 m^3/ha (the calculated spray rate for a parameter decreases as the concentration of the parameter in the drilling waste increases).

b) The maximum drilling waste spray rate does not exceed 40 m^3/ha for summer (unfrozen ground) operations.

c) The maximum drilling waste spray rate does not exceed 20 m^3/ha for winter operations, which are in effect when the soil is saturated with water, ice covered, snow covered, or frozen.

d) In winter operations, when the disposal area is snow covered, the disposal area is prepared so that the drilling waste is applied to the surface of the disposal area and not onto snow accumulation.

e) The drilling waste does not clump or pool on the land, migrate off the disposal area, or cause land erosion.

f) The sodium loading rate does not exceed 250 kg/ha, and the nitrogen loading rate does not exceed the rates in table 10. Licensees wishing to increase the nitrogen loading rate may refer to appendix 3 for more information and are required to apply to the AER for approval as per the process described in section 15 for alternative management methods.

g) The solids application rate does not exceed 6 t/ha when spraying onto vegetated lands, and the disposal material does not smother or stress the vegetation (i.e., clumping or uneven application resulting in vegetation coated with drilling waste).

h) Licensees must discuss compaction and access impact (rutting) with the landowner, department, or agency before disposal to ensure both parties have understood each other's expectations.

11.4 Landspray and Landspray While Drilling Post-Disposal Sampling Requirements

11.4.1 Landspray Sampling

122) Licensees must conduct post-disposal sampling and compare the results to the applicable soil endpoints set out in section 3 if predisposal testing (see sections 11.3.1, 11.3.2, and 11.3.3) resulted in any of the following outcomes:

a) The EC of the drilling waste exceeded 10 dS/m, the nitrogen loading rate exceeded 20 kg/ha, or the sodium loading rate exceeded 150 kg/ha (post-disposal analyses for EC, SAR, Na, and N [NH_3-N, NO_3-N, NO_2-N]).

b) The concentration of metals in the drilling waste exceeded any of those in tables 6 or 7(post-disposal analyses for metals).

c) A hydrocarbon flag was encountered, and the hydrocarbon concentration in the drilling waste exceeded the values for any of the parameters in table 4 (post-disposal analyses for BTEX and F1 to F4 hydrocarbon fractions).

11.4.2 Landspray While Drilling Sampling

123) Licensees must conduct post-disposal sampling and compare the results to the applicable soil endpoints set out in section 3 if any of the following criteria are met:

a) If the EC of the drilling waste exceeds 10 dS/m, then analyze for EC and SAR.

b) If the nitrogen loading rate exceeds 20 kg/ha, then analyze for N (NH_3-N, NO_3-N, NO_2-N).

c) If the sodium loading rate exceeds 150 kg/ha, then analyze for EC, SAR, and Na.

12 Landspread

12.1 Introduction

The landspread method involves spreading water-based drilling waste onto the shallow subsoil of a well site, pipeline right-of-way (provided the surface of the right-of-way is disturbed as per section 1.5 and the drilling waste is from the construction of the associated pipeline), or remote site (provided the drilling waste was stored on the remote site) and incorporating it with the shallow subsoil.

Typical landspread methods are

- rip the subsoil and spread (squeeze) and incorporate the waste from the sump **on site**
- spread (squeeze) the waste from the sump on site, dry it, and then incorporate it into the shallow subsoil

12.2 Landspread Receiving Soil Requirements

124) Licensees must conduct landspreading within shallow subsoils (i.e., no more than 1 m depth) on the well site, pipeline right-of-way, or remote site.

125) Licensees must collect samples for assessing pre- and post-disposal (where applicable) soil conditions as follows:

a) For disposal areas that are 3000 m^2 or less, collect a minimum of one composite sample comprising five subsamples.

b) For disposal areas that exceed 3000 m^2, divide the area into equal plots no larger than 3000 m^2 and collect one composite sample comprising five subsamples from each plot.

c) Collect each subsample from the 0 to 30 cm soil depth profile or the drilling waste depth incorporation, whichever is less.

d) Ensure the soil-waste mix sample is not diluted with soil from below the mix depth.

12.3 Landspread Disposal Requirements

126) Licensees must analyze the sample for the following parameters and use the results to determine the soil-waste mix ratio that will prevent the receiving soil from exceeding the soil endpoints set out in section 3:

a) pH, EC, SAR, Na

b) nitrogen (N) if the cumulative mass of N (NH_3-N, NO_3-N, NO_2-N) in additives or products added to the drilling mud system or drilling waste exceeds 300 kg or is unknown

c) metals if the cumulative concentration of metals in mud additives or products added to the drilling mud system exceeds the endpoint values set out in table 5 or is unknown

d) hydrocarbons (i.e., BTEX and F1 to F4 hydrocarbon components) if a hydrocarbon flag was encountered

e) toxicity if mud additives or products were used in concentrations above the luminescent bacteria toxicity test pass threshold (EC50[15] ≥75 per cent) or if toxicity data are unknown. The sample must pass the toxicity test; for drilling waste that only passes the toxicity test after being charcoal treated, disposal may only proceed if hydrocarbons are the likely source of toxicity (see section 4.3).

127) Licensees must ensure the pH of drilling waste being landspread is between 6 and 10.5.

128) Licensees must mix the subsoil and drilling waste at a ratio of at least three parts subsoil to one part drilling waste. (See appendix 3 for the lab protocol for mixing drilling waste with receiving soils.) In addition,

a) licensees must use predictive lab mixes to determine the soil-waste mix ratio if drilling waste has an EC of 8 dS/m or more, an Na concentration of 2000 mg/L or greater (in saturated paste extract or filtrate from oversaturated waste), or if the landspreading is to occur on soil within the fair soil rating category (see table 2); and

b) licensees must not proceed with landspreading operations when the predictive lab or calculated mix ratios exceed seven parts soil to one part waste (alternative options include treating and retesting the waste to verify the suitability of the method or using a different disposal method).

129) Licensees must not exceed a waste application rate of 1000 m^3/ha or a thickness of 10 cm.

130) Licensees must not exceed an N loading of 400 kg N/ha within the landspread disposal area; this value must be prorated to applicable mass of N based on the total area used for the landspread disposal (e.g., if the disposal area is 0.1 ha, then the mass of N allowed is 40 kg; 400 kg N/ha × 0.1 ha = 40 kg N).

12.4 Landspread Post-Disposal Sampling Requirements

131) Licensees must conduct post-disposal sampling of the soil-waste mix and compare the results to the applicable soil endpoints set out in section 3 if predisposal testing (see section 12.3) resulted in any of the following outcomes:

a) The EC of the drilling waste exceeded 8 dS/m, or the Na content of the drilling waste exceeds 2000 mg/L in saturated paste extract or filtrate from an oversaturated waste (post-disposal analyses for EC, SAR, and Na).

b) The concentrations of metals in the drilling waste exceeded any of those in tables 6 or 7 (post-disposal analysis for metals).

c) The hydrocarbon concentration in the drilling waste exceeded the values for any of the parameters in table 4 (post-disposal analyses for BTEX and F1 to F4 hydrocarbon fractions).

d) The nitrogen loading rate exceeded 300 kg/ha, prorated to the mass of N based on the total area used for the landspread disposal (post-disposal analysis for N [NH_3-N, NO_3-N, NO_2-N]).

13 Sending Drilling Waste to Approved Waste Management Facilities

132) Any required characterization, classification, and analyses must be done on the drilling waste before adding sorbent material.

133) Licensees must

a) keep information on the use of an approved waste management facility in the well file of the well that generated the waste or the pipeline file of the pipeline that generated the waste,

b) make the information available to the AER upon request, and

c) use the information to support an application for reclamation certification of the well site or associated remote site.

134) Licensees must not send drilling waste to registered landfill or landfill currently operating under an Alberta Public Health permit that will qualify for registration under the *Code of Practice for Landfills* under *EPEA*.

If the drilling waste qualifies for acceptance into a landfill (passes paint filter test, does not exceed any waste acceptance criteria for the landfill, and waste classification is appropriate for the class of landfill), the subsequent addition of **sorbent material** required to facilitate its handling and to manage any interstitial liquids that could shake out during transportation to the landfill is acceptable.

a) Drilling waste sent to approved class III landfills must be classified as a solid non-dangerous oilfield waste (non-DOW) and must be inert as set out in *Directive 058*.

b) Drilling waste classified as dangerous oilfield waste (DOW) destined for landfill disposal must only be sent to a class I landfill provided the drilling waste passes the paint filter test and does not exceed acceptance criteria for the landfill as set out in *Directive 058*.

135) Licensees must not send drilling waste to compost facilities or compost components at waste management facilities, including AEPA-regulated landfills.

136) Licensees must not send drilling waste to dedicated **land treatment** facilities (i.e., facilities approved by or registered with AEPA for the treatment of soils contaminated with refined hydrocarbons).

14 Mobile Thermal Treatment Units

Refer to *Directive 058* for requirements when using a mobile thermal treatment unit.

137) Licensees must notify the AER at least thirty days before starting thermal treatment operations. Send an email notification to Directive058@aer.ca with the notification requirements outlined in *Directive* 058 along with:

a) the well licence number and unique well identifier (UWI) if the mobile thermal treatment unit is on the well site, or

b) if the mobile thermal treatment unit is on a remote site, the well licence and UWI to which the remote site is linked (see requirement 72.

The AER will return incomplete notifications to the licensee and will consider the start of any activity associated with the notification as a noncompliance.

15 Alternative Management Methods

15.1 Introduction

This section outlines the information to be electronically submitted in an application to the AER to

- manage drilling waste using a technology or treatment method not set out in this directive;
- undertake the biodegradation disposal method involving the reduction of organic constituents in the drilling waste by a microbial process (see *Directive 058* for more information);
- land-apply drilling waste generated by a new or unique mud system using an option set out in this directive (e.g., mix-bury-cover, landspread, landspray, pump-off); or
- modify a method set out in this directive (e.g., exceed nitrogen application rate for a disposal method).

15.2 Alternative Management Methods Requirements

138) Licensees must provide sufficient information in the application to substantiate that the proposed systems, procedures, or technologies will achieve a level of environmental protection and safety equivalent to the methods set out in this directive. Details regarding the need for an alternative method, including supporting science and technical rationale, must be included in the application. If applicable, the AER will work with other government agencies (e.g., AEPA, Department of National Defence, Indian Oil and Gas Canada) to ensure any concerns are addressed in the developmental stages.

139) Licensees must obtain AER approval before implementing the alternative management method.

15.3 Application Information Requirements

The level of detail submitted in the application should reflect the scope and complexity of the proposed alternative management method. For mineable oil sands (MOS) sites that include a tailings pond within their *EPEA* approval, selected drilling waste and cement returns can be accepted and managed in the tailings pond. Drilling waste from the MOS *EPEA* approval holder's activities within the approval holder's scheme area can come from

- oil sands exploration programs,
- groundwater monitoring wells and other observation wells, and
- geotechnical programs.

140) The MOS *EPEA* approval holder must record these volumes as per the requirements in the MOS *EPEA* approval.

If the drilling waste is from activities within another scheme and under a separate *EPEA* approval held by the MOS *EPEA* approval holder, the waste for the activities listed above can be managed in the tailings pond on the nonproducing scheme area.

