A COMPILATION OF LABORATORY AND FIELD DATA

From: J. P. Salanitro, et al., (Equilon-Shell/Texaco) Advances in Agronomy 72, 53-105 (2001).

(Entries with less than 160 days remediation time have been deleted.)

CRUDE OILS	Init Conc (mg/kg)	Max Loss (%)	Time (days)
API 39 weath.	50000	80	350
API 21	"	56	"
API 55	4200	76	330
API 30	26200	67	"
API 14	14000	50	"
API 55	9600	88	270
API 30	25700	68	"
API 14	11900	10	"
GC medium	20600	79	285
"	31300	45	"
"	25800	43	"
Unk. Crude	50-100000	65	3285

COMPILATION OF DATA con't.

J. P. Salanitro, et al
Entries with less than 160 days deleted.

WASTE TYPE	Init Conc (mg/kg)	Max Loss (%)	Time (days)
Oily wastes	50000	63	160
"	"	80	"
Oily wastes	4375	63	180
"	"	45	"
"	"	47	"
Oily waste	10000	50	450
Oily waste	22000	35-89	960
"	34000	37-82	"
Oily waste	20-50000	65	420-600

COMPILATION OF DATA con't.

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Entries with less than 160 days deleted.

WASTE TYPE	Init Conc (mg/kg)	Max Loss (%)	Time (days)
Diesel drill cut.	1600	50	270
Diesel	230	74	405
Diesel	10000	95	500
Diesel	3000	93	720
Heating oil	13800	94	285
"	21800	80	"
"	14000	83	"
Bunker C	50000	6	336
Bunker C	32400	50	285
"	35100	32	"
"	25600	53	"

Conclusions on hydrocarbons in soil

- Lighter hydrocarbons remediate faster and more completely.
- The "remediation" of BTEX and light HCs is more evaporation than biological, transferring pollution from soil to air.

In lab and field studies, 40-90% of crude oil may be remediated, but the final TPH is often > 1000 mg/kg if the initial TPH is > 10,000 mg/kg.

Conclusions on hydrocarbons...

- Toxicity is reduced (but not always totally eliminated) by bioremediation.
- Bioremediation (by reducing the light HCs) can nearly eliminate seed toxicity, but plant growth may still suffer. The cause may or may not be toxicity.
- Studies by Lee et al. suggest an especially toxic compound is produced during bioremediation of diesel. It may not persist.

Conclusions on hydrocarbons...

- Residual hydrocarbons can damage plants by causing the soil to repel water and by restricting moisture to preferential channels.
- Petroleum HCs cause hydrophobicity, but there is no simple relationship between TPH and water repellancy.
- The MED test is suitable for petroleum-contaminated soils, avoiding false positive responses.

Conclusions regarding hydrocarbons ...

There is no particular TPH that will avoid either damage to a wide variety of plants or hydrophobicity of a variety of soils.

The smaller the TPH, the greater the protection for plants and soils.

10% is clearly too large, 1% is risky, 0.1% appears safe. But the tests were not done with native plants in arid environments.

OUTLINE

SCIENCE

- Modeling: absolute *vs* relative answers
- Salt, sodium, and chloride in soil
- Petroleum hydrocarbons in soil
- → Statistics and sampling

PROPOSED RULES AND CLOSURE

- Bonding
- Design of facilities
- Monitoring and sampling
- Bioremediation endpoint

SAMPLING AN AREA OF GROUND

How many samples do you acquire, and at what spacing across the ground, to assure that the concentrations of contaminants in a landfarm are less than regulatory limits?

"How many," "spacing," and "assure" are statistical concepts.

Concentrations vary from place to place, and from sample to sample even in the same place.

- Salanitro et al. (1997) mixed crude oils and soils in a cement mixer, and tested biodegradation in steel containers. From these ideally uniform mixtures, duplicate samples differed by 10-20%.

- Chaineau et al. (2003) examined bioremediation in a field experiment using a biopile and windrows. Standard deviations of hydrocarbon concentrations were as high as 50% of the mean in the biopile, and less than 25% of the mean for the windrows, indicating the mixing due to tilling of the windrows.

