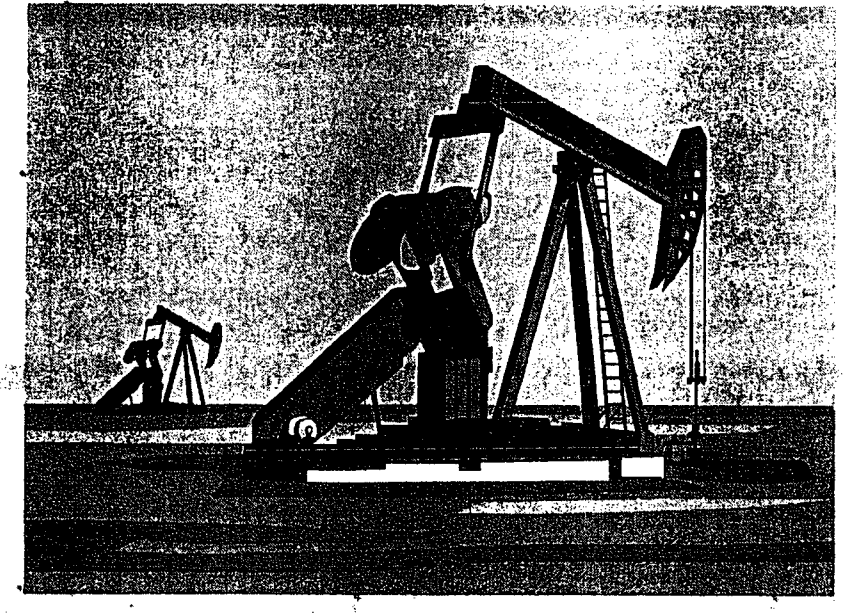
Soil Remediation for Oil and Gas Producers



Kerry L. Sublette
University of Tulsa
Integrated Petroleum Environmental Consortium (IPEC)

1/12/04

Bioremediation of Oil Spills

IPEC Guidelines for Bioremediation of Crude Oil Spills

What is bioremediation?

Using microorganisms that live in the soil to eat hydrocarbons from a spill

When you ***do*** bioremediation your job is to make it possible for the bugs to eat as much of the hydrocarbon as they can as fast as they can

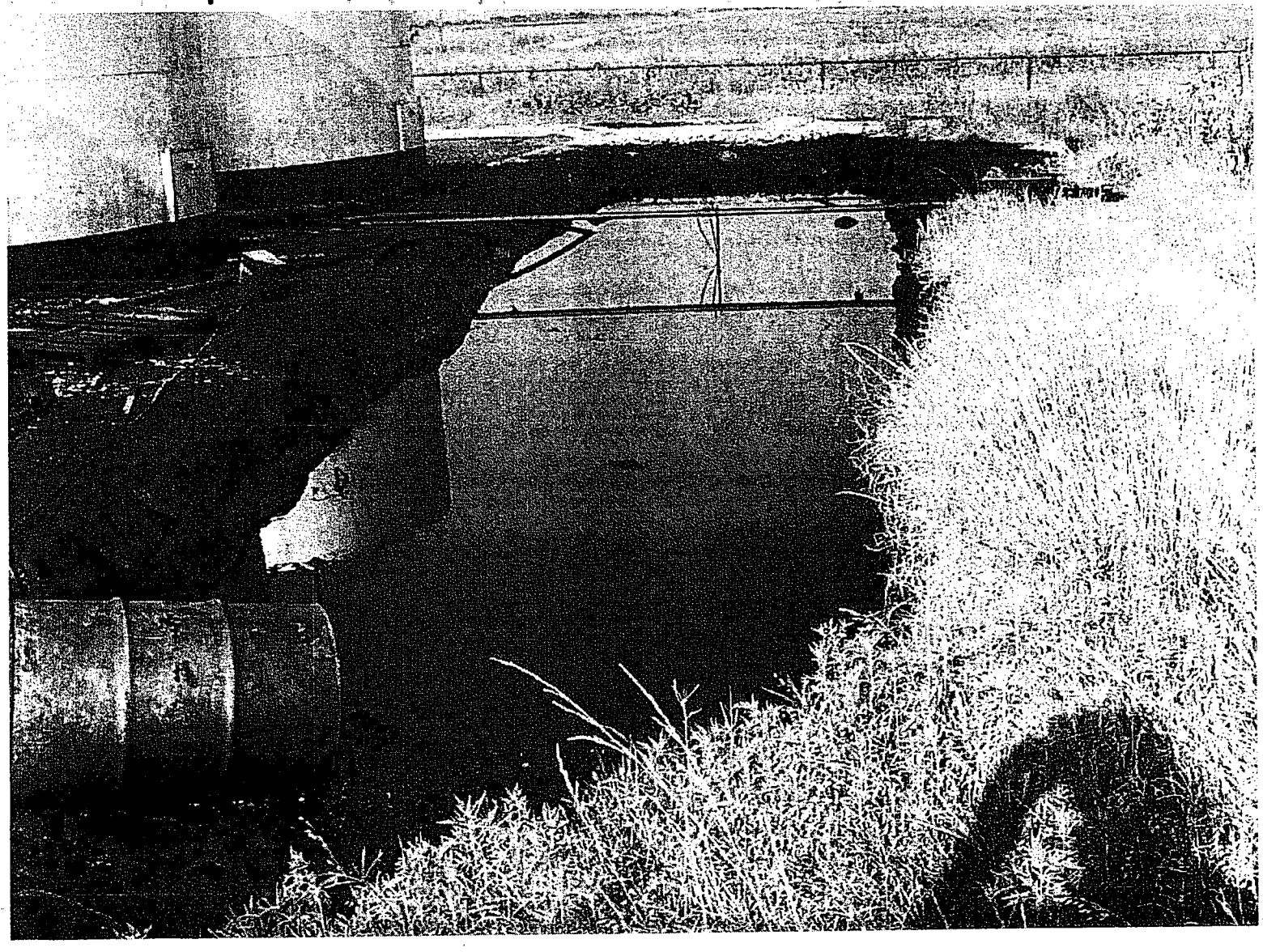
IPEC Guidelines for Bioremediation of Crude Oil Spills

Bioremediation is not your first response to a fresh oil spill

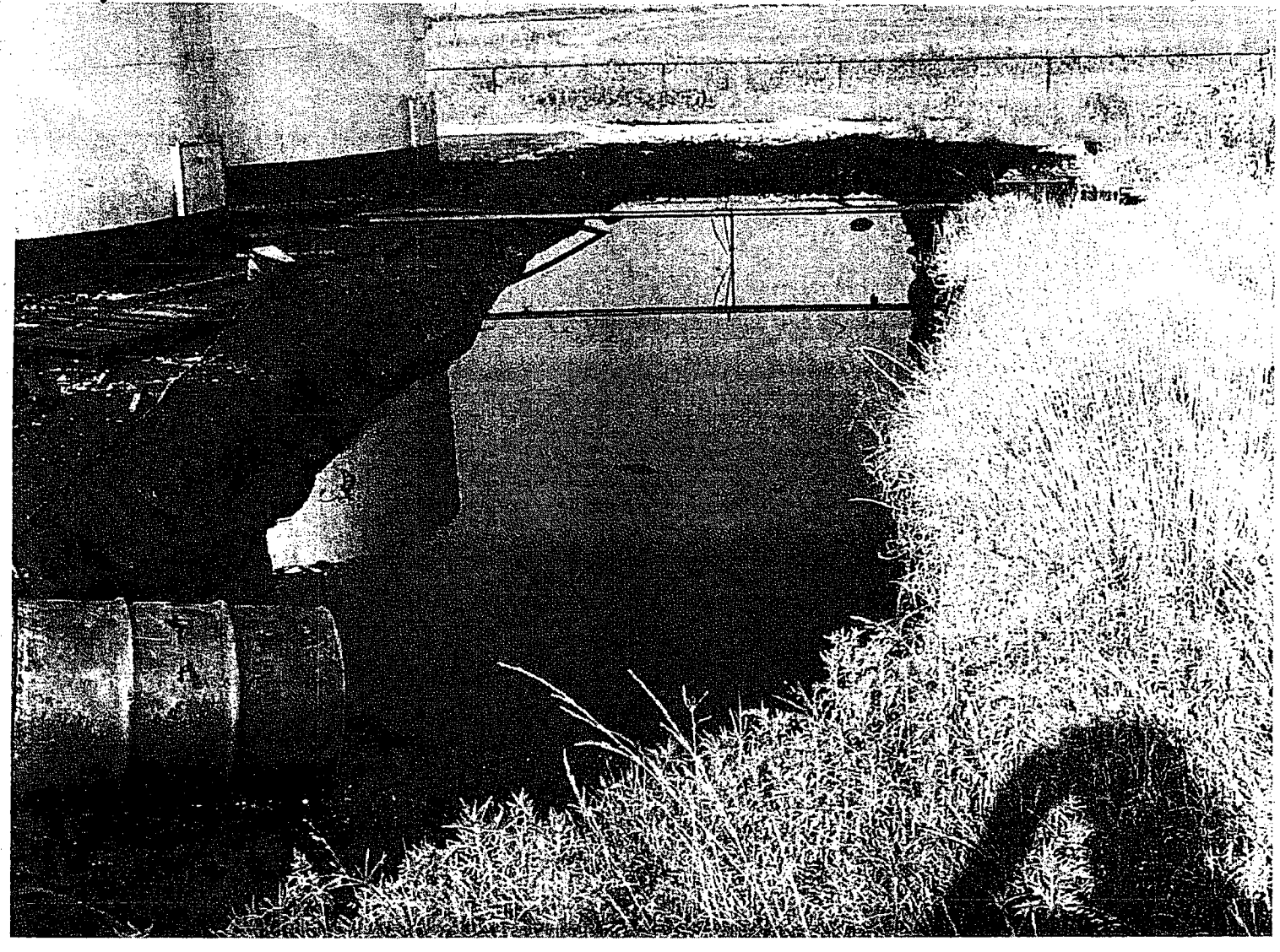
If it's a fresh spill:

- Recover free fluids (recycle back to the stock tank if possible)
- Use an absorbent to get fluids that can't be recovered (dispose of properly)
- It is to your benefit to bioremediate only those fluids that soak into the ground

Bioremediation is not the first response to this problem!



Bioremediation can be used to treat the oil-stained soil after fluids have been properly disposed of.



IPEC Guidelines for Bioremediation of Crude Oil Spills

2. Is there shallow groundwater under the contamination?

Why? We must have enough of a soil column between the oil and groundwater to prevent groundwater contamination.

Must answer **NO** to both questions to use the most basic form of bioremediation – *in situ* landfarming

IPEC Guidelines for Bioremediation of Crude Oil Spills

Basic Landfarming

The microorganisms that eat hydrocarbons need the same things as crops to thrive:

Fertilizer

Moisture

Good soil structure

Warm temperature

IPEC Guidelines for Bioremediation of Crude Oil Spills

2. Is there shallow groundwater under the contamination?

Why? We must have enough of a soil column between the oil and groundwater to prevent groundwater contamination.

Must answer **NO** to both questions to use the most basic form of bioremediation - *in situ* landfarming

IPEC Guidelines for Bioremediation of Crude Oil Spills

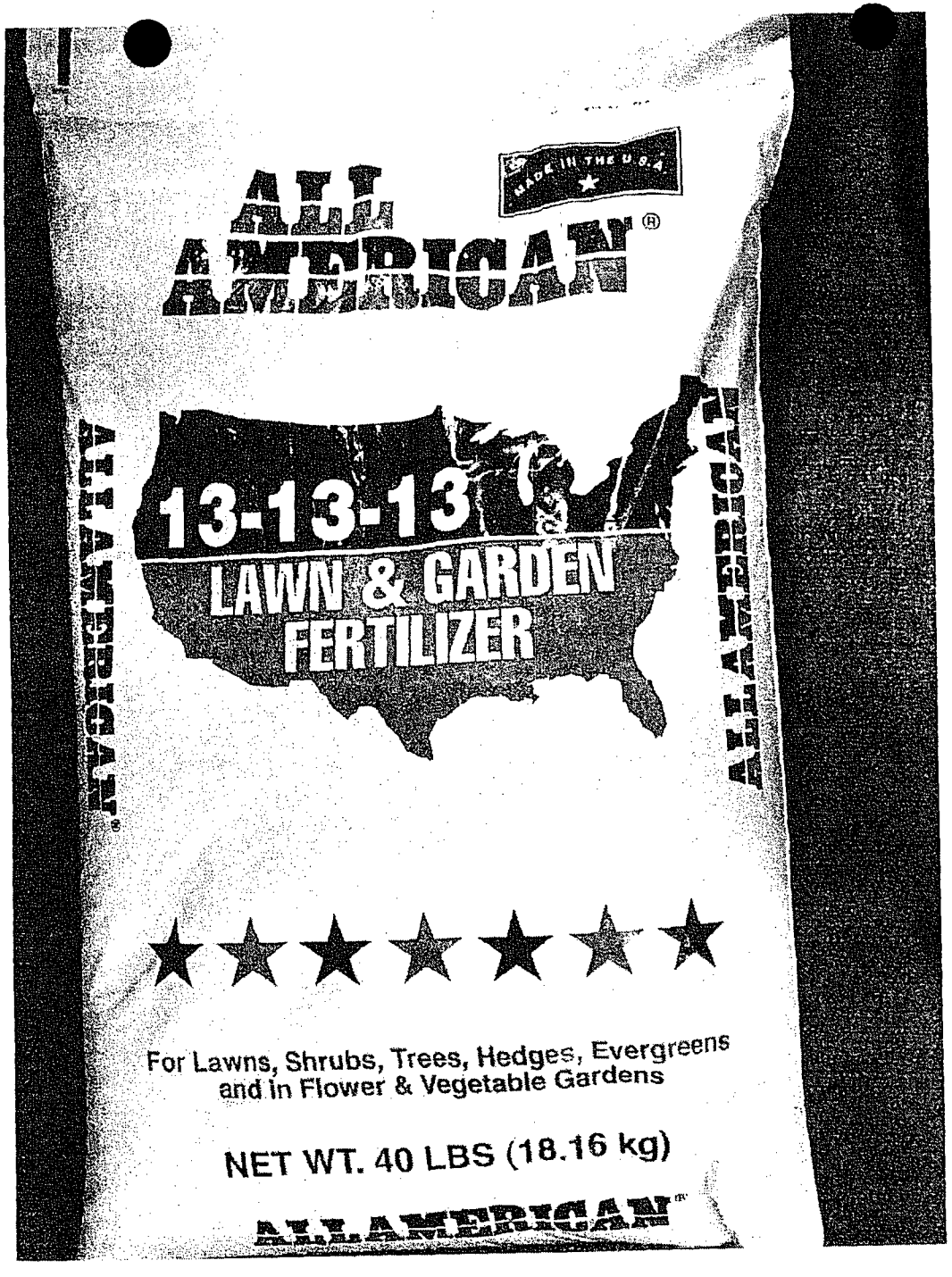
It's a bioremediation garden!

What's good for your tomatoes is good for the bugs!

IPEC Guidelines for Bioremediation of Crude Oil Spills

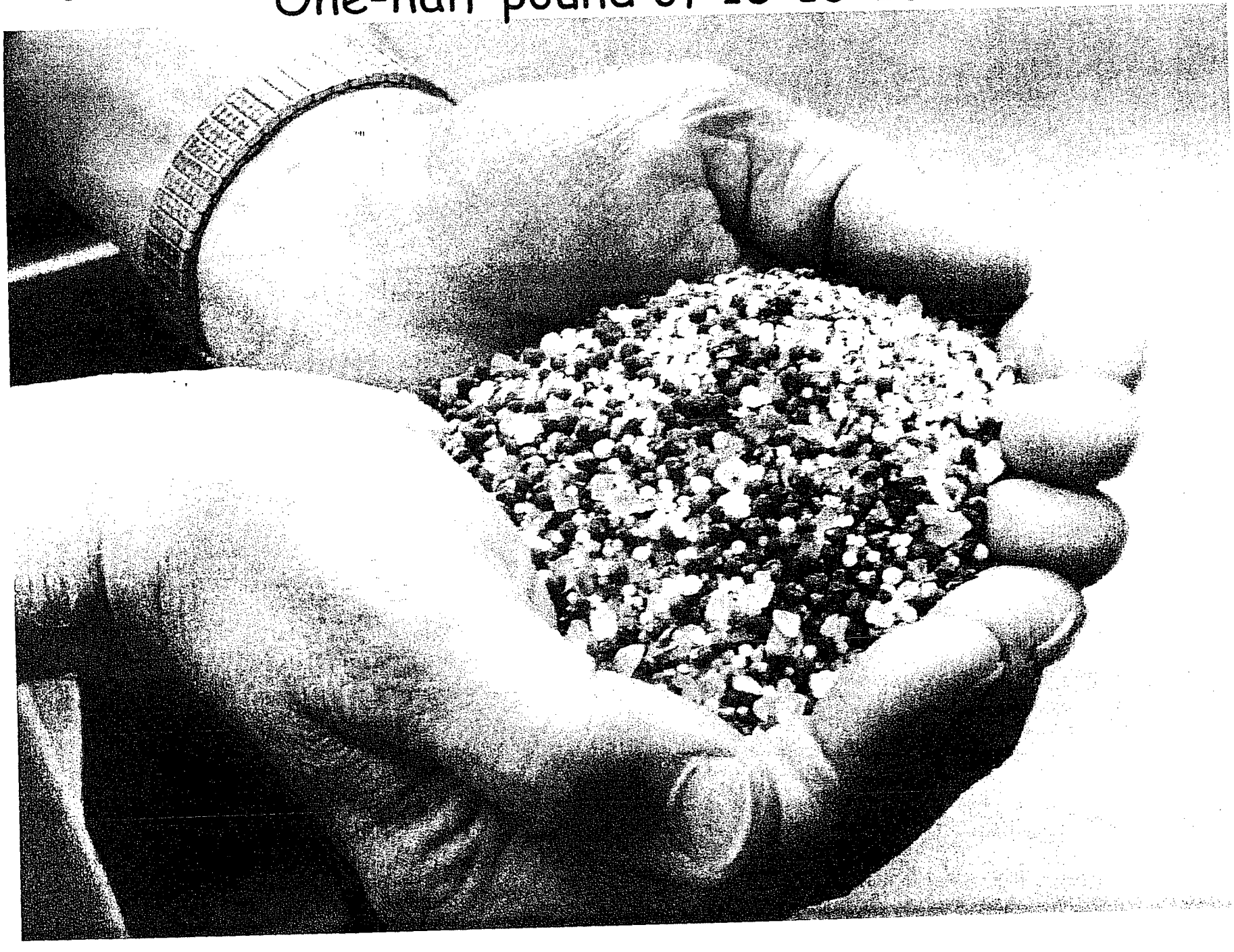
Step 1

- Add fertilizer
  - 13-13-13
  - 1/2 lb per square yard for a recent spill
  - 1/4 lb per square yard for an old spill



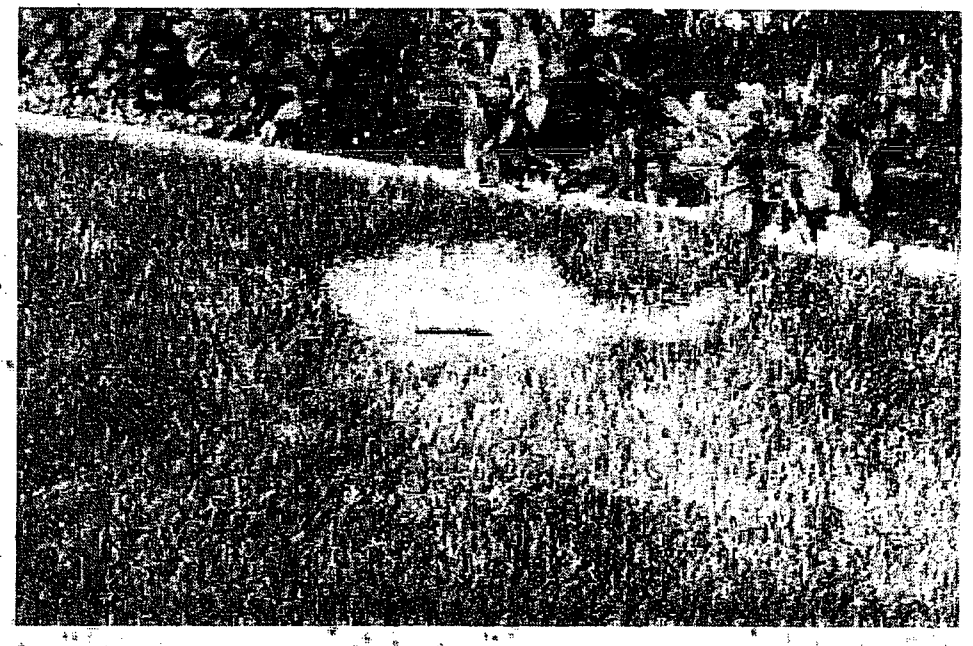
About $6/bag anywhere lawn and garden supplies are sold

One-half pound of 13-13-13



Don't use too much fertilizer

- You know what that does to your lawn
- It will do the same thing to the microorganisms that eat the oil
- And, it wastes money!