141) The licensee's application must include the following information:

a) legal land location (surface), pipeline or well licence number, and the UWI of the well that generated the drilling waste. Pipeline or well licence numbers for centrifuges (standalone) and recycling of water in oil sand exploration and steam-assisted gravity drainage operations must be submitted before the end of the drilling program.

b) legal land location of the site or area on which the alternative method is being used and, if it is a remote drilling waste storage or biodegradation site, the pipeline or well licence number and UWI to which the remote site is linked (see section 6.4)

c) current land use (e.g., agricultural, natural area, or parkland) of the site and adjacent lands and whether the site is on private land, public land, or any other land type identified in section 1.5.

d) written verification that the landowner, department, or agency has agreed to the proposed activity

e) proposed start date and date of completion

f) a general description of the proposed alternative method, including the overall purpose or goal of the method, an assessment of its need, and any literature or bench-scale work to substantiate the method's potential for success

g) any site assessment information, including

i) a plot plan at a scale that identifies site topography, surface drainage patterns, types of vegetation or tree cover, and the location of the proposed alternative method relative to other areas of activity or infrastructure on the site (e.g., gas-oil well, drilling sump, biodegradation area, on-site water well, storage tanks or other storage systems, pipelines, or utility lines)

ii) applicable background soil conditions as described in section 3 if the alternative method involves application of the drilling waste to land

h) A description of the process that will be used to measure the success of the alternative method, which may include

i) testing for analytes of interest

ii) developing a sampling protocol

iii) analyzing to monitor progress

iv) undertaking a detailed characterization of the drilling waste and, if applicable, the receiving soil or resulting by-products before and after the management method

16 Remixing a Former Drilling Waste Disposal

16.1 Requirements to Remix a Former Drilling Waste Disposal

142) Licensees must meet the following requirements when remixing old drilling waste disposals:

a) The remix must only occur on a licensed well site or remote site where the original drilling waste disposal occurred.

b) The old drilling waste disposal area must be vertically and horizontally delineated.

c) Representative samples must be taken and analyzed in a lab to determine background soil conditions and the quality of the drilling waste disposal area. Samples must be analyzed for hydrocarbons (BTEX components and F1 to F4 hydrocarbon fractions), metals, **major ions**, EC, and SAR that exceed the endpoints set out in tables 2, 3, and 5 for landspread and mix-bury-cover.

d) Predictive lab mixes must be done to determine the soil-waste mix ratio that will meet the soil endpoints for salts, hydrocarbons, and metals for landspread or mix-bury-cover as set out in tables 2, 3, and 5 (see appendix 3 for information about lab predictive mixes).

e) The mix ratio for the remix must not exceed three parts subsoil to one part drilling waste.

f) The remix must be done at the soil horizon depth that correlates to the salinities set out in table 2 for the landspread or mix-bury-cover option being used.

g) The volume of the drilling waste and soil to be remixed must be determined and used to gauge the size of disturbance needed for a successful remix.

h) Compare the pros and cons of the site disturbance required for the remix option with those of the dig and dump option.

i) If the site is on public lands, the AER must agree with the remix option.

16.2 Notification Requirements

143) Licensees must notify the AER at least 30 days before starting the remix activity. Send the email notification to Directive050@aer.ca and include the following information:

a) legal land location (surface) of the site on which the remix is to take place and the licence number and UWI of the well that generated the drilling waste or of the well to which the site is linked (see requirement 72)

b) a description of the proposed remix with supporting documentation to substantiate the appropriateness and applicability of the remix, which must include

   i) the history of the site, including the year of the original drilling waste disposal

   ii) a plot plan identifying the area of the original drilling waste disposal, the area encompassing the proposed remix, the location and depths of the boreholes and samples taken to delineate and assess the conditions of the original drilling waste disposal and background soils, the topographical features of the site, and any existing infrastructure

   iii) soil borehole logs from the site assessment, a summary of the analytical results and lab predictive mixes to substantiate that the remix will achieve the endpoints set out in tables 2, 3, and 5

   iv) the soil horizon depth at which the remix is to occur, the soil-waste mix ratio used for the remix, and the remix disposal method (i.e., landspread with good category subsoils, landspread with fair category subsoils, mix-bury-cover between 1 and 1.5 m deep with good or fair category subsoils, or mix-bury-cover at 1.5 m or deeper with no subsoil category restriction)

Ensure the attachment file name identifies it as a drilling waste remix notification, contains the applicable well licence number and the UWI of the well that generated the drilling waste or to which it is linked, and is formatted as DW_Licence#_UWI (e.g., RemixDW_0123456_00~12-14-025-12W4~0).

The AER will return incomplete notifications to the licensee and will consider the start of any activity associated with the notification as a noncompliance.

144) Licensees must notify the local AER field centre and give them the details of the intended remix at least 48 hours before beginning.

17 Record Keeping and Notification

17.1 Record Keeping Requirements for Well Licences

The AER requires licensees to maintain records to demonstrate compliance.

145) Licensees must document the following information and keep it in the well file of the well that generated the drilling waste and make the information available to the AER upon request:

a) surface land location, UWI, and well licence number of the well that generated the drilling waste

b) the type of drilling mud system used, including

   i) a list of all additives and mud products used

   ii) the volume of each fluid additive and mud product added

   iii) any luminescent bacteria toxicity documentation for all additives and mud products used

   iv) any metal content documentation for all additives and mud products used and the cumulative metal content of the mud system

   If different mud systems were used for different sections of the hole and were segregated and managed separately, the required information must be documented for each system.

c) the method used to store the drilling waste, including information to demonstrate compliance with section 6 and a plot plan identifying the location of the storage system, and the following as applicable:

   i) if a remote site was used to store drilling waste, in addition to the preceding information, include the legal land location of the remote site and a copy of the written agreement for use of the site from the landowner or Crown department, or agency managing the land (see section 1.5)

   ii) if more than one well contributed drilling waste to the storage system, include the licence of the well that first contributed drilling waste (i.e., the well licence to which the remote site is linked as set out in section 6.4)

d) the volume of drilling waste generated and the storage and disposal methods used, including

i) drilling waste assessment information, including analytical and field-testing results and a sketch of the storage system showing the locations and depths of the subsamples taken to obtain the representative composite drilling waste sample

ii) the name, location, and approval number of any waste management facility to which drilling waste was sent

iii) the following information for any land application disposal method used:

- receiving soil assessment information
- if applicable, post-disposal sampling information
- a detailed map of the disposal area
- proof of landowner, department, or agency consent
- the drilling waste disposal rates and supporting calculations

e) if different drilling waste types (as a result of different mud systems being used) or phases (e.g., clear liquids, fluids, solids, cuttings, total waste, cement returns, drillstem test fluids) were segregated, the information in (b), (c), and (d) above must be documented for the management of each segregated type or phase

146) Licensees must keep the information from requirement 145 above in the well file until the well site and any associated remote site have successfully been reclaimed (i.e., a reclamation certificate from the AER for sites designated as specified lands or alternative documentation from the department or agency responsible for nonspecified lands).

17.2 Record Keeping Requirements for Pipeline Licences

147) For drilling waste that has been generated from directional drilling activities, licensees must document the following information and keep it until the pipeline has been abandoned. If a remote site was used to manage the drilling waste, licensees must document the following information and keep it until the remote site has been successfully reclaimed (i.e., a reclamation certificate from the AER for sites designated as specified lands or alternative documentation from the department or agency responsible for nonspecified lands):

a) the pipeline segment (licence and line number) that generated the drilling waste

b) the pipeline “from” and “to” location (i.e., the LSD)

c) the legal land location (the LSD), the plot plan showing the entry and exit pits of the directional drill, and a description of the method used to prevent migration of drilling waste from the pit (e.g., tanks, liners, conductor barrels) if the pit does not consist of suitable clayey soils

d) if a remote site was used, its LSD and specific use (e.g., storage, including type of storage system, and disposal, including type of disposal method), and a plot plan showing the storage and disposal areas

e) the type of mud system used, the volume used, and a list of all additives, products, or chemicals used, and documentation to verify the mud system was nontoxic

f) the volume of drilling waste generated and the storage and disposal methods used, including documentation to demonstrate compliance with the requirements for the selected method

g) proof of landowner, department, or agency consent or agreement, including a plan of survey of the disposal sites

h) a copy of the completed Pipeline Drilling Waste Disposal form

17.3 Predisposal Notification Requirements

148) Proposed drilling waste storage and disposal information for well drilling activities must be submitted with the drilling activity notification through the Digital Data Submission (DDS) system and the Field Surveillance Inspection System (FIS) Drilling Activity Notification form.

149) Proposed drilling waste storage and disposal information for pipelines must be submitted through the DDS system using the Pipeline Drilling Waste Disposal form before the drilling waste activity occurs. Submit the following information:

a) horizontal directional drilling / boring operation information

b) type of drilling waste operation or activity

c) storage or disposal location

d) application rates or soil-waste mixture ratio (if applicable)

e) drilling waste volumes

f) environmental contractor contact information

The Pipeline Drilling Waste Disposal form mentioned above is not required for pipeline drilling waste operations when

- using nonsaline water or nonsaline water with bentonite as the drilling fluid and the total volume of drilling waste generated is <2 m^3, or
- all drilling waste is sent to an approved waste management facility.

150) Changes to the well drilling activity notification and the Pipeline Drilling Waste Disposal form can be made in the DDS up to 48 hours after the initial entry of these records. This time allows the licensee to input any changes to their planned activity. After the 48-hour cutoff, the licensee must contact the appropriate AER field centre and provide any changes to the planned activity.

Authorized AER customers require a login ID and password to access the DDS system. For help getting a login ID, please contact your company's AER DDS administrator. If you are unable to contact your company's AER DDS administrator, contact DDSAdministrator@aer.ca.

Detailed instructions for submitting information are in the FIS website user guide. Inquiries may also be directed to the FIS administrator by telephone at 403-297-4845 or by email at FIS.administrator@aer.ca.

17.4 Post-Disposal Notification Requirements

151) Well licensees must electronically submit post-disposal information identifying the drilling waste volumes generated, the storage systems used, the disposal methods used, the disposal locations, and exceedances of soil endpoints. A *Directive 050* Drilling Waste Management Disposal form must be completed for each well licence and submitted within 24 months of rig release.

152) Pipeline licensees must electronically submit post-disposal information identifying the drilling waste volumes generated, the storage systems used, the disposal methods used, and disposal locations. A *Directive 050* Pipeline Drilling Waste Disposal form must be completed within 12 months of each directional drilling activity.

153) Licensees must submit the disposal information through the DDS system on the AER website at www.aer.ca. The disposal form is in the DDS system under AER > Submissions > DrillingWasteData > SubmitWasteData. Select **Well Disposal** as the **Submission Type** or **Pipeline Disposal** as the **Submission Type**. Licensees must also keep a copy of the completed form in the well or pipeline file.

Authorized AER customers require a login ID and password to access the DDS system. For help getting a login ID please contact your company's AER DDS administrator. If you are unable to contact your company's AER DDS administrator, contact DDSAdministrator@aer.ca.