Conclusion:

Even if the wastes for a landfarm were from a single source, mechanically mixed before treatment, and the material disked during remediation, the spot-to-spot variation of concentrations would probably be greater than 25%.

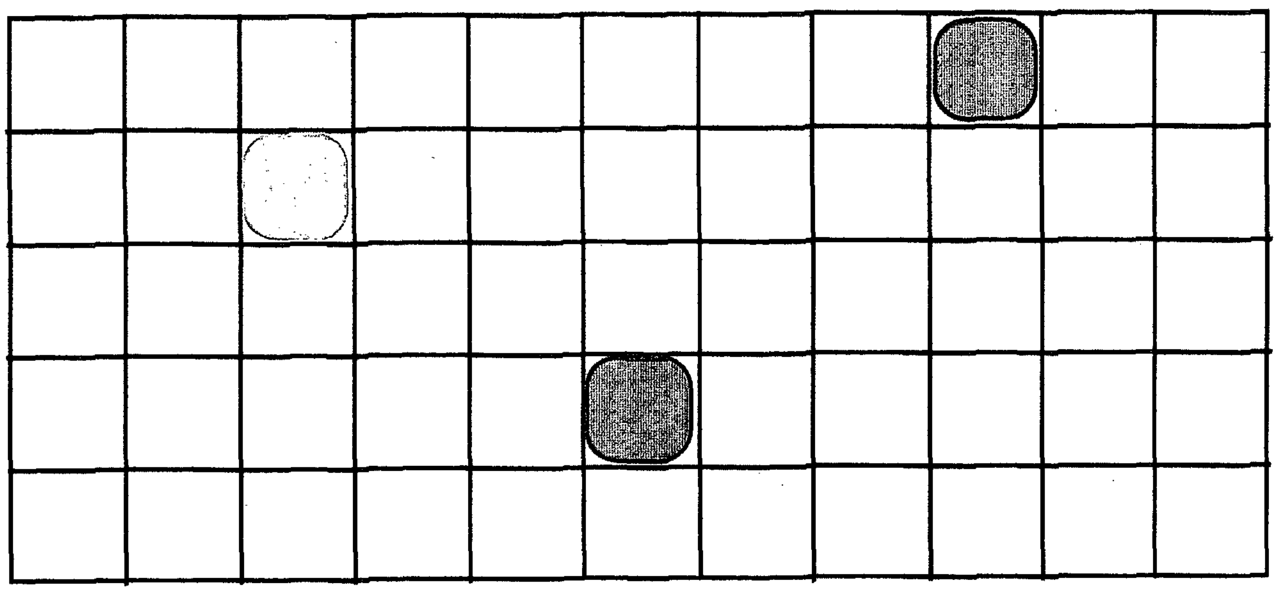
But what might the variability of the wastes *really* look like?

Example: A dump truck contains 20 cu. yd. of wastes, which form an 8-inch lift of 90 sq. yd. area. An acre of landfarm would acquire 54 truck loads in each lift.

The original concentrations of the wastes would vary within each truck load, and the nature (e.g. API gravity) would vary from load to load.

Even if the wastes mixed vertically, we would expect a large variation in TPH concentrations from one small area to the next.

Here’s one acre of landfarm, divided into 55 areas. How can we estimate that TPH concentrations in the three colored areas are not far beyond limits, while the concentrations in all other areas are far below limits?



Individual samples (even mixed vertically) probably do not have a normal distribution.

"*...it is unusual to encounter environmental data sets that are normally distributed.*" EPA-540-R-01-003

