Saskatchewan
Energy and Mines

Saskatchewan Drilling Waste Management Guidelines

Information Guideline GL 99-01
Saskatchewan Energy and Mines
Petroleum Development Branch
December 1, 1999

TABLE OF CONTENTS

INTRODUCTION

Although Saskatchewan Energy and Mines has exercised all reasonable care in the compilation, interpretation and production of this document, it is not possible to ensure total accuracy, and all persons who rely on the information contained herein do so at their own risk. Saskatchewan Energy and Mines and the Government of Saskatchewan do not accept liability for any errors, omissions or inaccuracies that may be included in, or derived from, the use of this document.

Background

Saskatchewan Energy and Mines (SEM) firmly believes that drilling wastes must be managed to protect the environment from adverse impacts and allow the disposal site utilized to return to equivalent land capability. SEM maintains the position that operators must continue to work on methods to minimize the impacts of drilling fluids on the environment. In this regard, such things as selecting environmentally friendly additives, using no-leak containment devices, minimizing the volume of drilling fluids used, re-using and recycling fluids, and selecting the best disposal option should be an integral part of all drilling programs.

These guidelines outline comprehensive methods and criteria for the handling and disposal of drilling wastes in Saskatchewan. The intent of these guidelines is to ensure environmentally safe and responsible management of drilling wastes. Operators using disposal methods other than the recommended methods described in these guidelines do so at their own risk. Ultimately, the operators are responsible for the proper disposal of their own wastes.

These guidelines replace all previous Saskatchewan Energy and Mines guidelines pertaining to the disposal of drilling muds, drilling fluids, drilling wastes and drill cuttings produced by the upstream petroleum industry, including but not limited to the following:

- Approval Guidelines for the On-lease and Off-lease Land Application of Freshwater Drilling System Fluids, GL 86-01;
- Guidelines for Disposal of Salt-Based Drilling Mud;
- Guidelines for Use-Approval of Alkali Sloughs and Salt Based Drilling Mud Disposal;
- Draft Guidelines for the Handling and Disposal of Hydrocarbon Based Drilling Fluids and Hydrocarbon Contaminated Cuttings in Saskatchewan;
- Interim Approval Guidelines Ammonium Sulfate Drilling Fluid Application Off-lease and Environmentally Sensitive Areas;
- Interim Approval Guidelines Calcium Sulfate Drilling Fluid Application Off-lease and Environmentally Sensitive Areas; and
- Interim Approval Guidelines Potassium Sulfate Drilling Fluid Application Off-lease and Environmentally Sensitive Areas.

SECTION 1 DISPOSAL METHODS AND INFORMATION REQUIREMENTS

1.1 General Discussion of Drilling Fluids

Drilling fluids account for a large portion of the waste generated by the upstream oil and gas industry. Most of the wells drilled for oil or gas use a liquid system to manage the wellbore during drilling. The drilling fluids become contaminated with formation material and the final result is a large volume of liquid and solid waste that must be disposed of. In some cases, the drilling fluid can be reused or recycled, but much of the time it is disposed of on the lease site or on nearby agricultural land (stubble fields and cultivated lands). There are many additives which can be used in drilling fluid systems, depending on the conditions encountered during drilling; however, most fluid systems are a combination of water and a small number of additives. Specialty systems, such as, salt based and hydrocarbon-based fluids, are increasingly being used to better manage the wellbore.

Please note, certain drilling wastes may be regulated as dangerous goods under *The Dangerous Goods Transportation Act* (i.e., drilling waste with pH less than 2.0 or greater than 12.5). For detailed information on waste management and applicable legislation, please refer to the *Waste Management Guidelines for the Saskatchewan Petroleum Upstream Oil and Gas Industry*, SPIGEC, February 1996. Although criteria for pH is not specified in these guidelines, we recommend operators should consider adjusting the pH of the drilling waste prior to disposal, if the pH is less than 4 or greater than 11.

If the drilling fluids cannot be reused or recycled, they must be disposed of in an environmentally acceptable manner. There are several methods of disposal which are acceptable for use in Saskatchewan:

1. On Lease Disposal Options Include:
   - On Lease Landspreading Method
   - Residual Solids Disposal Method
2. Off Lease Disposal Options Include:
   - Landspraying Disposal After Completion of Drilling
   - Landspraying While Drilling (LWD)
3. Land Treatment Disposal Options
4. Alternative Disposal Options

ALL OFF LEASE SURFACE APPLICATION DISPOSAL METHODS DESCRIBED IN THE GUIDELINES ARE LIMITED TO STUBBLE FIELDS AND CULTIVATED LANDS. SURFACE APPLICATION OF DRILLING WASTES ON VEGETATED LANDS (PASTURE, NATIVE GRASS OR FORESTED LANDS) IS NOT AUTHORIZED BY SEM.

1.2 Containment of Fluids During Drilling

Drilling fluids must be contained in a manner that protects the environment. The following containment methods shall be used as circumstances warrant:

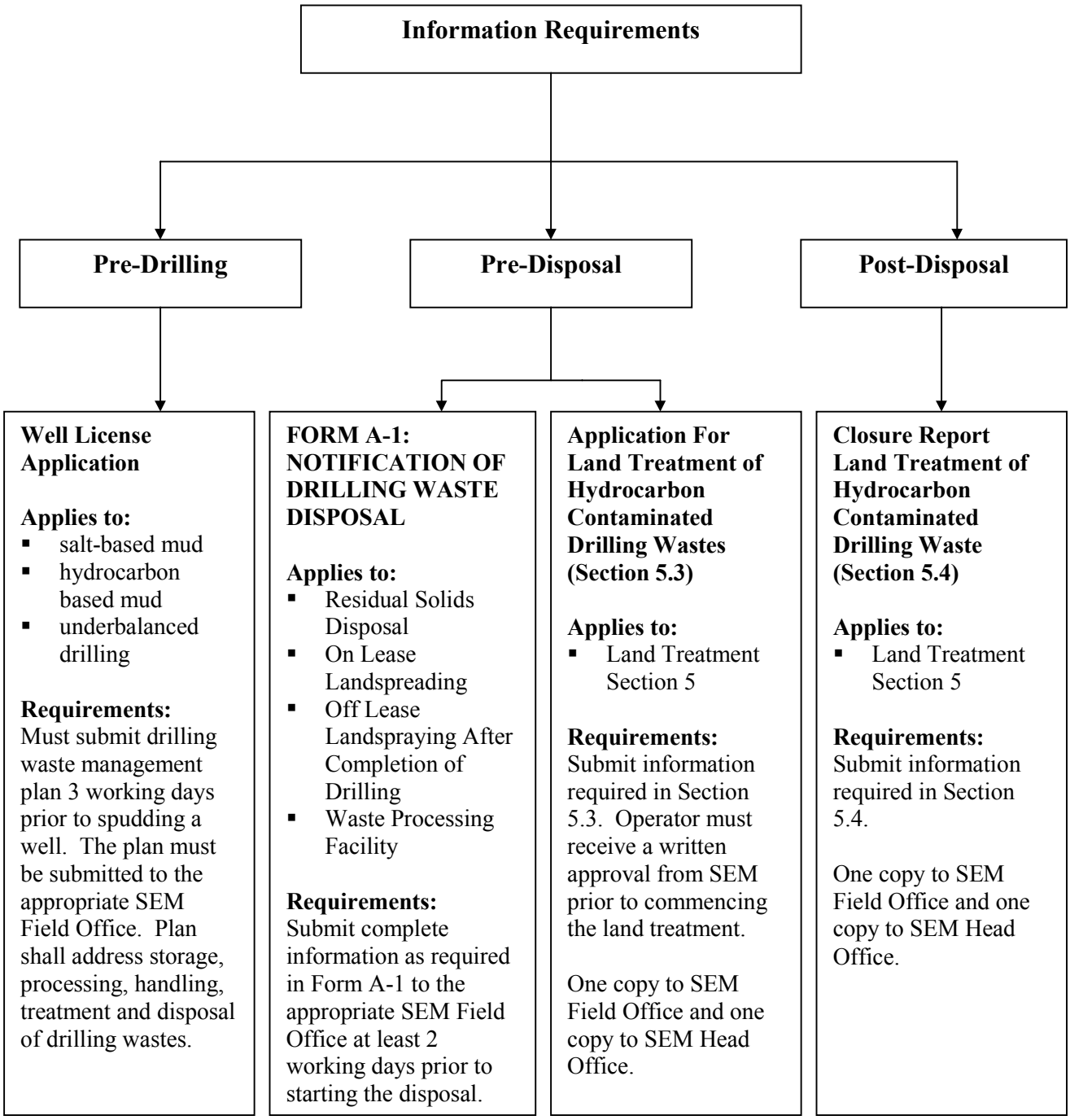
1. Earthen sumps may be used to contain freshwater drilling fluids, if the bottom of the pit is separated from the groundwater table by at least one metre of continuous impermeable subsoil. Sumps shall not be used to contain salt or hydrocarbon based drilling mud systems. The use of sumps on Crown lands may be prohibited, refer to the conditions in your surface lease agreement.
2. Synthetically lined sumps may be used to contain freshwater drilling fluids where containment using native soils is not possible. The liner shall be compatible with the fluid being stored and provide sufficient strength and durability for the intended application. Sumps shall not be used to contain salt or hydrocarbon based drilling mud systems.
3. Mud tanks must be used in areas where soil conditions are not suitable, where a high groundwater table exists, or where salt or hydrocarbon based drilling mud systems are being used.
4. A closed drilling fluid handling system[1] incorporating fluid containment tank(s) is required when it is reasonable to believe that explosion hazard(s) will be created and/or harmful gases will be emitted due to the drilling activities. The operator shall exercise the highest level of due diligence to prevent explosion, fire, harmful gas emission and deleterious impact to the environment.
5. Remote sumps may be used in areas where it is not practical to contain drilling fluids on lease or where multi-well programs are planned, provided the remote sump has prior approval from SEM. To obtain prior approval, the following must be submitted to the appropriate SEM Field Office:
   - a letter of application describing what is to be stored in the sump;
   - the length of time the sump is to be used;
   - a survey plan showing the location of the remote sump; and
   - a written consent from the landowner.

   SEM requires a minimum of two working days to review the application. If the application meets the requirements, written approval with all applicable site-specific conditions will be issued.

[1] Refer to appendix for definitions and conditions.

The drilling fluids should be disposed of in a timely manner upon the completion of drilling. Earthen pits or sumps shall be filled in and the surface restored to the contour of the site. **In all disposal cases, sump closure must be completed within 12 months of drilling rig release, unless permission is obtained from the appropriate SEM Field Office.** Placing hazardous wastes, waste dangerous goods (e.g. used oil and antifreeze) or garbage in drilling sumps/tanks is prohibited. Please refer to the *Waste Management Guidelines for the Upstream Oil and Gas Industry*, SPIGEC, February 1996, for more details**.**

1.3 Information Requirements



For Landspraying While Drilling (LWD): Pre Drilling Notification shall be submitted to the appropriate SEM Field Office as described in section 4.2., at least two working days prior to commencing drilling operations. SEM Form A-1 must be submitted to the appropriate SEM Field Office within 30 days after the completion of drilling. This form must be accompanied with Post Disposal Information as described in section 4.2.