Appendix 1 Definition of Terms Used in *Directive 050*

approved waste management facility	A facility approved under the *Oil and Gas Conservation Act* and the rules under that act or approved under the *Environmental Protection and Enhancement Act* and the regulations under that act to process, treat, dispose of, store, or recycle waste.
bentonite	A type of clay; the main constituent used in nonsaline gel-drilling mud system.
berm	A raised barrier constructed of clayey soils used for containment.
bioassay	The assessment of a potential biological impact of a substance by quantifying its effect on a representative test organism using a standardized protocol.
BTEX	The abbreviation for the light-end volatile hydrocarbons benzene (B), toluene (T), ethylbenzene (E), and xylene (X).
bulk density (soil)	The mass of dry soil per unit volume (kg/m^3). The bulk volume is determined before the soil is dried to constant weight at 105ºC.
bulking agent	Material added to increase the surface area of waste. Examples include woodchips, sawdust, and humalite.
calculated mix ratio	Soil-to-waste mix ratios determined using the calculations listed in appendices 2, 3, 4, and 6.
cement returns	Excess cement circulated to the surface after downhole cementing.
clay	A mineral soil consisting of particles less than 0.002 mm in diameter, a soil textural class, or a fine-grained soil.
clayey soil	Soil with greater than 50 per cent fines (defined as dry weight percentage passing a no. 200 sieve) equal to or greater than 28 per cent clay (i.e., 0.002 mm or smaller as defined by the hydrometer method).
clear liquids	Liquid separated from water-based drilling waste. The liquid appears nonturbid when sampled at the discharge point and qualifies for pump-off. The liquid may be colourless or have natural colour or staining.
composite sample	A sample consisting of equal parts of several subsamples taken from specific locations, areas, or depths such that the composite sample is representative of the whole volume or mass of material being sampled.
Crown disposition	The administrative and operating conditions assigned under the *Public Lands Act* for the use of public lands in the form of a lease, licence, permit, or letter of authority and are administered by the AER or AEPA.
cultivated land	Agricultural land that has been worked by ploughing, sowing, and raising crops.
cumulative concentration	The calculated value of a substance in a drilling system once all possible sources have been considered.
diluted	Mixing liquids or solids with liquid or solid waste to reduce the concentration of the waste.
disposal area	Land onto which drilling waste is applied or into which drilling waste is mixed.

disposal onto forested public lands	A drilling waste disposal method similar to landspray and landspray while drilling that allows higher application rates and is limited to provincial Crown lands for which the AER has issued specific types of Crown dispositions under the *Public Lands Act*.
drill cuttings	The fragments of formation rock and subsurface material dislodged by the drill bit and brought to the surface in the drilling mud.
drilling mud	A suspension, usually in water but sometimes in oil (diesel), used in rotary drilling, consisting of various substances in a finely divided state (commonly bentonitic clays and chemical additives), introduced continuously down the drill pipe under pressure and through openings in the drill bit and transported back up in the annular space between the pipe and the walls of the borehole to a surface pit or tank where it is conditioned and reintroduced into the wellbore. It is used to lubricate and cool the bit, carry the cuttings up from the bottom, and prevent blowouts and cave-ins.
drilling waste	Mud and cuttings generated while drilling a well and from directional drilling for pipeline construction.
drilling waste fluid	The fluid portion of drilling waste consisting of water, drilling mud, fine cuttings, and additives.
drilling waste solids	The solids portion of drilling waste consisting of water, drill cuttings, flocculated bentonite, weighting materials, and other additives.
dry bulk density	The weight of dry waste per unit volume of wet waste (kg/m^3).
earthen-bermed storage system	A system used to store drilling waste solids constructed of earth and built on grade that meets the design, construction, and operational requirements of this directive.
EC50(15)	In a luminescent bacterial toxicity test, the effective concentration of a sample that causes a 50 per cent decrease in light output at 15ºC after 15 minutes exposure.
electrical conductivity	The ability of a solution to carry an electrical current. Refers to the specific electrical conductance of the water, which is a function of the **total dissolved solids**. High salinity (high EC) affects plant growth and soil quality.
endpoint	Maximum concentration of a parameter in soil that has received drilling waste.
environment	All components of the earth and includes • air, land, and water, • all layers of the atmosphere, • all organic and inorganic matter and living organisms, and • all interacting natural systems that include components referred to above.
equivalent land capability	The ability of land to support various land uses after conservation and reclamation that are similar to the ability that existed before the activity was conducted on the land, but the individual land uses will not necessarily be identical.
expectations	Recommended best practices or guidelines. Enforcement is not assigned to expectations, but they should be given serious consideration.

flocculant	A chemical used to precipitate or coagulate compounds out of solution. Most flocculants are either multivalent cations, such as calcium, magnesium, and aluminum, or long-chain polymers. Often added to remove fines from drilling fluids.
fluid additive	A material added to a drilling fluid or mud system to perform one or more specific functions (e.g., a weighting agent, viscosifier, lubricant, corrosion inhibitor, defoamer, emulsifier, foaming agent, shale control inhibitor, or surfactant).
freeboard	The unused upper portion of a primary containment device.
grain size	The average size in microns of mineral particles making up soil.
groundwater	Subsurface water beneath the water table in soils and geological formations that are saturated.
hydrocarbon-based mud system	A mud system in which the external phase is a hydrocarbon (e.g., invert, HT40N, mineral oil).
hydrocarbon flags	A situation where hydrocarbons could be introduced into water-based drilling waste (including if the well is horizontal, adding a diesel pill, or other hydrocarbons through drilling practices such as underbalanced drilling or drillstem testing) or where hydrocarbons are visible in the drilling waste.
incorporation	An operational method in which the drilling waste is mixed into the soil structure, preventing potential migration. Mixing is done mechanically by combining the drilling waste into a consistent soil and waste mixture.
landowner	The person in whose name a certificate of title has been issued under the *Land Titles Act*, or if no certificate of title has been issued, the Crown or other body administering the land. In the case of Métis land, the person registered in the Métis Settlements Land Registry as owner of the Métis title under the *Métis Settlement Lands Registry Regulation*.
landspray(ing)	A waste disposal method where drilling waste fluids or total waste is sprayed onto a field at a specified constant rate from a vacuum truck or similar equipment.
landspray(ing) while drilling	A waste disposal method similar to landspray but limited to nontoxic water-based drilling muds, allowing for the testing requirements to be reduced and the disposal to proceed without first storing the drilling waste.
landspread	A waste disposal method where drilling waste solids or total waste is spread and incorporated into shallow subsoil with a backhoe or similar equipment.
licensee	The holder of a licence according to the records of the AER and includes a trustee or receiver-manager of property of a licensee.
limiting parameter	The analyte that provides the greatest restriction for a disposal method.
major ions	General term referring to water-soluble ions (includes anions and cations).
mix-bury-cover	A waste disposal method where drilling waste solids or total waste is spread onto the land surface and mixed into the subsoil at a depth of 1 m or more. The resulting mix is covered with at least 1 m of clean fill or subsoil.

mud product	A material added to a drilling fluid / mud system to perform one or more specific functions (e.g., weighting agents, viscosifiers, lubricants, corrosion inhibitors, defoamers, emulsifiers, foaming agents, shale control inhibitors, or surfactants).
mud density	The weight of a given volume of drilling mud. Usually expressed in kg/m^3.
off site	The management of drilling waste on an area of land outside of the boundaries of the well site, pipeline right-of-way, or a remote site.
oilfield waste	Waste as defined in section 1.020(12.1) of the *Oil and Gas Conservation Rules,* section 1(1) of the *Geothermal Resource Development Rules*, and section 1(1) of the *Brine-Hosted Mineral Resource Development Rules*.
on site	The management of drilling waste on the well site, pipeline right-of-way, or remote site.
oversaturated drilling waste sample	A drilling waste sample in which the pores of the solids are full of liquid, and there is excess liquid.
per cent moisture	The moisture content of a soil or sediment determined by weighing a subsample of the moist as-received material and drying it to constant weight (usually at 105ºC). The result is reported as either a percentage of the initial moist weight (as-received basis) or the final dry weight (dry weight basis). % moisture (as received) = 100 × weight loss on drying / as-received weight % moisture (dry basis) = 100 × weight loss on drying / oven-dry weight To convert one reported type to another: % moisture (as received) = 100 × % moisture (dry basis) / (100 + % moisture [dry basis]) % moisture (dry basis) = 100 × % moi. (as received) / (100 − % moi. [as received])
per cent saturation	The per cent saturation or saturation percentage of a soil is the moisture content of a saturated paste. The per cent saturation value is determined by drying a weighed subsample of the saturated paste of the soil to a constant weight at 105ºC. % saturation = 100 × weight loss on drying / oven-dry weight of paste sample
permeability	The ease with which gases or liquids can pass through a medium.
petroleum hydrocarbon fraction F1	C_6–C_{10}, excluding benzene, toluene, ethyl benzene, and xylene (BTEX), as defined by the Canadian Council of Ministers of the Environment *Canada-Wide Standards for Petroleum Hydrocarbons in Soil* (2006a).
petroleum hydrocarbon fraction F2	$C_{>10}$–C_{16}, as defined by the CCME (2006a).

petroleum hydrocarbon fraction F3 $C_{>16}$–C_{34}, as defined by the CCME (2006a).

petroleum hydrocarbon fraction F4 $C_{>34}$, as defined by the CCME (2006a).

pH A measure of hydrogen ion concentration which determines the degree of acidity or alkalinity of a substance. On this scale, pH 1 is a strong acid, pH 14 is a strong alkali, and pH 7 is the point of neutrality.

pump-off A waste disposal method where the nontoxic clear liquid portion of the drilling waste is pumped onto the land surface.

qualified person For verifying the presence or absence of a water body or characterizing and classifying soils, a qualified person possesses post-secondary education in an applicable discipline or educational equivalencies, has technical knowledge and experience in the specific area, and is acting within their area of expertise.

receiving soil Soils to which drilling waste is applied.

remote site A well site that is used to store drilling waste or cement returns generated at other wells off the well site or that is a standalone site specifically established to receive drilling waste or cement returns for storage, and for which access to the land for storing drilling waste or cement returns has been obtained by agreement with the landowner or from the department or agency managing the land on behalf of the provincial or federal Crown (e.g., disposition under the *Public Lands Act*).

rig release The date on which all drilling operations are completed and the contractor is released from the well site.

saline soil A nonalkali soil that contains enough soluble salts to interfere with the growth of most crop plants. The conductivity of the saturation extract is greater than 4 dS/m the exchangeable sodium percentage is less than 15, and the pH is usually less than 8.5.

saline-sodic soil A soil with a high content of water-soluble salts and high exchangeable sodium that meets the definitions of both saline soil and sodic soil.

saturated zone The saturated zone encompasses the below-ground area in which all interconnected openings within the geologic medium are filled with water.

sodic soil A soil containing sufficient sodium to interfere with the growth of most crop plants, or a soil having an exchangeable sodium percentage of 15 or more.

sodium adsorption ratio A calculated ratio to represent the relative activity of sodium, calcium, and magnesium for ion exchange reactions in soil. A surrogate for exchangeable sodium percentage.

soil The unconsolidated mineral or organic material at the surface of the earth that serves as a medium for plant growth.

solid	A substance that does not contain free liquids as determined by the US Environmental Protection Agency (EPA) Method 9095 Paint Filter Liquids Test (*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* EPA Publication SW-846) and is not gaseous at standard conditions.
sorbent material	Material added to facilitate waste handling and manage any interstitial fluids that could separate out during transportation of the waste.
specific gravity	The ratio of the density of a substance to the density of water.
storage system	A system designed to store generated waste materials. For drilling waste, such storage systems include sumps, aboveground tanks, bins, sumps lined with a synthetic liner, earthen-bermed storage systems, or other storage systems as per *Directive 055* or approved by the AER.
sump	A type of storage system designed to store drilling waste that is an earthen excavation that meets the design, construction, and operational requirements of this directive.
subsoil	The layer of soil directly below topsoil that consists of the B and C horizons and extends to bedrock. For salinity management, three depths are recognized: top of the subsoil to a depth of 1 m, subsoil from >1 to 1.5 m, and subsoil at a depth >1.5 m.
tank	As defined in *Directive 055*.
topsoil	The uppermost layers of soil that consist of L, F, H, O, and A horizons or depth of tillage, whichever is greatest.
total dissolved solids	The concentration of inorganic or mineral constituents dissolved in water expressed in mg/L. It can be calculated from electrical conductivity.
total waste	The entire volume of drilling waste in a storage system consisting of the fluid and the solid portions.
total waste sample	A waste sample from the entire depth of the drilling waste storage system. The fluid and solid phases are collected at the same time using a column sampling tube. The required sample is a composite of subsamples from several locations in the storage system.
undersaturated drilling waste sample	A drilling waste sample in which the pores of the solids are not full of liquids.
visible hydrocarbons	The observance of a rainbow sheen on drilling waste (fluid portion, clear liquid portion, or total waste), or a total petroleum content (sum of the concentrations of BTEX and F1 through F4 components) within a drilling waste (fluid portion, clear liquid portion, or total waste) that exceeds 100 mg/L.
water-based drilling mud	A drilling fluid / mud system in which the external phase is water.

water body A natural landform or man-made structure that contains or conveys water continuously, intermittently, or seasonally.