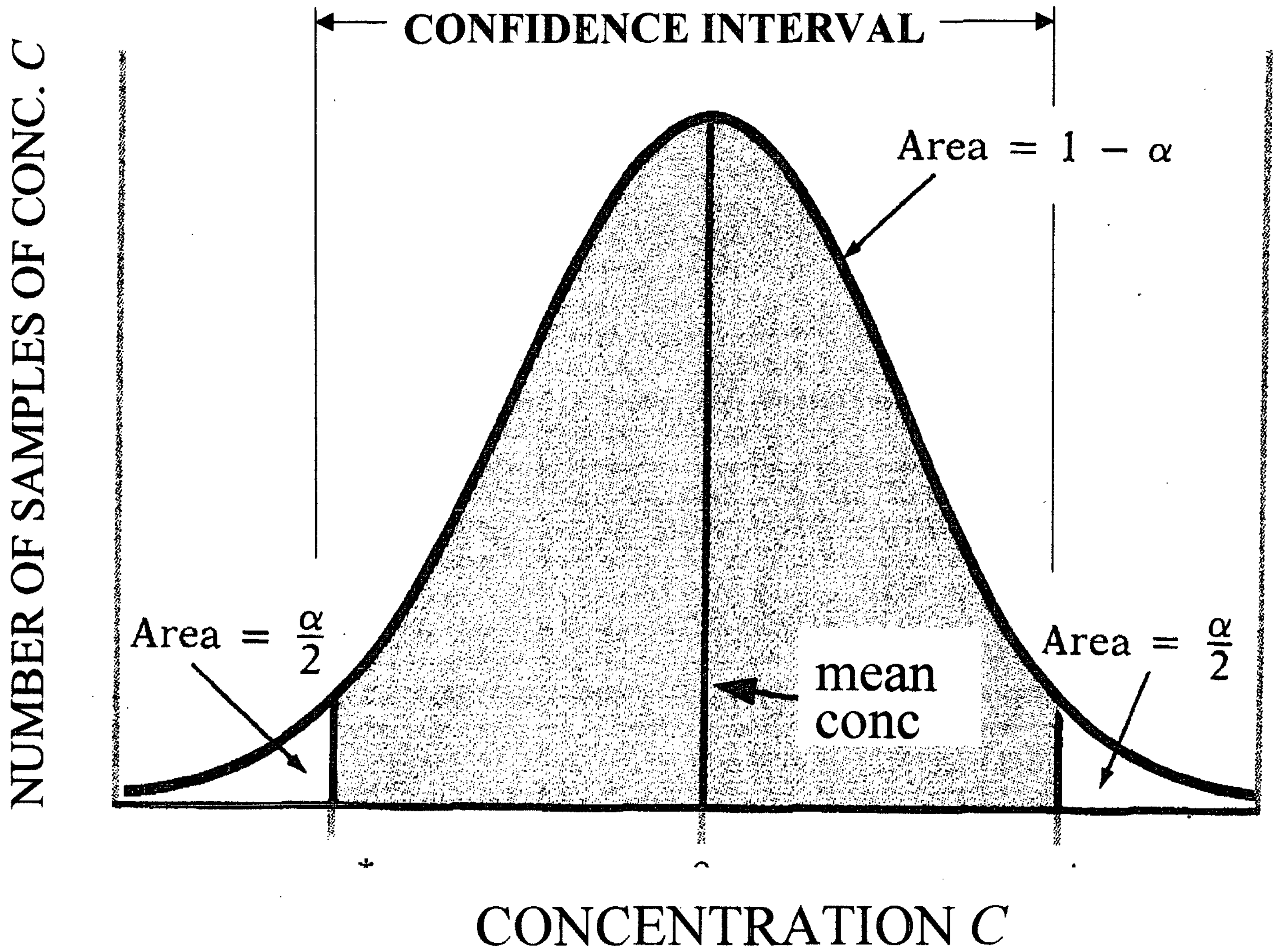
Many samples in one acre, composited into a single sample, would provide a good estimate of the average concentration. But we would know nothing of the variation.

Extreme example:

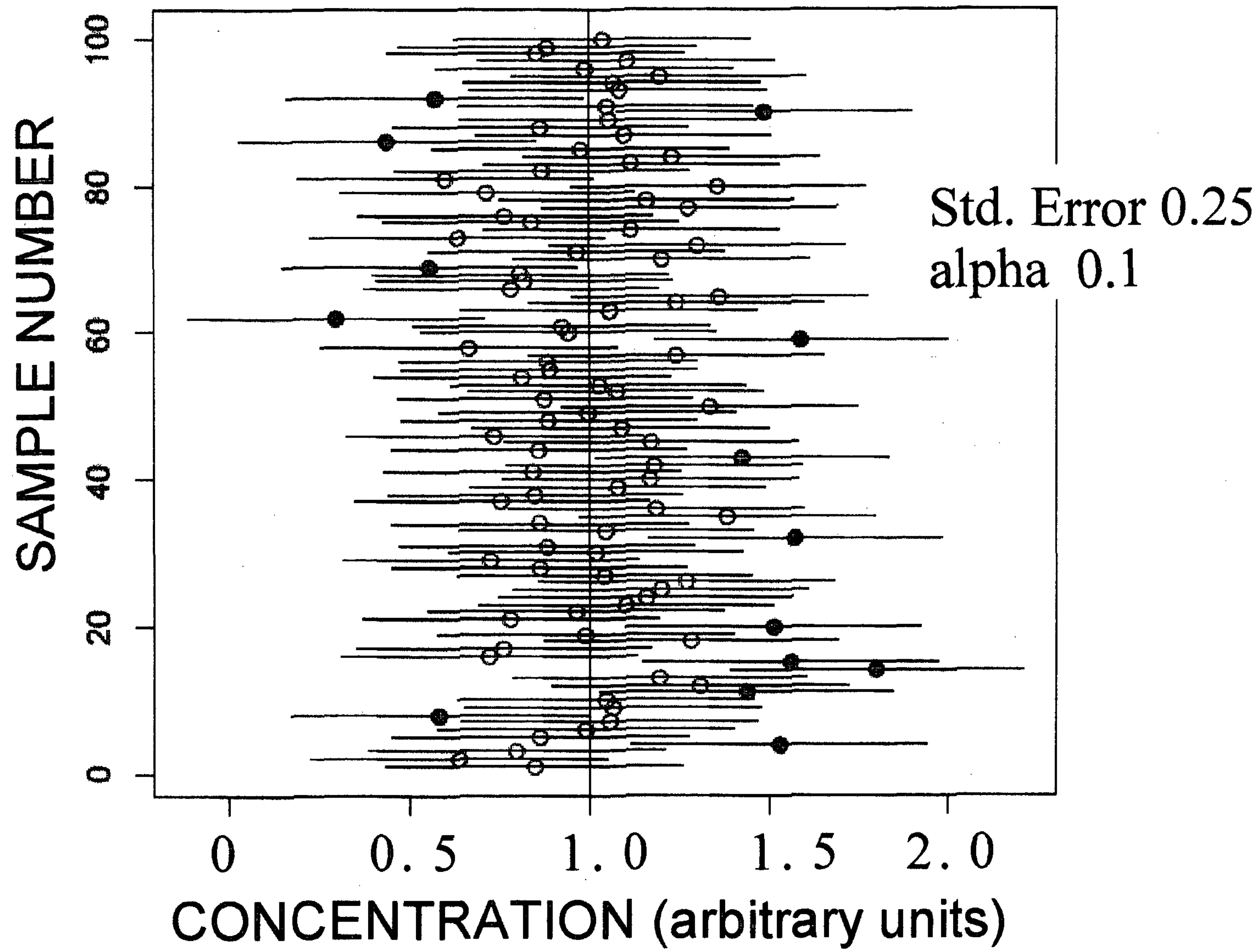
100	900

50 samples with concentration 900, mixed with 50 samples of concentration 100 will provide an average value of 500. If the standard is 600, half of the area is out of compliance. If the standard is 400, the operator is required to clean half the area that *is* in compliance.

NORMAL DISTRIBUTION OF SAMPLES



CONFIDENCE INTERVALS FOR 100 SAMPLES



R. Almond, Educational Testing Service,
private communication

For regular landfarms,

we're not asking whether the *average* exceeds the standard.

We want to know, as best we can, whether *any* wastes exceed the standard.

Set the standard so that fewer than 5% of samples would exceed the standard, according to the measured standard deviation.

For landfarms with bioremediation endpoint,

we're asking if the concentration *changes* from one time to the next. The *change* of an average may indicate the change of the whole.

Acquire a composite of many samples over a small area, so the resulting sample represents an average for that area. Acquire a set of composite samples at two times for the same areas.