SECTION 2 SAMPLING METHODS AND SAMPLE PREPARATION

2.1 Recommended Sampling Methods

Collection, preservation and storage of soil samples are critical to the results of testing. The data is only as valid as the sample itself. Collected samples need to be free of secondary contamination and representative of each of the fluid and solid phases of waste from each sump at a given location. Representative samples from each sump are required because wastes may be from specialty mud systems that may require different disposal techniques.

The minimum distance at which samples should be obtained from the edge of the sump is one metre.

For sumps with an area less than or equal to 500 m^2, samples should be collected from five locations. For sumps with an area greater than 500 m^2, one sample should be collected for each 100 m^2 to a maximum of 10 samples. Collect a representative sample from fluid and solid phases of the waste material at each location. The suction and discharge points represent two fixed sampling locations if they are identifiable. Please note, the number of samples recommended is the minimum number of samples required to obtain a reasonable representation of the drilling waste characteristics. The operator shall obtain more samples where there may be greater variance in the range of contaminants in the drilling wastes.

The following sampling techniques are recommended for each phase.

2.1.1 Sampling of Fluid Phase in the Sump

- Collect individual sub-samples. The hydrocarbon layer should be included in the sample, if hydrocarbons are not intended to be removed prior to disposal.
- Prepare a composite sample by placing equal amounts of sub-samples into a large clean plastic bucket. Mix the sample thoroughly in the bucket. Then place an appropriate amount of the thoroughly mixed sample into a container as described below.
- Portions of the composite sample required are as follows:
  - For trace element and major ion analysis, place one litre of the thoroughly mixed sample into an uncoloured plastic container, or as recommended by the laboratory.
  - For hydrocarbon analysis, place one litre of the thoroughly mixed sample into a properly cleaned glass jar and seal with a Teflon lined lid.

2.1.2 Sampling of Solid Phase in the Sump

- Collect individual sub-samples.
- Prepare a composite sample. Place two kilograms of the thoroughly mixed sample into an uncoloured plastic container.
- For hydrocarbon analysis, place one litre of the thoroughly mixed sample into a properly cleaned glass jar and seal with a Teflon lined lid.

2.1.3 Sampling of Total Phase in the Sump

- If the fluid and solid phases in the sump are to be disposed of together, a **total phase** sample must be taken. A total phase sample is a sample that is taken from the entire depth of the fluids and solids at one time. A total phase sample must not be made up of individually sampled fluid or solid phases.
- Collect individual sub-samples.
- Prepare a composite sample. Place an appropriate amount of the thoroughly mixed sample into a container as described below.
- Portions of the composite sample required are as follows:
  - For trace elements and major ions analyses, place one litre of the thoroughly mixed sample into an uncoloured plastic container, or as recommended by the laboratory.
  - For hydrocarbon analysis, place one litre of the thoroughly mixed sample into a properly cleaned glass jar and seal with a Teflon lined lid.

2.1.4 Sampling "On Lease" Receiving Soil (Pre-Application)

- Obtain representative sub-samples from the soil horizon.
- Prepare a composite sample. Place a minimum of one kilogram of the thoroughly mixed sample in an uncoloured plastic container.

2.1.5 Sampling "Off Lease" Receiving Soil (Pre-Application)

- One sampling site is required for every 8 hectares of the disposal area.
- For a multi-well project or large drilling program that requires a large area of land, four sampling sites per project will be allowed. A project is defined as a disposal area that is less than or equal to 64.76 hectares (quarter section) which is owned by the same landowner and the soil within the disposal area has similar (statistically representative) soil chemistry.
- The sampling site should be a circular area with a 10m radius, with location coordinates known for subsequent re-sampling, if necessary.
- Ten (10) cores of topsoil are required to be taken randomly within the sample site. These samples are then mixed to form one composite sample.
- A minimum of one kilogram of the composite sample is required.

2.1.6 Sample Preparation

Prepare one composite sample of the fluid phase material by combining equal volumes of the fluid material from each sample location. Composite samples should be collected in a clean container and then transferred to the appropriate sample container as soon as possible. Follow the same procedure for preparing a composite solid phase sample. The samples should be placed in containers according to the type of analysis to be conducted. In general, properly washed glass jars with Teflon lids are required for samples intended for hydrocarbon. Uncoloured plastic containers (bags or bottles) are required for samples to be analyzed for inorganic parameters (salt, metals, and pH). Please consult with the analytical laboratory to obtain information on specific sample containers, storage, handling, preparation and shipping requirements.

Fluid Phase

- Sample preparation depends on the method of analysis. As a minimum, fluid samples should be clarified by filtration or centrifuging to pass through a Whatman #1 (11µ) filter paper to remove any solids.

Solid Phase

- Oversaturated solids samples should be clarified by filtration or centrifuging to pass through a Whatman #1 (11µ) filter paper. The analysis will be done on the clarified extract. Drying, grinding, sieving and rewetting into a saturated paste is not required.
- Undersaturated solids samples should be brought to a saturated paste condition by adding distilled water. After standing for a minimum of four hours, the analysis will be done on the saturated paste extract.

Total Phase

- As a minimum, the samples should be clarified by filtration or centrifuging to pass through a Whatman #1 (11µ) filter paper. Drying, grinding, sieving and rewetting into a saturated paste is not required.
- Hydrocarbon and trace metals analysis must be done for the whole sample and not on the individual phases.

Receiving Soil

- The soil sample can either be dried and a saturated paste prepared, or the sample can be handled as undersaturated solids. Drying, grinding, sieving and rewetting into a saturated paste is not required.

Composite Waste Sample - Landspraying Disposal Method

- Landspraying composite waste samples should be clarified by filtration or centrifuging to pass through a Whatman #1 (11µ) filter paper. Drying, grinding, sieving and rewetting into a saturated paste is not required.

2.2 Drilling Waste Characterization

All drilling wastes (fluids, solids and total waste) intended to be disposed of by using options listed in these guidelines are required to be tested for the parameters listed in the Table 2.2.1, with the exception of the following disposal methods:

- landspraying while drilling - refer to Section 4.3 for specific testing requirements
- disposed at an approved waste processing facility - analyze according to the requirements as specified by the waste processing facility operator

Table 2.2.1 Testing Requirements for Drilling Wastes

Physical Parameter							
Oversaturated Drilling Waste	**Specific Gravity measurement using API mud balance (g/ml)**						
Undersaturated Drilling Waste	**Specific Gravity measurement by saturation extraction method (saturated paste) (g/ml)**						
Chemical Parameters							
		Extraction and Preparation		**Instrumentation**			
		solid/total waste	**liquid**	**units**	**solids/total waste**	**units**	**liquids**
Detailed Salinity	pH	saturation extraction	filtrate extract	na	field or lab	na	field or lab
	electrical conductivity (EC)	saturation extraction	filtrate extract	dS/m	field or lab	dS/m	field or lab
	sodium adsorption ratio (SAR)	calculated as mmol/L	calculated as mmol/L	na	$[Na]/[Ca+Mg]^{0.5}$	na	$[Na]/([Mg]+[Ca])^{0.5}$
	saturation %	saturation extraction	filtrate extract	%	measured	%	measured
	total dissolved solids	calculated	measured	mg/L	TDS = 700 x E.C	mg/L	measured
	ions Ca, Mg, Na, K, Cl, SO_4	saturation extraction	filtrate extract	mg/L	ICP/AAS/equivalent	mg/L	ICP or equivalent
	nitrogen[1] (NO_3+NO_2-N)	saturation extraction	filtrate extract	mg/L	ICP/AAS/ equivalent	mg/L	ICP or equivalent
metals[2]	B	hot water-soluble	lab digested	mg/L	ICP/AAS/ equivalent	mg/L	ICP or equivalent
	Cd, Cr, Cu, Pb, Ni, V and Zn	lab digested	lab digested	mg/L	ICP/AAS/equivalent	mg/L	ICP or equivalent
hydrocarbon - **for all disposal methods except Section 5**		oil in moist sample toluene extraction	total fluids	%	Dean & Stark dry weight basis	%	Oil and Grease gravimetric method
total extractable hydrocarbon **for Section 5**		soxhlete extraction	separatory funnel extraction	µg/g	**S.5 land treatment disposal** GC/FID	mg/L	**S.5 land treatment disposal** GC/FID

Legend: nitrogen[1]: nitrogen must be analyzed if more than 400kg of nitrogen has been added to the drilling fluids.
metals[2]: all metals must be analyzed if additives added in the drilling fluids contain(s) one or more metal(s) in excess of the following: 2.5 kg boron, 0.75 kg cadmium, 50 kg chromium, 100 kg copper, 50 kg lead, 12.5 kg nickel, 5 kg vanadium and/or 150 kg zinc.

2.3 Pre-disturbance Receiving Soil Characterization

Prior to the application of any drilling waste, the receiving soil shall be tested for the following:

- pH
- electrical conductivity (EC) dS/m
- major ions sodium, calcium, magnesium, potassium, chloride and sulphate
- Sodium Adsorption Ratio (SAR) calculated as follows:

$$\mathbf{SAR = [Na^{+}] \div ([Ca^{2+}] + [Mg^{2+}])^{0.5}}$$

where	Na	concentration of sodium ion in millimol per litre
	Ca	concentration of calcium ion in millimol per litre
	Mg	concentration of magnesium ion in millimol per litre
	mol	mole
	millimol	mol ÷ 1000

mg/L to mmol/L conversion formula:

mass of the ion per volume (mg/L) ÷ atomic weight (mmol/mg)

atomic weight	sodium	22.99
	calcium	40.08
	magnesium	24.31

OR

$$\mathbf{SAR = [Na^{+}] \div (([Ca^{2+}] + [Mg^{2+}])/2)^{0.5}}$$

where concentrations of ions are in milliequivalent per litre (meq/L)

SECTION 3 ON LEASE DISPOSAL OPTIONS

3.1 On Lease Landspreading Method

Landspreading is a disposal method whereby the drilling waste is spread on lease and incorporated into the subsoil. The landspreading area is based on a calculated loading rate. The goal of landspreading is to dispose of the waste in a manner that preserves the subsoil's chemical, biological and physical properties by limiting the accumulation of salts and protecting the quality of surface water and groundwater. Landspreading is not intended for wastes resulting from the use of salt or hydrocarbon based mud systems or wastes generated from underbalanced drilling. Typical methods for on lease landspreading are as follows:

- Ripping subsoil and spreading and incorporating the waste on lease.
- Spreading (squeezing) the waste on lease, letting it dry and incorporating it into the subsoil.
- Only drilling solids and total wastes generated from freshwater based drilling mud systems are acceptable for on lease landspreading.