A natural water body is a location where water is present or flows (whether the presence or flow of the water is continuous, seasonal, intermittent, or occurs only during a flood and includes the bed and shore of a river, stream, lake, creek, lagoon, swamp, marsh, slough, muskeg, or other natural drainages, such as ephemeral draws, wetlands, riparian areas, floodplains, fens, bogs, coulees, and rills).

Man-made water bodies include canals, drainage ditches, reservoirs, dugouts, or other man-made surface features.

Appendix 2 Abbreviations

AEPA	Alberta Environment and Protected Areas
AER	Alberta Energy Regulator
API	American Petroleum Institute
BTEX	benzene, toluene, ethylbenzene, and xylene
CCME	Canadian Council of Ministers of the Environment
cm	centimetre
DBD	dry bulk density
DDS	Digital Data Submission
DFPL	disposal onto forested public lands
DOW	dangerous oilfield waste
dS/m	decisiemens per metre
EC	electrical conductivity
EPEA	*Environmental Protection and Enhancement Act*
FIS	Field Surveillance Inspection System
g	gram
ha	hectare
ID	interim directive
kg	kilogram
L	litre
LOC	licence of occupation
LWD	landspray while drilling
m	metre
m^2	square metre
m^3	cubic metre
MBC	mix-bury-cover
Mg	magnesium
MGD	minimum-ground-disturbance
mL	millilitre

mm	millimetre
MOS	mineable oil sands
MSL	mineral surface lease
N	nitrogen
Na	sodium
NaCl	sodium chloride
QA/QC	quality assurance / quality control
SAR	sodium adsorption ratio
SG	specific gravity
t	tonnes
UWI	unique well identifier

Appendix 3 Salinity and Nitrogen

Table 8 lists the various equations found in this appendix.

Table 8. List of appendix 3 equations

Equation number	Waste application	Parameter	Description
1	Mix-bury-cover	Electrical conductivity (EC)	Soil-to-waste mix ratio of oversaturated waste
2	Mix-bury-cover	EC	Soil-to-waste mix ratio of undersaturated waste
3	Landspread	EC	Waste application rate
4	Landspread	Soil correction factor for EC	Subsoil
5	Landspread, landspray, landspray while drilling, and pump-off	Soil correction factor for EC	Topsoil
6	Landspray with soil incorporation	EC	Waste application rate for oversaturated waste
7	Landspray with soil incorporation	EC	Waste application rate for undersaturated waste
8	Landspray with or without soil incorporation, landspray while drilling, landspray onto forested public lands, and pump-off	Sodium	Waste application rate for oversaturated waste
9	Landspray with or without soil incorporation, landspray onto forested public lands	Sodium	Waste application rate for undersaturated waste
10	Landspray with no soil incorporation and landspray while drilling	EC	Waste application rate for oversaturated waste
11	Landspray with no soil incorporation	EC	Waste application rate for undersaturated waste
12	Pump-off	EC	Waste application rate for oversaturated waste
13	Landspray, landspray while drilling, pump-off, and disposal onto forested public lands	Nitrogen	Amount of N in waste application rate
14	Landspray, landspray while drilling, pump-off, and disposal onto forested public lands	Nitrogen	EC to waste N concentration ratio
15	Landspray, landspray while drilling, pump-off, and disposal onto forested public lands	Nitrogen	Waste application rate for oversaturated waste
16	Landspray, landspray while drilling, pump-off, and disposal onto forested public lands	Nitrogen	Waste application rate for undersaturated waste

Salinity Calculations

Mix-Bury-Cover

The following simplified calculations may be used as an alternative to predictive lab mixes for waste with an electrical conductivity (EC) less than 10 dS/m.

Electrical Conductivity

Use either equation (1) or (2) to determine the mix ratio as a function of waste EC.

Equation (1) for oversaturated waste:

$$\text{Mix ratio of soil to waste} = \frac{Waste\ EC \times \Phi}{EC\ target\ increase} - 1 \qquad (1)$$

where:

Waste EC	electrical conductivity (dS/m) of saturated paste extract
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an American Petroleum Institute (API) mud balance
EC target increase	maximum EC increase from table 2 (dS/m)

Equation (2) for undersaturated waste:

$$\text{Mix ratio of soil to waste} = \frac{Waste\ EC \times SLR}{EC\ target\ increase \times (1 - \Phi)} - 1 \qquad (2)$$

where:

Waste EC	electrical conductivity (dS/m) of saturated paste extract
SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp - 1)}{(2.65 - SGsp)}$
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
EC target increase	maximum EC increase from table 2 (dS/m)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Landspread

Electrical Conductivity

For landspreading, use equations (1) and (2) to determine a mix ratio and then calculate the waste application rate using equation (3):

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{Tillage\ depth \times 100}{Mix\ ratio + 1} \qquad (3)$$

where:

Tillage depth	depth of tillage (cm) from top of waste layer
100	unitless value (constant, factor, or unit conversion)
Mix ratio	ratio of soil to waste (v/v)

Soil Correction Factor for Electrical Conductivity

Equations (1) and (2) target a given increase in soil EC regardless of background soil EC. Table 2 indicates the maximum post-disposal EC when landspreading occurs above the 1 m depth. Apply a correction factor for soils with a background EC greater than 1 dS/m to ensure the maximum EC is not exceeded. Multiply the waste application rate by the soil correction factor for all soils with a background EC greater than 1 dS/m.

Use equation (4) to calculate the soil correction factor for subsoil and equation (5) to calculate the soil correction factor for topsoil:

$$\text{Soil correction factor (subsoil)} = \frac{3 - Background\ soil\ EC}{2} \qquad (4)$$

$$\text{Soil correction factor (topsoil)} = 2 - Background\ soil\ EC \qquad (5)$$

where:

Background soil EC	electrical conductivity of soil before waste application (dS/m)

Do not use equations (4) and (5) when background soil EC is 1 dS/m or less.

Landspray

The application rate for drilling waste should be based on EC and sodium loading rates. Specific requirements also apply to nitrogen content.

Soil Correction Factor for Electrical Conductivity

The following equations allow a 1 dS/m increase in soil EC. Apply a correction factor for soils with a background EC greater than 1 dS/m to ensure the maximum 2 dS/m EC limit is not exceeded. Use equation (5) (repeated below) to calculate the soil correction factor. Multiply the waste application rate by the soil correction factor for all soils with a background EC greater than 1 dS/m.

$$\text{Soil correction factor} = 2 - Background\ soil\ EC \qquad (5)$$

where:

Background soil EC	electrical conductivity of soil before waste application (dS/m)

Do not use equation (5) when background soil EC is 1 dS/m or less.

Landspray With Soil Incorporation – Electrical Conductivity

Use the following equations to calculate the application rate as a function of waste EC for soil with a background EC of 1 dS/m or less for oversaturated waste and undersaturated waste.

Equation (6) for oversaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{Tillage\ depth \times 54}{Waste\ EC \times \Phi} \qquad (6)$$

where:

Tillage depth	depth of tillage (cm) (maximum 10 cm)
54	unitless value (constant, factor, or unit conversion)
Waste EC	electrical conductivity (dS/m) of waste slurry
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (7) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{Tillage\ depth \times SLR \times 54}{Waste\ EC \times (1 - \Phi)} \qquad (7)$$

where:

Tillage depth	depth of tillage (cm) (maximum 10 cm)
SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp-1)}{(2.65-SGsp)}$
54	unitless value (constant, factor, or unit conversion)
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance

Waste EC	electrical conductivity (dS/m) of saturated paste extract
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

The maximum tillage depth in equations (6) and (7) is 10 cm because it is a reasonable average depth for incorporation. Waste applied to **cultivated land** should be incorporated before seeding the crop.

Landspray With Soil Incorporation – Sodium

The maximum sodium application rate is 250 kg/ha. Use the following equations to calculate the sodium loading rate for oversaturated or undersaturated waste.

Equation (8) for oversaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{250\ 000}{\textit{Waste}\ \text{Na concentration} \times \Phi} \qquad (8)$$

where:

250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (9) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{SLR \times 250\ 000}{\text{Waste Na concentration} \times (1 - \Phi)} \qquad (9)$$

where:

SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp-1)}{(2.65-SGsp)}$
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
250 000	the sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)

Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Landspray With No Soil Incorporation – Electrical Conductivity

Use the following equations to calculate the application rate as a function of waste EC for oversaturated or undersaturated waste.

Equation (10) for oversaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{160}{Waste\ \mathrm{EC} \times \Phi} \qquad (10)$$

where:

160	unitless value (constant, factor, or unit conversion)
Waste EC	electrical conductivity (dS/m) of waste slurry
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (11) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{SLR \times 160}{Waste\ EC \times (1 - \Phi)} \qquad (11)$$

where:

SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp - 1)}{(2.65 - SGsp)}$
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
Waste EC	electrical conductivity (dS/m) of saturated paste extract
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

A minimum application rate of 10 m^3/ha is recommended for calculating salinity loading rates.

Landspray With No Soil Incorporation – Sodium

Use equations (8) or (9) (repeated below) to calculate the sodium-based loading rate for oversaturated or undersaturated waste.

Equation (8) for oversaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{250\ 000}{\text{Waste Na concentration} \times \Phi} \tag{8}$$

where:

250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (9) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{SLR \times 250\ 000}{Waste\ Na\ concentration \times (1-\Phi)} \tag{9}$$

where:

SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp-1)}{(2.65-SGsp)}$
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Other Restrictions

Exercise caution when applying saline waste to hay or pastureland where salt-sensitive plant species are present. Salt-sensitive plant species include red clover, alsike clover, alfalfa, and timothy.

The potential for damage to vegetation is high when the soil is dry. Use caution when conducting landspray disposals onto no-till fields in the spring before seeding.