IPEC Guidelines for Bioremediation of Crude Oil Spills

Step 2

- Add organic matter
  - Builds soil structure and allows the soil to breathe
  - Hay, straw, etc. (but not wood!)
  - Hay: 5 small square bales per 1000 square feet

One round bale is about 8-10 small square bales

An example of the desired soil structure in a landfarm

IPEC Guidelines for Bioremediation of Crude Oil Spills

Step 3

Till the fertilizer and organic matter into the soil to a depth of 6-8 inches

IPEC Guidelines for Bioremediation of Crude Oil Spills

Step 4

- Repeat the addition of fertilizer with tilling after about 30 days and again after about 60 days if the weather is warm (March-November)
- After this initial three-month start up period add fertilizer only **every other** month as long as the weather is warm.
- Don't add fertilizer during the cold months (December-February)
- Try to till every month whether you fertilize or not, even when it's cold
- Continue fertilizer additions and tilling on this schedule until you no longer smell hydrocarbon in the soil
- Revegetate to prevent erosion

Example 1. Bioremediation started March 22, 2004

Fertilize and till

Till only

2004

JANUARY

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

FEBRUARY

S	M	T	W	T	F	S
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8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29						

MARCH

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14	15	16	17	18	19	20
21	■	23	24	25	26	27
28	29	30	31			

APRIL

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18	19	20	21	■	23	24
25	26	27	28	29	30	

MAY

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	■
23/30	24/31	25	26	27	28	29

JUNE

S	M	T	W	T	F	S
		1	2	3	4	5
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13	14	15	16	17	18	19
20	21	⁚	23	24	25	26
27	28	29	30			

JULY

S	M	T	W	T	F	S
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11	12	13	14	15	16	17
18	19	20	21	■	23	24
25	26	27	28	29	30	31

AUGUST

S	M	T	W	T	F	S
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⁚	23	24	25	26	27	28
29	30	31				

SEPTEMBER

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OCTOBER

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17	18	19	20	21	⁚	23
24/31	25	26	27	28	29	30

NOVEMBER

S	M	T	W	T	F	S
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14	15	16	17	18	19	20
21	■	23	24	25	26	27
28	29	30				

DECEMBER

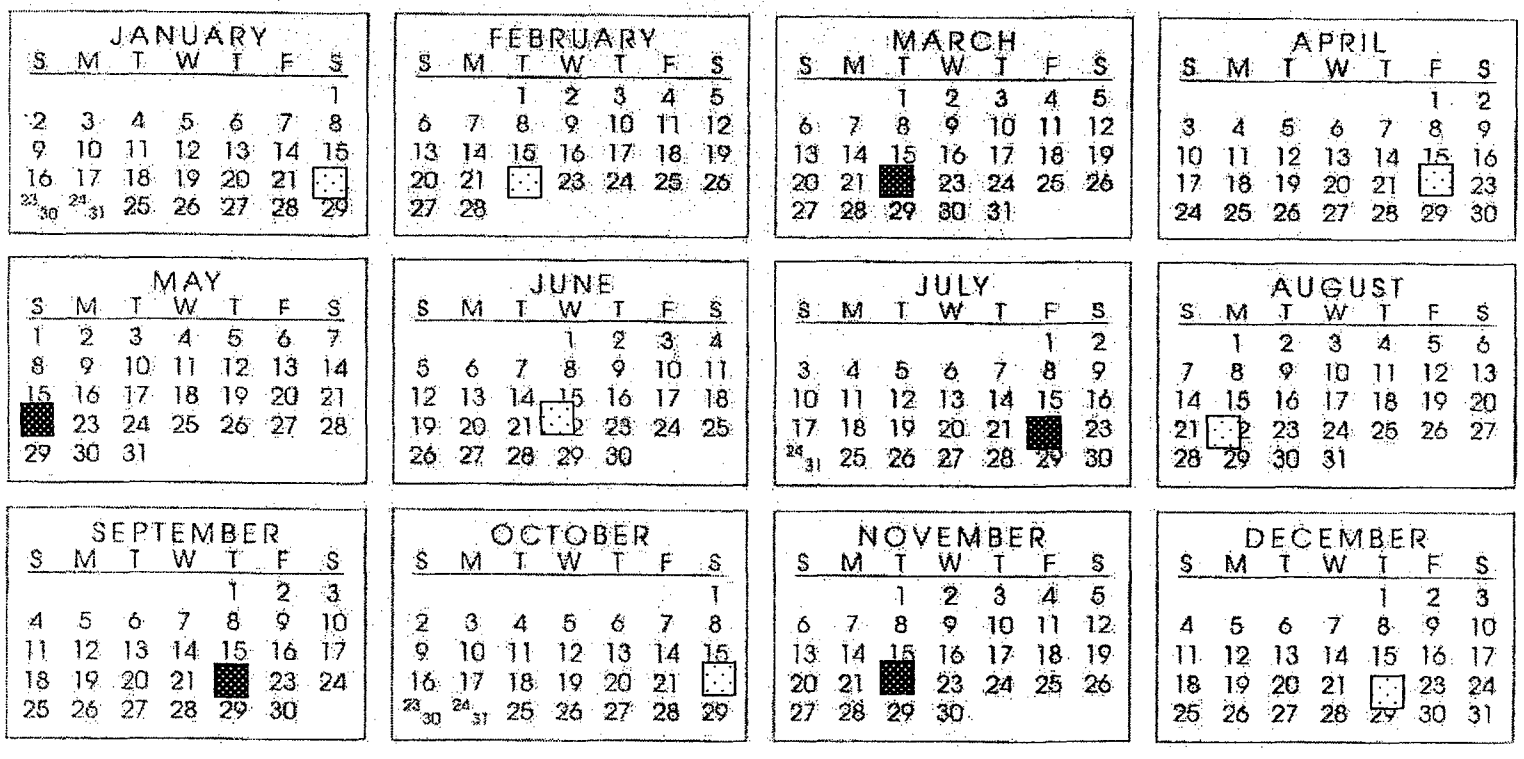
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	⁚	23	24	25
26	27	28	29	30	31	

Example 1. Bioremediation started March 22, 2004

■ Fertilize and till

⊡ Till only

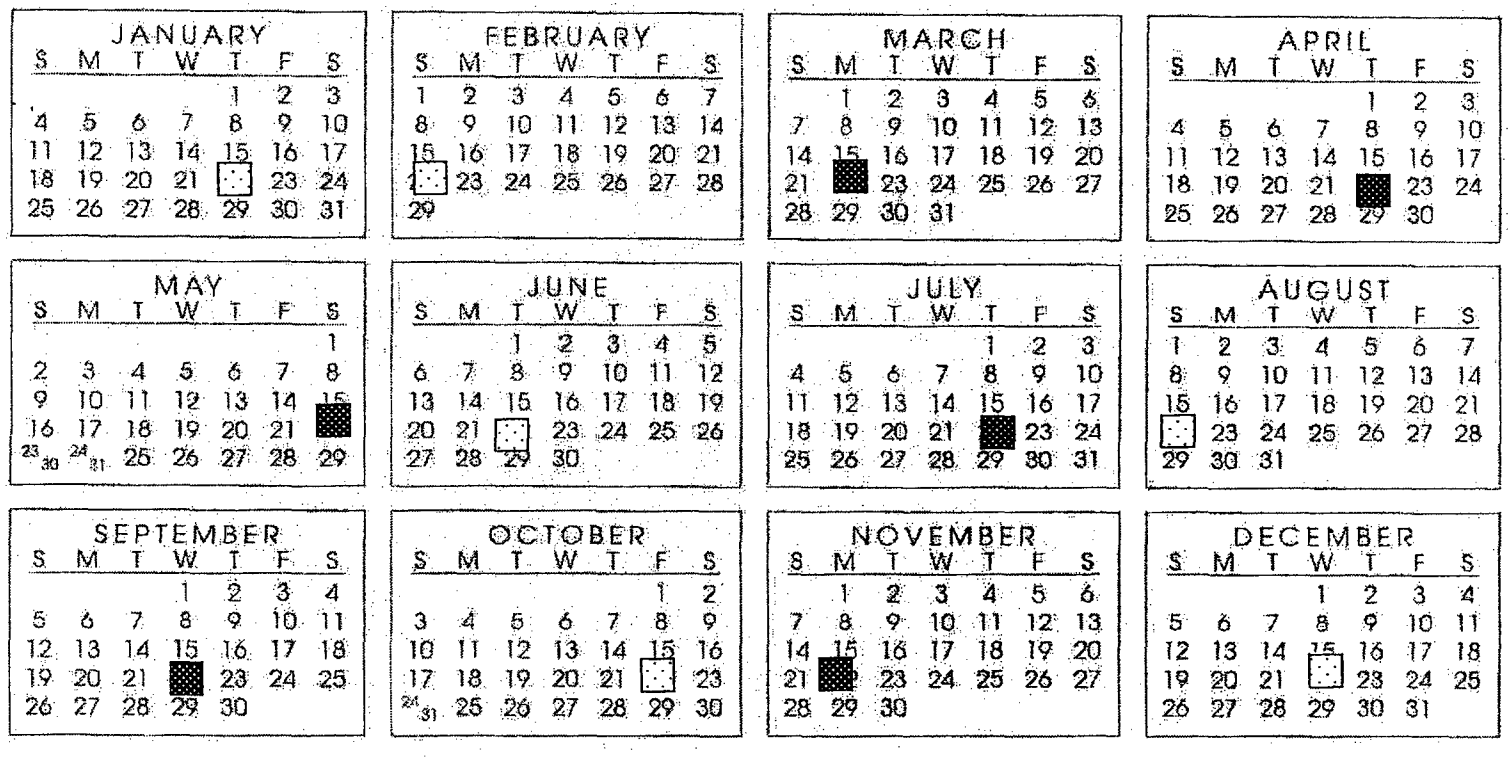
2005



Example 2. Bioremediation started January 22, 2004

Fertilize and till

Till only

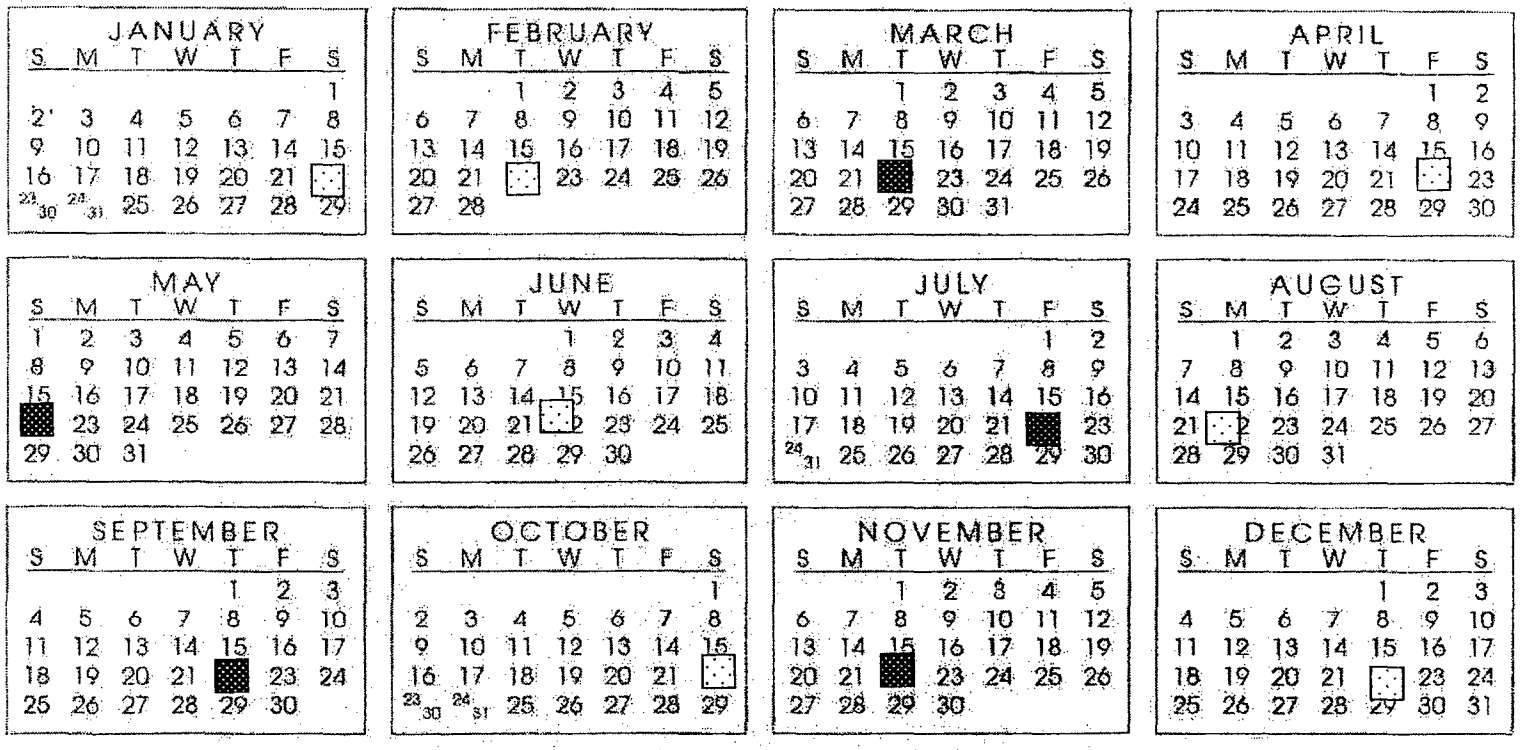


Example 2. Bioremediation started January 22, 2004

■ Fertilize and till

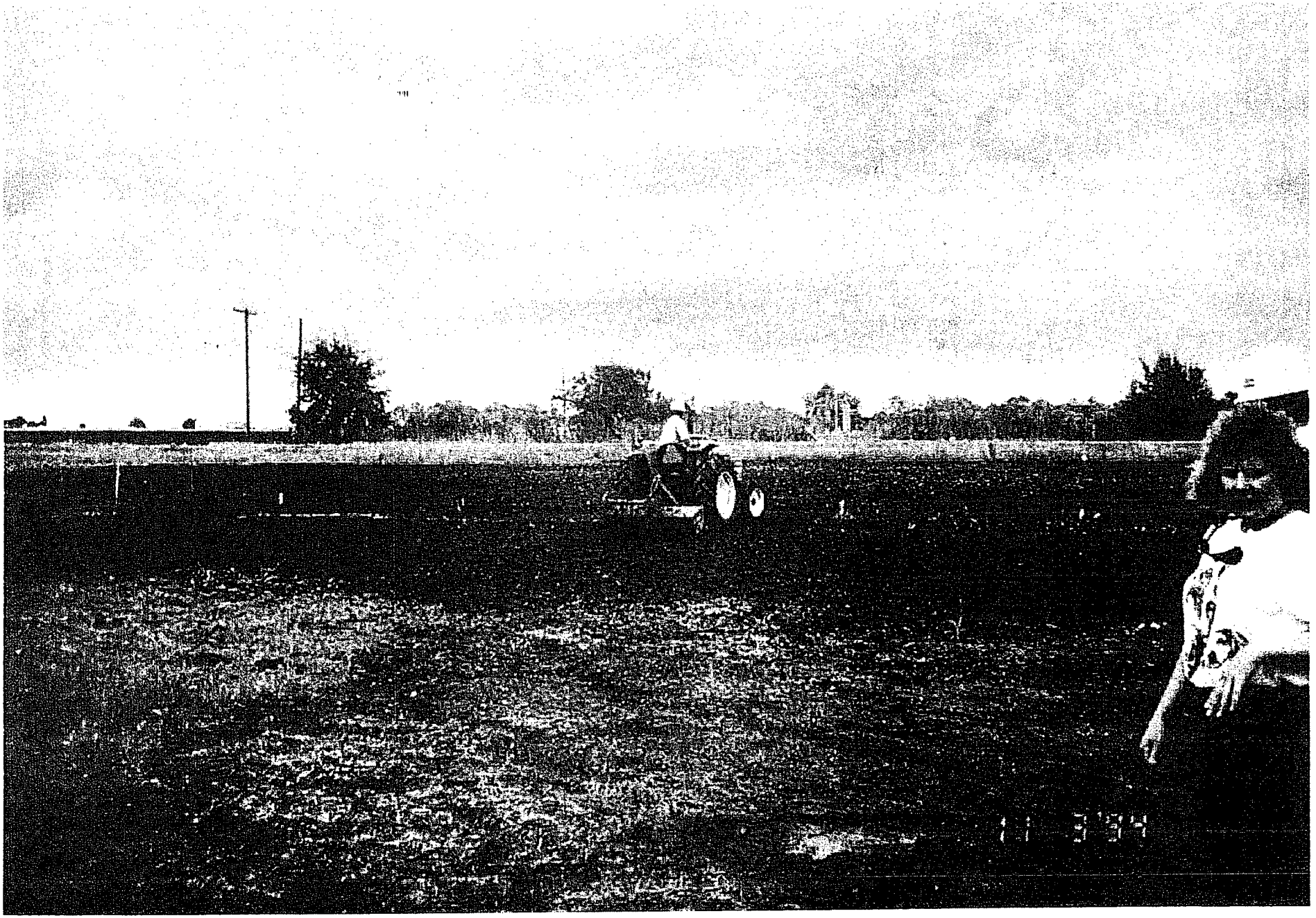
⊡ Till only

2005



These guidelines apply equally well to small jobs and.....

..... big jobs!



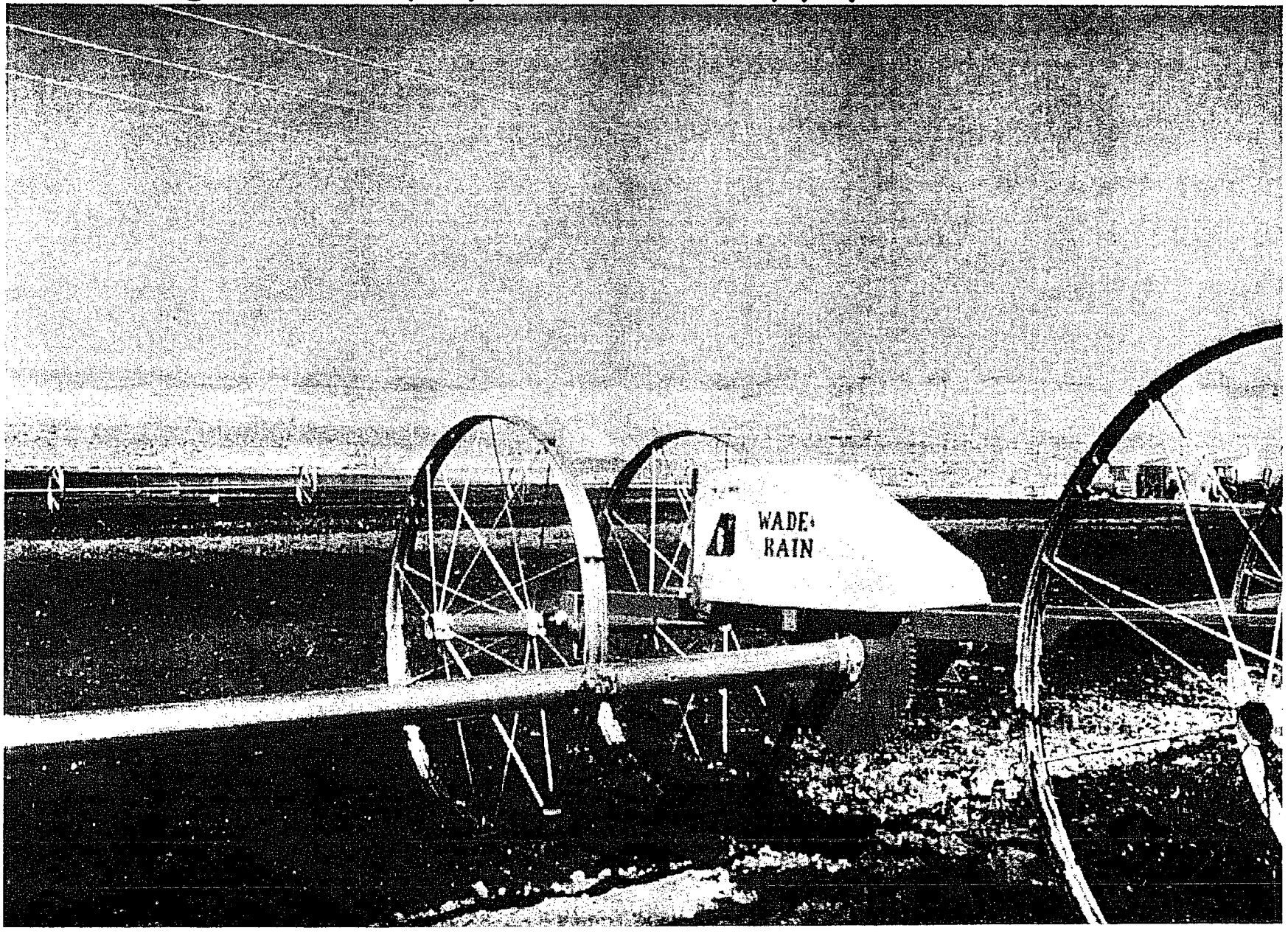
IPEC Guidelines for Bioremediation of Crude Oil Spills

What about moisture?

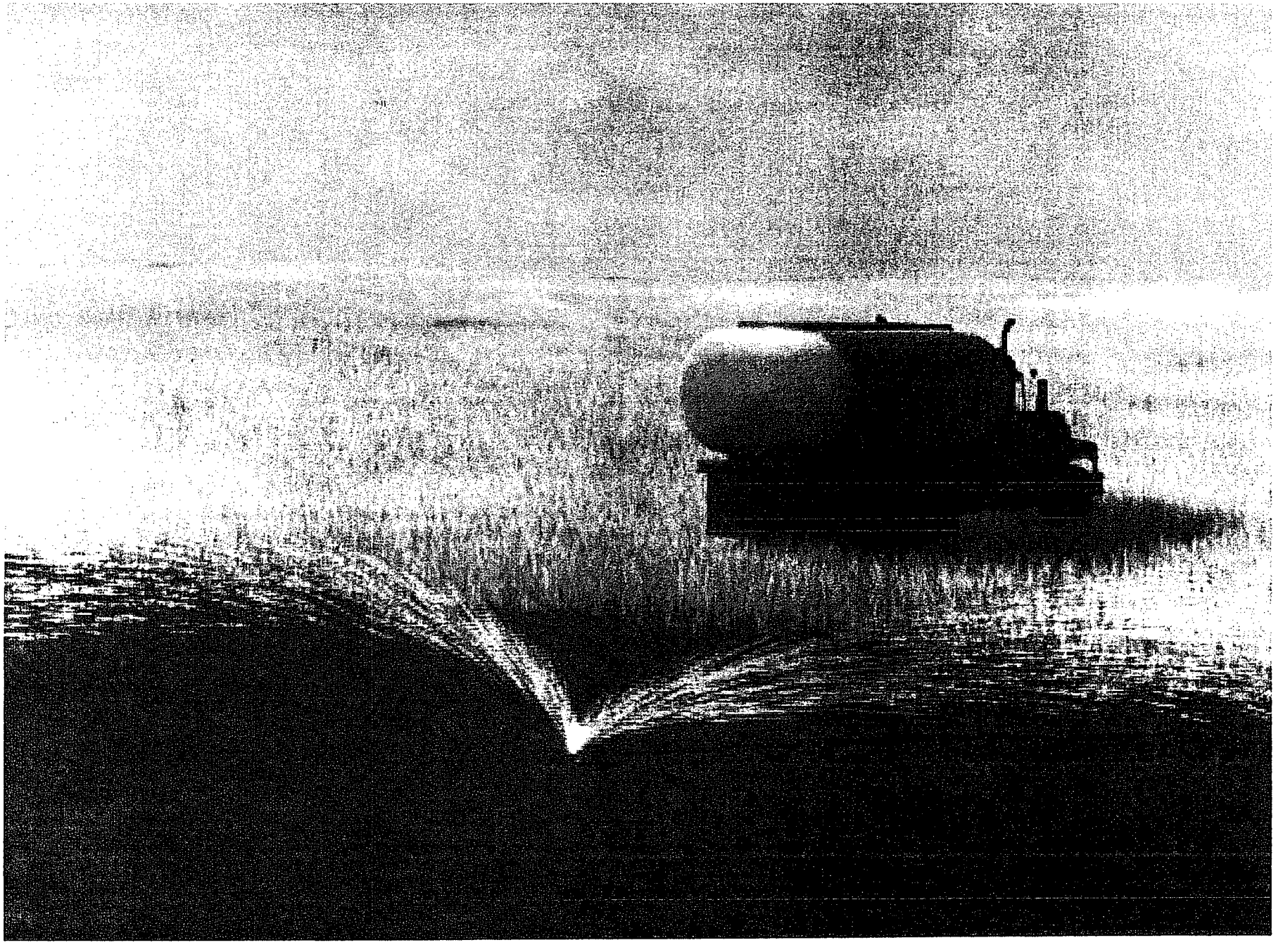
- We can speed the process up by keeping the soil moist but most of the time we depend on rain.