The following disposal criteria must be met when using the on lease landspreading method:

- Waste may not be applied more than 1000 m^3 per hectare and/or thicker than 10 cm.
- Waste must be incorporated into the subsoil in a ratio of at least 3 parts subsoil to1 part waste.
- Trace elements must be spread at a rate less than the following:

10 kg boron/ha	**1.5 kg cadmium/ha**	**100 kg chromium/ha**	**200 kg copper/ha**
100 kg lead/ha	**25 kg nickel/ha**	**100 kg vanadium/ha**	**300 kg zinc/ha**

- Lifetime loading of trace elements per site, by any combination of disposal methods, must not exceed:

10 kg boron	**3 kg cadmium**	**200 kg chromium**	**400 kg copper**
200 kg lead	**50 kg nickel**	**200 kg vanadium**	**600 kg zinc**

- The maximum chloride application rate is less than or equal to:
  - 800 kg/ha for subsoil if incorporated in less than 30 cm
  - 1200 kg/ha for subsoil if incorporated in greater than 30 cm
- When a combination of disposal methods are used, the total lifetime chloride loading limit is 1600 kg per disposal site.
- The maximum sodium application rate is less than or equal to:
  - 500 kg/ha for subsoil if incorporated in less than 30 cm
  - 750 kg/ha for subsoil if incorporated in greater than 30 cm
- Total nitrogen application rate must not exceed 400 kg nitrogen per hectare.
- The maximum Total Dissolved Solids (TDS) application rate is less than or equal to:
  - 3500 kg/ha for subsoil if incorporated in less than 30 cm
  - 5000 kg/ha for subsoil if incorporated in greater than 30 cm
- Total hydrocarbon concentrations in the drilling waste (prior to spreading) must be less than or equal to 2%. Predicted hydrocarbon content of the subsoil and waste mix, when disposed, must be less than 0.1% on a dry weight basis calculated using a subsoil density of 1700 kg/m^3.
- Calculate criteria using appendix 3.2 on lease landspreading disposal equations.

3.2 Residual Solids Disposal Method (RSD)

RSD disposal method occurs when drilling solids - **shale and solids left in the bottom of the sump after the fluids are pumped out and disposed through an approved method** - are stabilized by mixing with subsoil. RSD is not intended for residual solids resulting from salt based or hydrocarbon based mud systems or wastes generated from underbalanced drilling. The following describes the typical RSD methods:

- Mix the residual solids with subsoil in the sump and cover.
- Only solid wastes associated with freshwater based drilling mud systems are acceptable.

The following criteria must be met when using this method or any combination of methods:

- Base of the subsoil and residual solid mixture must be separated from the groundwater table by at least one metre of a continuous layer of impermeable subsoil material ($k_w=10^{-8}$ m/s).
- Subsoil and residual solids must be mixed at least three parts subsoil to one part waste (v/v).
- A minimum of one metre of clean subsoil must be placed over the subsoil and residual solids mixture and then topsoil must be replaced.
- Lifetime loading of trace elements at disposal site, by any combination of disposal methods, must not exceed:

10 kg boron	**3 kg cadmium**	**200 kg chromium**	**400 kg copper**
200 kg lead	**50 kg nickel**	**200 kg vanadium**	**600 kg zinc**

- Post-disposal chloride concentration must be less than 2000 mg/kg (dry solid basis) in the subsoil and waste mix with a lifetime loading limit of 1600 kg per disposal site, by any combination of disposal methods.
- Post-disposal nitrogen loading must be less than a lifetime loading limit of 400kg of nitrogen per disposal site, by any combination of disposal method.
- Total hydrocarbon concentrations in the drilling waste (prior to mixing) must be less than or equal to 2%. The hydrocarbon content of the disposed subsoil and waste mixture must be less than 0.1% (1000 mg/kg) on a dry weight basis calculated using a subsoil density of 1700 kg/m^3.
- Calculate criteria using appendix 3.1 RSD disposal equations.

SECTION 4 OFF LEASE DISPOSAL OPTIONS

ALL OFF LEASE SURFACE APPLICATION DISPOSAL METHODS DESCRIBED IN THE GUIDELINES ARE LIMITED TO STUBBLE FIELDS AND CULTIVATED LANDS. SURFACE APPLICATION OF DRILLING WASTE ON VEGETATED LAND (PASTURE, NATIVE GRASS OR FORESTED LANDS) IS NOT AUTHORIZED BY SEM.

4.1 Off Lease Landspraying After Completion of Drilling

After the completion of drilling operations fluids may sprayed off lease on to cultivated lands and subsequently incorporated into the topsoil during normal farming practices. The landspraying area is determined based on a calculated loading rate or a maximum application rate. The goal of landspraying is to apply drilling fluids on to the topsoil in a manner that preserves its chemical, biological and physical properties by limiting the accumulation of salts while protecting the quality of surface water and groundwater. Landspraying is not intended for wastes resulting from the use of salt or hydrocarbon based mud systems or wastes generated from underbalanced drilling.

- Applying the waste on stubble fields or cultivated lands and incorporating by cultivation.
- Only drilling solids and total wastes generated from freshwater based drilling mud systems are acceptable for landspraying.
- Landowner approval is required.

The following disposal criteria must be met when using the off lease landspraying method:

- To minimize migration and pooling of drilling wastes:
  - the slope must be less than 5%
  - summer operations are limited to a maximum landspraying rate of 40 m^3/ha and landspraying cannot occur within 100 m of any water body or drainage courses
  - winter operations (frozen ground) are limited to a maximum landspray rate of 20 m^3/ha and landspraying cannot occur within 200 m of any water body or drainage courses
- Trace elements must be spread at a rate less than the following:

5 kg boron/ha	**1.5 kg cadmium/ha**	**100 kg chromium/ha**	**200 kg copper/ha**
100 kg lead/ha	**25 kg nickel/ha**	**100 kg vanadium/ha**	**300 kg zinc/ha**

- The maximum chloride application rate must not exceed 400 kg/ha for topsoil.
- The maximum sodium application rate is less than or equal to 250 kg/ha.
- Total nitrogen application rate must not exceed 200 kg per hectare.
- The maximum total dissolved solids application rate must not exceed 1800 kg/ha.
- Total hydrocarbon concentrations in the drilling waste (prior to spraying) must be less than or equal to 4%. The predicted hydrocarbon content in the waste/soil mixture must be less than 0.5% on a dry weight basis and the waste must be incorporated into the topsoil within two weeks.
- Disposal may only occur if the receiving soil (prior to spraying any drilling waste) EC is less than or equal to 2 dS/m and SAR is less than or equal to 6.
- Calculate criteria using appendix 3.3 landspraying disposal equations.

4.2 Off Lease Landspraying While Drilling (LWD)

Off Lease Landspraying While Drilling (LWD) is conducted while drilling is underway. This method of disposal is utilized when drilling sumps are not considered a viable option. The goal when utilizing LWD is the same as when an operator conducts the more commonly used Off Lease Landspraying After Completion of Drilling. The goal of landspraying is to apply drilling fluids on to the topsoil in a manner that preserves its chemical, biological and physical properties by limiting the accumulation of salts while protecting the quality of surface water and groundwater. Drilling fluid systems presently approved for LWD are limited to freshwater gel, gypsum water and nitrate gypsum water systems.

Pre-Drilling Notification
A written pre-notification must be submitted to the appropriate field office at least two working days prior to the start of drilling and it must include the following information:

- Intent to use the LWD disposal option and of mud system type;
- Name of the licensee, well license number, well location, drilling start date, contact name and phone number;
- Drilling waste disposal company, contact name and phone number; and
- Off lease disposal location, landowner name and phone number.

Post Disposal Notification

- SEM Form A-1 must be completed and submitted within 30 days of finished drilling date.
- SEM Form A-1 must be accompanied by the following information:
  - mapped location of the spray area
  - volume of drilling waste disposed
  - rate of application
  - analytical data of the waste (EC, SAR, Na, Ca, Mg, hydrocarbon if required) for each sections of the hole tested
  - analytical data of the receiving soil (prior to spraying any drilling waste) (EC, SAR, Na, Mg, Ca, K, Cl and SO_4)
  - hydrocarbon analysis of the soil/waste mixture (after incorporation), if the hydrocarbon concentration in the drilling waste was greater than 0.5%
  - name of landowner, legal land description, date of consent and copy of the consent

Waste Prohibited from LWD:

- Any drilling wastes, which have hydrocarbons concentration greater than 2%, must not be disposed by LWD.
- If there is any uncertainty about the drilling wastes passing the chloride or metal limits due to a change in the drilling program, the drilling wastes must be disposed of by another method.
- Cement returns must be isolated from the drilling fluid wastes and must be buried under one metre of clean fill or disposed of at an appropriate landfill. Burying cement returns on a lease requires written landowner approval with a copy kept on file.

Type of Waste Acceptable for LWD:
- Fresh water gel and polymers.
- Gypsum (calcium sulphate) water.
- Nitrate gypsum water.

Types of Waste Acceptable for LWD with Special Conditions:
- Potassium sulphate drilling fluids.
- Ammonium sulphate drilling fluids.

Landowner Approval
- All off lease disposals require the approval of the landowner.

Sampling and Testing Requirements for LWD
- Sampling requirements:
  - individual samples must be collected and tested from each section of the hole.
  - samples required in each section of the hole include:
    - source water
    - drilling waste generated from the surface hole section
    - drilling waste generated from the fast hole section (prior to mud-up)
    - representative sample of the drilling waste generated from main hole section, e.g., final mud mix after conditioning at TD (mud-up)
    - any activities that potentially changes the quality of the drilling waste
    - it is the responsibility of the operator to ensure that an adequate number of samples are taken and analyzed to ensure the loading rates specified in the guidelines are not being exceeded.

Analytical Requirements for Drilling Waste:

Parameter	units	Suggested methods
EC	dS/m	EC meter
total dissolved solids (TDS)	mg/L	TDS meter or calculated TDS = 700 x EC (dS/m)
sodium, calcium, magnesium	mg/L	field salinity kits
SAR		calculated from Na, Ca, Mg
hydrocarbon, if present >0.5%	%	field instruments (e.g. portable FID)

Disposal Criteria
- To minimize migration and pooling of drilling wastes:
  - the slope must be less than 5%
  - summer operations are limited to a maximum spraying rate of 40 m^3/ha and spraying cannot occur within 100 m of any water body or drainage course
  - winter operations (frozen ground) are limited to a maximum spraying rate of 20 m^3/ha and spraying cannot occur within 200m of any water body or drainage course
  - landsprayed waste must be incorporated into the soil as soon as practical
- The maximum total dissolved solids (TDS) application rate is less than 1800 kg/ha.
- The sodium application rate is less than 250 kg/ha.