Landspray While Drilling

The maximum EC for all landspray while drilling (LWD) operations is 16 dS/m except for nitrogen systems (see Recommended Nitrogen Loading Rate Objectives). Disposal with soil incorporation is at the landowner's discretion. The LWD method is designed to ensure the drilling soil-waste mix meets all applicable endpoints without incorporation.

Soil Correction Factor for Electrical Conductivity

The following equations allow a 1 dS/m increase in soil EC. Apply a correction factor for soils with a background EC greater than 1 dS/m to ensure the maximum 2 dS/m EC limit is not exceeded. Use equation (5) (repeated below) to calculate the soil correction factor. Multiply the waste application rate by the soil correction factor for all soils with a background EC greater than 1 dS/m.

$$\text{Soil correction factor} = 2 - Background\ soil\ EC \qquad (5)$$

where:

Background soil EC	electrical conductivity of soil before waste application (dS/m)

Do not use equation (5) when background soil EC is 1 dS/m or less.

Electrical Conductivity

Use equation (10) (repeated below) to determine the application rate as a function of waste EC.

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{160}{Waste\ EC \times \Phi} \qquad (10)$$

where:

160	unitless value (constant, factor, or unit conversion)
Waste EC	electrical conductivity (dS/m) of waste slurry
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

A minimum application rate of 10 m^3/ha is recommended for calculating salinity load rates.

Sodium

Use equation (8) (repeated below) to calculate the sodium-based loading rate.

$$\text{Waste application rate } (m^3/ha) = \frac{250\,000}{\textit{Waste Na concentration} \times \Phi} \qquad (8)$$

where:

250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Other Restrictions

Exercise caution when applying saline waste to hay or pastureland where salt-sensitive plant species are present. Salt-sensitive plant species include red clover, alsike clover, alfalfa, and timothy.

The potential for damage to vegetation is high when the soil is dry. Use extreme caution when conducting LWD disposals onto no-till fields in the spring before seeding.

Landspraying Onto Forested Public Lands

Electrical Conductivity

The maximum waste EC is10 dS/m.

Sodium

Use equations (8) or (9) (repeated below) to calculate the sodium-based application rate for oversaturated or undersaturated waste.

Equation (9) for oversaturated waste:

$$\text{Waste application rate } (m^3/ha) = \frac{250\,000}{\textit{Waste Na concentration} \times \Phi} \qquad (8)$$

where:

250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (9) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{SLR \times 250\,000}{Waste\ Na\ concentration \times (1 - \Phi)} \qquad (9)$$

where:

SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(SGsp - 1)}{(2.65 - SGsp)}$
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65 - SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Pump-off

Soil Correction Factor

The following equation allows a 1 dS/m increase in soil EC. Apply a correction factor for soils with a background EC greater than 1 dS/m to ensure the maximum 2 dS/m EC limit is not exceeded. Use equation (5) (repeated below) to calculate the soil correction factor. Multiply the waste application rate by the soil correction factor for all soils with a background EC greater than 1 dS/m.

$$\text{Soil correction factor} = 2 - Background\ soil\ EC \qquad (5)$$

where:

Background soil EC	electrical conductivity of soil before waste application (dS/m)

Do not use equation (5) when background soil EC is 1 dS/m or less.

Electrical Conductivity

Waste EC should not exceed 10 dS/m.

The application rate for waste not containing nitrogen should be based on the EC and sodium loading rate. Use equation (12) to determine the application rate as a function of waste EC:

$$\text{Waste application rate } (m^3/ha) = \frac{1600}{\textit{Waste EC}} \quad (12)$$

where:

1600	unitless value (constant, factor, or unit conversion)
Waste EC	electrical conductivity (dS/m) of waste slurry (maximum 10 dS/m)

Sodium

Use equation (8) (repeated below) to calculate the sodium-based loading rate.

$$\text{Waste application rate } (m^3/ha) = \frac{250\ 000}{\textit{Waste Na concentration}} \quad (8)$$

where:

250 000	sodium application rate limit (g/ha)
Waste Na concentration	sodium concentration in waste filtrate (mg/L)

Other Restrictions

Exercise caution when applying saline waste to hay or pastureland where salt-sensitive plant species are present. Salt-sensitive plant species include red clover, alsike clover, alfalfa, timothy, and many forest species.

The potential for damage to vegetation is high when the soil is dry. Use caution when conditions are dry, and it might be necessary to use another disposal option.

Recommended Nitrogen Loading Rate Objectives

Landowners may wish for nitrogen-containing drilling waste to be applied to their land to increase the amount of nitrogen in the soil. Depending on the composition of the drilling waste, either salinity or nitrogen might be the **limiting parameter** when waste is surface applied.

Application rates based on product addition that result in <25 kg N/ha do not require specific nitrogen analysis and should be disposed of according to EC and SAR requirements. Use equation (13) to estimate the nitrogen application rate:

$$\text{Amount of N in waste application rate (kg/ha)} = \frac{\textit{Units of product used} \times \textit{mass/product unit} \times \textit{N in product}}{\textit{Disposal area} \times 100} \quad (13)$$

where:

Units of product	number of product containers used (e.g., sack, pail, drum)
Mass / product unit	mass of product in container (kg/container)
N in product	concentration of N in product (%)
Disposal area	area to which the waste will be applied (ha)
100	unitless value (constant, factor, or unit conversion)

Consider all sources of nitrogen and all product additions (e.g., all mud additions for previous and current wells).

Assessing Salinity in Nitrogen-Based Waste

If the calculated nitrogen application rate is equal to or greater than 25 kg/ha, use the nitrogen loading limits in table 10 or site-specific application rates. Because nitrogen and non-nitrogen salts both contribute to salinity, use equation (14) to determine whether non-nitrogen salinity constraints override nitrogen-based application rates.

If the EC-to-nitrogen ratio (EC:N) measured in the waste is greater than the critical ratio calculated by equation (14), base the waste application rate on EC (or sodium, whichever is lower) loading limits, as specified in equation (13).

$$\text{Critical EC:N} = \frac{\textit{Mixing depth} \times 0.027}{\textit{N application rate}} + \textit{Conductivity factor} \quad (14)$$

where:

Critical EC:N	ratio of waste EC (dS/m) to waste N concentration (mg/L)
Waste N concentration	sum of all mineral N species (NH_3-N, NO_3-N, NO_2-N) (mg/L)

Mixing depth	depth of tillage or infiltration (cm): • If waste is incorporated into the soil, use the tillage depth to a maximum of 10 cm. • If waste is not incorporated into the soil, use 30 cm for pump-off and 3 cm for landspray, landspray while drilling, and disposal onto forested public lands.
0.027	unitless value (constant, factor, or unit conversion)
N application rate	amount of N applied in waste (kg/ha) from table 10
Conductivity factor	electrical conductivity (dS/m per mg N) because of nitrogen salts (from table 9)

Table 9. Conductivity factors for equation (14)

Conductivity factor	
$Ca(NO_3)_2*4(H_2O)$	0.012
KNO_3	0.010
NH_4NO_3	0.0041
$(NH_4)_2SO_4$	0.0076
$NaNO_3$	0.0087

Nitrogen Application Rates

Use the guidelines in table 10 when nitrogen application rates will be equal to or greater than 25 kg/ha. Site-specific nitrogen application rates may also be used, based on a soil fertilizer recommendation determined by a qualified agrologist from soil test data. The landowner or leaseholder should be informed of the nitrogen rate applied.

Use equations (15) and (16) to calculate the nitrogen-based waste application rate for oversaturated or undersaturated waste.

Equation (15) for oversaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{N\ application\ rate \times 1000}{Waste\ N\ concentration \times \Phi} \tag{15}$$

where:

N application rate	amount of N applied in waste (kg/ha) from table 10
1000	unitless value (constant, factor, or unit conversion)
Waste N concentration	sum of all mineral N species (NH_3-N, NO_3-N, NO_2-N) (mg/L)

Φ	volume fraction of water in waste = $\frac{2.65-SGfm}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Equation (16) for undersaturated waste:

$$\text{Waste application rate (m}^3\text{/ha)} = \frac{\text{N } application \text{ rate} \times SLR \times 1000}{Waste\ N\ concentration \times (1\text{-}\Phi)} \tag{16}$$

where:

N application rate	amount of N applied in waste (kg/ha) from table 10
SLR	ratio of solids to liquid in saturated paste extract of waste = $\frac{(\text{SGsp}-1)}{(2.65-\text{SGsp})}$
1000	unitless value (constant, factor, or unit conversion)
SGsp	specific gravity of a saturated paste made from the waste as measured using an API mud balance
Waste N concentration	sum of all mineral N species (NH_3-N, NO_3-N, NO_2-N) (mg/L)
Φ	volume fraction of water in waste = $\frac{2.65-\text{SGfm}}{1.65}$
SGfm	specific gravity of the field-moist waste as measured using an API mud balance

Table 10. Recommended nitrogen loading limits (kg N/ha) for disposal methods except MBC

	Cropped, dryland	Cropped, irrigated	Tame forage (including pasture)	Native prairie	Forest
No landowner / leaseholder-applied nitrogen	70	140	50	50	200
Landowner / leaseholder-applied moderate rate of nitrogen but no soil test	35	70	25	25	n/a
Landowner / leaseholder-applied nitrogen to meet soil test recommendation	0	0	0	0	0

Nitrogen loading limits are expressed as the mass (kg) of N per hectare measured as mineral nitrogen (nitrate + nitrite + ammonium).

Nitrogen loading limits may be adjusted using guidance from tables 2 and 3 of the *Alberta Fertilizer Guide* (2004 or as updated by Alberta Agriculture, Forestry and Rural Economic Development) and in consultation with the landowner.

Lab Protocol for Mixing Drilling Waste with Receiving Soil

Analytical data for lab-made mixtures can be used to estimate mix characteristics after disposal and the minimum soil-to-waste mix ratio needed in the field to meet post-disposal criteria. Good field sampling and submission to the lab of manageable quantities of homogeneous material will reduce discrepancies caused by sample variability.

Field conditions are difficult to reproduce in a lab, making accurate estimates of the required mix ratio difficult. Samples of receiving soil are generally disturbed and thus less dense than in the field. Clay samples, in particular, may be lumpy and have large voids. For this reason, weighing a sample of the receiving soil and assuming a set **bulk density** appropriate for the type of soil involved is considered the best way to estimate a desired field condition volume.

The suggested protocol is described below:

Step 1: Homogenize the moist soil, if necessary, by screening up to 1 kg through a 5 mm sieve.

- If the waste is undersaturated but moist, screen up to 400 (5 mm) and dry at 105ºC.
- If the waste is already completely dry, break it up in a mortar and pestle to pass a 5 mm sieve.
- Agitate oversaturated waste having a separate liquid phase (e.g., shake the container well).

After homogenizing the soil and waste, take the following steps to minimize interlab discrepancies, allow for changes in bulk density during collection and shipping of soil samples, and mirror on-site bulk volume mixing methods.

Step 2: Determine **per cent moisture** (% moi.) of the soil by drying a subsample at 105ºC.

Step 3: Fill a tared, 1 L plastic pail with enough moist soil to make a routine saturated paste.

Step 4: Weigh the pail and contents to determine the moist weight of the soil.

Step 5: Calculate dry weight of the soil.