- If you do water don't saturate the soil.

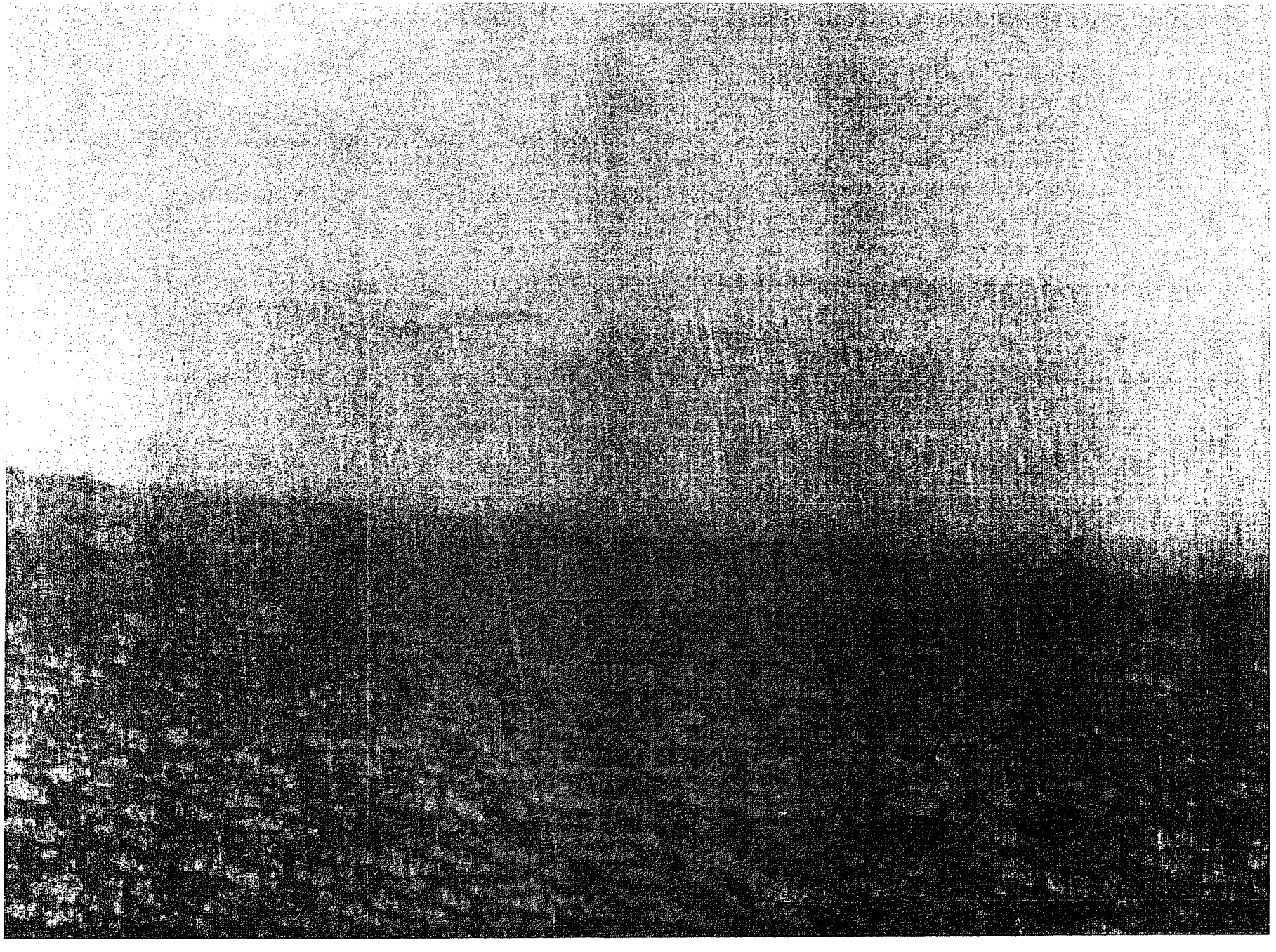
Here's a large project in a dry climate using irrigation equipment to supply moisture



One way to supply moisture to a small project



When we can we just depend on rainfall



IPEC Guidelines for Bioremediation of Crude Oil Spills

What is the best time to start a bioremediation project?

- If you have a spill in December – February go ahead and till in organic matter to keep hydrocarbons from moving offsite until warm weather returns.
- Rule of thumb: It takes a hydrocarbon concentration in the soil of less than 5% to prevent a sheen in runoff!

IPEC Guidelines for Bioremediation of Crude Oil Spills

- If the impacted area is sloped it may be necessary to construct a low earthen dike at the bottom to prevent runoff.
- If the spill occurs at any other time of the year go ahead and get started.

IPEC Guidelines for Bioremediation of Crude Oil Spills

How long does it take to bioremediate a site?

- It depends:
  - Tilling and fertilizer schedule
  - Organic matter (soil structure)
  - Rain
  - Age of the spill
- Should see results in 1-2 growing seasons

Soil B is an old spill and Soil A is a fresh spill

The Take Home Lesson?

Don't wait, remediate!

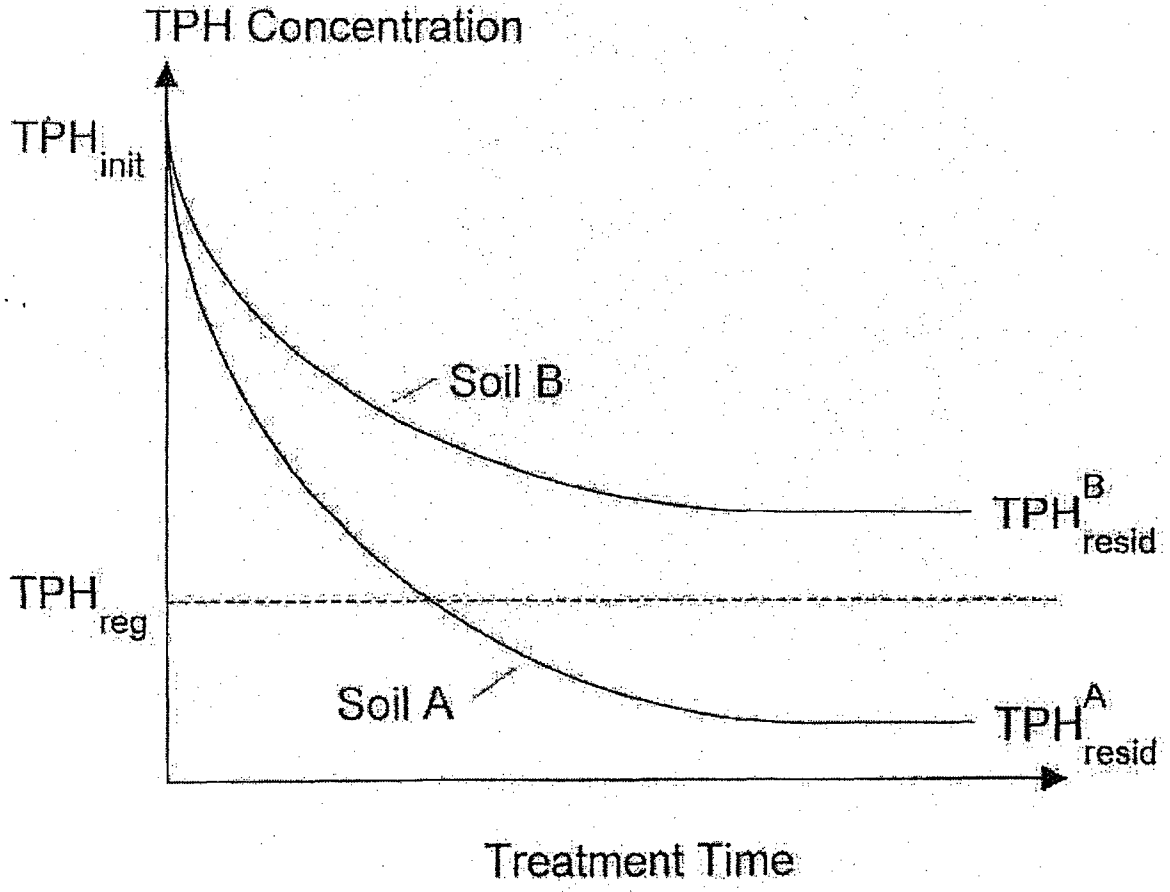
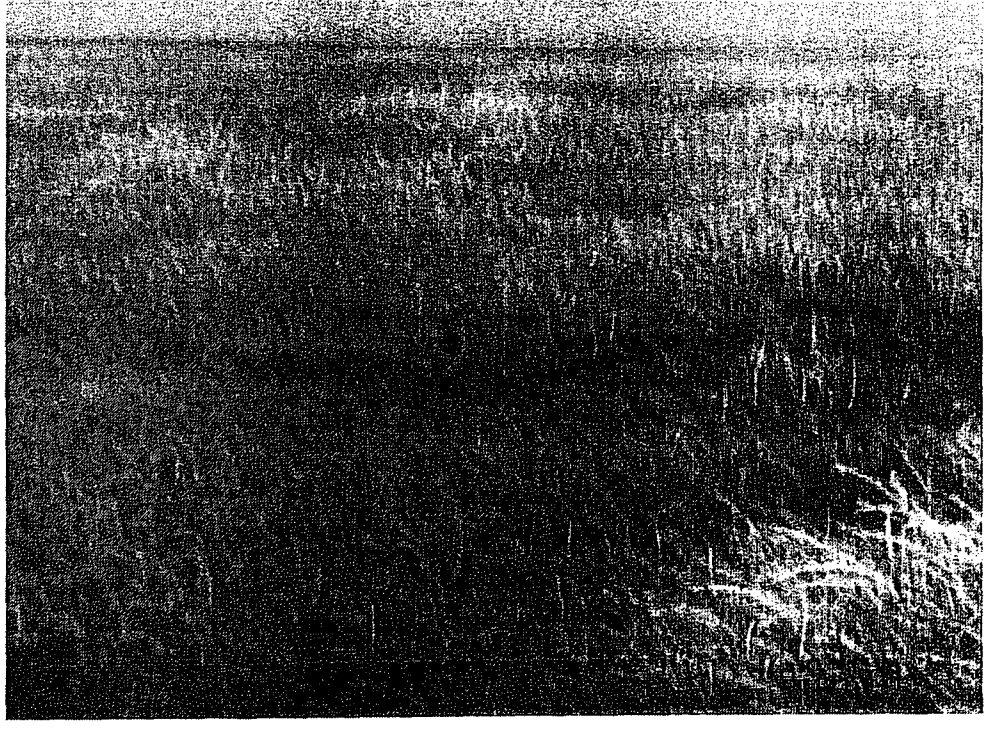


Figure 1. Typical TPH concentration profiles during bioremediation of contaminated soils.

Apply these guidelines and you can turn this →

Into this →



IPEC Guidelines for Bioremediation of Crude Oil Spills

What about brine?

- Cleaning up a spill of oil + brine uses the same basic process as remediating a spill of oil with one difference: You need to think about **drainage!**

IPEC Guidelines for Bioremediation of Crude Oil Spills

An example of brine + oil remediation?

- Initial salt concentrations of 1.5 - 2.0 %
- TPH concentrations up to 1.6%
- TPH half-life of 59 days (compare to 56 days in absence of salt)
- 75% removal of salt in two years

IPEC Guidelines for Bioremediation of Crude Oil Spills

Remember those two questions?

1. Is the contamination deeper than 8 inches?
2. Is there shallow groundwater under the contamination?

IPEC Guidelines for Bioremediation of Crude Oil Spills

What if you can't answer no to both of those two questions?

Treatment in place will remediate the top 6-8 inches. In order to remediate the deeper contamination you must:

- Excavate the soil and spread 6-8 inches deep at a location where there is no shallow groundwater
- Landfarm the excavated soil as usual
- Transfer treated soil back to the source

IPEC Guidelines for Bioremediation of Crude Oil Spills

Notice we didn't say anything about <u>adding</u> bugs!

Why?

Because you don't need to, they're already there in the soil!

Don't buy bugs!

IPEC Guidelines for Bioremediation of Crude Oil Spills

What about other products that are supposed to enhance bioremediation?

- Enzymes
- Surfactants
- Ionized water
- Magic pixie dust

Don't waste your money!

IPEC Guidelines for Bioremediation of Crude Oil Spills

How to recognize snake oil:

- Claims of bioremediation in hours or days
- Claims that the product is useful for a wide range of applications (you can even put it down your well and increase oil production!)
- No independent test data

Watch out for fertilizer disguised as a miracle product!

IPEC Guidelines for Bioremediation of Crude Oil Spills

In conclusion:

- Bioremediation of crude oil spills on soil is not rocket science – it's gardening!

- All you need is what nature gives you, a cheap bag of fertilizer from the hardware store, and a little know-how!

Questions on bioremediation?

Remediation of Brine Spills

IPEC Guidelines for Remediation of Brine Spills

First response to a fresh spill:

- Isolate and stop the source
- Contain the fluids
- Recover the fluids
- Notify authorities
- Initiate remediation as soon as possible

IPEC Guidelines for Remediation of Brine Spills

If we respond in a timely manner:

- Depth that brine soaks into the soil is minimized
- Minimize additional damage
- Less costly remediation and restoration of the site

IPEC Guidelines for Remediation of Brine Spills

If we ignore a brine spill:

- Loss of plants results in erosion and loss of topsoil
- Bad relationship with landowner
- Ultimate restoration becomes very expensive $$$$
- You could get sued and lose the lease

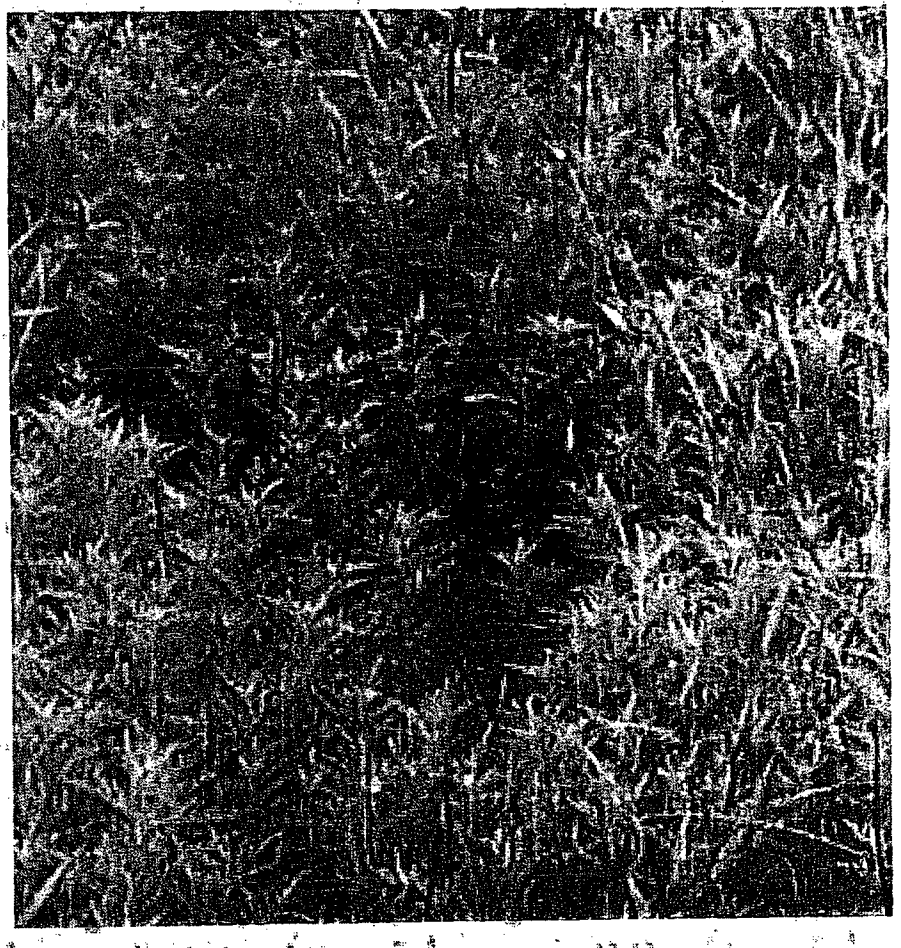
IPEC Guidelines for Remediation of Brine Spills

Brine Spill Remediation Strategy

- Reduce soil salinity
- Revegetation – any kind of vegetation!
  - Reduction in soil salinity and revegetation
    - stops loss of topsoil
    - stimulates soil biota
    - improves soil structure (which further improves reduction in salinity)
- Longer term goals may be the restoration of original vegetation and land use

IPEC Guidelines for Remediation of Brine Spills

Learn to love ragweed!



IPEC Guidelines for Remediation of Brine Spills

We need to be able to test for soil salinity:

Why?

- To see how well a remediation effort is working (the immediate effects of a successful remediation effort are not visible!)
- To find "hot spots"

IPEC Guidelines for Remediation of Brine Spills

IPEC Soil Salt Analysis Kit

Contents:

- 1 L saturated $CaSO_4$ solution
- Chloride test strips
- Two 50-mL beakers
- Sampling recommendations
- Instructions for use
- Chart for estimating soil chloride concentration
- Table of plant salt tolerances


IPEC Soil Salt Analysis Kit
IPEC SOIL SALT ANALYSIS KIT
INSTRUCTIONS FOR USE
IPEC Soil Salt Analysis Kit

IPEC Guidelines for Remediation of Brine Spills

Sampling Recommendations

- The salt content of soil at brine impacted sites is highly variable over the area of the spill
- No single soil sample will tell you what you really want to know – the ***average*** soil salt concentration

The soil from the hole on the left had twice the salt concentration as the soil from the hole on the right and they were only about 18 inches apart! And the hole on the left was actually farther away from the source of the spill!

IPEC Guidelines for Remediation of Brine Spills

Sampling Recommendations

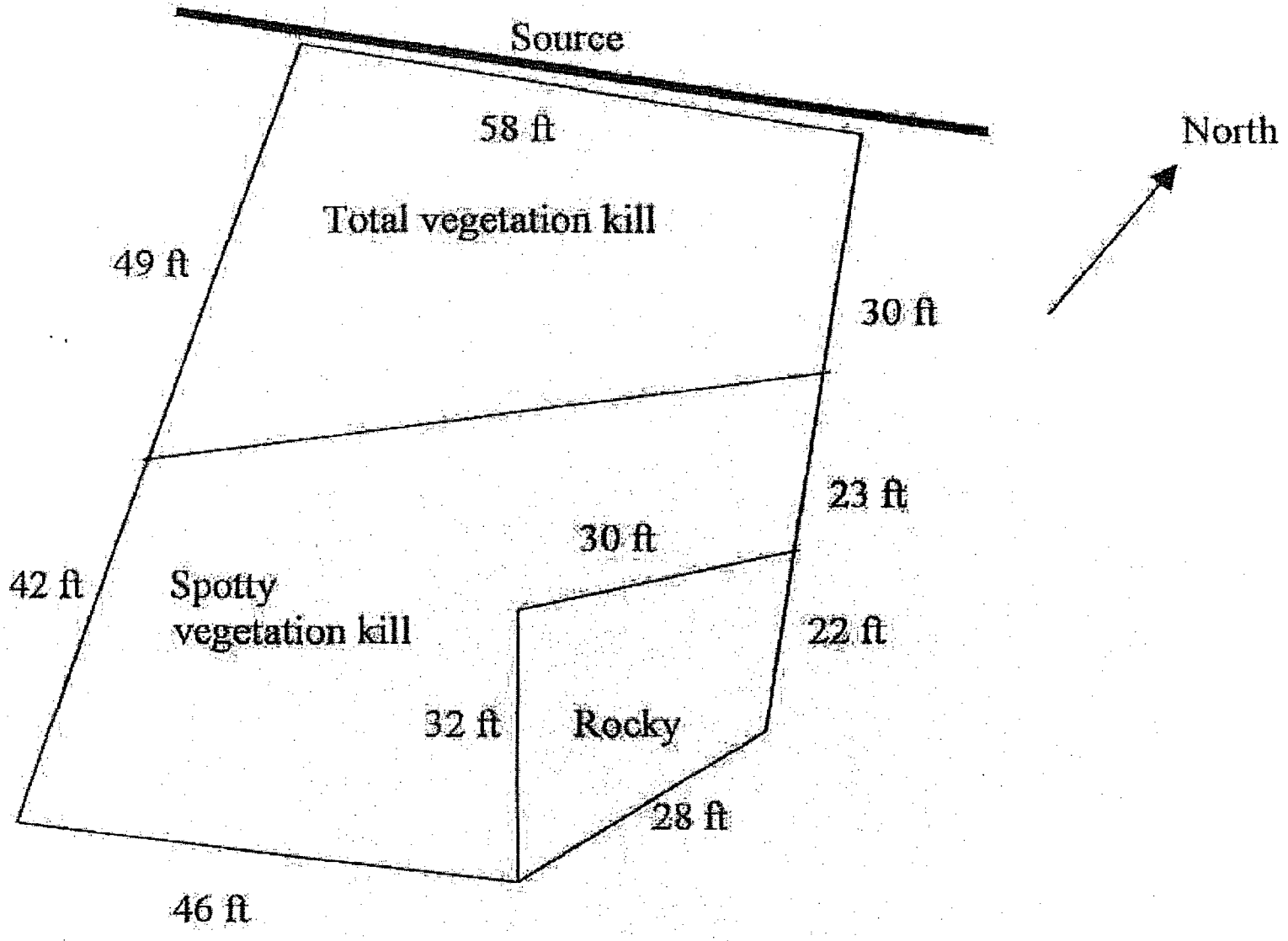
- The easiest way to estimate the average soil salt concentration is to prepare a ***composite*** sample
- Take several individual soil samples in an area, mix them together, then analyze the mixture for the salt content

IPEC Guidelines for Remediation of Brine Spills

Sampling Recommendations

- Make a sketch of the site
- Note easily recognizable features:
  - Clearly different soil types
  - Different amounts of plant kill
  - Different slopes
  - Very rocky conditions
- Pace off the site and put dimensions on your sketch

Example of a salt spill site map



IPEC Guidelines for Remediation of Brine Spills

Sampling Recommendations

- Each different section of the spill may respond differently to remediation efforts and should be sampled separately
- Dig at least 5 holes about 6 inches deep
- Scrape soil from the sides of the hole and mix in the hole breaking up clumps
- Take equal amounts of soil from each hole and mix well - this is your composite sample

IPEC Guidelines for Remediation of Brine Spills

Do you always use 5 holes to prepare the composite sample?