- The total nitrogen application rate is less than 200 kg/ha (calculated based on amount of nitrogen additives used in the drilling mud system).
- Where hydrocarbon is present in the drilling waste:
  - the drilling waste must not contain hazardous waste(s) and/or waste dangerous goods
  - hydrocarbon concentrations in the drilling waste must be less than or equal to 2% and it must be incorporated into the topsoil within two weeks
  - immediately after the incorporation, the soil must be tested for hydrocarbon. The hydrocarbon concentration in the topsoil, after the incorporation, must be less than 0.5% on a dry weight basis. If the hydrocarbon concentration exceeds this amount, the operator will be responsible for site remediation
  - this is a one-time disposal method
  - this information must be submitted with SEM Form A-1
- If drill cuttings remain after LWD, they may be disposed of, following the criteria for Residual Solids Disposal or landspraying disposal methods. A separate notification is not required.
- LWD disposal may only occur if the receiving soil (prior to spraying any drilling waste) EC is less than or equal to 2 dS/m and SAR is less than or equal to 6.
- Calculate criteria using appendix 3.3 landspraying-while-drilling disposal equations.

LWD Special Conditions

For potassium sulphate and ammonium sulphate drilling wastes the following additional LWD conditions applies:

- **The soil loading rate for potassium sulphate and ammonium sulphate drilling wastes should be adjusted to suit the soil type and type of crops grown on the land. The only sure way to know how much sulphate is required in any area is to conduct soil tests and consult with the local agrologist and the landowner to determine the appropriate rate of sulphate application.**
- **The recommended maximum loading rates for total sulfur as sulphate ($S\text{-}SO_4$) are as follows:**
  - **33 kg/hectare for oilseed crops (e.g. canola)**
  - **22 kg/hectare for cereal crops (e.g. wheat and barley)**
  - **the ideal spreading time is spring prior to seeding or late fall after harvesting**
  - **if the recommended maximum loading rates are to be exceeded, it is the responsibility of the operator to provide written justification to the appropriate SEM Field Office**
- **The operator must submit a written report with the Application Form A-1 showing loading rate calculations.**

Example of Loading Rate Calculations:

Given: 413 bags of ammonium sulphate 21-0-0-24 (N:P:K:S), 25 kg per bag, total volume of drilling fluid is 400 m^3

mass of $S\text{-}SO_4$ = (number of bags added)x (mass of each bag) x (percentage of sulphate)
$\therefore$ mass of $S\text{-}SO_4$ = (413 bag) x (25 kg/bag) x (0.24) = 2478 kg

area required = (mass of $S\text{-}SO_4$) ÷ (maximum loading rate)
$\therefore$ for oilseed area required = (2478 kg) ÷ (33 kg/ha) = 75 ha
$\therefore$ for cereal crop area required = (2478 kg) ÷ (22 kg/ha) = 113 ha

spread rate = maximum loading rate/(mass of $S\text{-}SO_4$ ÷ volume of drilling fluids)
$\therefore$ for oilseed crop = 33 kg/ha ÷ (2478 kg ÷ 400 m^3) = 5.3 m^3/ha
$\therefore$ for cereal crop = 22 kg/ha ÷ (2478 kg ÷ 400 m^3) = 3.6 m^3/ha

SECTION 5 LAND TREATMENT DISPOSAL

5.1 Method Description

Land treatment is a waste treatment and disposal method whereby applications from one waste site are made on a dedicated parcel of land. The land is managed in a manner that allows the soil system to degrade, transform and assimilate the waste constituents. The land treatment site can be used only once.

The goal of land treatment is to biodegrade the organic constituents in the waste using natural soil processes in a manner that protects soil and groundwater quality. The land treatment disposal method, or an alternative disposal method (see Section 6) must be used when hydrocarbon based mud systems have been employed. Elevated hydrocarbon levels may also occur when drilling conditions result in the unforeseen production of hydrocarbons, such as during Drill Stem Testing or when drilling in an underbalanced condition. Land Treatment should be considered in these cases.

Waste that requires land treatment may have high salt content; thus management practices must deal with both the salt and the hydrocarbon. Please note there are other bioremediation techniques that are acceptable or preferred substitutes for land treatment. They include composting, leachate bed reactors and bioreactors (slurry phase aerated or solid phase forced air systems). These systems offer a smaller footprint, and it may be easier to add processes to mitigate high salt problems.

Land treatment is an active practice that requires frequent tillage and application of nutrients to break down the hydrocarbon in the waste. Organic amendments (e.g. manure, straw) are added to increase biological activity and aeration of the soil. Sampling and analysis are necessary to monitor the progress of the remediation. Remediation may take place over several years to achieve closure.

Land treatment may be conducted off lease, in either the topsoil or the subsoil.

On lease land treatment is permitted only under the following conditions:

- low toxic mineral oil is used as drilling mud - requires landowner consent;
- bioreactor or compost (treatment takes place within a contained area) technologies are used to degrade majority of the hydrocarbon contaminants prior to on lease land treatment- requires landowner consent; or
- operator must make a written application as per section 5.3 and obtain SEM approval prior to commencing operations.

When considering the land treatment disposal method, the operator should also be familiar with other guidelines that address the storage, transportation, and bioremediation of hydrocarbon wastes.

Types of Waste Acceptable for Land treatment:

- Hydrocarbon based mud systems.
- Elevated hydrocarbon content levels due to unforeseen production of hydrocarbons, such as during Drill Stem Testing or when drilling in an underbalanced condition.

5.2 Disposal Criteria

- If conducted on the subsoil:
  - maximum chloride application rate in the subsoil is <800 kg/ha
  - maximum sodium application rate in the subsoil is <500 kg/ha
  - upon closure the total extractable hydrocarbons content must be:
    - C_{11}-C_{22} 1000 µg/g as analyzed by GC/FID
    - C_{23}-C_{60} 4000 µg/g as analyzed by GC/FID
  - upon closure the EC of the subsoil must be ≤4 dS/m
  - upon closure the SAR of the subsoil must be ≤8
- If conducted on the topsoil:
  - maximum chloride application rate in the topsoil is <400kg/ha.
  - maximum sodium application rate in the subsoil is <250kg/ha.
  - upon closure the total extractable hydrocarbons content must be:
    - C_{11}-C_{22} 1000 µg/g as analyzed by GC/FID
    - C_{23}-C_{60} 4000 µg/g as analyzed by GC/FID
  - upon closure the EC of the topsoil must be ≤2 dS/m.
  - upon closure the SAR of the topsoil must be ≤5 .
  - trace elements must be spread at a rate less than the following:

5 kg boron/ha	**1.5 kg cadmium/ha**	**100 kg chromium/ha**	**200 kg copper/ha**
100 kg lead/ha	**25 kg nickel/ha**	**100 kg vanadium/ha**	**300 kg zinc/ha**

5.3 Information Requirements: Application to Land Treat Hydrocarbon Contaminated Drilling Waste

A detailed report must be prepared and submitted to SEM prior to any drilling waste movement or disposal. The detailed disposal plan must include the following information:

- Mud Systems
  - type of hydrocarbon used in the mud system
  - brine type if a salt system or bridging agent was used
  - detailed list of mud components and additives
- Land Treatment Operation
  - waste characterization in accordance with Section 2.2, Table 2.2.1
  - landspraying calculation in accordance with Appendix 3.2
    - waste volume to be land treated
    - waste application thickness (cm)
    - depth of initial incorporation (cm)
    - estimated initial hydrocarbon content in soil and waste mix (%)
    - estimated chloride, sodium, nitrogen or metals loading (kg/ha)
  - legal location of land treatment site
  - minimum buffer distance of 100m is required between the land treatment area and residences, water wells or surface water body
  - current land use (land treatment is only allowed on stubble fields and cultivated lands)
  - soil horizon to be used for land treatment
  - land treatment area (ha) and surveyed drawing of the treatment area
  - description of topography or slope

- surface run-off and run-on containment measures
- depth to ground water table
- subsoil containment features. Please note, a minimum of 2 metres of continuous impermeable subsoil material ($k_w=10^{-8}$ m/s) must separate the base of the land treatment area from the ground water table. If this is not possible, an engineered base may be required (e.g., synthetic liners).
- soil and waste sampling and monitoring plan
- estimated time period for successful closure of the land treatment operation
- confirmation of landowner approval
- one copy of the application shall be submitted to the respective Petroleum Development Branch Field Office and one copy of the report shall be submitted to the Petroleum Development Branch Head Office

5.4 Post-Disposal

The operator shall submit a closure report confirming all requirements have been met. One copy of the closure report shall be submitted to the respective Petroleum Development Branch Field Office and one copy of the report shall be submitted to the Petroleum Development Branch Head Office. The number of samples taken to confirm achieving closure criteria shall be statistically significant. They are as follows:

Monitoring Frequency:

- land treatment area operated for less than one year: a minimum 3 sets of monitoring is required (immediately after landspraying, mid-point of the land treatment operation and end point of the land treatment operation).
- operated more than one year: a minimum of 2 sets of monitoring are required per year.

Number of Samples:

- a minimum of 2 composite samples are required per hectare; each composite sample shall be made up of a minimum of 5 individual subsamples taken to the full incorporation depth.

Testing Requirements:

- as per Section 2.2, Table 2.2.1

Table 5.1 Loading Criteria for Land Treatment Disposal Method

Pre-Application Condition	Maximum Application Rate	Closure Criteria
If on topsoil: EC ≤2dS/m SAR ≤6	If on topsoil: chloride < 400kg/ha sodium < 250kg/ha	If on topsoil: EC ≤2dS/m SAR ≤6 TEH: C_{11}-C_{22} 1000 µg/g & C_{23}-C_{60} 4000 µg/g
Receiving Soil If on subsoil: EC ≤4dS/m SAR ≤8	If on a subsoil: chloride <800kg/ha sodium <500kg/ha	If on subsoil: EC ≤4dS/m SAR ≤8 TEH: C_{11}-C_{22} 1000 µg/g & C_{23}-C_{60} 4000 µg/g

Calculations:

- refer to on lease landspreading calculations in appendix 3.2

SECTION 6 ALTERNATIVE DISPOSAL OPTIONS

6.1 Approved Alternative Methods

Waste Processing Facility
A number of waste processing facilities are approved to treat and dispose of a wide variety of drilling wastes in Saskatchewan. These waste processing facilities must have a "Waste Processing Facility" (WPF) approval from Saskatchewan Energy and Mines or an "Industrial Effluent Works" (IEW) permit from Saskatchewan Environment and Resource Management.

Drilling wastes taken to these facilities do not require testing as outlined in Section 2.2 or 2.3. Operators will be only required to complete Form A-1, Notification of Drilling Waste Disposal Sections 1, 2 and 8. The operators must submit a copy of the receipt verifying that the drilling waste(s) was received and treated at the waste processing facility.