Dry weight (g) = moist soil weight (g) × (100 − % moi. [as received]) ÷ 100

or:

Dry weight (g) = moist soil weight (g) × 100 ÷ (% moi. [dry basis] + 100)

Step 6: Determine the required waste volume to add using the following formula:

Waste volume (mL) = dry weight of soil (g) ÷ factor

The “factor” to use in the step 6 equation depends on the intended field soil-to-waste mix ratio listed below:

Factor	Mix volume ratio
4.6	3:1
7.7	5:1
10.8	7:1

Factor = mix ratio × undisturbed on-site soil density (default value for mineral soils = 1.54 kg/L). If the receiving soil density is likely to differ substantially from the default value, calculate the appropriate factor using the actual soil bulk density.

Step 7: Measure out the required waste volume and add it to the soil in the 1 L pail.[1] For undersaturated waste, use a weight of homogenized, dry waste from step 1(a) or 1(b) corresponding to the required waste volume determined by the following equation:

$$\text{Dry waste weight (g)} = \textit{Waste volume (mL)} \times \textit{DBD} \div \textit{1000}$$

where:

DBD	**Dry bulk density** (DBD) of the waste (kg/m^3) (see appendix 7)

Step 8: Add water, blend, and bring the mixture to a saturated paste condition. Allow lumps to soak before blending. Use an electric blender if desired.

Step 9: Cover the pail loosely and leave the blended mixture for at least four hours or preferably 16 hours to allow soluble salts to approach equilibrium.

Step 10: Blend in more water, if necessary, to re-establish saturation.

Step 11: Measure weight loss at 105ºC on a subsample of paste to obtain **per cent saturation**.

Step 12: Record pH of the paste, filter, and test filtrate for salinity parameters.

Reference: Ashworth and Webster. 2004. *Proceedings of the 41st Alberta Soil Science Workshop*, p. 61–67.

[1] Suggestion: Using water (density = 1.00 g/mL) instead of waste, weigh the calculated required volume in a disposable cup, marking the outside of the cup at the water level. Discard the water and add homogenized waste to the mark (settling it by tapping the cup base on the bench top), then transfer the waste into the pail of soil, rinsing the cup with the minimum amount of deionized water.

Appendix 4 Hydrocarbons

Introduction

Changes or updates to soil quality or remediation guidelines require that the methods of applying waste to land be re-evaluated to ensure the resulting soil-waste mix does not exceed the updated guideline values. Hydrocarbon endpoints for soils receiving drilling waste have been established based on these guidelines and are set out in table 3 of this directive.

Hydrocarbon flags remain a valid indicator of the presence of hydrocarbons in drilling waste. *Directive 050* requires that drilling waste be tested for hydrocarbons if hydrocarbon flags have been encountered and that the results be used to make decisions about disposal methods and rates and about the need to sample the resulting soil-waste mix after disposal.

Hydrocarbon Flags

Data on hydrocarbon contamination in drilling waste were collected as part of the 1994 Drilling Waste Review Project, which took place during an earlier review of *Directive 050.* This information was considered in the development of this appendix.

The 1994 information identified that drilling waste sample containing significant hydrocarbon levels came from locations where hydrocarbon flags were indicated.

Waste generated from a drilling operation is hydrocarbon flagged if

- the well is a horizontal oil well,
- a diesel pill was added,
- other hydrocarbons were added through drilling practices (e.g., underbalanced drilling or drillstem testing), or
- visible hydrocarbons are present in the drilling waste.

The *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* set out the hydrocarbon guidelines for benzene, toluene, ethyl benzene, and xylene (BTEX) and hydrocarbon fractions C_6 to C_{10} (F1), > C_{10} – C_{16} (F2), > C_{16} – C_{34}(F3), and > C_{34}(F4). As the guideline values for volatile hydrocarbons are quite low, licensees are cautioned that a visible indicator may not capture BTEX and F1 exceedances.

Hydrocarbon Analysis

The following calculation can be used to predict the concentration of hydrocarbons in the final soil-waste mix, assuming a mix ratio of one part waste to three parts soil (substitute appropriate numbers for other mix ratios as applicable; see appendix 7 for more calculations):

$$P_m = \frac{Pw \times DBD}{(3 \times 1540) + DBD}$$

where:

P_m	parameter concentration in soil-waste mix on a dry weight basis *(mg/kg or %)*
P_w	parameter concentration in the waste on a dry weight basis *(mg/kg or %)*
1540	receiving soil density (subsoil) (*kg/m³*)
DBD	dry bulk density of the solids or total waste calculated from specific gravity *(kg/m³)*

Appendix 5 Metals

Introduction

Changes or updates to soil quality or remediation guidelines require that the methods of applying waste to land be re-evaluated to ensure the resulting soil-waste mix does not exceed the updated guideline values. Metal endpoints for soils receiving drilling waste are set out in table 5.

Rationale for Including or Excluding Metals

Various drilling additives and mud products are used to ensure the fluid properties are compatible with the geological conditions encountered during drilling. The fluid additive or mud product used, including the amount used, could be a source of metal. Data collected during the 1994 Drilling Waste Review Project concluded that metal analysis of drilling waste was only required when additives or mud products containing significant metal concentrations were added to the drilling mud system.

Metal sources of concern include

- zinc carbonate ($ZnCO_3$), which is commonly used to remove hydrogen sulphide. In some cases, $ZnCO_3$ is contaminated with cadmium. If the drilling waste needs to be analyzed for $ZnCO_3$, cadmium should also be measured;
- barite ($BaSO_4$), which is used to increase fluid density; and
- chrome lignosulphonates, which were commonly used as thinners at one time but have been largely phased out.

Use the following equation to calculate the concentration of a metal after mixing the drilling waste with the receiving soil, assuming a soil-waste mix ratio of 3:1 (substitute appropriate numbers for other mix ratios as applicable):

$$P_m = \frac{(P_W \times DBD) + (P_S \times 3 \times 1540)}{(3 \times 1540) + DBD}$$

where:

P_m	parameter concentration in soil-waste mix on a dry weight basis *(mg/kg or %)*
P_w	parameter concentration in the waste on a dry weight basis *(mg/kg or %)*
DBD	dry bulk density of the solids or total waste calculated from specific gravity *(kg/m³)*

P_s	parameter concentration in the soil on a dry weight basis *(mg/kg or %)*
1540	dry bulk density of the solids or total waste calculated from specific gravity *(kg/m³)*

The metal concentrations set out in table 6, which trigger the requirement to post-disposal sample the soil-waste mix, are in mg/kg wet weight and are correlated to the specific gravity of the drilling waste.

The boron concentrations set out in table 7, which also trigger the requirement to post-disposal sample the soil-waste mix, are in mg/L of waste filtrate or saturated paste extract and are correlated to the specific gravity of the drilling waste.

Appendix 6 Toxicity Testing

Introduction

Various drilling additives and mud products are used to ensure the fluid properties are compatible with the geological conditions encountered during drilling. Some additives and mud products might be considered toxic. When routine chemical analysis does not detect the presence of components that might be harmful to vegetation, microorganisms, aquatic species, wildlife, or humans, use toxicity testing for drilling waste analysis. Toxicity testing can also be useful in predicting the influence of environmental factors on ecotoxic responses and the short- and long-term effects of drilling waste.

Toxicity tests for drilling waste material should be responsive to organic, metallic, organometallic, or gaseous components and not be highly dependent on major nutrient or ion concentrations.

Toxicity tests are conducted on drilling waste to

- determine the presence or absence of toxicity;
- ascertain the nature, extent, and probable cause of toxicity;
- assist in developing and evaluating waste treatment options; and
- assist in making waste disposal decisions.

The following sections are focused on water-based drilling fluids. Other mud systems require specific management and disposal plans.

Luminescent Bacteria Toxicity Test and Pass Threshold

This edition of *Directive 050* uses the luminescent bacteria toxicity test as a standard with a pass threshold of 75 per cent for an EC50(15). See the references below for the methodology and procedures for toxicity testing using luminescent bacteria.

Aqueous Phase Samples

MicrotoxOmni Software, v. 1.18 ©2003 Strategic Diagnostics Inc. (for additional information, call 800-544-8881 or visit www.sdix.com).

American Public Health Association, American Water Works Association, and Water Environment Federation. Method 8050: Bacterial Bioluminescence. *Standard Methods for the Examination of Water and Wastewater*, 21st edition.

Western Canada Microtox Users Committee. *Standard Procedures for Microtox Analysis*. 1994. Report AECV94-G1.

Environment Canada. *Biological Test Method: Toxicity Test Using Luminescent Bacteria*. Report EPS 1/RM/24, 1992.

The Open Environmental Pollution & Toxicology Journal, 2010, Volume 2: 1–7. *Turbidity and Color Correction in the Microtox^{TM} Bioassay*. John Ashworth, Erik Nijenhuis, Bozena Glowacka, Lang Tran, and Lisa Schenk-Watt.

Solid Phase Samples

Environment Canada. *Biological Test Method: Reference Method for Determining the Toxicity of Sediment Using Luminescent Bacteria in Solid-Phase Test.* Report EPS 1/RM/42, 2002.

Luminescent Bacteria Toxicity Test Limitations, Interferences, and Sample Handling

Under advisement from the Western Canada Microtox users committee, sample preparation techniques specific to the luminescent bacteria test method for the assessment of drilling waste toxicity have been kept in this edition of *Directive 050* and are set out below. However, licensees are reminded that methods used to assess drilling waste are required to be recognized and published, as set out in section 5, and that the preferred methods to assess drilling waste are methods for which accreditation by the Standards Council of Canada or Canadian Association for Laboratory Accreditation have been obtained or is expected.

Luminescent Bacteria Toxicity Test: Limitations and Interferences

Colour (especially red and brown), turbidity, suspended solids, and floating or emulsified substances interfere with this test by absorbing or reflecting light, thereby affecting or causing nonspecific reductions in light output. The absorbance (colour) correction procedure should be used to correct these interferences. The procedure provides a means for mathematically adjusting the light emission readings to account for light lost due to adsorption and allows the testing of coloured or slightly turbid test samples. Highly turbid or emulsified samples should be clarified as much as possible by centrifuging and decanting before testing.

A high salt concentration in test samples (i.e., above 30 g/L NaCl) may produce hyperosmotic effects upon the addition of NaCl as required in the toxicity test. No osmotic adjustment should be made if the salt concentration in the sample is between 30 to 50 g/L NaCl equivalent.

The presence of volatiles may affect the test results or reproducibility. However, unless aeration or excessive mixing is performed on the samples, there should not be any excessive loss of volatile components.

The pH of the test sample might inhibit light output and affect the test results. Ideally, the pH should not be adjusted because the test relevance and sample integrity may become questionable.

Altering the test sample pH will usually change the solubility of both organic and inorganic constituents. Modifying the pH can also cause chemical reactions that will change the sample matrix and integrity and greatly alter the exhibited toxicity of the sample. The pH should be adjusted only in samples that have a pH below 6.0 or above 8.8 to minimize any potential effects from pH alone.

Luminescent Bacteria Toxicity Test: Fluids Sample Handling – Clarification

There are three possible phases for drilling waste: fluid, sludge, or solid. In practice, samples cannot be neatly categorized as they may range from clear liquids to slightly turbid or highly turbid waste to thick sludge to solids.

Perform the toxicity test on a liquid portion of the samples as received. Toxicity testing in the lab should be done with minimal sample preparation to match on-site disposal as much as possible. Use turbidity / colour-correction procedures to accurately correct for any effects on apparent sample toxicity caused by colour or sample turbidity (measured in nephelometric turbidity units).