Ask if the change at each area is zero, within the statistics provided by the set of changes at all areas.

conclusion regarding sampling:

There is no perfect way to use a small number of samples to assure that a condition has or has not been met. Given the greater diversity of materials expected in a commercial landfarm as contrasted with a centralized landfarm, it seems wise to use a smaller sampling area for the commercial unit.

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53 C (5) bond requirements

Centralized: $25k or $50k blanket bond

Commercial: $25k or estimated cost

We suggest that the "estimated cost" for a landfarm should be based on waste removal and site restoration, and that this should apply to centralized and commercial facilities.

Bonding and closure costs

Suppose a landfarm fails to achieve closure conditions. What is the cost to remove the contents and restore the site, even for one acre?

<u>Assumed unit costs</u>

Waste acceptance fee at landfill	$14/yd^3$
Dump truck, 20 yd^3 capacity	$85/hr
Loading at landfarm	$1.50/yd^3$

Costs per acre (4840 square yards)

Volume of wastes, 2 ft deep	3226 yd^3
Haul distance, round trip	50 miles
Trip time, round trip (incl. loading)	1 hr, 15 min
Landfill fee 3226 yd^3 x $14	$45,164
Truck, 201 hrs x $85	17,085
Loading cost 3226 yd3 x $1.50	4,839
Vegetation and site restoration	5,000
Tax (Lea County, 5.25%)	3,785
Total, per acre	$75,872

Conclusion regarding bonding

Bonding for landfarms should include a realistic cost proportional to the area. The proposed bonding invites an operator to accept wastes, neglect remediation, and abandon the site.

We agree that a landfarm operator should be allowed to show that his costs for removal and restoration are less than the standard, and bonding set accordingly.

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53 E (1) depth to ground water

The proposed minimal depth to ground water beneath a surface waste facility is 50 ft, based on a model of presumed infiltration and consideration of small landfarms. The 50-ft depth allowed chlorides of the model to contaminate groundwater nearly to the standard.

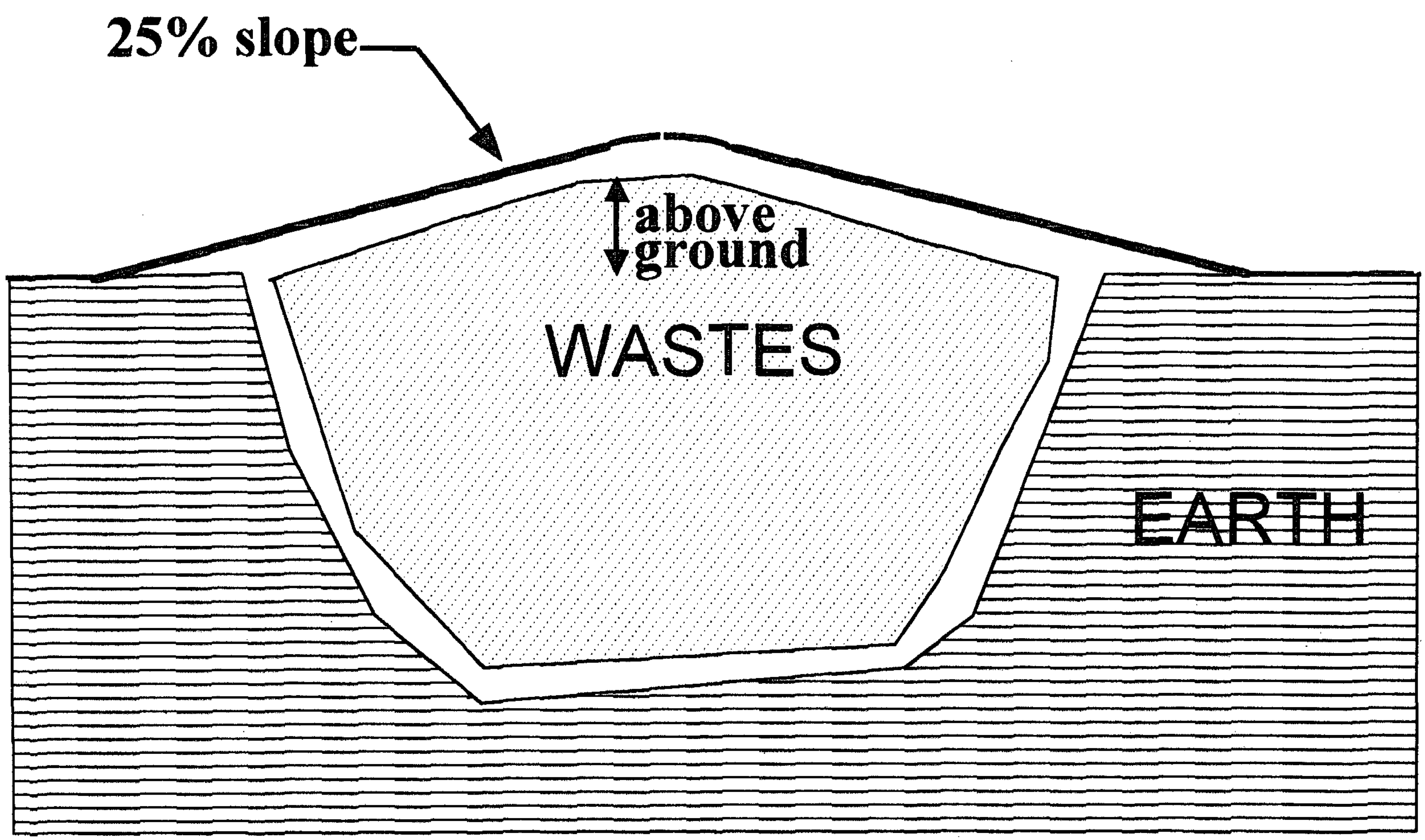
We suggest that no surface waste management facility, except a small landfarm, be located where ground water is less than 100 ft below the lowest waste.