Road Bed Incorporation
Under Information Guideline GL 97-02 Section B, certain hydrocarbon contaminated drilling solids (cuttings from under-balanced drilling) may be disposed of by roadbed incorporation methods. Roadbed incorporation refers to a technique of encapsulating the OBS in the sub-structure of the road for the purpose of improving the base of the road. Operators using this method must comply with all of the conditions outlined in GL 97-02. A copy of the GL 97-02 may be obtained from any SEM Field Office.

Encapsulation
Encapsulation refers to mixing solidifying agent(s) with salt-based drilling mud or salt contaminated drilling wastes to form a monolithic matrix. The monolithic matrix must be resistant to leaching soluble ions and other contaminants into the environment and placed in an engineered containment system with appropriate capping materials. In addition, anyone using this method must carry-out demonstration trials to verify the technology they propose to utilize, carry out long term monitoring, and provide a comprehensive computer model predicting the fate of contaminants in the encapsulated matrix. The use of this method also requires landowners consent.

Solids Washing
Salt-based drilling mud or salt contaminated drilling wastes may be washed with fresh water until they can be spread on lease, conforming to section 3.1 On Lease Landspreading Method. Drilling fluids and water used in washing operation must be disposed into an approved salt water disposal well. Prior approval from the appropriate SEM field office is required.

6.2 New or Innovated Alternative Disposal Methods

If a new or innovative disposal method is being considered, SEM Head Office must be advised and the operator must receive an approval prior to implementing any drilling waste treatment or disposal. SEM will request specific information on a case by case basis. Some new technologies may require review by other regulatory agencies. New mud formulations or additives will require review by SEM. Early notification to SEM will help to avoid delays.

6.3 Exceptional Circumstances

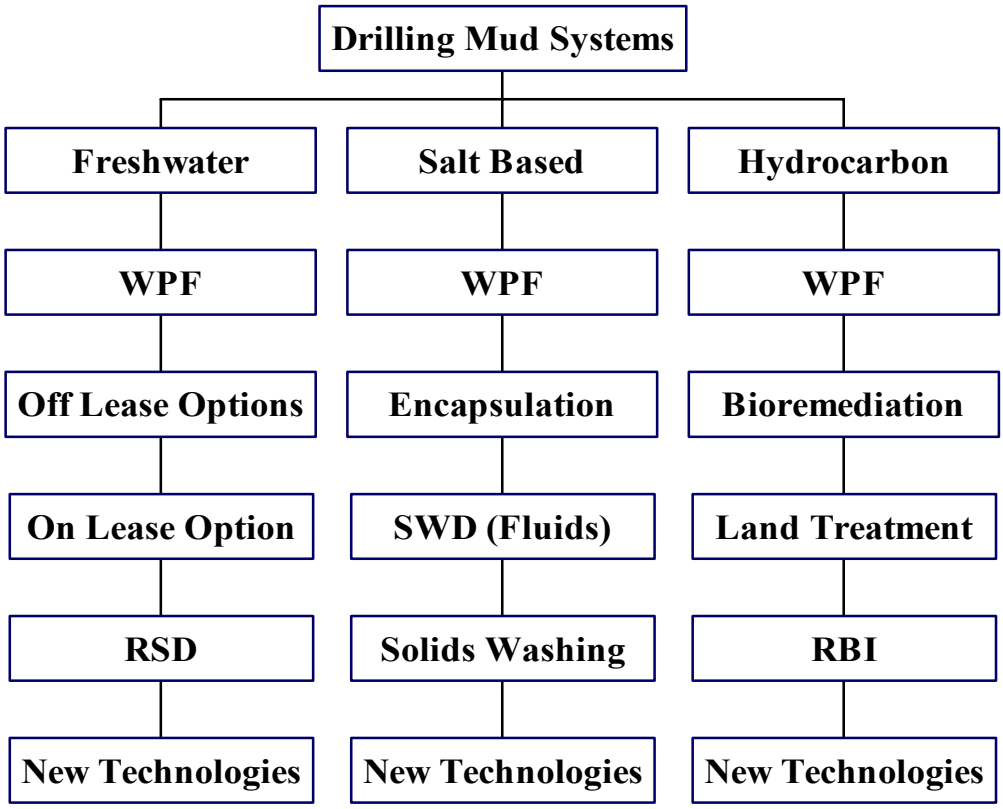
In rare and exceptional circumstances, there may be no practical options other than to dispose of the drilling wastes onto pasture, native grass or uncultivated lands to minimize further ecological and environmental disturbances. These disposal requests must be forwarded to Saskatchewan Environment and Resource Management (SERM). The disposal requests may be reviewed under *The Environmental Assessment Screening Process for Oil and Gas Industry Projects* as described in SERM Environmental Assessment Update, February 1999. The review process may apply to Crown and private lands. For further information on environmental assessment review process, contact Director of Environmental Assessment Branch, SERM, (306) 787-5786 or Provincial Oil and Gas Coordinator, SERM, (306) 933-7933. In addition, the operator must receive consent from the landowner.

Once the approval is obtained from SERM and the consent is obtained from the landowner, the operator may proceed to make an application to SEM. The operator shall submit the following information:

- all required notification as described in the guidelines; and
- copy of the approval from SERM.

SECTION 7 MANAGEMENT OPTIONS FLOW CHART

Figure 1. Waste Disposal Management Options Flow Chart



Legend:

WPF: waste processing facilities as described in section 6.1
Off Lease Options: landspraying after completion of drilling and land spraying while drilling as described in section 4
On Lease Option: land spreading as described in section 3.1
RSD: residual solids disposal as described in section 3.2
Encapsulation: as described in section 6.1
SWD: salt water disposal well as described in section 6.1
Solids Washing: as described in section 6.1
Bioremediation: includes on-lease composting and bioreactors as described in section 5
Land Treatment: off lease land treatment as described in section 5
RBI: roadbed incorporation as described in GL97-02 Section B

Appendix 1: Glossary

Anion: negatively charged ion, e.g. chloride (Cl^-), sulphate (SO_4^{2-}) or nitrate (NO_3^-).

Bulk Density (soil): the mass of dry soil per unit bulk volume (kg/m^3). The bulk volume is determined before the soil is dried to constant weight at 105°C.

Cation: positively charged ion, e.g. sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}).

Cation Exchange Capacity (CEC): measure of the amount of ions that can be adsorbed, in an exchangeable fashion, on the negatively charged sites of the soil particle.

Cement Returns: excess cement circulated to surface after downhole cementing.

Closed Drilling Fluid Handling System: normally consists of rotating blow-out preventer (RBOP), mud-gas separator and enclosed tank(s), tied into a gas flaring unit . The conditions that may trigger these requirements include but are not limited to; drilling underbalanced, drilling through a sour formation or drilling with a low flash point drilling fluid (i.e., less than 61°C). Certain modification(s) may be permitted. A written request must be made to the appropriate SEM Field Office and the operator must obtain a written approval prior to making the modifications. A closed drilling fluid handling system is recommended when drilling a well or portion of a well using refined petroleum hydrocarbon based drilling mud with a flash point greater than 61°C (i.e., petroleum distillates and diesel).

Composite Sample: a sample consisting of a number of thoroughly mixed sub-samples representative of the whole.

Disposal Site: the land used for disposal of waste. For the purpose of the total mass limit, a disposal site is assumed to be 1 hectare.

Drilling Fluids (fluid phase): a mixture of water, drilling muds, additives and various other wastes that are specifically related to the drilling activity.

Drilling Solids (solid phase): the bottom layer of drilling waste material, found in a sump, composed of water, drill cuttings, flocculated bentonite, weighting materials and other additives.

Dry Bulk Density (DBD): the weight of dry waste per unit volume of wet waste (kg/m^3).

Electrical Conductivity (EC): the ability of a solution to carry an electric current.

Gas Chromatography/Flame Ionization Detector (GC/FID): instrumentation used to quantify hydrocarbons.

Groundwater: subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Inductively Coupled Plasma or Atomic Absorption Spectroscopy (ICP/AA): instrumentation used to quantify inorganic parameters (cations, anions and trace metals).

Impermeable Subsoil Material: continuous subsoil layer soil with water coefficient of permeability (k_w) less than 10^{-8} m/s. For the purpose of the guideline it refers to the continuous layer of clay.

Incorporation: an operational method where the drilling waste is assimilated into the soil structure preventing potential migration. This is accomplished by mechanically combining the drilling waste into a consistent soil and waste mixture.

Landowner: the owner of the surface land whose name is in the certificate of title issued under *The Land Titles Act*.

Low Toxic Mineral Oil: defined by National Energy Board guidelines and approved by SEM.

Mud Systems:

Fresh Water Based Drilling Mud System where fresh water is the continuous phase:

- Fresh Water Gel: basic mud system that uses fresh water as the base and bentonite (sodium montmorillinite or gel) as the viscosifier.
- Gypsum Water: mud system where gypsum is added to the drilling fluids to inhibit clay swelling or to harden the water to enhance flocculation of solids in a clear water system. Gypsum ("gyp") muds usually contain the same products as fresh water mud.
- Nitrate Gypsum Water: mud system, where calcium nitrate is used in place of gypsum to accomplish the same results as a gypsum mud system. Most clear water systems now use calcium nitrate ($CaNO_3$) instead of gypsum (Na_2S0_4).
- Fresh Water Polymer: (acceptable for LWD disposal)
  - Extended Bentonite Muds: fresh water gel mud system with addition of polymer to increase the viscosity. Polymers are usually in a form of polyacrylamide.
  - Water Viscosifying Polymer Mud System: mud systems with water viscosifying polymers used in low solids and higher viscosity environment are required. The water viscosifying polymers commonly used are xanthan gums, guar gums, carboxymethylcellulose (hi-vis), polyanionic cellulose

Hydrocarbon Based Drilling Mud Systems where hydrocarbon is the continuous phase.

- Oil only, including crude oil, diesel oil (invert mud) or mineral oil.
- Fresh or Saline Water Emulsified in the oil.

Salt Water Based Drilling Mud Systems where salt water is the continuous phase. The use of saline inhibitive muds is primarily restricted to areas where water sensitive formations are exposed for prolonged periods of time or where water sensitive producing formations are encountered. The salts commonly used in inhibitive (to water sensitivity) muds are potassium chloride (KCl), potassium sulphate (K_2SO_4) or diammonium sulphate ($(NH_4)_2SO_4$). The most common saline inhibitive mud system us the KCl-polymer mud system.

Off Lease: area of land where topsoil is used for the disposal of drilling waste. This includes cultivated land, stubble field and non-stripped portion of a well site or drilling waste storage area.

On Lease: area of land where subsoil is used for the disposal of drilling waste. This includes stripped wellsites and remote sump locations.

Operator: means a person, company, syndicate or partnership or the agent of any of them that has the right to a mineral or the right to drill for or produce or recover a mineral;

Oversaturated Solids: where the pores of the solids are full of liquids and there is excess liquid.

Remote Sump: any sump which is not on the lease of the well which is being drilled.
Specific Gravity (SG): the ratio of the density of a substance to the density of water

Sodium Adsorption Ratio (SAR): calculated ratio used to represent the relative activity of sodium, calcium and magnesium with respect to ion exchange reactions in soil. .