Luminescent Bacteria Toxicity Test: Solids Sample Handling – Aqueous Extraction Procedure

The testing of solids samples, such as thick sludges, solids, and **drill cuttings**, will require the preparation of an aqueous extract before toxicity testing as follows:

Step 1: Perform a 1:1 extraction as follows:

- in a clean glass container, add 25 mL of demineralized water to 25 g of the solids sample as received, and
- close the container with a Teflon-lined cap or parafilm.

Step 2: Place the container on a wrist-action shaker at the maximum mixing arc for one hour. If a wrist-action shaker is unavailable, a suitable mechanical shaker may be used, provided there is complete mixing between the solid and fluid phases. Ensure maximum surface contact is obtained. Record the type of shaker used (this is not required to be reported but is used for interpreting and comparing results).

Step 3: Transfer the aqueous extract solution to a glass centrifuge tube using a glass pipette. If glass centrifuge tubes are unavailable, nontoxic plastic tubes may be used. Record the type of centrifuge tube used (this is not required to be reported but is used for interpreting and comparing results).

Step 4: Clarify the extract by centrifuging at 16 000 × g for 10 minutes in a refrigerated centrifuge at about 10 to 15°C if possible. If refrigerated centrifuge at this g-force is unavailable, cool the sample to 10°C before centrifugation at the maximum attainable g-force for your centrifuge. Record the speed, g-force, and temperature used for centrifugation. If the aqueous phase does not appear clear after centrifugation, re-centrifuge in a clean centrifuge tube. (The sample should be clarified so that colour correction has little or no effect.)

Step 5: Immediately transfer the aqueous supernatant to a clean glass container. Close the container with a Teflon-lined cap or parafilm.

Luminescent Bacteria Toxicity Test: Drilling Waste Charcoal Treatment Procedure

Charcoal treating a drilling waste sample will identify the toxicity level in the drilling waste (i.e., the concentration of weakly water-soluble chemicals such as hydrocarbons). If the test is expected to show toxic effects because of the addition of hydrocarbons in the drilling waste, the initial toxicity test can be conducted on the charcoal-treated sample of drilling waste.

Drilling waste that demonstrates a toxic response to luminescent bacteria should have a sample retested after treatment with charcoal to identify whether hydrocarbons are contributing to the observed toxicity or whether further characterization is required to determine the source of toxicity. Understanding the source of toxicity can provide insight into potential field treatment methods that could reduce drilling waste toxicity.

Charcoal treatment will help determine whether the toxic components will adsorb in similar environmental conditions following disposal. (This treatment has historically been used to successfully remove hydrocarbon contamination from a sample, but it should not be considered solely indicative of hydrocarbon contamination.)

Follow the procedures below for lab analyses to achieve comparable results for charcoal treatment of drilling waste. Deviation from these procedures will result in invalid results.

Preparation of Charcoal

Step 1: Use a good-quality, granular-activated charcoal, such as bone- or hardwood-derived charcoal suitable for use in fish aquariums, 10 to 20 mesh size. The use of Nuchar or other powder forms of charcoal is not acceptable.

Step 2: Prewash the charcoal by placing about 2 kg in a plastic colander or fine nylon mesh sieve and rinsing for several minutes with hot tap water followed by high-purity demineralized water. Ensure that all charcoal fines are removed during this step. Repeat the rinsing step if necessary.

Step 3: Dry the washed charcoal at 105°C in a clean, organic-vapour-free drying oven for 16 hours.

Step 4: Cool to room temperature and store in a tightly closed clean glass container.

Charcoal Treatment Procedure

Step 1: Transfer 5 mL of a clarified, pH-adjusted sample into a clean 10 mL glass test tube fitted with a polyethylene cap.

Step 2: Add 0.60 g of prepared activated charcoal.

Step 3: Shake the tube gently for about 10 seconds every 2 minutes over 10 minutes.

Step 4: Allow the charcoal to settle for no more than 30 minutes. After 30 minutes, shake the tube gently.

Step 5: Perform the toxicity test on the sample using the standard assay procedure or increased sensitivity assay procedure.

Quality Control for Charcoal Treatment Procedure

Follow this quality control procedure whenever charcoal treatment is used.

Step 1: Regularly test the prewashed activated charcoal for toxicants by substituting high-purity, toxicant-free demineralized water for the test sample and following the charcoal treatment procedure described above.

Step 2: Perform the toxicity test on the charcoal-treated demineralized water and the untreated demineralized water (as an analytical blank).

Alternative Toxicity Testing

The luminescent bacteria toxicity test may not be suitable for testing all drilling mud products and drilling waste. Certain categories of products, such as starches or those that are insoluble, yield atypical dose responses with the luminescent bacteria and do not allow an accurate endpoint for the products to be established.

Terrestrial toxicity testing is an additional step in the toxicity assessment process and can be used to

- provide soil toxicological data on the effect of a known concentration of an additive or mud product on plants and invertebrate species native to Alberta;
- establish a threshold toxicity level for an additive or mud product; or
- assess the potential to land-apply drilling waste.

The strength of terrestrial toxicity tests is that organisms from different terrestrial trophic levels are used to assess toxicity and the suitability of land application of drilling waste. The specific procedures for terrestrial toxicity testing of additives and mud products or drilling waste are outlined in the following Environment Canada soil toxicity test methods, which should be used to develop a plan for approval of land application of the drilling waste:

- *Test for Measuring Emergence and Growth of Terrestrial Plants Exposed to Contaminants in Soil* (Report EPS 1/RM/45, 2005)
- *Test for Measuring Survival and Reproduction Effects in Springtails Exposed to Contaminants in Soil* (Report EPS 1/RM/47, 2007)
- *Tests for Toxicity of Soil Contaminants to Earthworms* (Eisenia Andrei, Eisenia fetida or Lumbricus terrestris) (Report EPS 1/RM/43, 2004)

The plan should include the development of a suitable matrix that reflects conditions in the field. The matrix should be a blend of one part product, mud system, or drilling waste to three parts soil. Incorporation of waste into artificial or site-referenced soil is allowed. However, the use of artificial soil following the recipe outlined in the Environment Canada methods will reduce variability in sample handling, allow standardized base soil to be used between labs, and allow any effects observed to be discerned from the product or waste being tested rather than from natural impairment that might be imparted from the site soil.

The Environment Canada soil toxicity test methods use inhibition concentration that causes a 50 per cent effect on exposed test organisms (IC50) as a principal endpoint. IC50 is used when quantitative (or continuous) data are being analyzed (i.e., growth or reproduction), whereas LC50, the concentration of material in water, soil, or sediment that is estimated to be lethal to 50 per cent of the test organisms, and EC50 are statistical endpoints for tests using a quantal (or count) type approach (i.e., survival, avoidance behaviour). Further explanation on this matter, as well as on statistical methods of analyzing toxicity test data, can be found in the Environment Canada Guidance Document on Application and Interpretation of Single-species Tests in Environmental Toxicology (Report EPS 1/RM/34, 1999) and Guidance Document on Statistical Methods for Environmental Toxicity Tests (Report EPS 1/RM/46, 2005).

Other references related to soil and toxicity assessment include the following:

- *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (Alberta Environment and Protected Areas, latest edition)
- *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (Alberta Environment and Protected Areas, latest edition)
- *A Protocol for the Derivation of Human Health and Ecological Soil Quality Guidelines* (Canadian Council of Ministers of the Environment [CCME], 2006, PN 1332)

- *Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil* (CCME, Draft, 2007)
- *Tier 2 Eco-contact Guideline Derivation Protocol (*Alberta Environment, Draft, 2007)

The onus is on licensees to obtain toxicity testing information for additives and mud products used in the drilling mud formulation. Where luminescent bacteria toxicity information is not available, the licensee may develop an alternative toxicity testing program to gather data to develop toxicity threshold levels equivalent to those developed using the luminescent bacteria testing method. Apply as per section 15 for approval of alternatives.

Where the reason why the drilling waste failed the luminescent bacteria **bioassay** cannot be determined and the licensee wishes to land-apply drilling waste, the onus is on the licensee to develop a toxicity testing program and gather data that supports the disposal of the drilling waste as not toxic to the soil (as per section 3 and requirement 42) and apply as per section 15 for approval of alternatives.

Appendix 7 Drilling Waste Sample Handling, Analytical Methods, and Calculations

Sample Handling and Preparation

Drilling waste samples are usually collected in an oversaturated condition where the pores of the solids are full, and there is excess liquid. Occasionally an undersaturated condition occurs where not all the pores of solids are filled with liquid.

Sample handling and preparation differ depending on whether the drilling waste is undersaturated or oversaturated. Drilling waste fluids and total waste samples are typically oversaturated, whereas drilling waste solids can be undersaturated.

The phase analyzed depends upon the parameter. Use the liquid phase of an oversaturated sample or a saturated paste extract of an undersaturated sample for analysis of soluble parameters.

The following provides guidance for sample preparation for analysis of soluble parameters.

Fluids sample: Sample preparation depends on the method of analysis. At a minimum, the fluids sample should be clarified by filtration or centrifuging to pass through a Whatman no. 1 (11 micron) filter paper or equivalent to remove any solids. Further clarification may be necessary.

Clear liquids sample: The sample should already be clear. However, to remove any floating particles, the sample should be clarified by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent. The analysis will be done on the clarified extract.

Solids sample: An oversaturated solids sample should be clarified by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent. The analysis will be done on the clarified extract. Drying, grinding, sieving, and rewetting into a saturated paste is not required.

An undersaturated solids sample should be brought to a saturated paste condition by adding distilled water and mixing thoroughly. Let the sample stand for a at least four hours before analysis.

Total waste sample: The sample should be clarified by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent. Drying, grinding, sieving, and rewetting into a saturated paste is not required.

Use the whole sample and not the individual phases for hydrocarbon content and metals analysis.

Composite waste samples – landspraying disposal method: The landspraying composite waste sample should be clarified by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent. Drying, grinding, sieving, and rewetting into a saturated paste is not required.

Receiving soil sample: The soil sample can be either dried and ground and a saturated paste prepared, or a moist subsample can be brought to a saturated paste condition (drying, grinding, sieving, and rewetting into a saturated paste is not required). Allow the paste to equilibrate for at least four hours.

Use the dry weight basis to compare analyte concentrations in soil, drilling waste, and drilling soil-waste mixes with regulatory limits or endpoints. Dry bulk density (DBD), the dry weight of solids in a given volume of wet waste, is determined from the specific gravity (SG) and is used to calculate concentrations on a dry weight basis.

Specific Gravity

Specific gravity measurements of fluids, solids, and total waste are required for calculating the DBD and the volume fraction of water.

The SG is measured using an API mud balance or equivalent.

Oversaturated Drilling Waste

The SG is measured after adding the as-received fluid, solid, or total waste to the API mud balance cup to fill it completely. This value is used to calculate **mud density**, DBD, and the volume fraction of water (Φ).

Undersaturated Drilling Waste

The SG is measured after filling the API mud balance cup with the as-received solid without significantly compressing the sample and adding water to the cup to fill any pore spaces. This first SG value is used to calculate the mud density and DBD.

A separate SG measurement is required on a saturated paste prepared from an undersaturated solid. This second SG value is used to calculate the volume fraction of water (Φ_U) and the concentrations of analytical parameters in mg/kg.