53 F (3) (a) depth to ground water - landfills

In the proposed rule, a landfill operator may propose an alternative base liner if depth to ground water is more than 100 ft.

To be consistent with our desire for 100 ft to groundwater beneath conventional landfarms and landfills, and to encourage operators to seek sites with better geology, we suggest that a landfill operator may propose an alternative base if the depth is more than 125 ft, **or** if there is a geologic layer beneath the wastes that provides protection equivalent to that of the prescribed base layer.

53 F (3) & 53 J (4) Landfill design



not to scale

53 F (3) Landfill design specifications

The rule implicitly allows burial of wastes at any height above ground level.

Erosion of a cap over above-ground wastes would expose the wastes to dispersal on the ground surface.

We suggest that wastes should not be "buried" above ground level.

53 J (4) (b) Landfill cell closure standard

The proposed rule would allow a 25% slope on a landfill cover. This would encourage erosion of an entombment that is intended to remain secure for all history.

We suggest the slope **not exceed 8%.**

"Erosion … is a potentially severe problem if the slope is steep (e.g. greater than 8%)."

American Petroleum Institute Publication 4663 (1997).

53 F (3) (h) Landfill top cover design

The proposed rule would require a gas vent layer of **sand or gravel**, 12 inches thick, above waste.

We suggest that this layer be of **gravel only**, thereby serving not only as a gas vent but also as a capillary barrier to the upward transmission of salts.

Delete the words <sand or>.

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53 G (2) Background testing of landfarms

The proposed rule specifies four samples per cell. “Cell” is defined only as a confined area. The entire landfarm may be a “cell.”

We suggest specifying a maximum cell area of 10 acres, with a berm around each cell.

When “cell” is limited in area, sampling can be better defined. Otherwise, in principle, the rule specifies 4 samples per landfarm.

53 G (5) (a) vadose zone monitoring depth

The proposed rule specifies sampling at 3-4 ft beneath the "cell's original surface," and comparison of test results with background concentrations.

This may lead to arguments regarding statistical comparison of the variation of both the background and the monitor samples.

We suggest the monitoring requirement be that **no** sample exceeds **closure** conditions.

53 G (5) (a) vadose monitoring ...

Contamination approaching 4 feet beneath the treatment zone may not be detected before the landfarm closes, or if it is detected, the release may be too large to correct by revising operating conditions.

We suggest monitoring **at a 2 foot depth**.

53 G (5) (a) vadose monitoring depth

For sampling at 2 ft depth:

It may be argued that the operator does not know where the bottom of the treatment zone is.