Sump: surface excavation or tank to hold water, drilling mud, sludge and discharged matter from drilling operations.

Sump Closure: **IN ALL DISPOSAL CASES, SUMP CLOSURE MUST BE COMPLETED WITHIN 12 MONTHS OF DRILLING RIG RELEASE, UNLESS OTHERWISE APPROVED BY THE APPROPRIATE SEM FIELD OFFICE.**

Topsoil (Surface Soil): the uppermost soil layers (A and B horizon). Subsoil: the layer of unweathered material (C horizon) which lies under soil profile A and B.

Total Dissolved Solids: concentration of inorganic or mineral constituents dissolved in water expressed in milligram per litre.

Total Extractable Hydrocarbon (TEH): petroleum hydrocarbons with carbon number between C_{11} to C_{60}, quantified by appropriate solvent extraction (soxhlet) followed by GC/FID.

Total Phase Sample: waste sample from the entire depth of the drilling waste sump. The fluids and solid phases are collected at the same time using a column sampling tube. The required sample is a composite of sub-samples from several locations in the sump.

Undersaturated Solids: where all of the pores of the solids are not filled with liquid.

Vegetated Land: land that has a permanent or annual plant cover, which does not allow for incorporation.

Water Table: area between the zone of saturation and the zone of aeration; that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere. By definition water table is the upper surface of the zone of permanent saturation.

Appendix 2 Regulatory Contacts

Saskatchewan Energy and Mines

Head Office
2101 Scarth Street, Regina, S4P 3V7

Petroleum Development Branch

General Inquiry	(306) 787-2594
Director, J. A. Brian Mathieson	(306) 787-2593
Manager, Environmental Affairs, Todd H. Han	(306) 787-2221
Fax	(306) 787-2478

Engineering Services Branch

Special Projects Engineer, Les Bernier	(306) 787-2609

Communications Branch

Publications Orders	(306) 787-2528
Fax	(306) 787-7338

Petroleum Development Branch Field Offices

Estevan
P.O. Box 5000, 1219 - 5th Street, Estevan, S4A OZ1

General Inquiry	(306) 637-4541
District Manager, Jim Wysminity	(306) 637-4542
Fax	(306) 637-4547

Kindersley
P.O. Box 850, 113 2nd Avenue E. Kindersley, SOL 1SO

General Inquiry	(306) 463-5400
District Manager, Kirk Hogarth	(306) 463-5402
Fax	(306) 463-5405

Lloydminster
4815 - 50th Street, Lloydminster, S9V OM8

General Inquiry	(306) 825-6434
District Manager, Gary Ericson	(306) 825-6436
Fax	(306) 825-6433

Swift Current
P. O. Box 5000, 350 Cheadle Street West, Swift Current, S9H 4G3

General Inquiry	(306) 778-8252
District Manager, David Monuik	(306) 778-8252
Fax	(306) 778-8256

Appendix 3 Calculations

Unlike soils, drilling wastes are rarely collected in a saturated condition (where the pores of the solids are full of liquids, but there is no excess liquid). Drilling wastes 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 when all of the pores of the solids are not filled with liquid.

3.1 RSD DISPOSAL CALCULATIONS

Oversaturated drilling waste material equations

For oversaturated drilling wastes, the analyses for chloride and nitrogen are to be done on an as-received filtrate. The drilling waste samples should be clarified by filtration or centrifuging to pass through a Whatman #1 (11µm) filter paper or equivalent. The analysis will be done on the clarified extract. Oil content and trace element analysis must be done on the sample as received, and report on a dry-weight basis.

RSD Equation 1

The dry bulk density (dry weight of solids in a given volume of wet waste) of over saturated solids or total wastes is calculated by measuring the specific gravity of the wet solids using and API mud balance.

$$\text{DBD (kg/m}^3\text{)} = \frac{[\text{measured mud density (kg/m}^3\text{)} - 1000\ (\text{kg/m}^3\text{)}] \times 2.65\ (\text{g/ml})}{[2.65\ (\text{g/ml}) - 1\ (\text{g/ml})]}$$

Where:

- **DBD (kg/m^3) - dry weight of solids in a given volume of wet waste**
- **measured mud density (kg/m^3) - specific gravity x1000**
- **2.65 (g/ml) - particle density of solids**
- **density of water - 1000 kg/m^3 = 1 g/ml**

RSD Equation 2

To convert a parameter from mg/L of filtrate from the as-received (over-saturated) sample to mg/kg of dried waste solids.

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

Where:

- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the as-received filtrate**
- **DBD (kg/m^3) - dry weight of solids in a given volume of wet waste**
- **2.65 (g/ml) - particle density of solids**
- **2650 - 2.65 x 1000**

Undersaturated Drilling Waste Material Equation

The as-received dry bulk density of an undersaturated sample can be estimated using RSD Equation 1. Fill the cup of the mud balance level with the brim without significantly compressing the sample, add water (if necessary) to the cup to fill any pore spaces, then measure the specific gravity.

Analysis of undersaturated solids requires as a separate, additional step, the preparation of a saturated paste, as follows:

1. Add distilled water to bring a sub-sample to a saturated paste condition, and allow to sit for **a minimum of four hours** so that the salts can equilibrate with the added water.
2. Determine the specific gravity of the saturated paste using an API mud balance.
3. Filter the saturated paste and analyze the extract for chlorides and nitrogen (if required).

RSD Equation 3
To determine the volume fraction of water in a saturated paste made from undersaturated waste material.

$$\text{volume fraction water } (\Phi_v) = \frac{(2.65 - SG)}{1.65}$$

where:
- **SG - the specific gravity of the saturated paste measured using the API mud balance**
- **2.65 (g/ml) - particle density of solids**

RSD Equation 4
To convert a parameter from mg/L of filtrate from a saturated paste extract to mg/kg of dried Waste Solids.

$$P_w \text{ (mg/kg)} = P_{filtrate} \text{ (mg/L) x } \left(\frac{\Phi_v}{2.65 \text{ x } (1 - \Phi_v)} \right)$$

where:
- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the as-received filtrate**
- **Φ_v - the volume fraction of water (calculated using RSD Equation 3)**
- **2.65 (g/ml) - particle density of solids**

Disposal Limit Equations

RSD Equation 5
To predict the mass of chloride, nitrogen or trace elements in either the oversaturated or undersaturated waste material.

$$\text{mass (kg)} = \left(\frac{Pw \text{ (mg/kg)} \text{ x } DBD \text{ (kg/m}^3\text{)} \text{ x volume (m}^3\text{)}}{10^6 \text{ (mg/kg)}} \right)$$

where:
- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **DBD (kg/m^3) - the dry bulk density (calculated from RSD Equation 1)**
- **volume (m^3) - volume of drilling waste material**

RSD Equation 6
Calculation of the volume mix ratio needed to meet the chloride criteria.

$$\text{volume ratio} = \left(\frac{DBD}{1700 \text{ (kg/m}^3\text{)}} \right) \text{ x } \left(\frac{Cl_w}{2000 \text{ (mg/kg)}} - 1.0 \right)$$

where:
- **volume ratio - volume parts of subsoil to mixed with one part of waste**
- **DBD (kg/m^3) - dry bulk density of the Solids or Total Waste**
- **Cl_w (mg/kg) - chloride content from RSD Equation 2 or 4**
- **1700 (kg/m^3) - receiving soil density (subsoil)**
- **2000 (mg/kg) - post disposal chloride concentration criteria in the subsoil and waste mix**

RSD Equation 7
Calculation of the volume mix ratio needed to meet hydrocarbon content of 0.1%.

$$\text{volume ratio} = \left(\frac{\text{DBD}}{1700\ (\text{kg/m}^3)} \right) \times \left(\frac{\text{OC}_w}{0.1\ (\%)} - 1.0 \right)$$

where:
- **volume ratio - volume part of subsoil to be mixed with one part of waste**
- **DBD (kg/m^3) - dry bulk density of the Solids or Total Waste**
- **OC_w (%) - oil content from analysis (on a dry weight basis)**
- **1700 (kg/m^3) - receiving soil density (subsoil)**
- **0.1 (%) - hydrocarbon content criteria in the subsoil and waste mix**

Note: If the required volume mix ratio for oil content from RSD Equation 7 is less than three, the wastes must be mixed at a three to one volume ratio

RSD Equations 6 and 7 assume that there is no chloride or oil in the receiving soil. If the wastes are to be buried in a location that has been impacted by disturbances or spills, the salts or oil in the soil must be accounted for.

RSD Equation 8
Calculation of the amount of any parameter in the soil and waste mix after Residual Solids Disposal disposal.

$$P_m = \frac{P_w \times V_w\ (\text{m}^3) \times \text{DBD}\ (\text{kg/m}^3)}{([3 \times V_w\ (\text{m}^3)] \times 1700\ (\text{kg/m}^3)) + (V_w\ (\text{m}^3) \times \text{DBD}\ (\text{kg/m}^3))}$$

- **where:**
- **Pm (mg/kg or %) - parameter amount in the soil and waste mix on a dry-weight basis**
- **Pw (mg/kg or %) - parameter amount of the waste on a dry-weight basis**
- **Vw (m3) - volume of the waste**
- **1700 kg/m3 - receiving soil density (subsoil)**
- **DBD (kg/m3) - the dry bulk density of the solids or total waste from RSD Equation 1**

The above calculation assumes a soil and waste mix ratio of 3:1. Substitute appropriate numbers in the equation for other ratios as applicable.

3.2 ON LEASE LANDSPREADING CALCULATIONS

On Lease Landspreading Equation 1
The dry bulk density (dry weight of solids in a given volume of wet waste) of over saturated solids or total wastes is calculated by measuring the specific gravity of the wet solids using an API mud balance and substituting the measured mud density into Landspreading Equation 1.

$$\text{DBD}\ (\text{kg/m}^3) = \frac{[\text{measured mud density}\ (\text{kg/m}^3) - 1000\ (\text{kg/m}^3)] \times 2.65\ (\text{g/ml})}{[2.65\ (\text{g/ml}) - 1\ (\text{g/ml})]}$$

where:
- **DBD (kg/m^3) - dry weight of solids in a given volume of wet waste**
- **measured mud density (kg/m^3) - specific gravity x1000**
- **2.65 (g/ml) - particle density of solids**
- **density of water - 1000 kg/m^3 = 1 g/ml**

On Lease Landspreading Equation 2
To determine the volume fraction of water in the as received (oversaturated) waste materials.

$$\text{volume fraction water } (\Phi) = 1 - \left(\frac{\text{mud density - 1000}}{1650} \right)$$

where:
- **SG - the specific gravity of the saturated paste measured using the API mud balance**
- **mud density (kg/m^3) - specific gravity x 1000**

On Lease Landspreading Equation 3
To convert a parameter from mg/L of filtrate from the as-received (over-saturated) sample to mg/kg of dried waste solids.