Major Ion Analytes

Analysis for electrical conductivity, sodium adsorption ratio (sodium, calcium, magnesium), chloride, and forms of nitrogen in oversaturated drilling waste samples are to be done on an as-received filtrate. The drilling waste samples are to be clarified by filtration or centrifuging to pass through a Whatman no. 1 filter paper or equivalent; the analyses are to be done on the clarified filtrate.

Major ion analysis of undersaturated drilling waste or soil samples is to be done on a saturated paste extract.

When assessing nitrogen, include both the ammonium-nitrogen and nitrate-nitrogen forms.

Trace Elements and Hydrocarbons

Trace element and hydrocarbon content analyses of drilling waste solid samples and total waste samples are to be done on the samples as received. Although screening methods can be used to determine the hydrocarbon content in drilling waste samples, use the procedure and methods set out in the latest edition of *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* to determine hydrocarbon content in soils and soil-waste mixtures. Hydrocarbon analysis of drilling waste fluids samples are done on as-received samples.

Calculations

Calculations for Drilling Waste

The following equations can be used to determine the concentration of a parameter on a dry weight basis or the total mass of a parameter in a volume of drilling waste.

Oversaturated Drilling Waste Materials Equations

The DBD of oversaturated solids or total waste is calculated by measuring the SG of the wet solids using an API mud balance.

$$\text{DBD (kg/m}^3\text{)} = \frac{(Measured\ mud\ density - 1000) \times 2.65}{2.65 - 1}$$

where:

DBD	dry weight of solids in a given volume of wet waste (kg/m^3)
Measured mud density	specific gravity x 1000 (kg/m^3)
1000	density of water (kg/m^3) or 1 g/mL
2.65	particle density of solids (g/mL)

Use the following equation to convert a parameter from mg/L of filtrate from the as-received (oversaturated) sample to mg/kg of dried waste solids:

$$P_w \text{ (mg/kg)} = P_{filtrate} \times \left(\frac{2650 - DBD}{2.65 \times DBD}\right)$$

where:

P_w	parameter concentration in the dried waste solids (mg/kg)
$P_{filtrate}$	parameter concentration in the as-received filtrate (mg/L)
2650	2.65 x 1000

DBD	dry bulk density as calculated from the preceding equation (kg/m^3)
2.65	particle density of solids (g/mL)

Determine the volume fraction of water in the as-received (oversaturated) waste materials using the following equation:

$$\text{Volume fraction of water } (\Phi) = 1 - \left(\frac{Mud\ density - 1000}{1650}\right)$$

where:

Mud density	specific gravity x 1000 (kg/m^3)

Undersaturated Drilling Waste Materials Equations

The DBD of an undersaturated sample is estimated using the same equation as for an oversaturated sample; however, the SG is measured as described in subsection Oversaturated Drilling Waste Materials Equations.

Analysis of undersaturated solids requires the following additional steps to prepare a saturated paste:

Step 1: Add distilled water to bring a subsample to a saturated paste condition, mix and allow to sit for at least four hours for the salts to equilibrate with the added water.

Step 2: Determine the SG of the saturated paste using the API mud balance.

Step 3: Filter the saturated paste and analyze the extract for major ions and nitrogen if required.

Step 4: Determine the volume fraction of water in a saturated paste made from an undersaturated waste material using the following formula:

$$\text{Volume faction water } (\Phi_U) = \frac{(2.65 - SG)}{1.65}$$

where:

SG	specific gravity of the saturated paste as measured using the API mud balance
2.65	particle density of solids (g/mL)

Use the following equation to convert a parameter from mg/L of filtrate from a saturated paste extract to mg/kg of dried waste solids:

$$P_w\ (\text{mg/kg}) = P_{filtrate} \times \frac{\Phi_U}{2.65 \times (1 - \Phi_U)}$$

where:

P_w	parameter concentration in the dried waste solids (mg/kg)
$P_{filtrate}$	parameter concentration in the saturated paste filtrate (mg/L)
Φ_U	the volume fraction of water
2.65	particle density of solids (g/mL)

Equations to Predict the Mass of a Parameter in Drilling Waste

Use the following equation to predict the mass of trace elements in a given volume of either oversaturated or undersaturated waste material:

$$\text{Mass (kg)} = \frac{P_w \times DBD \times Volume}{1\,000\,000}$$

where:

P_w	parameter concentration in the waste on a dry weight basis (mg/kg or %)
DBD	dry bulk density as calculated from specific gravity (kg/m^3)
Volume	volume of drilling waste material (m^3)
1 000 000	unitless value (constant, factor, or unit conversion)

Use the following equation to calculate the mass of a parameter in a given volume of a clear waste liquid:

$$\text{Mass (kg)} = P_L \times \frac{Clear\ waste\ liquid\ volume}{1000}$$

where:

P_L	parameter concentration in the clear waste liquid (kg)
Volume	volume of clear waste liquid (m^3)
1000	unitless value (constant, factor, or unit conversion)

Disposal Limit Equations

Use the following equations to predict soil-waste mix ratios, maximum waste application rates, minimum disposal areas, amounts of a parameter per hectare of land, and amounts of a parameter in the resulting soil-waste mix. For all salinity equations, see appendix 3.

Mix-Bury-Cover Equations

Use the following equations to calculate the concentration of any parameter in the soil-waste mixture for a 3:1 mix ratio of soil to waste (substitute appropriate numbers for other mix ratios as applicable) when, for practical purposes, it can be assumed that the receiving soil contains none of that parameter (e.g., hydrocarbon):

$$P_m = \frac{P_w \times DBD}{(3 \times 1540) + DBD}$$

where:

P_m	parameter concentration in the soil-waste mix on a dry weight basis (mg/kg or %)
P_w	parameter concentration in the waste on a dry weight basis (mg/kg or %)
DBD	dry bulk density of the solids or total waste as calculated from specific gravity (kg/m^3)
1540	receiving soil density (subsoil) (kg/m^3)

To calculate the concentration of a parameter after mixing when the receiving soil already contains a background level of that parameter (i.e., a trace element) for a 3:1 mix ratio of soil to waste (substitute appropriate numbers for other mix ratios as applicable):

$$P_m = \frac{(P_w \times DBD) + (P_s \times 3 \times 1540)}{(3 \times 1540) + DBD}$$

where:

P_m	parameter concentration in the soil-waste mix on a dry weight basis (mg/kg or %)
P_w	parameter concentration in the waste on a dry weight basis (mg/kg or %)
P_s	parameter concentration in the soil on a dry weight basis *(mg/kg or %)*
1540	receiving soil density (subsoil) (kg/m^3)
DBD	dry bulk density of the solids or total waste as calculated from specific gravity (kg/m^3)

Equations for Landspreading, Landspraying, Disposal Onto Forested Public Lands, and Landspray While Drilling

Use the following equation to calculate the maximum application rate that will not exceed the kg/ha loading limit for a given parameter (e.g., sodium):

$$\text{Maximum application rate (m}^3\text{/ha)} = P_{max} \times \left(\frac{1\,000\,000}{P_w \times DBD}\right)$$

where:

P_{max}	maximum amount of a parameter (limit) allowed on 1 ha
1 000 000	unitless value (constant, factor, or unit conversion)
P_w	parameter concentration in the dry solids (calculated from filtrate results) (mg/kg)
DBD	dry bulk density of the solids or total waste as calculated from specific gravity (kg/m^3)

Use the following equation to calculate maximum application thickness (m^3/ha) (cannot exceed one-third of the incorporated depth or 10 cm, whichever is less):

$$\text{Maximum application thickness (cm)} = \frac{Maximum\ application\ rate}{100}$$

Where the maximum application rate is in m^3/ha and 100 is a unitless value (constant, factor, or unit conversion).

Use the following equation to calculate the minimum area required for disposal so that the limit for a given parameter (e.g., sodium) is not exceeded. Licensees are encouraged to use more than the minimum area if available.

$$\text{Minimum disposal area (ha)} = \frac{Volume\ of\ undersaturated\ solids}{a,b,or\ c\ whichever\ is\ less}$$

Where the volume of undersaturated solids in m^3 is divided by the lesser of:

- *a*: the maximum calculated application rate (m^3/ha)
- *b*: 1000 m^3/ha
- *c*: the incorporated depth (cm)/3 × 100

Where applicable, a simple approach to determine the minimum disposal area is to divide the waste volume by the maximum application rate equation.

Use the following equation to calculate the amount of any parameter added to the receiving soil:

$$\text{Amount (kg/ha)} = \frac{P_w \times DBD \times Maximum\ application\ rate}{1\ 000\ 000}$$

where:

P_w	parameter concentration in the dry solids (calculated from filtrate results) (mg/kg)
DBD	dry bulk density of the solids or total waste as calculated from specific gravity (kg/m^3)
Maximum application rate	Value calculated from the preceding equation (m^3/ha)

Use the following equation to calculate the amount per hectare of any parameter added to the receiving soil:

$$\text{Amount (kg/ha)} = \frac{Mass\ of\ paramter}{Planned\ disposal\ area}$$

Where mass is in kg and area in ha.

Equation Specific for Landspraying and Landspray While Drilling

Use the following equation to calculate the maximum application rate that will not exceed 6 t/ha loading limit for landspraying and landspray while drilling disposal methods:

$$\text{Maximum application rate (m}^3\text{/ha)} = \frac{6 \times 1000}{DBD}$$

where:

6	Loading limit (t/ha)
1000	kg/t
DBD	dry bulk density of the solids or total waste as calculated from specific gravity (kg/m^3)

Pump-off Equations

Use the following equation to calculate the maximum application rate of clear drilling waste liquid that will not exceed the rate limitation for a dissolved parameter:

$$\text{Maximum application rate (m}^3\text{/ha)} = \frac{P_{max} \times 1000 \times 1\ 000\ 000}{P_L}$$

where:

P_{max}	maximum application rate (limit) allowed on 1 ha
100	m^3/L

1 000 000	mg/kg
P_L	parameter concentration in the clear waste liquid

If the calculated rate is greater than 1000 m^3/ha, apply the clear waste liquid at a maximum rate of 1000 m^3/ha. This is equivalent to a 10 cm layer of application.

Use the following equation to calculate the minimum area required for disposal of clear waste liquid without exceeding the parameter limit. Licensees are encouraged to use more than the minimum disposal area if it is available.

$$\text{Minimum disposal area (ha)} = \frac{Volume\ of\ clear\ waste\ liquids}{a\ or\ b\ whichever\ is\ less}$$

Where the volume of undersaturated solids in m^3 is divided by the lessor of the following:

- *a*: the maximum calculated application rate (m^3/ha)
- *b*: 1000 m^3/ha

Where applicable, a simple approach to determine minimum disposal area is to divide the waste volume by the maximum application rate equation.

Use the following equation to calculate the amount per hectare of any dissolved parameter added to the receiving site:

$$\text{Amount (kg/ha)} = P_L \times \left(\frac{Application\ rate}{1000}\right)$$

where:

P_L	parameter concentration in the clear waste liquid (mg/L)
Application rate	(m^3/ha)
1000	unitless value (constant, factor, or unit conversion)

Appendix 8 References

AER Documents

Directive 055: Storage Requirements for the Upstream Petroleum Industry

Directive 058: Oilfield Waste Management Requirements for the Upstream Petroleum Industry

Brine-Hosted Mineral Resource Development Rules

Geothermal Resource Development Act

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Oil and Gas Conservation Act

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