But, he needs to know that for sampling of the treatment zone.

A few cement-block monuments at the edge of the cell could serve as an enduring indicator of depth.

53 G (5) (b,c) vadose zone monitoring

The proposed collection of four samples is unlikely to detect releases, which may occur at particular locations, such as preferential pathways and drainages.

We suggest increasing the number of samples to 8 per event, and doubling the interval between events to reduce costs. At least one sample should be obtained in any area where rainfall may have collected.

53 G (4); (6)(d) treatment zone standards ...

Based on the impacts to plant growth:
We recommend the **treatment zone** and **closure** standards for chloride should **not exceed 500 mg/kg**.

This would still allow an operator to accept a limited amount of waste with chloride up to the waste acceptance standard of 1000 mg/kg.

53 G (6) (a,b,e) treatment zone standards ...

BTEX and VOC standards

In addition to BTEX, some other VOCs may occasionally occur in landfarms. If they do, the vapors may briefly diffuse into and back out of the underlying vadose zone when a new lift is applied. To avoid both unnecessary testing or a false alarm, we suggest **it may not be necessary to test the vadose zone samples for VOCs (including BTEX) routinely, but only prior to adding a new lift.**

53 G (6) (e) treatment zone standards ...

The proposed closure standard for lead (Pb) is set according to human exposure, but humans do not graze upon the land like cattle and wildlife.

We recommend that the closure standard for lead be 56 mg/kg, in agreement with the EPA standard for mammalian wildlife.

Ecological Soil Screening Levels for Lead

Interim Final

OSWER Directive 9285.7-70

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

March 2005

Table 2.1 Lead Eco-SSLs (mg/kg dry weight in soil)

Plants	Soil Invertebrates	Wildlife	
		Avian	Mammalian
120	1,700	11	56

53 H (5) (a) (iv) Small landfarm standard

As with other landfarm closure, we recommend that chloride shall not exceed 500 mg/kg.

53 H (5) (b) (iv) Small landfarm sampling

As with other landfarms, we recommend that sampling be done at 2 ft beneath the treatment zone. The proposed single sample at 3-5 ft would detect only a large release.

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53 G (8) Bioremediation endpoint

We have specifically agreed that a permitted landfarm using the bioremediation endpoint may employ a 1% closure standard in lieu of the requirement for 80% reduction. This is because we focus on the closure situation rather than the reduction.

We have agreed that the SAR closure standard for these landfarms might be 13, rather than 5 as we otherwise recommend. This is because these landfarms would have $EC < 4$, and we believe as a practical matter that the SAR would not become large if the landfarm were managed as advocated.

53 G (8) Bioremediation endpoint ...

We have agreed that landfarms using the bioremediation endpoint might have asphaltic particles of < 1/2 inch size, covering < 1% of the surface. This is in exchange for the superior vegetation that we hope would result from the application of soil amendments and water in these landfarms. We would not regard the 1% TPH limit and these asphaltic standards as acceptable in landfarms that do not have the maintenance, water, and assurances that must accompany the bioremediation endpoint option.

53 G (8) Bioremediation endpoint ...

If the bioremediation endpoint proves successful, then we feel it would be well to look for compliance mechanisms (assurance of water and closure) that would allow this approach for small landfarms.

Although we are skeptical that this approach will indeed work in the climate of New Mexico, we suggest it should not be prematurely rejected. We simply assert that compliance with moisture and closure conditions must be financially assured.

53 G (8) Bioremediation endpoint ...

For this endpoint to be permitted, we maintain that the operator must demonstrate **his** access to water that **he** may legally use for **this** irrigation, and that the water is physically available.

We understand that purchase of ranch water for landfarm irrigation is not legal.

OCD rules should not encourage a black market in water.

53 G (8) Bioremediation endpoint ...

To assure achievement of closure conditions, bioremediation endpoint landfarms must be covered by financial assurance adequate to remove the wastes, dispose of the wastes, and revegetate the site. This implies that the required bonding must vary according to the **active** area of landfarm. The **permit** should require assurance of $75,000 per acre of active landfarm, **or** the amount that is demonstrated sufficient to cover **removal** of wastes and **restoration** of **all active areas.**