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

where:
- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the as-received filtrate**
- **DBD (kg/m^3) - dry bulk density (landspreading equation 1)**
- **2.65 (g/ml) - particle density of solids**
- **2650 - 2.65 x 1000**

On Lease Landspreading Equation 4
To convert a Total Dissolved Solids (TDS) from dS/m to mg/L of an oversaturated sample filtrate so that it can be substituted into Landspreading Equation 3.

$$TDS \text{ (mg/L)} = 700 \times EC_{filtrate} \text{ (dS/m)}$$

where:
- **TDS (mg/L) - Total Dissolved Solids of an oversaturated sample**
- **$EC_{filtrate}$(dS/m) - the Electrical Conductivity of the filtrate from the oversaturated wastes**

Undersaturated Drilling Waste Material Equation
The as-received dry bulk density of an undersaturated sample can be estimated using Landspreading Equation 1. Fill the cup of the mud balance level with the brim without significantly compressing the sample, add water (if necessary) to the cup to fill any pore spaces, then measure the specific gravity.

Analysis of undersaturated solids requires as a separate, additional step, the preparation of a saturated paste, as follows:
1. Add distilled water to bring a sub-sample to a saturated paste condition, and allow to sit for **a minimum of four hours** so that the salts can equilibrate with the added water.
2. Determine the specific gravity of the saturated paste using an API mud balance.
3. Filter the saturated paste and analyze the extract for EC, sodium, calcium, magnesium, chlorides and nitrogen.

On Lease Landspreading Equation 5
To determine the volume fraction of water in a saturated paste made from undersaturated waste material.

$$\text{volume fraction water } (\Phi_\upsilon) = \frac{(2.65 - SG)}{1.65}$$

where:
- **SG - the specific gravity of the saturated paste measured using the API mud balance**
- **2.65 (g/ml) - particle density of solids**

On Lease Landspreading Equation 6

To convert a parameter from mg/L of filtrate from a saturated paste extract to mg/kg of dried Waste Solids.

$$P_w \text{ (mg/kg)} = P_{filtrate} \text{ (mg/L)} \times \left(\frac{\Phi_v}{2.65 \times (1 - \Phi_v)} \right)$$

where:

- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the saturated paste filtrate**
- **Φ_v - the volume fraction of water (landspreading Equation 3)**
- **2.65 (g/ml) - particle density of solids**

On Lease Landspreading Equation 7

To predict the mass of chloride, sodium, TDS, nitrogen or trace elements in either the oversaturated or undersaturated waste material.

$$\text{mass (kg)} = \left(\frac{Pw \text{ (mg/kg)} \times DBD \text{ (kg/m}^3\text{)} \times \text{volume (m}^3\text{)}}{10^6 \text{ (mg/kg)}} \right)$$

where:

- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **DBD (kg/m^3) - the dry bulk density (landspreading Equation 1)**
- **volume (m^3) - volume of drilling waste material**

On Lease Landspreading Equation 8

To calculate the maximum application rate that will not exceed the kg/ha loading limit for a parameter.

$$\text{maximum application rate (m}^3\text{/ha)} = P_{max} \text{ (kg/ha)} \times \left(\frac{10^6 \text{ (mg/kg)}}{Pw \text{ (mg/kg)} \times DBD \text{ (kg/m}^3\text{)}} \right)$$

where:

- **Pmax (kg/ha) - the maximum amount of a parameter allowed on 1 ha**
- **Pw (mg/kg) - the concentration of a parameter in the dry solids (landspreading equation 3 or 6)**
- **DBD (kg/m3) - the dry bulk density (landspreading equation1)**

On Lease Landspreading Equation 9

To calculate the maximum application thickness. The thickness cannot exceed 1/3 of the incorporated depth or 10cm, whichever is less.

$$\text{maximum application thickness (cm)} = \left(\frac{\text{maximum application rate (m}^3\text{/ha)}}{100} \right)$$

where:

- **max. application rate (m^3/ha) - calculated from landspreading equation 8**

On Lease Landspreading Equation 10

Substitute either (a) the maximum application rate calculated from landspreading equation 8, or (b) 1000 m3/ha, or (c) incorporated depth (cm)/3 x 100, whichever is less, into the following equation to calculate the minimum area required for disposal so that the limit for a given parameter is not exceeded. Operators are encouraged to use more than the minimum area, if available.

$$\textbf{minimum disposal area (ha)} = \left(\frac{\textbf{volume of drilling waste } (m^3)}{\textbf{maximum application rate } (m^3/ha)} \right)$$

On Lease Landspreading Equation 11
To calculate the amount per hectare of any parameter added to the receiving soil.

$$\textbf{amount (kg/ha)} = \left(\frac{\textbf{mass of the parameter (kg)}}{\textbf{planned disposal area (ha)}} \right)$$

OR

On Lease Landspreading Equation 12
To calculate the amount per hectare of any parameter added to the receiving soil.

$$\textbf{amount (kg/ha)} = \left(\frac{\textbf{Pw (mg/kg) x DBD } (kg/m^3) \textbf{ x max. application rate } (m^3/ha)}{10^6 \textbf{ (mg/kg)}} \right)$$

where:

- **Pw (mg/kg) - the concentration of a parameter in the dry solids (landspreading equation 3 or 6)**
- **DBD (kg/m^3) - the dry bulk density (landspreading equation1)**
- **maximum application rate (m^3/ha) - calculate from landspreading equation 8**

On Lease Landspreading Equation 13
To predict the percent hydrocarbon in the final soil and waste mix.

$$\textbf{\% hydrocarbon}_{(mix)} = \left(\frac{\textbf{\% hydrocarbon(waste) x DBD } (kg/m^3) \textbf{ x volume}}{\textbf{[DBD } (kg/m^3) \textbf{ x volume] + [soil density } (kg/m^3) \textbf{ x mix ratio x volume]}} \right)$$

where:

- **% hydrocarbon$_{(mix)}$ - the % hydrocarbon in the final soil and waste mix**
- **% hydrocarbon$_{(waste)}$ - analytical results (on a dry weight basis)**
- **DBD (kg/m^3) - the dry bulk density (landspreading equation1)**
- **volume (m^3) - volume of drilling waste material**
- **mix ratio - the soil and waste mix ratio that will be used for disposal (volume part of subsoil to be mixed with one part of waste)**
- **soil density (kg/m^3) - receiving soil density; for surface soil use 1300 kg/m^3, for subsoil use 1700 kg/m^3**

3.3 OFF LEASE LANDSPRAYING AFTER COMPLETION OF DRILLING AND LANDSPRAYING WHILE DRILLING DISPOSAL CALCULATIONS

Off Lease Landspraying After Completion of Drilling Equation 1
The dry bulk density (dry weight of solids in a given volume of wet waste) of over saturated solids or total wastes is calculated by measuring the specific gravity of the wet solids using an API mud balance and substituting the measured mud density into Landspraying Equation 1.

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

where:
- **DBD (kg/m^3) - dry weight of solids in a given volume of wet waste**
- **mud density (kg/m^3) - specific gravity x1000**
- **2.65 (g/ml) - particle density of solids**
- **density of water - 1000 kg/m^3 = 1 g/ml**

Off Lease Landspraying After Completion of Drilling Equation 2
To convert a parameter from mg/L of filtrate from the as-received (over-saturated) sample to mg/kg of dried waste solids.

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

where:
- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the as-received filtrate**
- **DBD (kg/m^3) - dry bulk density (landspraying equation 1)**
- **2.65 (g/ml) - particle density of solids**
- **2650 - 2.65 x 1000**

Off Lease Landspraying After Completion of Drilling Equation 3
To convert a Total Dissolved Solids (TDS) from dS/m to mg/L of an oversaturated sample filtrate so that it can be substituted into Landspraying Equation 3.

$$\text{TDS (mg/L)} = 700 \times EC_{filtrate}\ (\text{dS/m})$$

where:
- **TDS (mg/L) - Total Dissolved Solids of an oversaturated sample**
- **$EC_{filtrate}$(dS/m) - the Electrical Conductivity of the filtrate from the oversaturated wastes**

Undersaturated Drilling Waste Material Equation
The as-received dry bulk density of an undersaturated sample can be estimated using Landspraying Equation 1. Fill the cup of the mud balance level with the brim without significantly compressing the sample, add water (if necessary) to the cup to fill any pore spaces, then measure the specific gravity.

Analysis of undersaturated solids requires as a separate, additional step, the preparation of a saturated paste, as follows:
1. Add distilled water to bring a sub-sample to a saturated paste condition, and allow to sit for **a minimum of four hours** so that the salts can equilibrate with the added water.
2. Determine the specific gravity of the saturated paste using an API mud balance.
3. Filter the saturated paste and analyze the extract for EC, sodium, calcium, magnesium, chlorides and nitrogen.

Off Lease Landspraying After Completion of Drilling Equation 4
To determine the volume fraction of water in a saturated paste made from undersaturated waste material.

$$\text{volume fraction water } (\Phi_v) = \frac{(2.65\ (\text{g/ml}) - SG)}{1.65}$$

where:
- **SG - the specific gravity of the saturated paste measured using the API mud balance**
- **2.65 (g/ml) - particle density of solids**

Off Lease Landspraying After Completion of Drilling Equation 5

To convert a parameter from mg/L of filtrate from a saturated paste extract to mg/kg of dried Waste Solids.

$$P_w \text{ (mg/kg)} = P_{filtrate} \text{ (mg/L)} \times \left(\frac{\Phi_\upsilon}{2.65 \times (1 - \Phi_\upsilon)} \right)$$

where:

- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **$P_{filtrate}$ (mg/L) - the concentration of the parameter in the saturated paste filtrate**
- **Φ_υ - the volume fraction of water (landspraying Equation 4)**
- **2.65 (g/ml) - particle density of solids**

Disposal Limit Equations

Off Lease Landspraying After Completion of Drilling Equation 6

To predict the mass of chloride, sodium, TDS, nitrogen or trace elements in either the oversaturated or undersaturated waste material.

$$\text{mass (kg)} = \left(\frac{P_w \text{ (mg/kg)} \times DBD \text{ (kg/m}^3\text{)} \times \text{volume (m}^3\text{)}}{10^6 \text{ (mg/kg)}} \right)$$

where:

- **P_w (mg/kg) - the concentration of the parameter in the dried solids**
- **DBD (kg/m^3) - the dry bulk density (landspraying Equation 1)**
- **volume (m^3) - volume of drilling waste material**

Off Lease Landspraying After Completion of Drilling Equation 7

To calculate the maximum application rate that will not exceed the kg/ha loading limit for a parameter.

$$\text{maximum application rate (m}^3\text{/ha)} = P_{max} \text{ (kg/ha)} \times \left(\frac{10^6 \text{ (mg/kg)}}{P_w \text{ (mg/kg)} \times DBD \text{ (kg/m}^3\text{)}} \right)$$

where:

- **Pmax (kg/ha) - the maximum amount of a parameter allowed on 1 ha**
- **Pw (mg/kg) - the concentration of a parameter in the dry solids (landspraying equation 2 or 5)**
- **DBD (kg/m3) - the dry bulk density (landspraying equation1)**

Off Lease Landspraying After Completion of Drilling Equation 8

To calculate the maximum application thickness. The thickness cannot exceed 1/3 of the incorporated depth or 10cm, whichever is less.

$$\text{maximum application thickness (cm)} = \left(\frac{\text{maximum application rate (m}^3\text{/ha)}}{100} \right)$$

where:

- **max. application rate (m^3/ha) - calculated from landspraying equation 7**

Off Lease Landspraying After Completion of Drilling Equation 9

Substitute either (a) the maximum application rate calculated from landspraying equation 7, or (b) 40 m^3/ha in summer and 20 m^3/ha in winter operation, or (c) incorporated depth (cm)/3 x 100, whichever is less, into the following equation to calculate the minimum area required for disposal so that the limit for a given parameter is not exceeded. Operators are encouraged to use more than the minimum area, if available.

$$\text{minimum disposal area (ha)} = \left(\frac{\text{volume of drilling waste (m}^3\text{)}}{\text{maximum application rate (m}^3\text{/ha)}} \right)$$

Off Lease Landspraying After Completion of Drilling Equation 10
To calculate the amount per hectare of any parameter added to the receiving soil.

$$\text{amount (kg/ha)} = \left(\frac{\text{mass of the parameter (kg)}}{\text{planned disposal area (ha)}} \right)$$

OR

Off Lease Landspraying After Completion of Drilling Equation 11
To calculate the amount per hectare of any parameter added to the receiving soil.

$$\text{amount (kg/ha)} = \left(\frac{\text{Pw (mg/kg) x DBD (kg/m}^3\text{) x max. application rate (m}^3\text{/ha)}}{10^6 \text{ (mg/kg)}} \right)$$

where:
- **Pw (mg/kg) - the concentration of a parameter in the dry solids (landspraying equation 2 or 5)**
- **DBD (kg/m^3) - the dry bulk density (landspraying equation 1)**
- **maximum application rate (m^3/ha) - calculate from landspraying equation 7**

Off Lease Landspraying After Completion of Drilling Equation 12
To predict the percent hydrocarbon in the final soil and waste mix.

$$\text{\% hydrocarbon}_{(mix)} = \left(\frac{\text{\% hydrocarbon(waste) x DBD (kg/m}^3\text{) x volume}}{\text{[DBD (kg/m}^3\text{) x volume] + [soil density (kg/m}^3\text{) x mix ratio x volume]}} \right)$$

where:
- **% hydrocarbon$_{(mix)}$ - the % hydrocarbon in the final soil and waste mix**
- **% hydrocarbon$_{(waste)}$ - analytical results (on a dry weight basis)**
- **DBD (kg/m^3) - the dry bulk density (landspraying equation1)**
- **volume (m^3) - volume of drilling waste material**
- **mix ratio - the soil and waste mix ratio that will be used for disposal (volume part of subsoil to be mixed with one part of waste)**
- **soil density (kg/m^3) - receiving soil density; for surface soil use 1300 kg/m^3, for subsoil use 1700 kg/m^3**

Off Lease Landspraying After Completion of Drilling Equation 13
To calculate the maximum application rate which will not exceed the 6 tonnes/ha loading limit for landspraying on vegetated land. Please note, prior approval from Saskatchewan Environment and Resource Management is required, see section 6.3:

$$\text{maximum application rate (m3/ha)} = \left(\frac{\text{6(tonnes/ha) x 1000 (kg/tonne)}}{\text{DBD (kg/m}^3\text{)}} \right)$$

SEM FORM A-1: NOTIFICATION OF DRILLING WASTE DISPOSAL

1. WELL INFORMATION

Well Licensee: (OWNER NAME)	Well License Number:
Surface Location: LSD SEC TWP 0 RGE W	Sump Location: LSD SEC TWP 0 RGE W
Date of Sampling: DATE MONTH YEAR	Date of Proposed Disposal: DATE MONTH YEAR

2. COMPANY INFORMATION

OPERATOR CONTACT	SAMPLING COMPANY CONTACT
COMPANY NAME	COMPANY NAME
MAILING ADDRESS	MAILING ADDRESS
CITY / POSTAL CODE	CITY / POSTAL CODE
PHONE NUMBER / FAX NUMBER	PHONE NUMBER / FAX NUMBER

3. MUD INFORMATION

MUD SYSTEM TYPE
- ❑ Fresh Water, specify_____
- ❑ Hydrocarbon, specify_____
- ❑ Salt, specify _____

ADDITIVE AND DRILLING INFORMATION
- ❑ Hydrocarbons ❑ Metals ❑ Nitrogen
- ❑ Underbalanced Drilling
- ❑ Horizontal Well

CONTAINMENT FEATURES
- ❑ Earthen Sump ❑ Lined Sump
- ❑ Remote Sump ❑ Tank
- ❑ Closed Fluid Handling System

4. ON-LEASE DISPOSAL

FLUIDS VOLUME m^3 | SOLIDS VOLUME m^3 | TOTAL WASTE m^3

SOIL TEXTURE
❑ Clay ❑ Silt ❑ Sand

ON-LEASE LANDSPREADING ❑

APPLICATION THICKNESS cm	INCORPORATION DEPTH cm
RECEIVING SOIL EC dS/m	RECEIVING SOIL SAR

PARAMETERS	minimum area ha	max application rate m^3/ha	max amount added kg/ha
chloride			
sodium			
nitrogen			
TDS			

predicted oil content after mixing: %

proposed application rate: m^3/ha

proposed area used for disposal: ha

RESIDUAL SOLIDS DISPOSAL ❑

ESTIMATED WATER TABLE DEPTH m	INTENDED MIX RATIO

VOLUME TO BE DISPOSED m^3

Has the site been used before? ❑ YES ❑ NO

chloride mg/kg	total mass chloride kg
oil %	total mass nitrogen kg

LAND OWNER NAME

PHONE NUMBER

DATE OF CONSENT

OFF-LEASE DISPOSAL

FLUIDS VOLUME m^3 | SOLIDS VOLUME m^3 | TOTAL WASTE m^3

SOIL TEXTURE ❑ Clay ❑ Silt ❑ Sand | HORIZON THICKNESS cm

OFF-LEASE LANDSPRAYING ❑ LWD ❑

APPLICATION THICKNESS cm	INCORPORATION DEPTH cm
RECEIVING SOIL EC dS/m	RECEIVING SOIL SAR

PARAMETERS	minimum area ha	max application rate m^3/ha	max amount added kg/ha
chloride			
sodium			
nitrogen			
TDS			

predicted oil content after mixing: %

potassium sulphate/ammonium sulphate added? ❑ YES ❑ NO

mass of S-Sulphate added (**see S. 4.2**): kg

proposed application rate: m^3/ha

proposed area used for disposal: ha

Has the site been used before? ❑ YES ❑ NO

LAND OWNER NAME

PHONE NUMBER

DATE OF CONSENT

NOTE: YOU MUST SUBMIT A LIST OF ADDITIVES ADDED TO THE DRILLING MUD AND A COPY OF LAND OWNER APPROVAL WITH THE APPLICATION. A SEPARATE SHEET OF ANALYSIS MAY BE SUBMITTED FOR LWD WASTE CHARACTERIZATION.

NOTES: IF THE DRILLING WASTE IS DISPOSED AT AN APPROVED WASTE MANAGEMENT FACILITY, YOU ARE ONLY REQUIRED TO FILL OUT SECTIONS 1,2 AND 8.

5. DETAILED INFORMATION

Oversaturated Solids, Fluids or Total Waste		Undersaturated Solids		Receiving Soil	
As received sample		As received sample		As received sample	
SG (meas)		SG (meas)		soil density (optional)	kg/m^3
mud density (calc)	kg/m^3	mud density (calc)	kg/m^3	oil content (optional)	% dry wt
DBD (calc)	kg/m^3	DBD (calc)	kg/m^3		
oil content (meas)	% dry wt	oil content (meas)	% dry wt		
ϕ (calc)					
		Saturated Paste			
		SG (meas)			
		ϕ_u (calc)			
As received filtrate		Saturated paste extract		Saturated paste extract	
pH (meas)		pH (meas)		pH (meas)	
EC (meas)	dS/m	EC (meas)	dS/m	EC (meas)	dS/m
TDS (calc)	mg/L	TDS (calc)	mg/L	SAR (calc)	
chloride (meas)	mg/L	chloride (meas)	mg/L	sodium (meas)	mg/L
sodium (meas)	mg/L	sodium (meas)	mg/L	calcium (meas)	mg/L
nitrogen (meas)	mg/L	nitrogen (meas)	mg/L	magnesium (meas)	mg/L
calcium (meas)	mg/L	calcium (meas)	mg/L	potassium (meas)	mg/L
magnesium (meas)	mg/L	magnesium (meas)	mg/L	chloride (meas)	mg/L
SAR (calc)		SAR (calc)		sulphate (meas)	mg/L

6. TRACE ELEMENT ANALYSIS

Trace Elements Results		Landspreading/Landspraying/LWD				Residual Solids Disposal	
threshold kg	concentration mg/kg	minimum area ha	application rate m^3/ha	loading rate kg/ha	max loading rate kg/ha	total mass kg	max allowable kg
B 2.5					5		10
Cd 0.75					1.5		3
Cr 50					100		200
Cu 100					200		400
Pb 50					100		200
Ni 12.5					25		50
V 50					100		200
Zn 150					300		600

NOTE: TRACE ELEMENTS AND NITROGEN ANALYSIS IS ONLY REQUIRED IF THE AMOUNT OF TRACE ELEMENT(S) OR NITROGEN ADDED TO THE MUD EXCEED(S) THE ANALYSIS THRESHOLD(S). NITROGEN THRESHOLD IS 400KG.

7. OFF-LEASE DISPOSAL LOCATION

LSD				SEC		TWP			REG		MER		LSD				SEC		TWP			RGE		MER	
13	14	15	16			0					W		13	14	15	16								W	
12	11	10	9	COMMENTS:									12	11	10	9	COMMENTS:								
5	6	7	8										5	6	7	8									
4	3	2	1										4	3	2	1									

8. DISPOSAL AT WASTE MANAGEMENT FACILITY

CONTACT NAME	WPF NUMBER (if available)	PHONE NUMBER	FAX NUMBER
COMPANY NAME	MAILING ADDRRESS	CITY OR TOWN	POSTAL CODE

NOTE: A COPY OF THE CONFIRMATION OF RECIEPT OF DRILLING WASTE(S) FROM THE WASTE MANAGEMENT FACILITY MUST BE SUBMITTED TO THE APPROPRIATE FIELD OFFICE.

9. COMMENTS