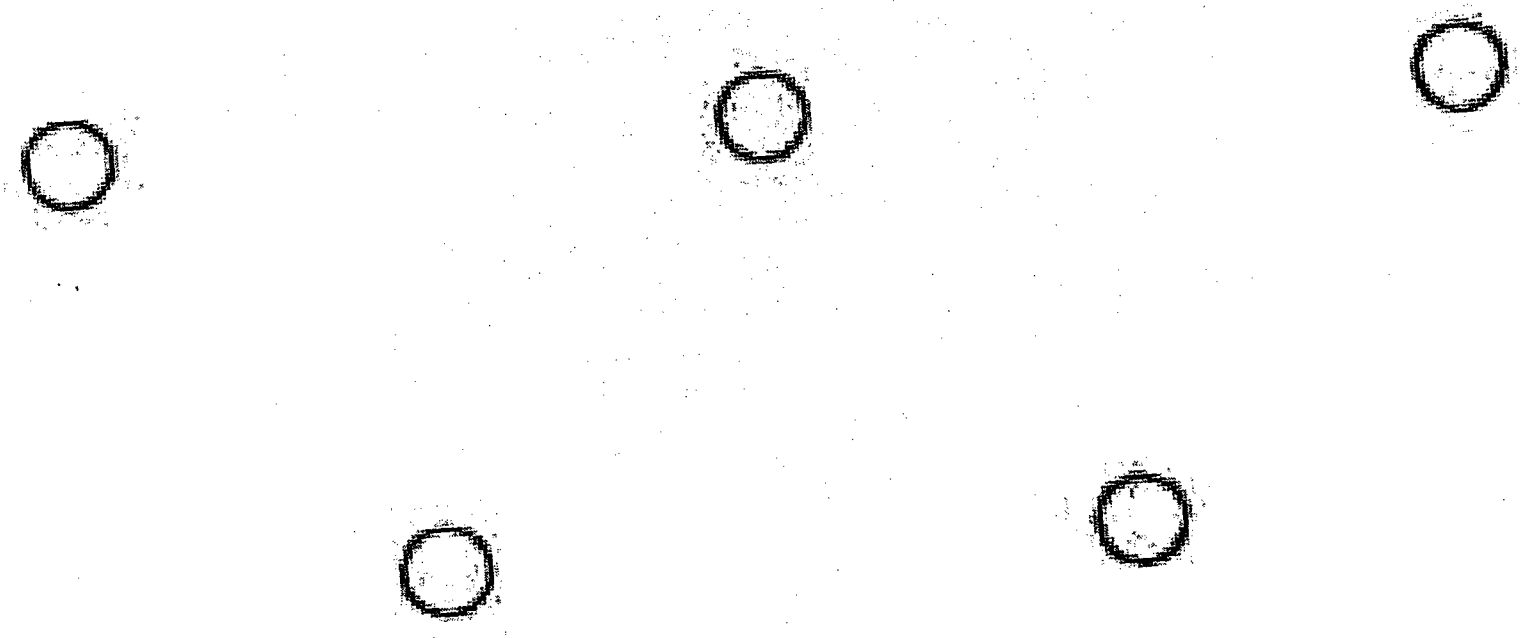
- Less than 5000 square feet - use 5 holes
- 6000 square ft - use 6 holes
- 7000 square feet - use 7 holes
- And so on....

IPEC Guidelines for Remediation of Brine Spills

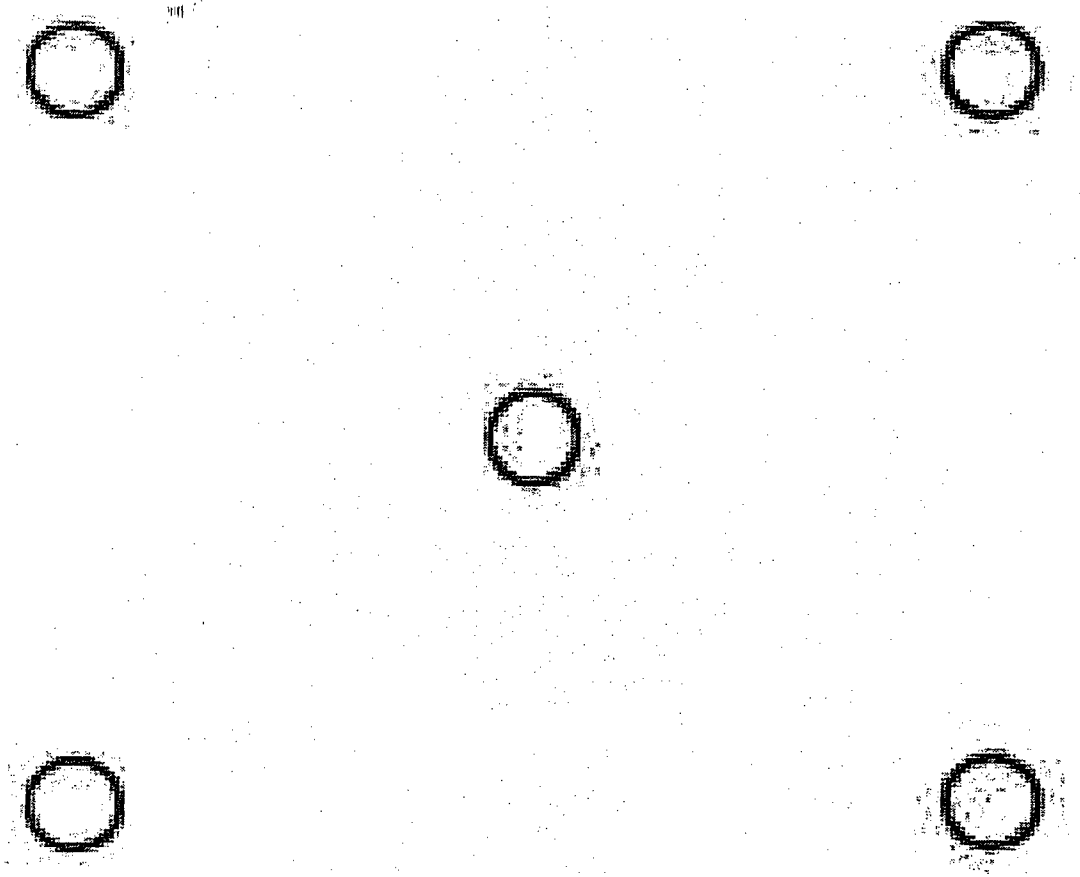
Where should you dig the holes?

- At random
- Use a pattern
- Avoid small unusual areas and edges

A W sampling pattern



A five-spot sampling pattern



IPEC Guidelines for Remediation of Brine Spills

When is the best time to sample?

- When the soil is relatively dry and it is easy to break up clumps and mix the soil

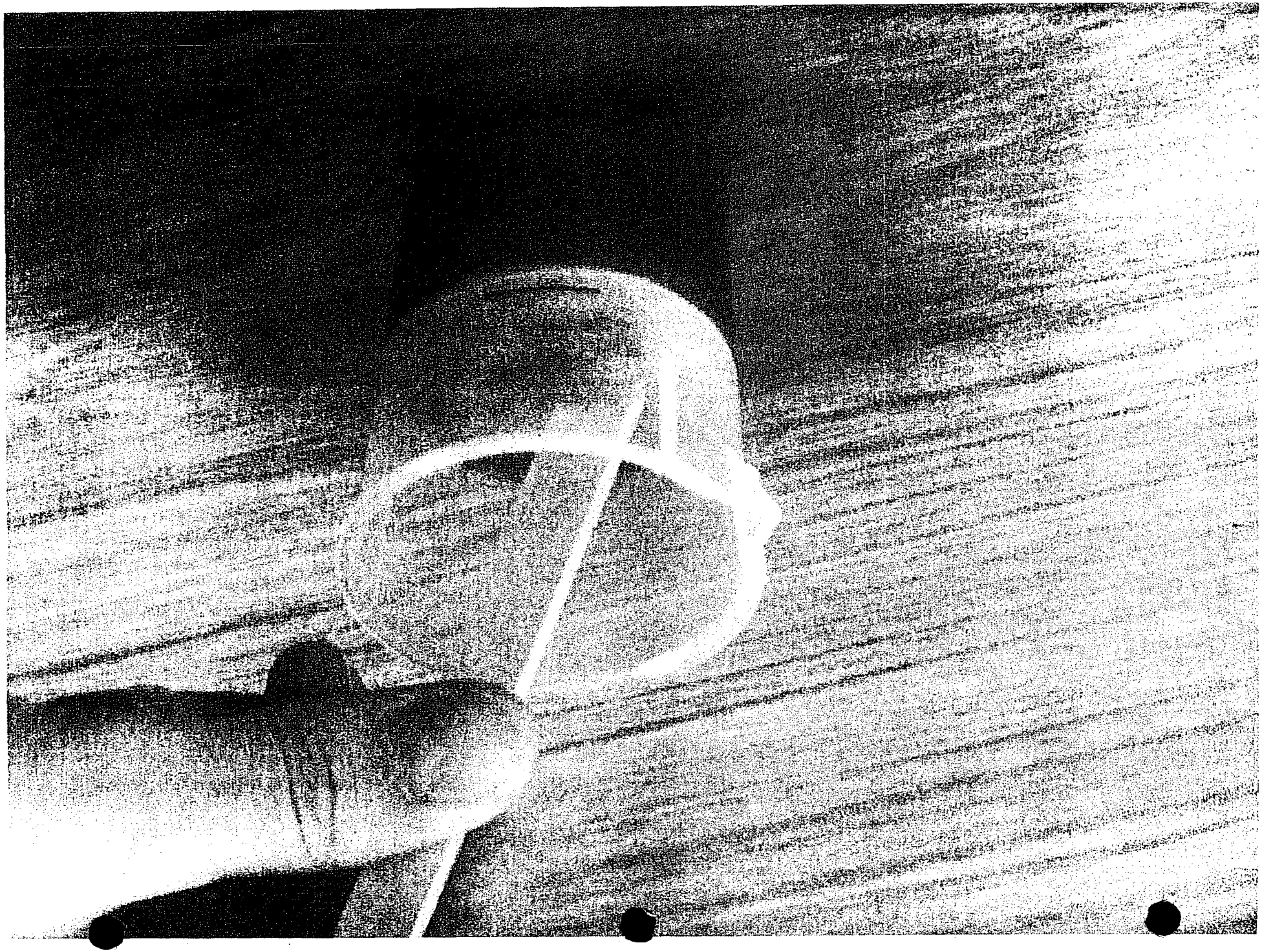
IPEC Guidelines for Remediation of Brine Spills

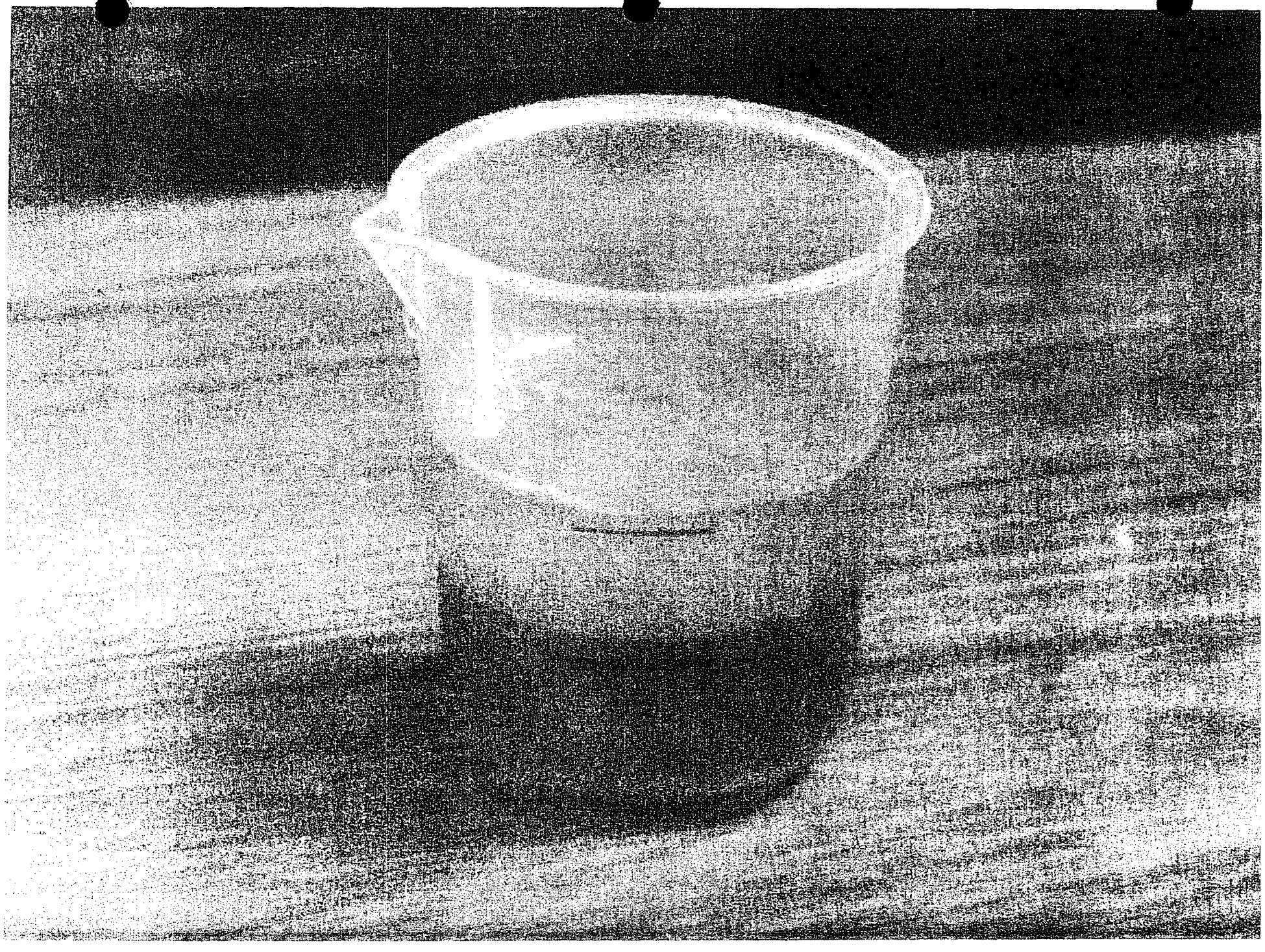
How to use the IPEC Soil Salt Analysis Kit

- Start by transferring soil from your composite sample to the sample cup – fill to the blue line

IPEC Guidelines for Remediation of Brine Spills

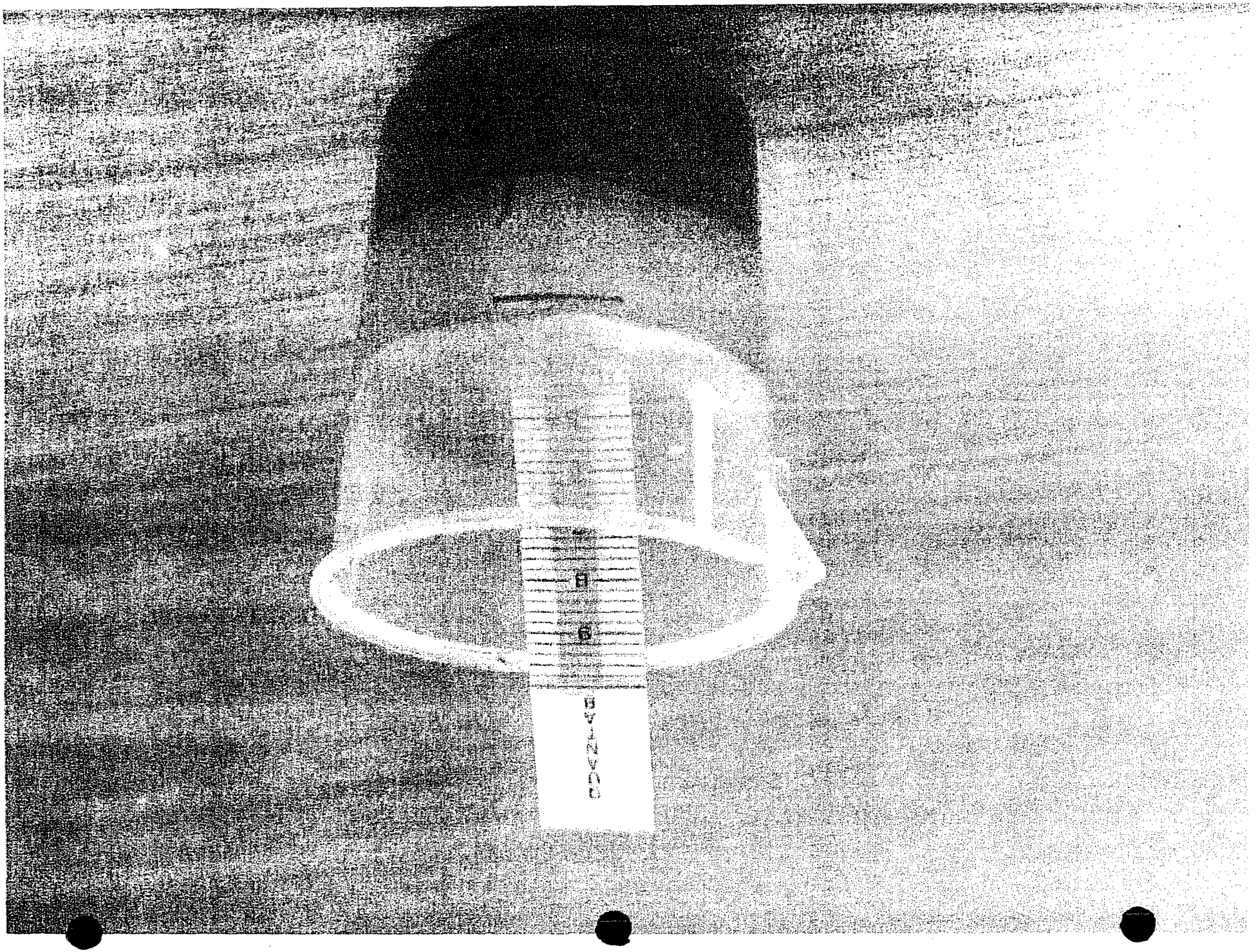
- Add salt extraction solution until level is between red and blue lines
- Stir until soil is fully wetted
- Add more extraction solution until level is up to the red line
- Stir again then allow to settle

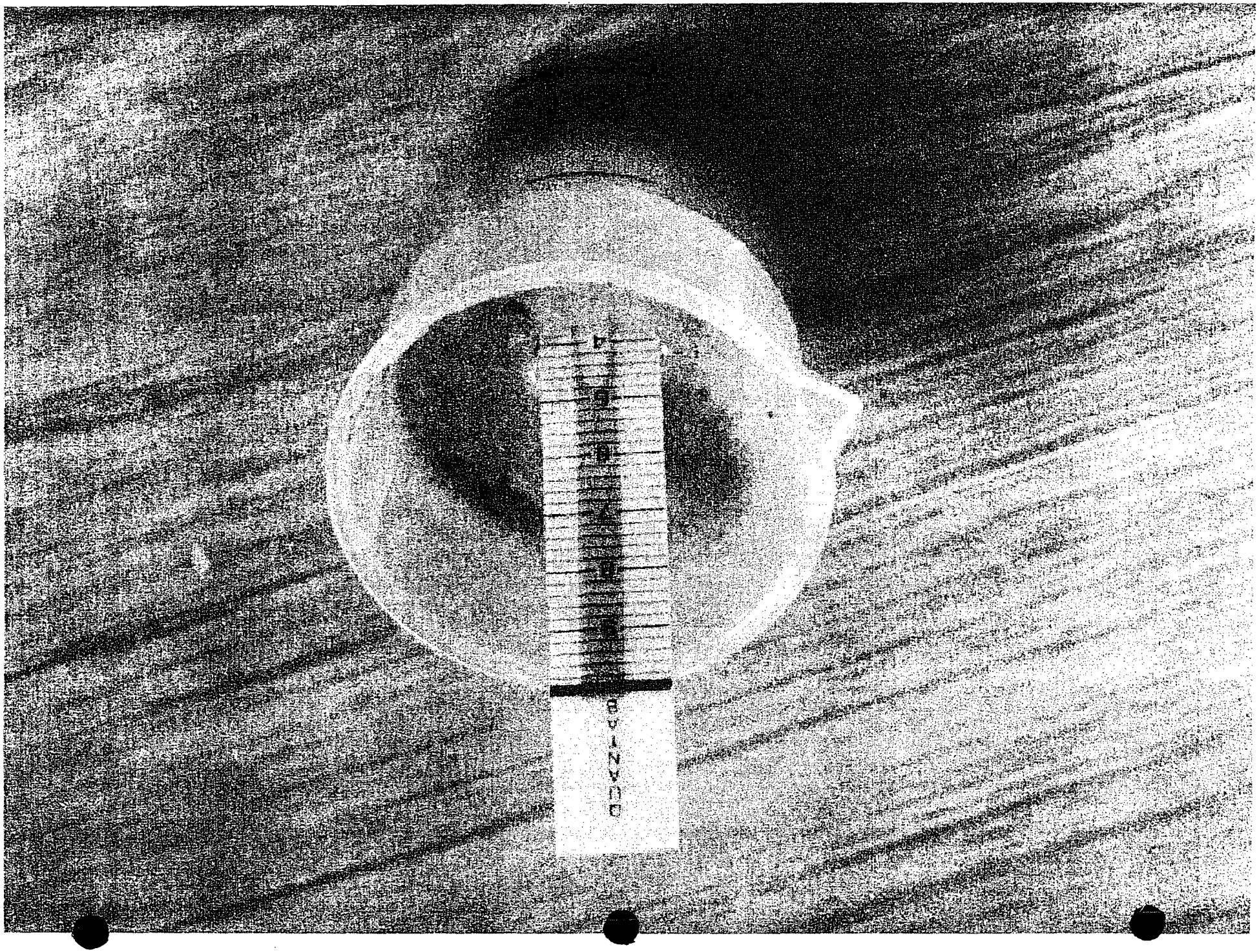




IPEC Guidelines for Remediation of Brine Spills

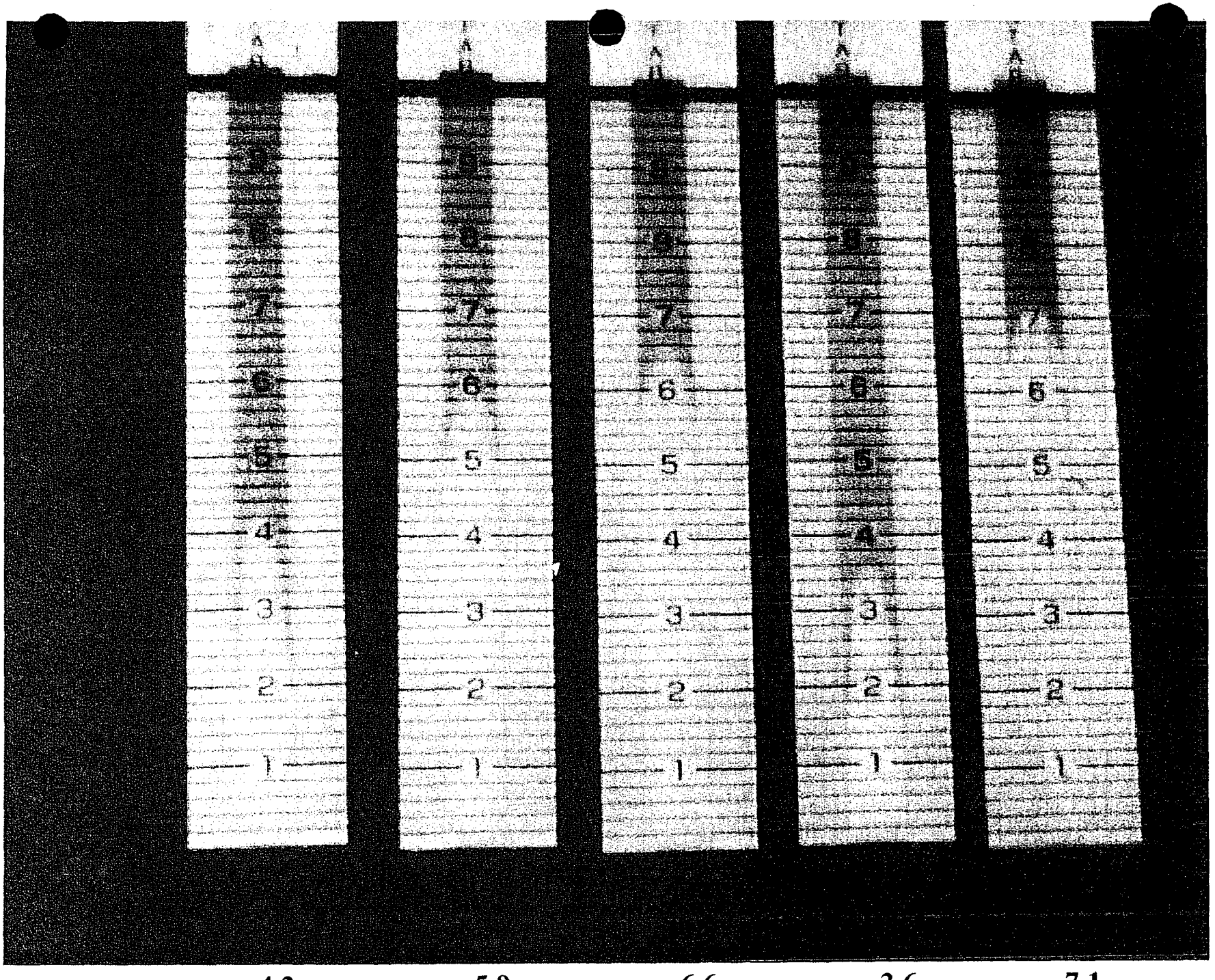
- Insert lower end of test strip into mixture in sample cup (It's OK if the strip sinks down into the settled soil)
- The solution will start to move up the orange wick (The wick will darken as it gets wet)
- Allow the solution to move up the strip until the yellow band at the top completely turns dark





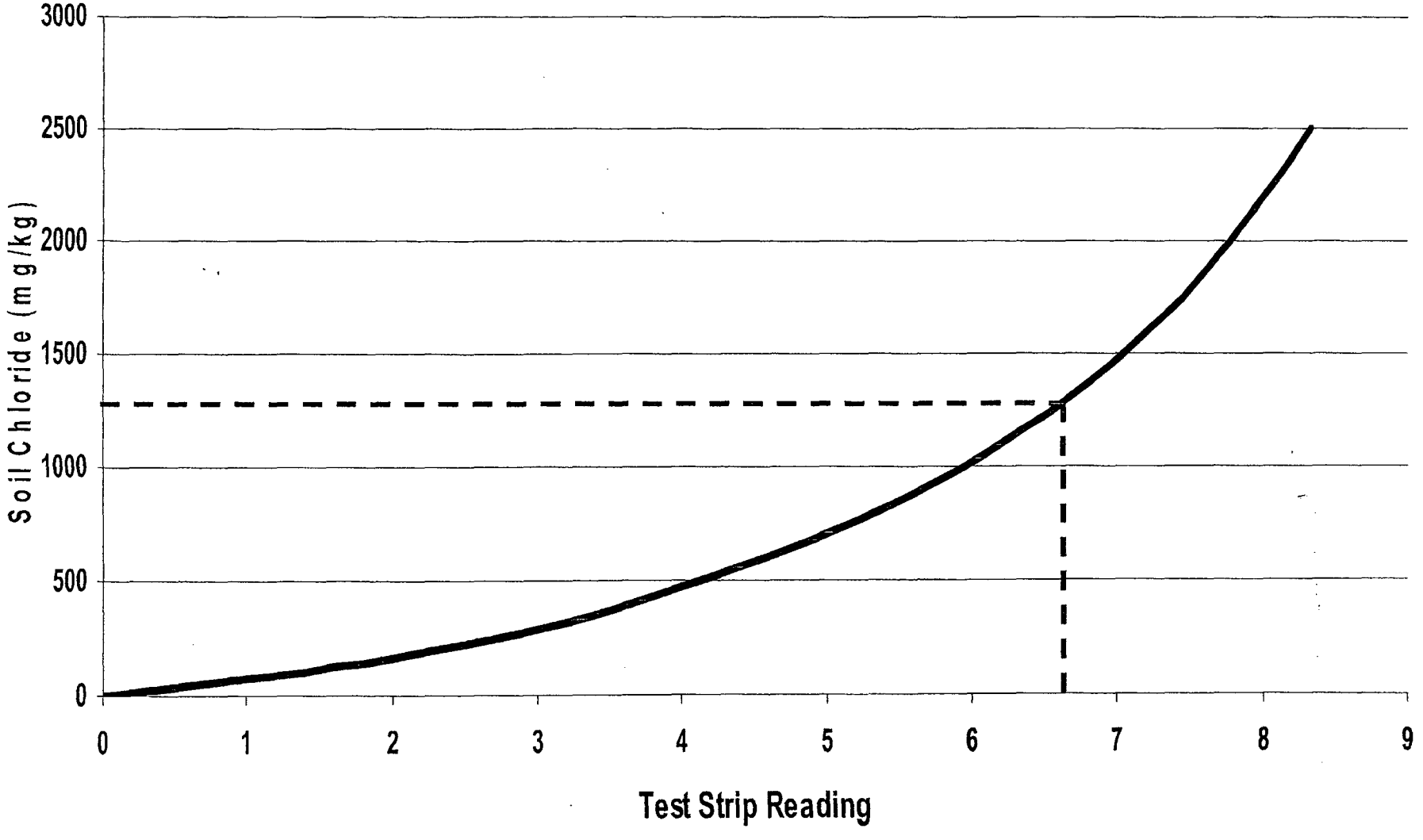
IPEC Guidelines for Remediation of Brine Spills

- Remove the test strip and wipe off any soil
- The more salt in the soil the further up the strip the white color extends
- Relate the strip reading to the soil chloride concentration or the salt tolerances of various plants



4.2 5.9 6.6 3.6 7.1

Soil Chloride Concentration
IPEC Soil Salt Analysis Kit



(mg/kg = ppm)

IPEC Guidelines for Remediation of Brine Spills

Total salt (NaCl) concentration can be estimated from the chloride concentration:

ppm NaCl = ppm chloride X 1.65

IPEC Soil Salt Analysis Kit Strip Reading

Grasses and Forage	Threshold*	50% Yield Reduction
Clover, alsike	2.8	6.0
Clover, Berseem	2.8	7.8
Clover, ladino	2.8	6.0
Clover, red	2.8	6.0
Clover, strawberry	2.8	6.0
Foxtail, meadow	2.8	6.5
Orchard grass	2.8	7.5
Corn (forage)	3.0	7.0
Love grass	3.3	7.0
Alfalfa	3.5	7.0
Trefoil, big	3.5	5.5
Wheat, Durum (forage)	3.5	Off scale
Sphaerophysa	3.7	7.4
Sesbania	3.8	7.5
Cowpea (forage)	4.0	6.5
Wild rye (beardless)	4.2	7.8
Vetch, common	4.3	6.8
Sudan grass	4.3	Off scale
Fescue, tall	4.7	Off scale
Wheat grass (standard)	4.7	Off scale
Harding grass	5.3	7.8
Wheat (forage)	5.3	Off scale
Trefoil, narrowleaf	5.5	7.5
Ryegrass, perennial	6.0	8.0
Barley (forage)	6.2	8.3
Bermuda grass	6.5	Off scale
Wheat grass (tall)	6.8	Off scale

*Lowest level at which an effect on mature plants is seen. This is also the level where seed germination is often inhibited.

IPEC Guidelines for Remediation of Brine Spills

- The threshold tolerance is the salt concentration in the soil
  - which inhibits seed germination
  - kills young plants
  - produces visible effects on mature plants

IPEC Guidelines for Remediation of Brine Spills

For example:

- Tall fescue has a threshold tolerance of 4.7 in terms of the strip reading from the IPEC Soil Salt Analysis Kit
- If a brine impacted soil gives a strip reading of <u>over</u> 4.7
  - tall fescue seeds will not germinate in the soil
  - plugs of tall fescue will die
  - any mature tall fescue in the impacted area will show signs of stress

IPEC Guidelines for Remediation of Brine Spills

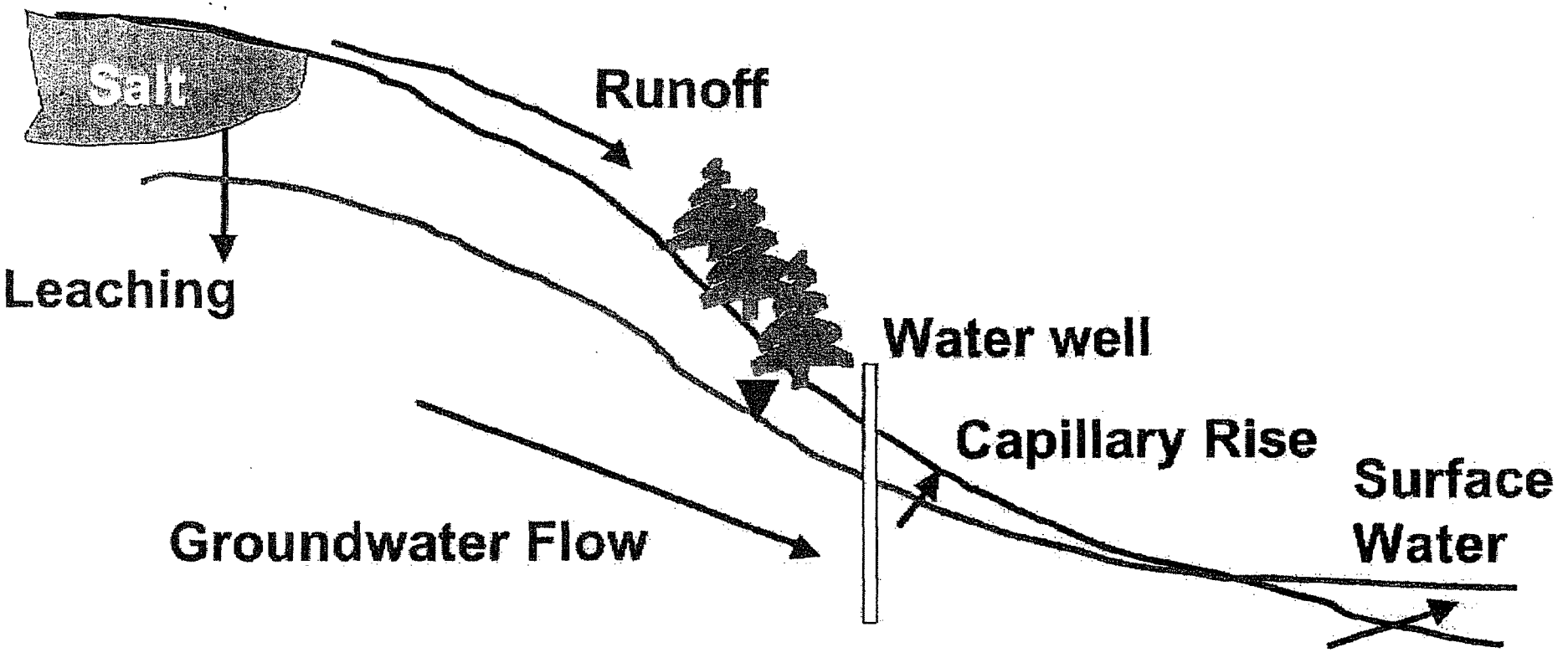
The three rules of brine remediation:

- Drainage!
- Drainage!
- Drainage!

The salt has to go somewhere! It will <u>not</u> be destroyed like the oil in bioremediation!

It must be diluted to a concentration that it is no longer harmful.

Brine components must have a pathway through which to migrate out of the root zone for revegetation to occur



IPEC Guidelines for Remediation of Brine Spills

Drainage

- Examples of impediments to drainage include:
  - a seasonal high water table less than 2 m from the surface (vertical drainage)
  - a slowly permeable soil or bedrock within 2 m of the surface (vertical drainage)
  - lack of sufficient slope on the surface (lateral)
  - High clay content (vertical or lateral)

IPEC Guidelines for Remediation of Brine Spills

IPEC recommends:

A staged response to recent brine spills

Keep costs down!

IPEC Guidelines for Remediation of Brine Spills

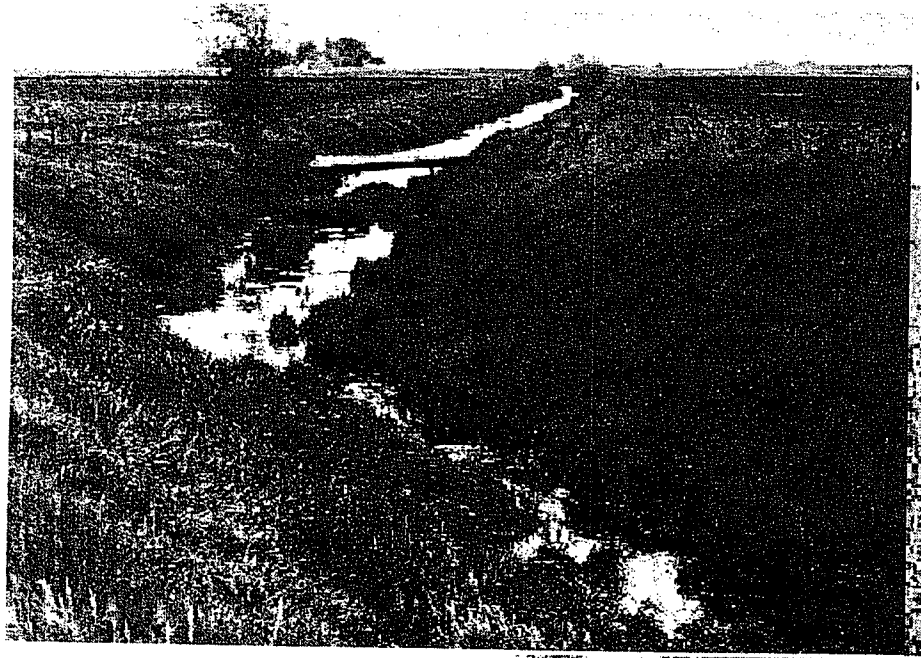
Stage 1

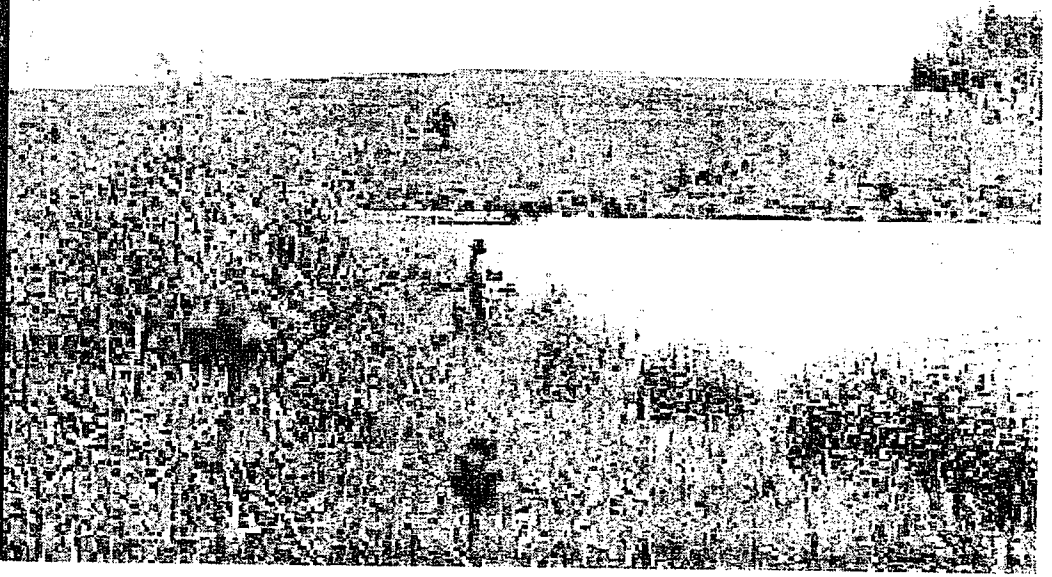
Drainage control

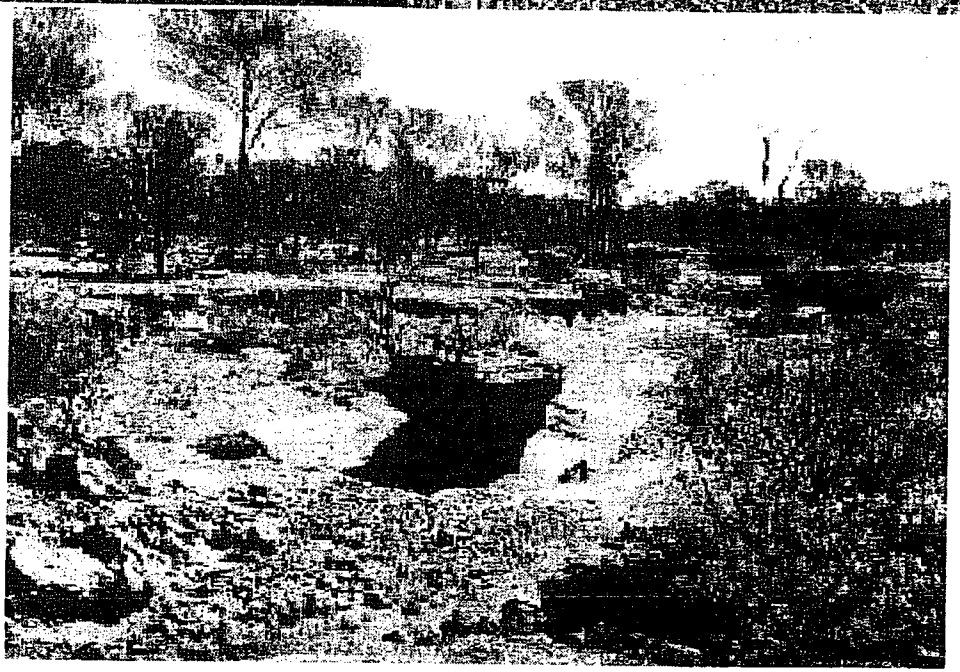
- Vertical vs lateral drainage
  - Latest research from USGS shows that vertical movement of brine components can be unpredictable
- Goal is gradual leaching of salt and dilution over a large area
- Minimize erosion of topsoil
- Protect downhill streams, creeks, and ponds (even if they are dry) from contamination from lateral movement of brine components

Take advantage of natural drainage patterns

Protect creeks and ponds and even dry creek beds







IPEC Guidelines for Remediation of Brine Spills

Stage 1

Next till in hay and fertilizer

- Enhances movement of brine components through the soil
- Stimulates soil biota and nutrient cycling which aids in revegetation
- Biodegradation of hay improves soil structure by enhancing aggregate formation which in turn improves soil permeability

IPEC Guidelines for Remediation of Brine Spills

Why not gypsum as a first response?

- Gypsum displaces bound sodium from clay particles
- Gypsum interferes with phosphorous cycling in the soil
- Effects of gypsum occur primarily throughout the depth incorporated; the effects of plant growth occur throughout the root zone

IPEC Guidelines for Remediation of Brine Spills

Hay and Fertilizer Application

Hay

- About 5 small square bales per 1000 ft^2
- Repeat as necessary to maintain good soil structure

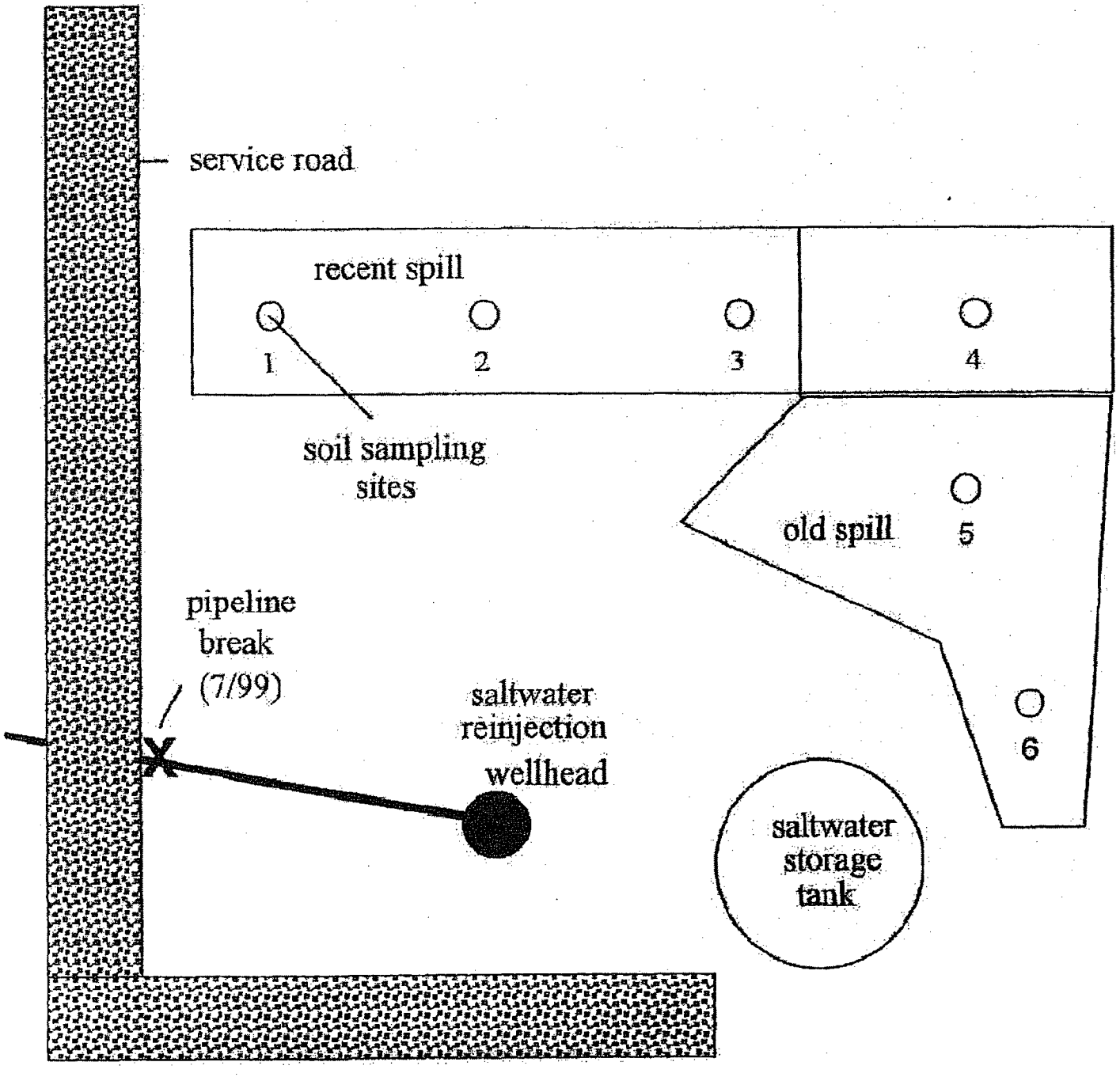
Fertilizer

- Add along with the hay or other organic matter
- 13-13-13
- About 28 lbs per 1000 ft^2

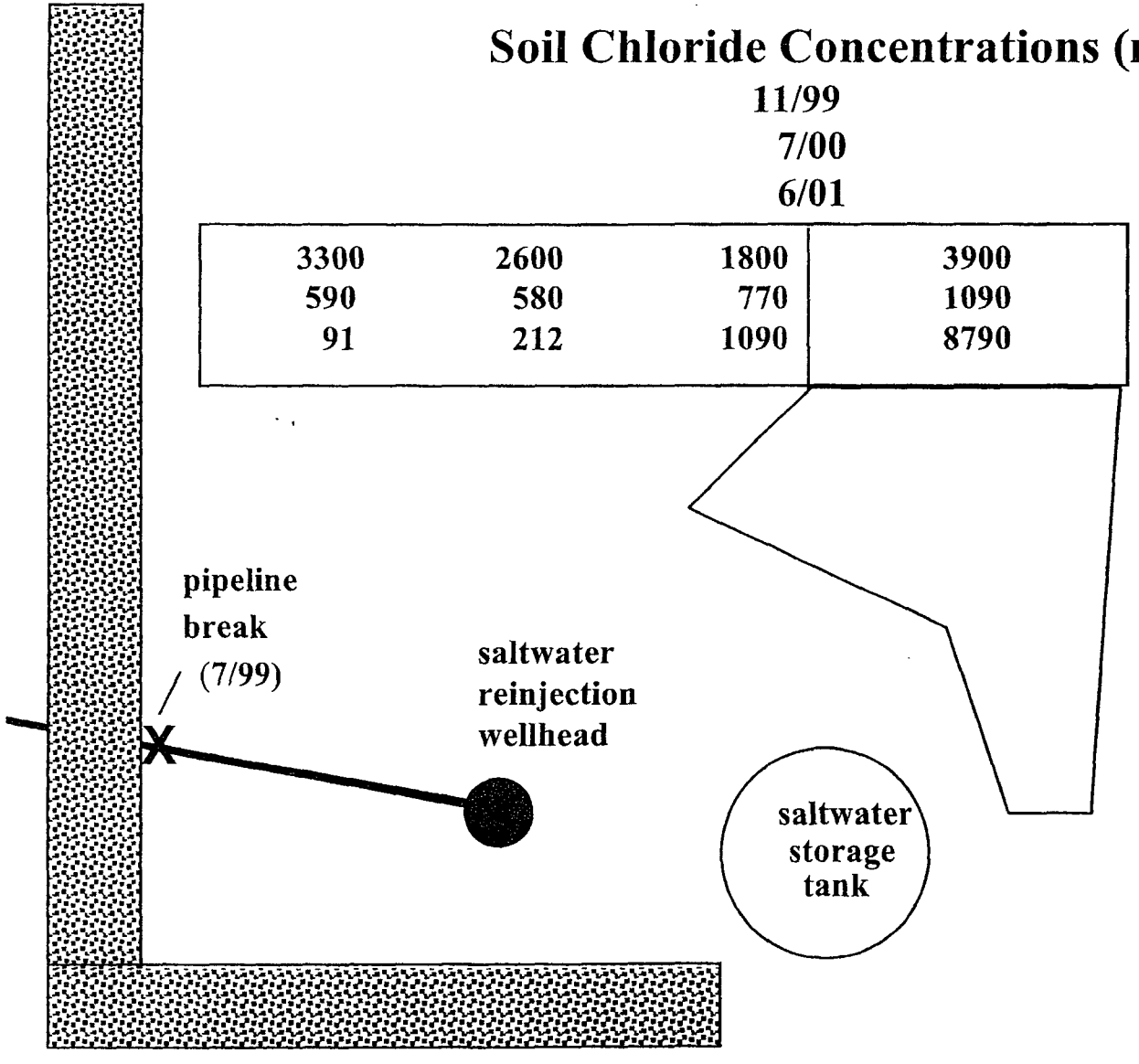
IPEC Guidelines for Remediation of Brine Spills

An example of a Stage 1 remediation response:

- Rupture of a salt water line in July 1999 in Osage County, OK
- Hay and fertilizer tilled in November 1999

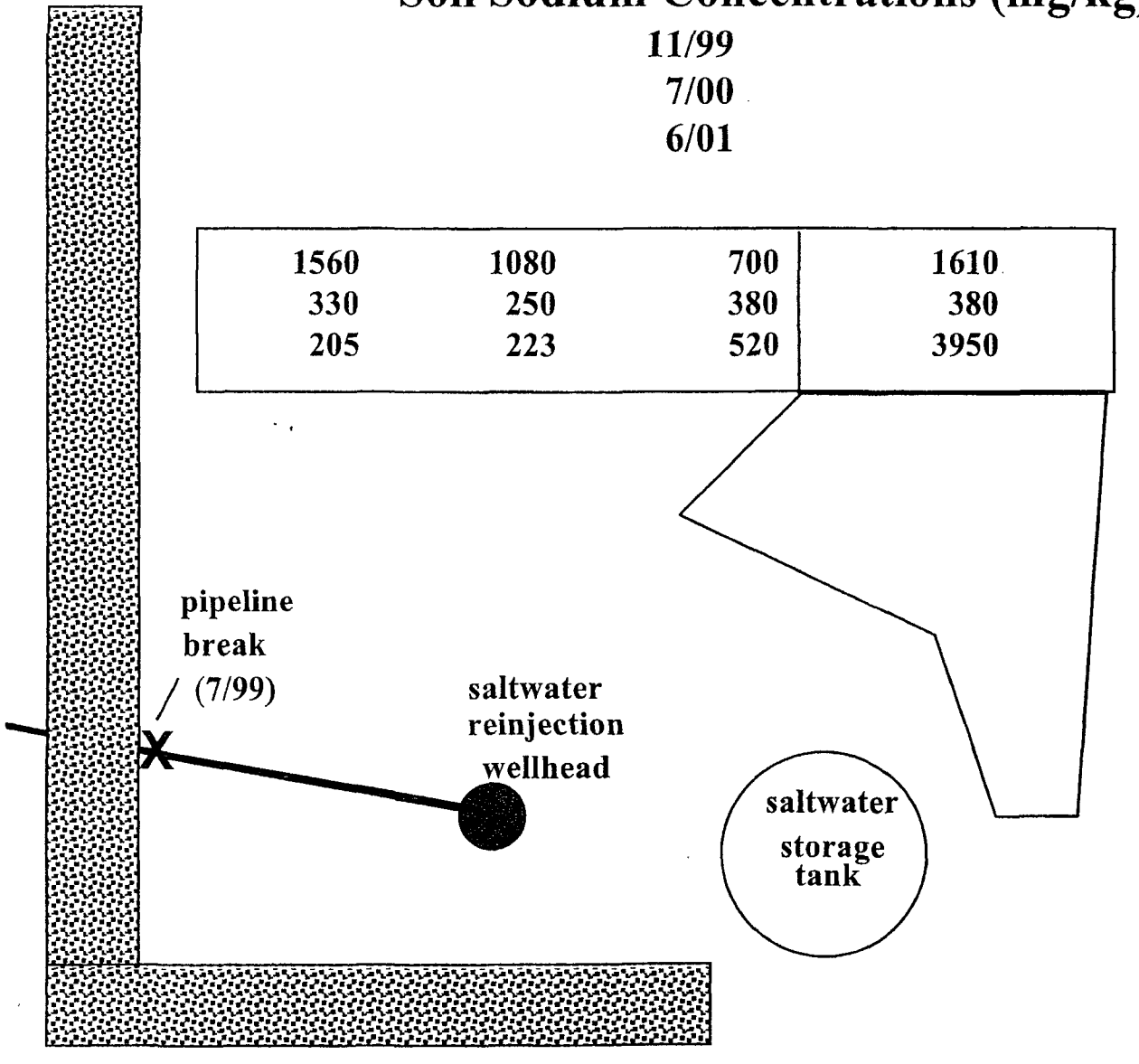

service road
recent spill
1
2
3
4
soil sampling sites
old spill
5
6
pipeline break (7/99)
saltwater reinjection wellhead
saltwater storage tank

Soil Chloride Concentrations (mg/kg)

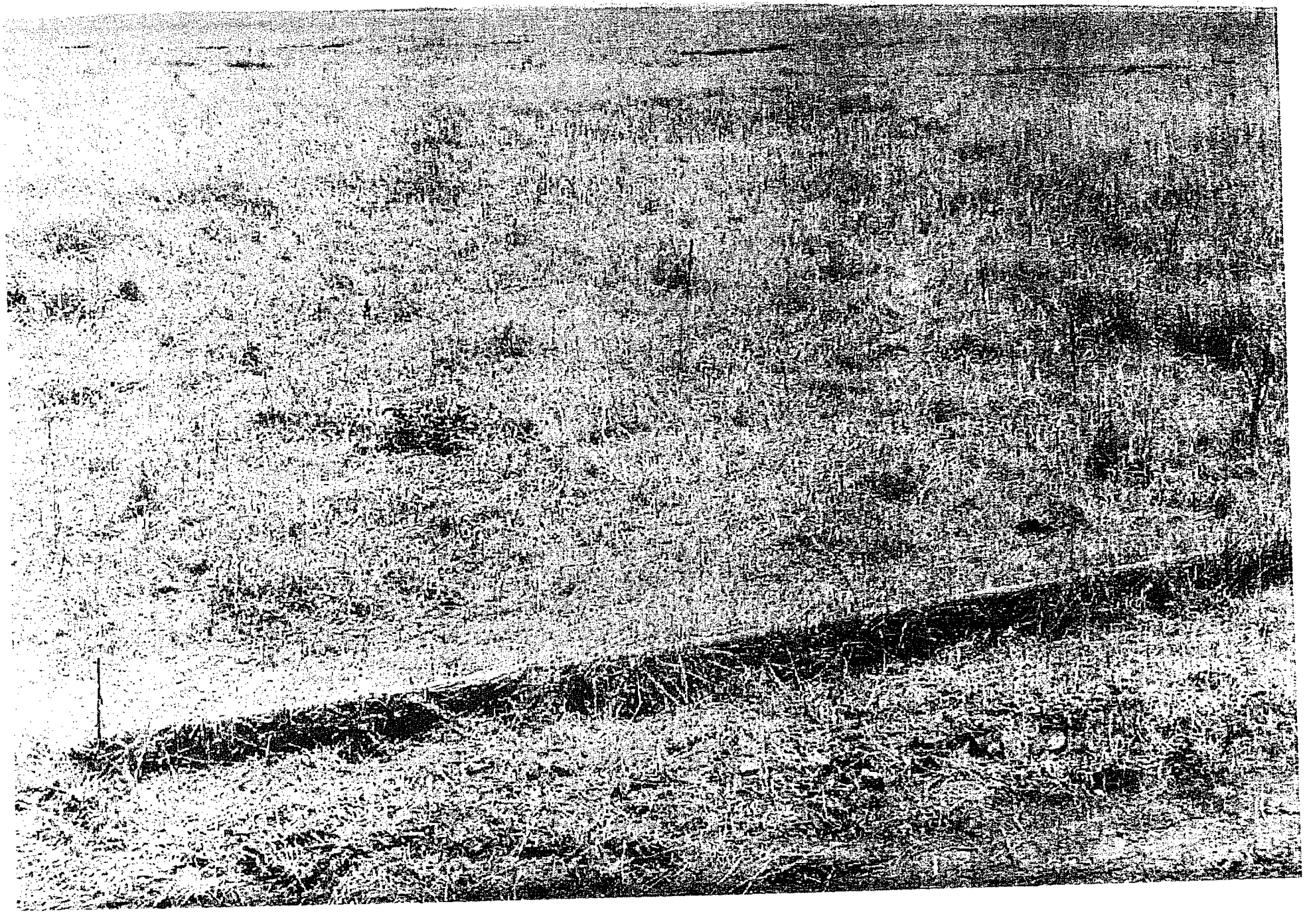


Soil Sodium Concentrations (mg/kg)

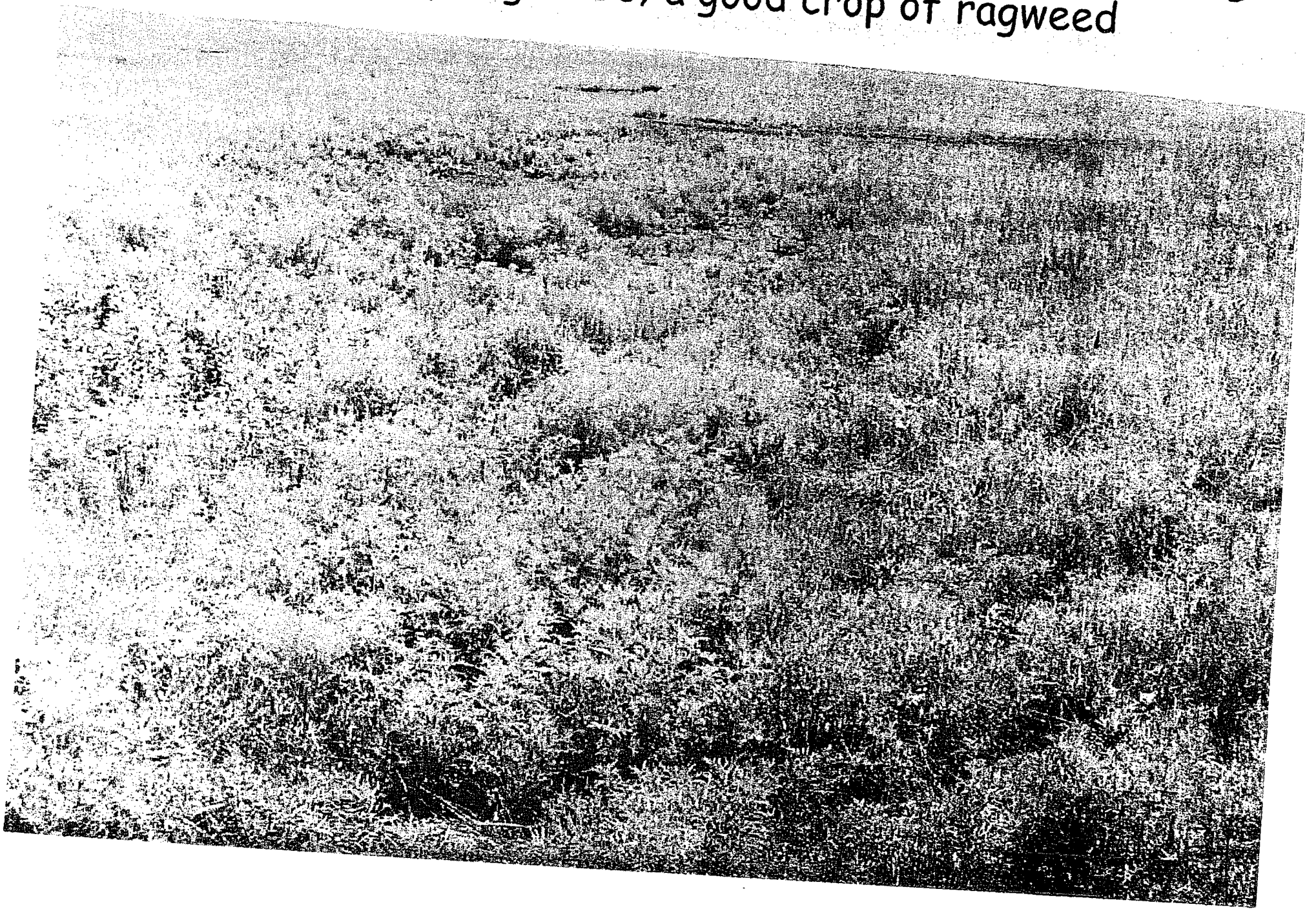
11/99
7/00
6/01



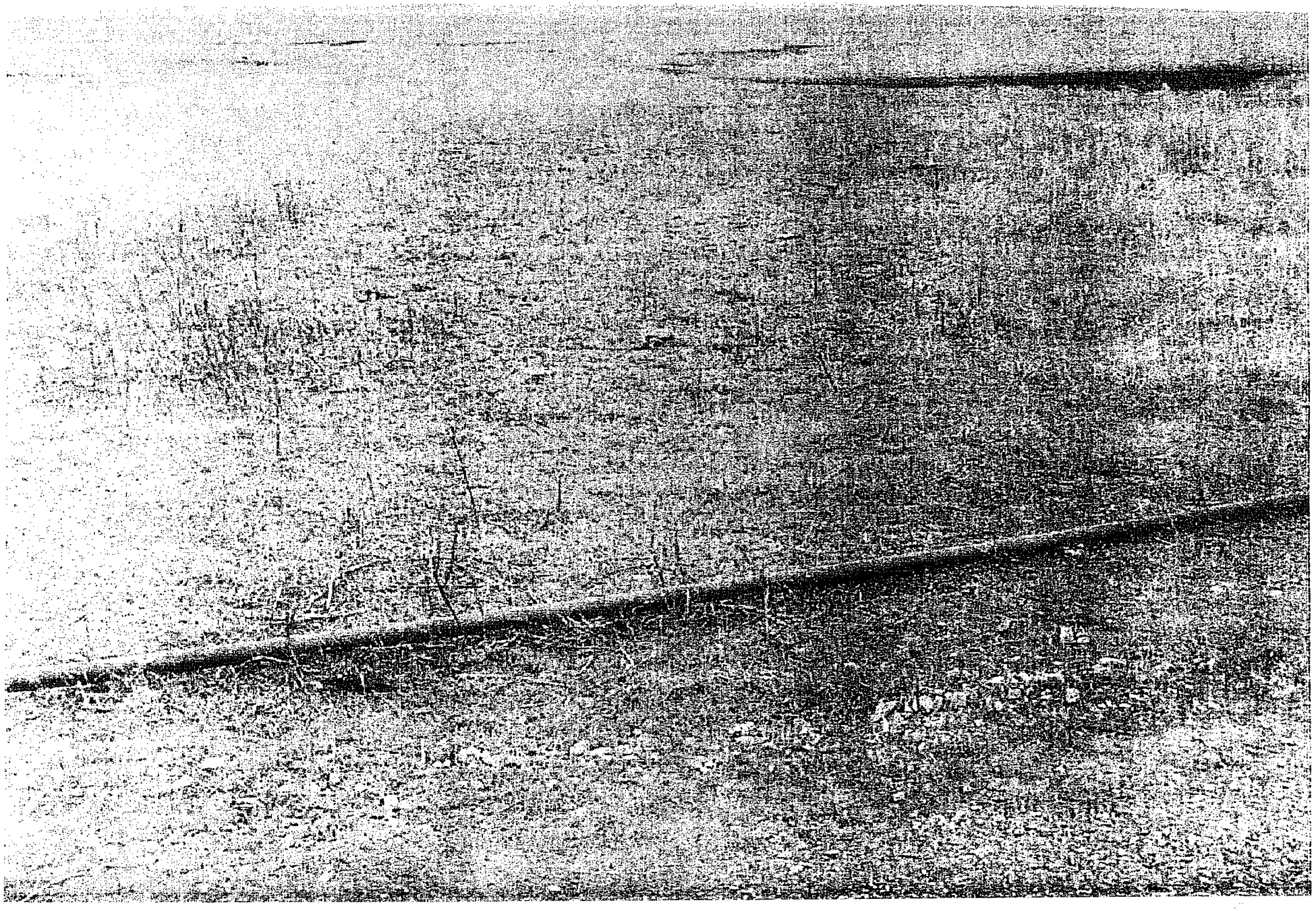
July 1999



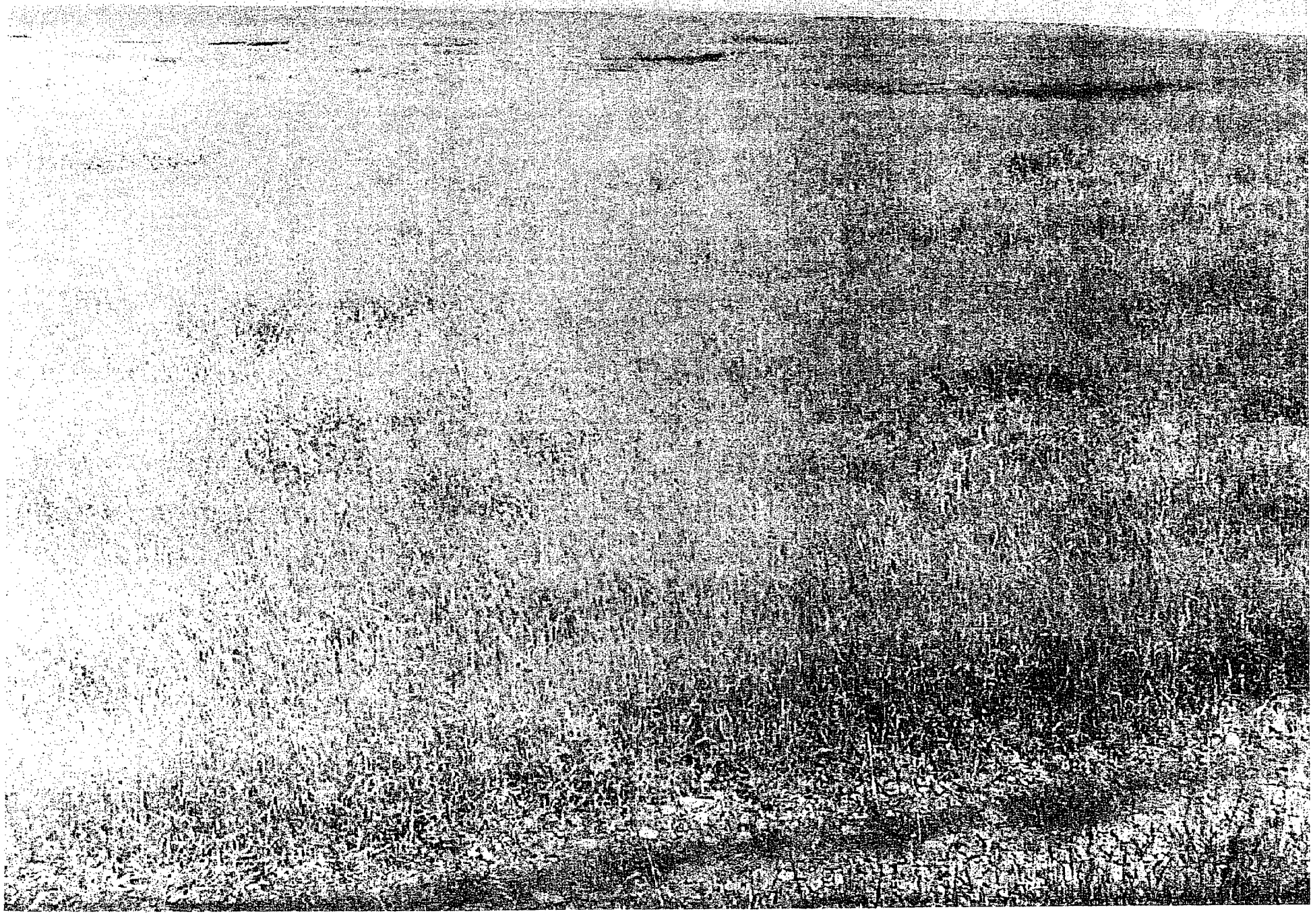
Late spring 2000; a good crop of ragweed



Early spring 2001; grasses evident



Late spring 2001; still some ragweed but lots of grasses



Late spring 2001; a closer look

IPEC Guidelines for Remediation of Brine Spills

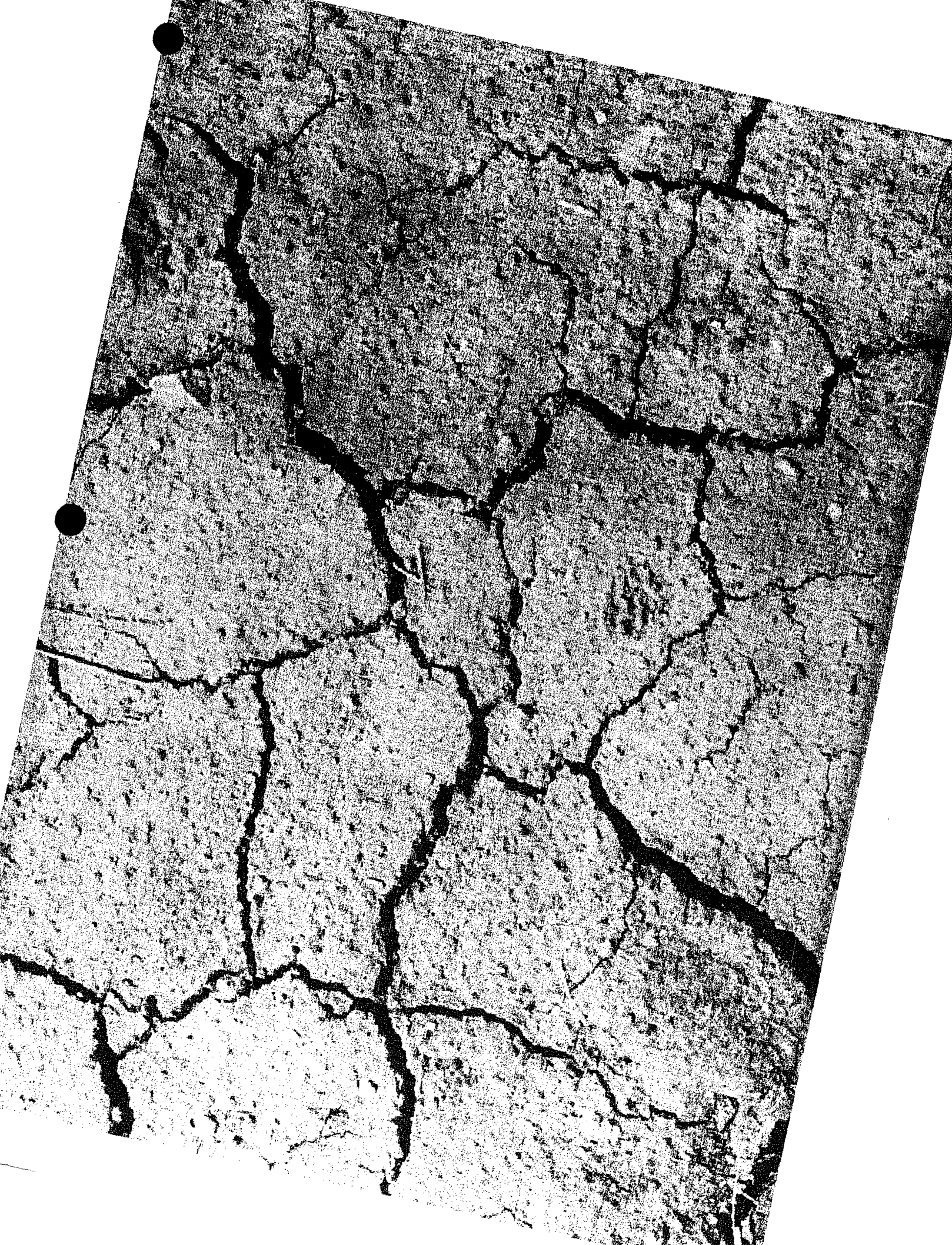
What if a Stage 1 approach can't be used or doesn't work?

- Can't work?
  - No safe place to drain leachate
- Doesn't work?
  - Hot spots aren't remediating
  - Sodicity

IPEC Guidelines for Remediation of Brine Spills

What is sodicity?

- An excess of sodium held tightly by clay particles
- Result is:
  - Clay particles disperse and pack tightly
  - Hardpan
  - Poorly draining soil

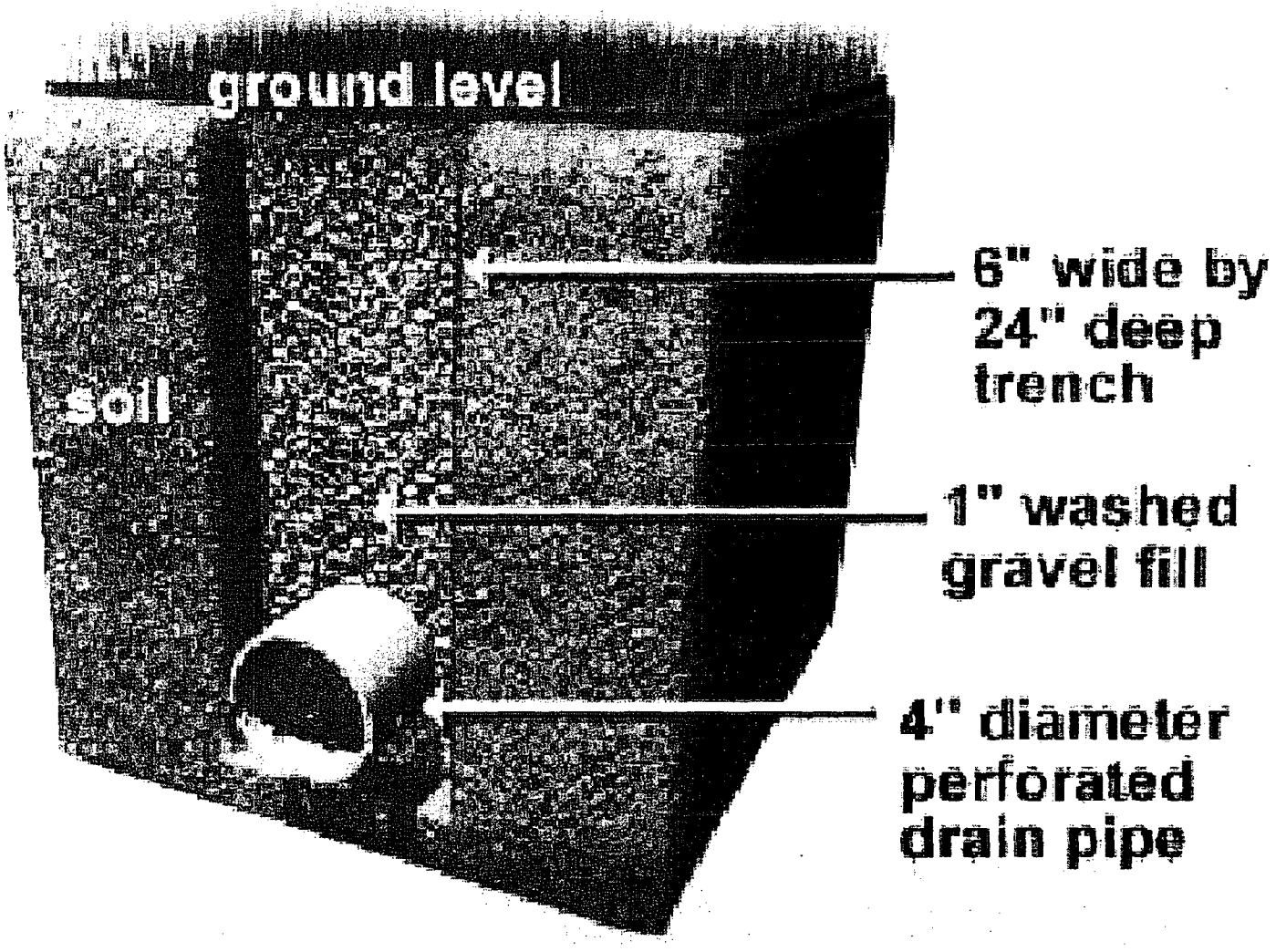


IPEC Guidelines for Remediation of Brine Spills

Stage 2

- Install subsurface drainage
  - Collect and dispose of leachate
- Till in gypsum
  - Displaces bound sodium from clay particles
  - Enhances movement of brine components in through the soil

French drain construction



IPEC Guidelines for Remediation of Brine Spills

How much gypsum?

Rule of Thumb: 13 lb per 100 ft^2

Treat:

- "Hot spots"
- Areas that consistently have poor soil structure and do not revegetate (do not respond to hay and fertilizer) - sodicity

IPEC Guidelines for Remediation of Brine Spills

An example of a Stage 2 remediation response:

- Rupture of a salt water line in December 1995 in Osage County, OK; about two acres impacted
- Essentially untreated for two years
- Underlying clay layer at about 3 ft
- Site drained to a farm pond 600 yds away
- All aquatic life in pond killed

IPEC Guidelines for Remediation of Brine Spills

Stage 2 response

- Drainage was a major issue
- Installed subsurface drains above clay layer
  - French drain pipe in gravel bed
  - Drained to underground sump
  - Operator pumped leachate to salt water storage tank each day
- Installed berms downgradient of each subsurface drain to increase penetration of rainfall into the soil
- Tilled in hay and fertilizer in January 1998

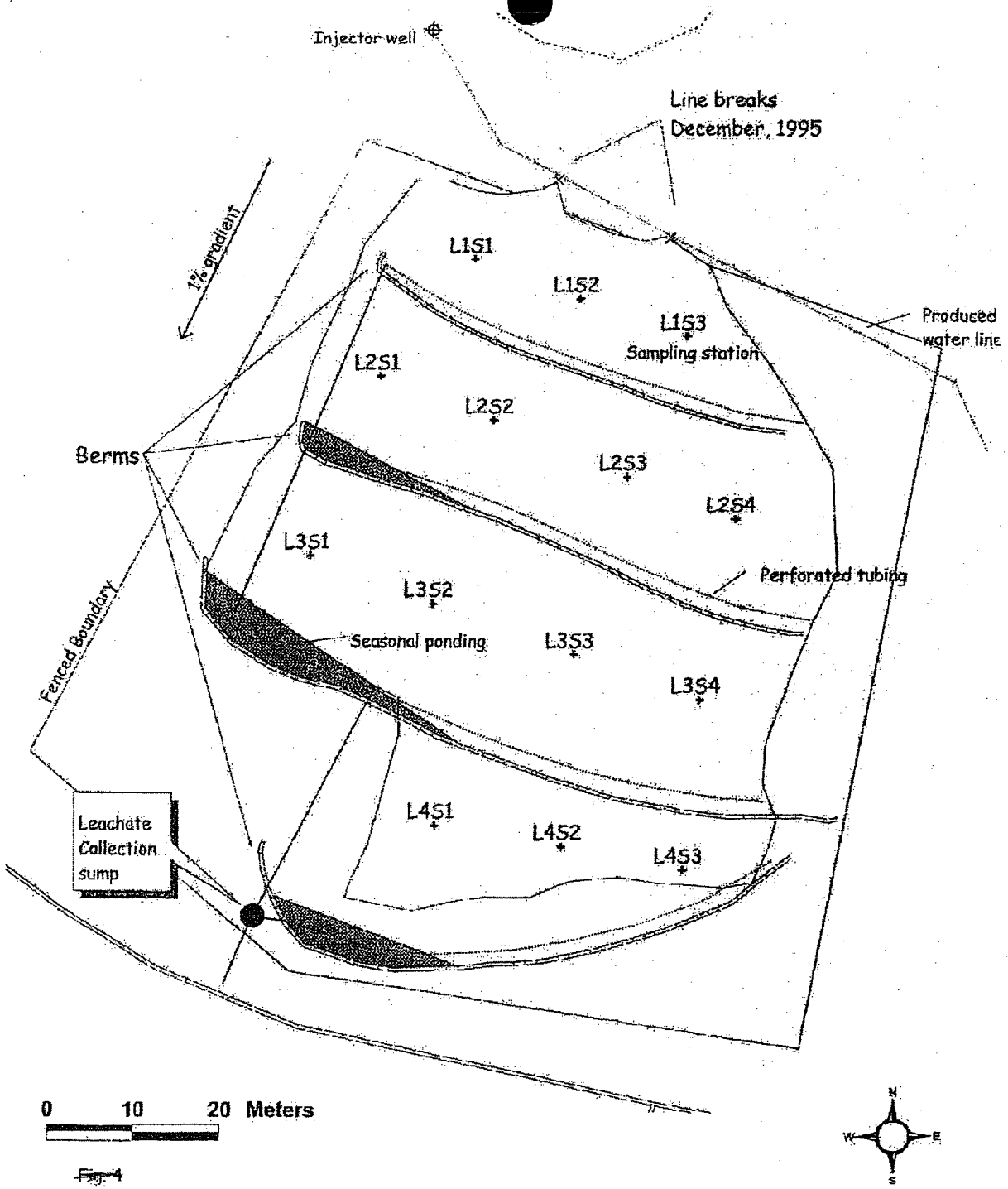

Injector well
Line breaks
December, 1995
1% gradient
L1S1
L1S2
L1S3
Sampling station
Produced
water line
L2S1
L2S2
Berms
L2S3
L2S4
L3S1
Perforated tubing
L3S2
Fenced Boundary
Seasonal ponding
L3S3
L3S4
L4S1
Leachate
Collection
sump
L4S2
L4S3
0 10 20 Meters
N
W
E
S

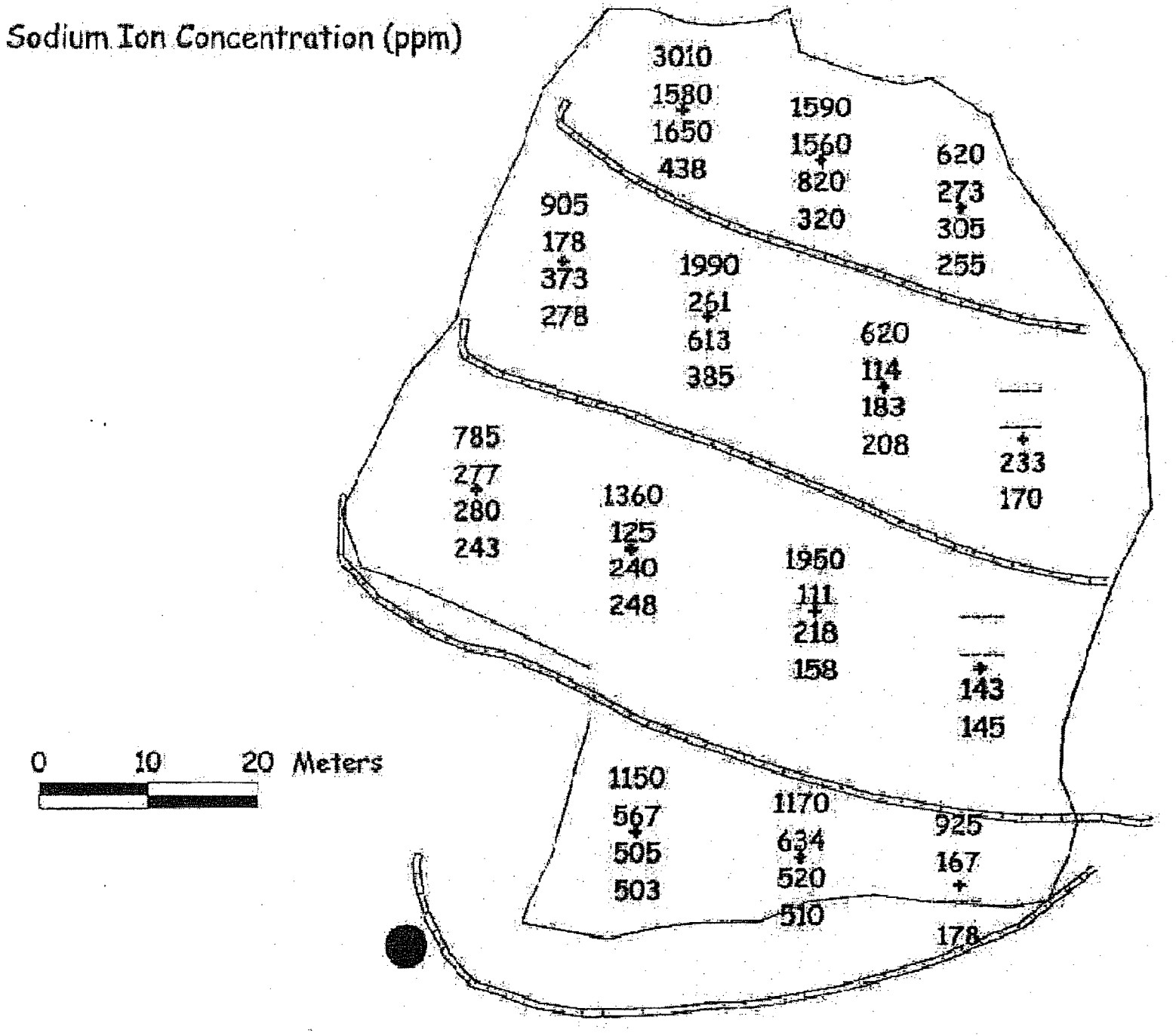
Fig 4

IPEC Guidelines for Remediation of Brine Spills

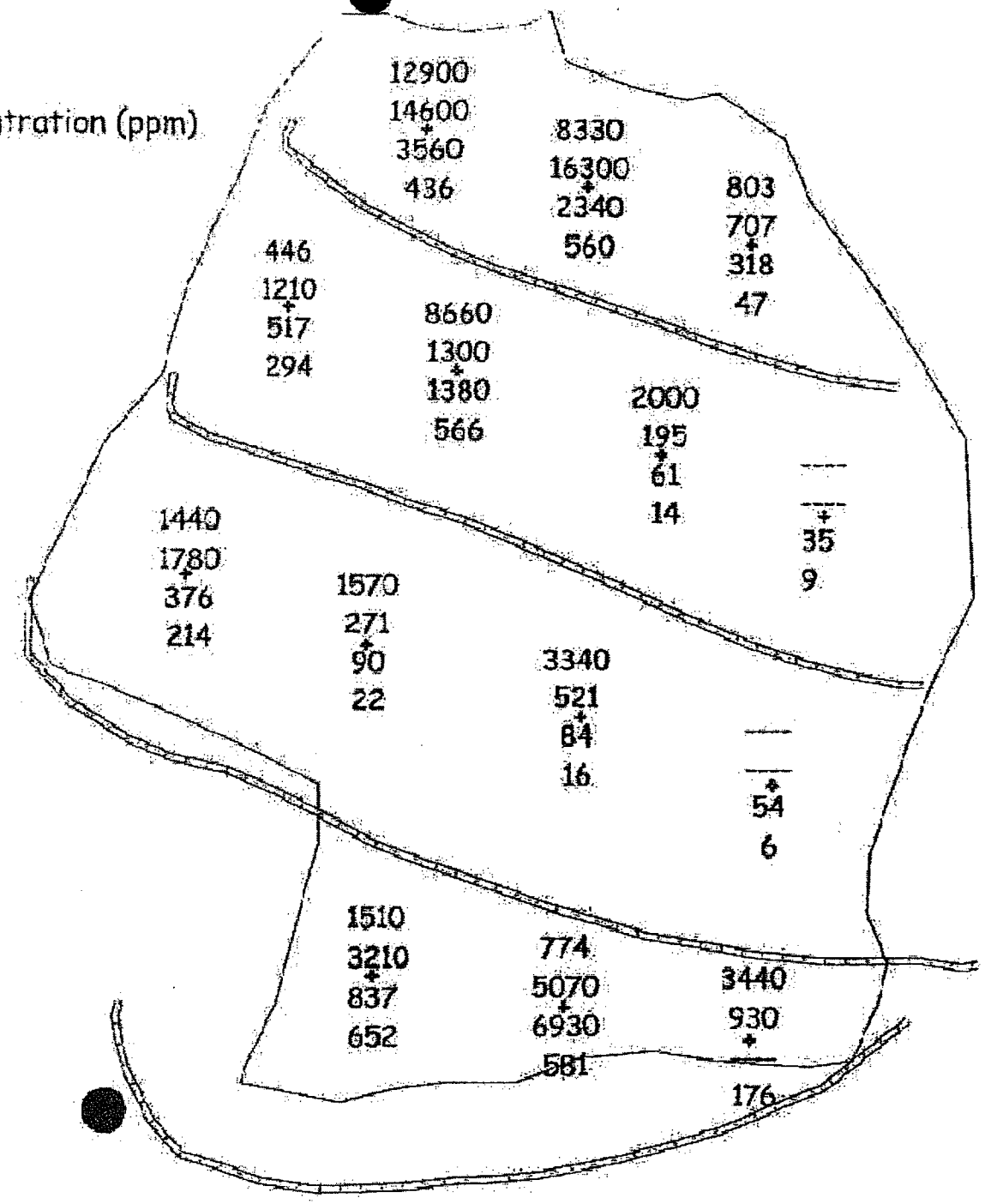
Sampling Dates Subsurface Drainage Site

- 2/98
- 3/99
- 7/00
- 5/01

Sodium Ion Concentration (ppm)

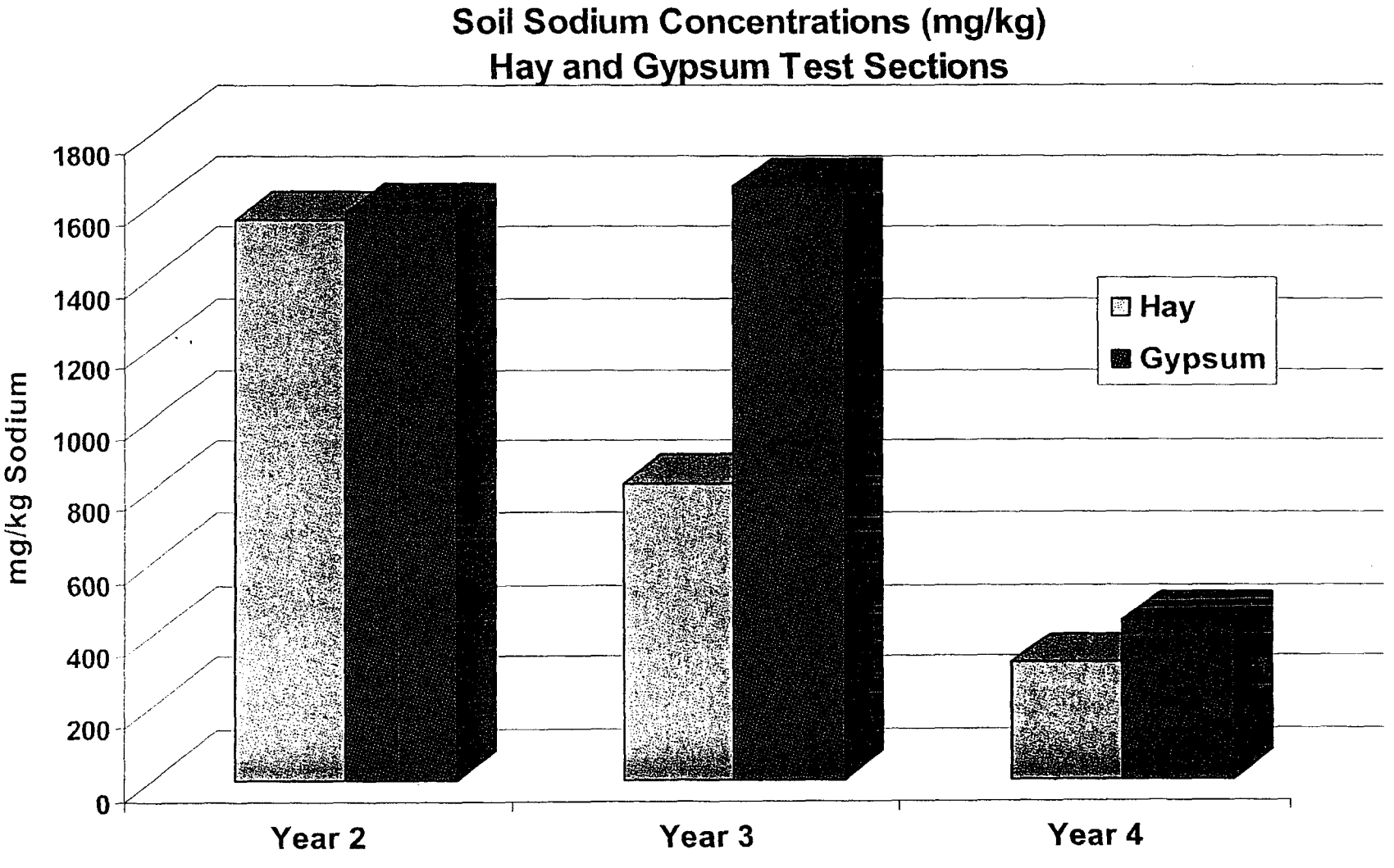


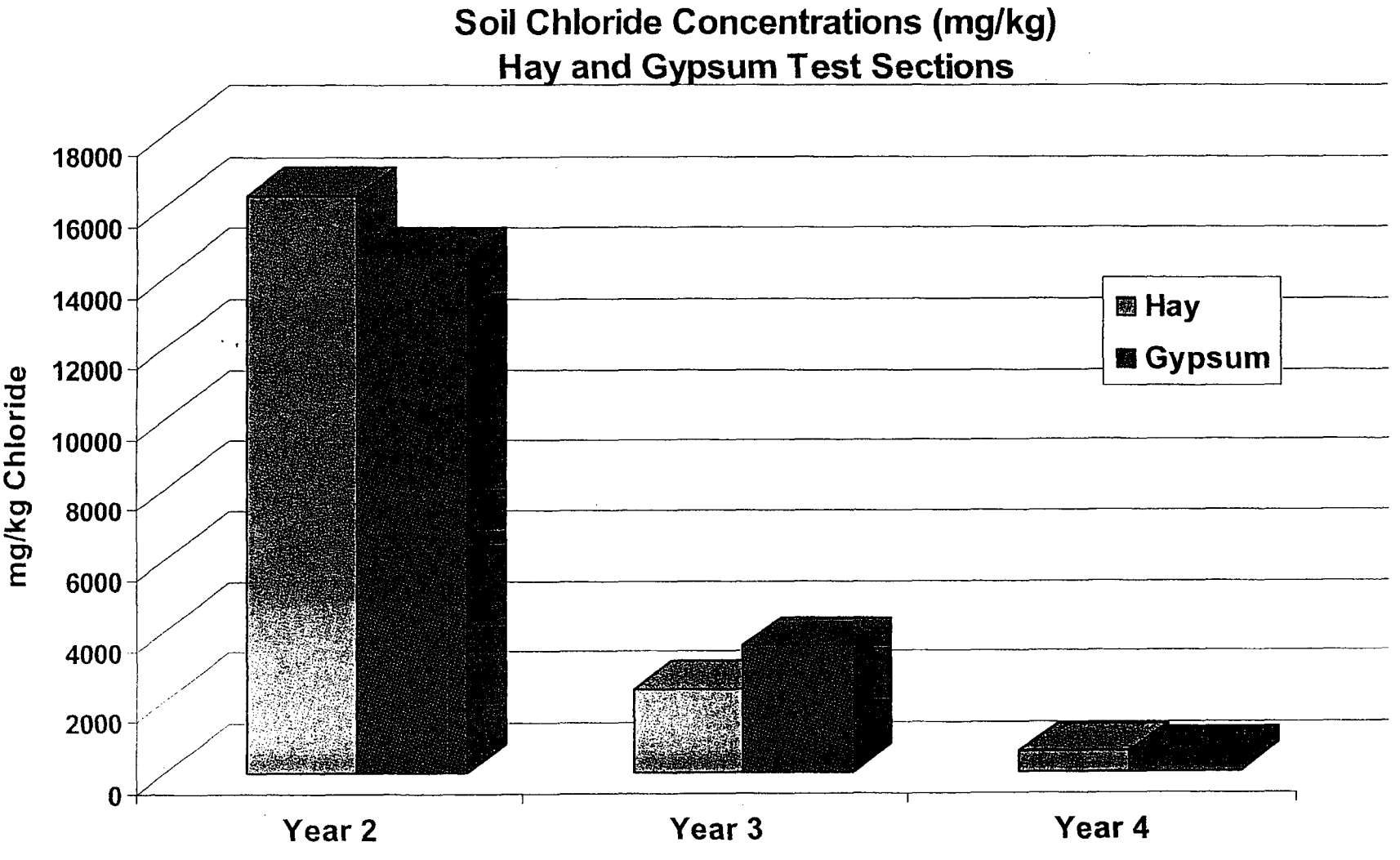
Chloride Ion Concentration (ppm)



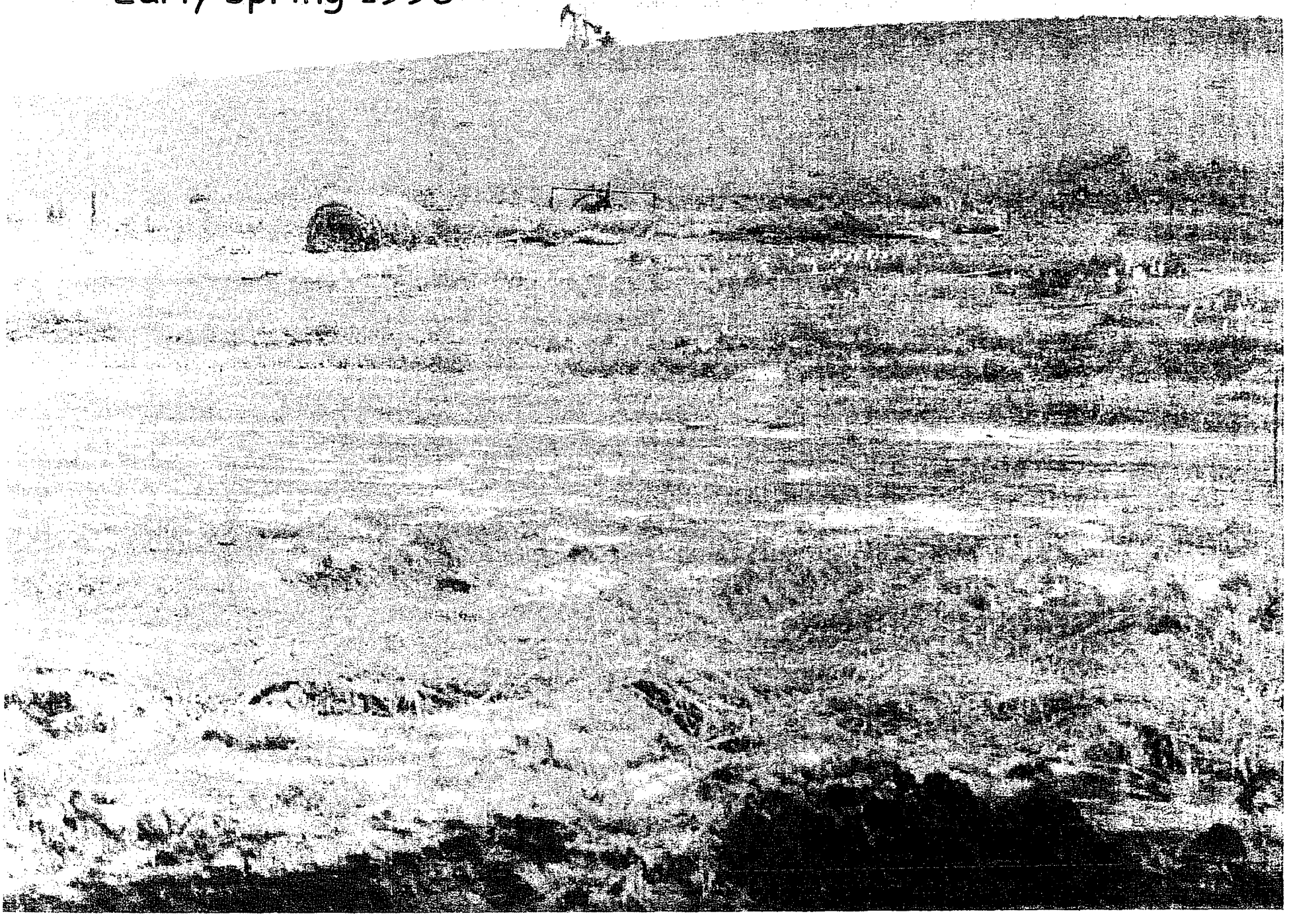
IPEC Guidelines for Remediation of Brine Spills

- In year 2 the effect of the addition of more hay vs gypsum application was compared in the two most contaminated sections nearest the source (upper left in previous diagrams):
- Observations:
  - Faster sodium removal with hay
  - Faster revegetation with hay – section with hay was two years ahead of the section treated with gypsum

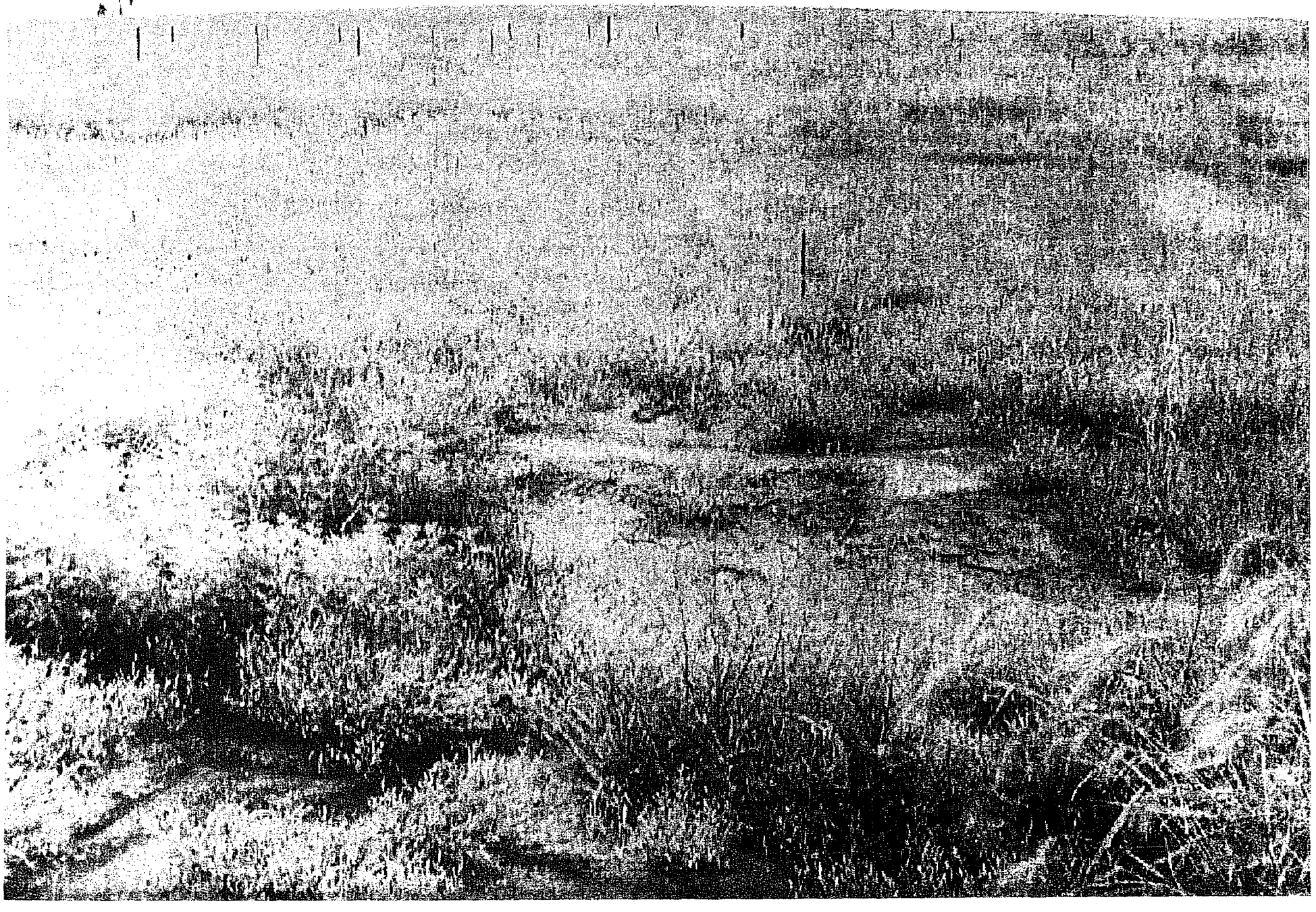

Soil Sodium Concentrations (mg/kg)
Hay and Gypsum Test Sections
mg/kg Sodium
1800
1600
1400
1200
1000
800
600
400
200
0
Year 2
Year 3
Year 4
Hay
Gypsum


Soil Chloride Concentrations (mg/kg)
Hay and Gypsum Test Sections
mg/kg Chloride
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Year 2
Year 3
Year 4
Hay
Gypsum

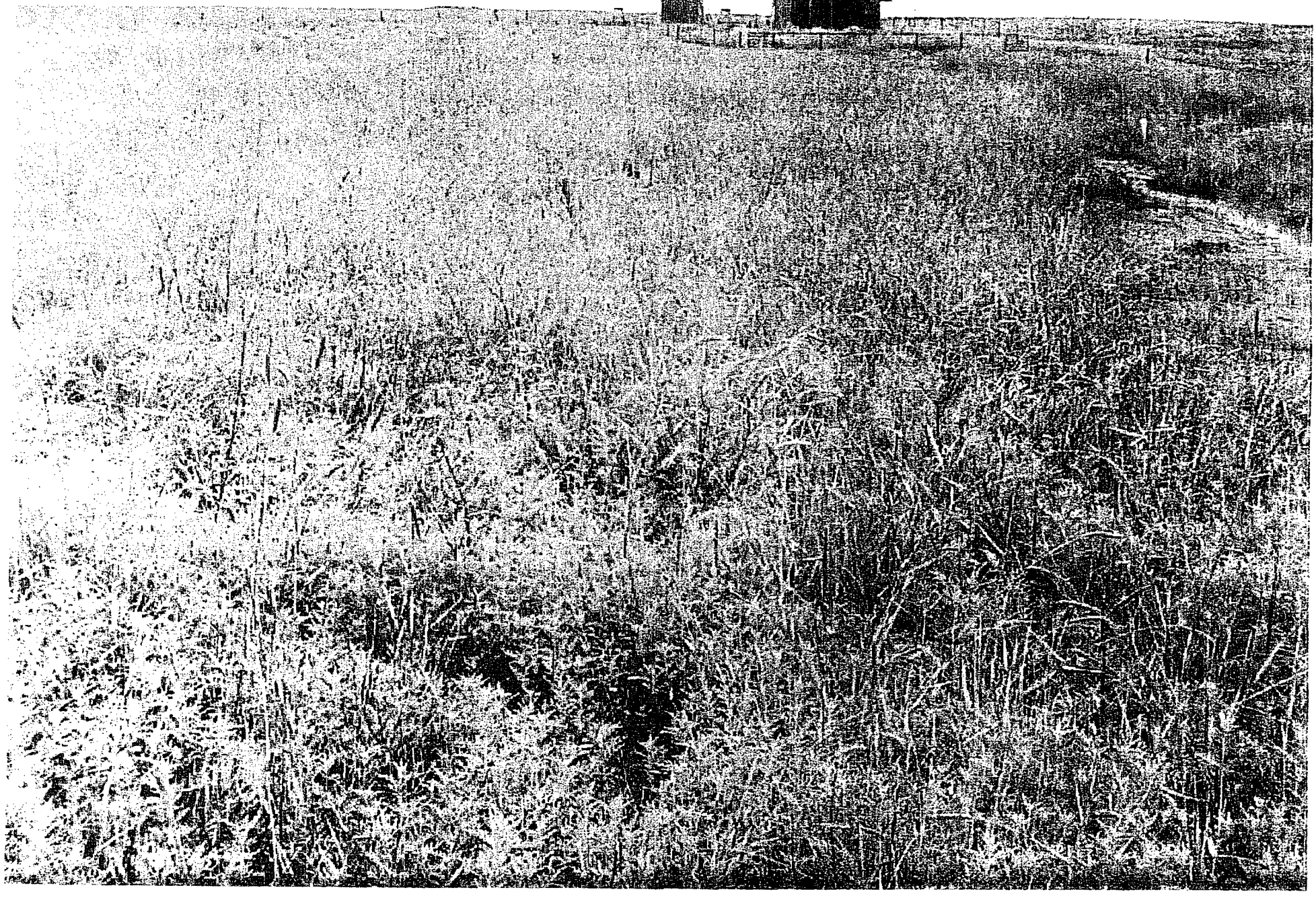
Early spring 1998



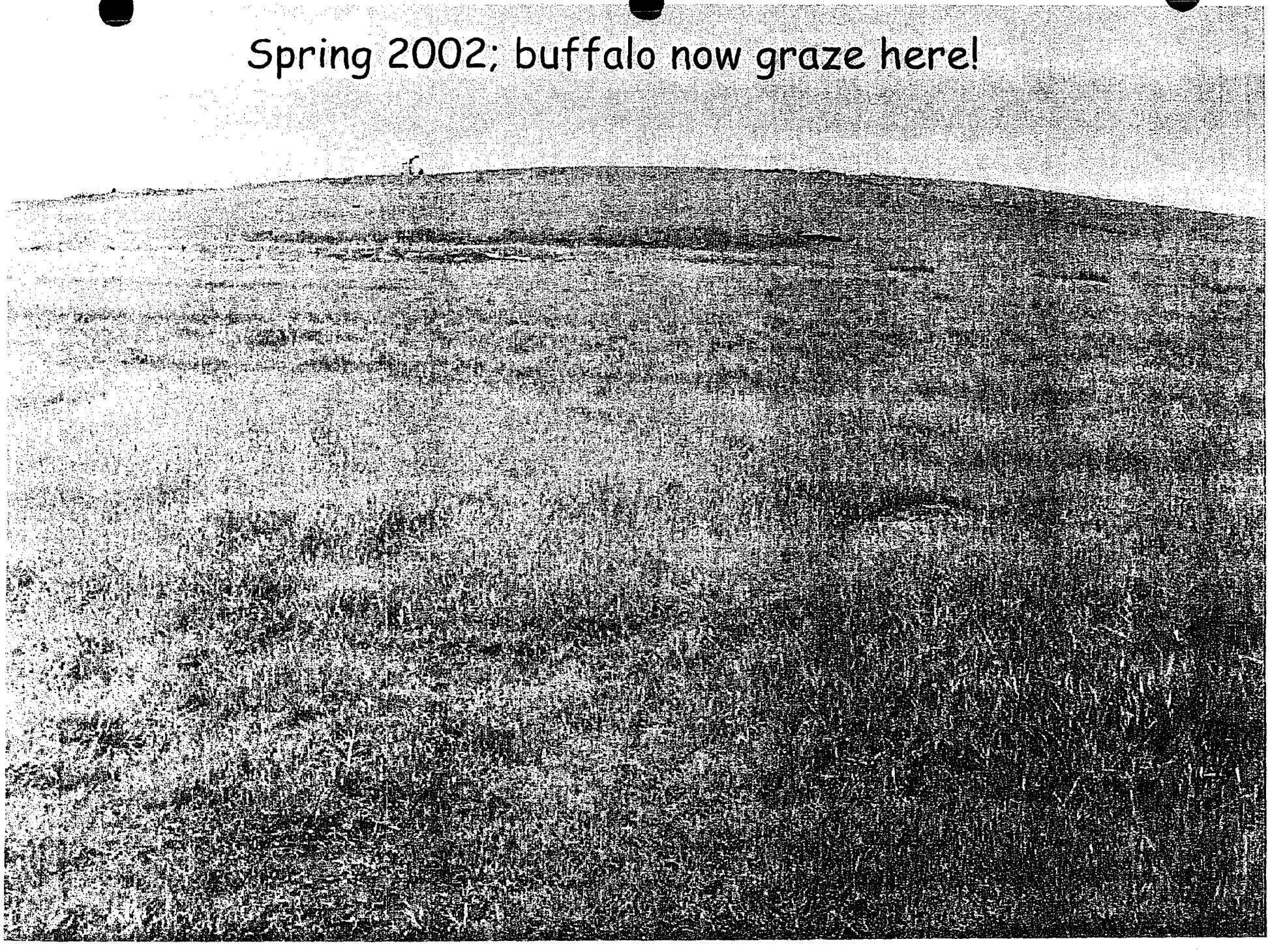
Late spring 1999; good crop of ragweed, some bare spots still



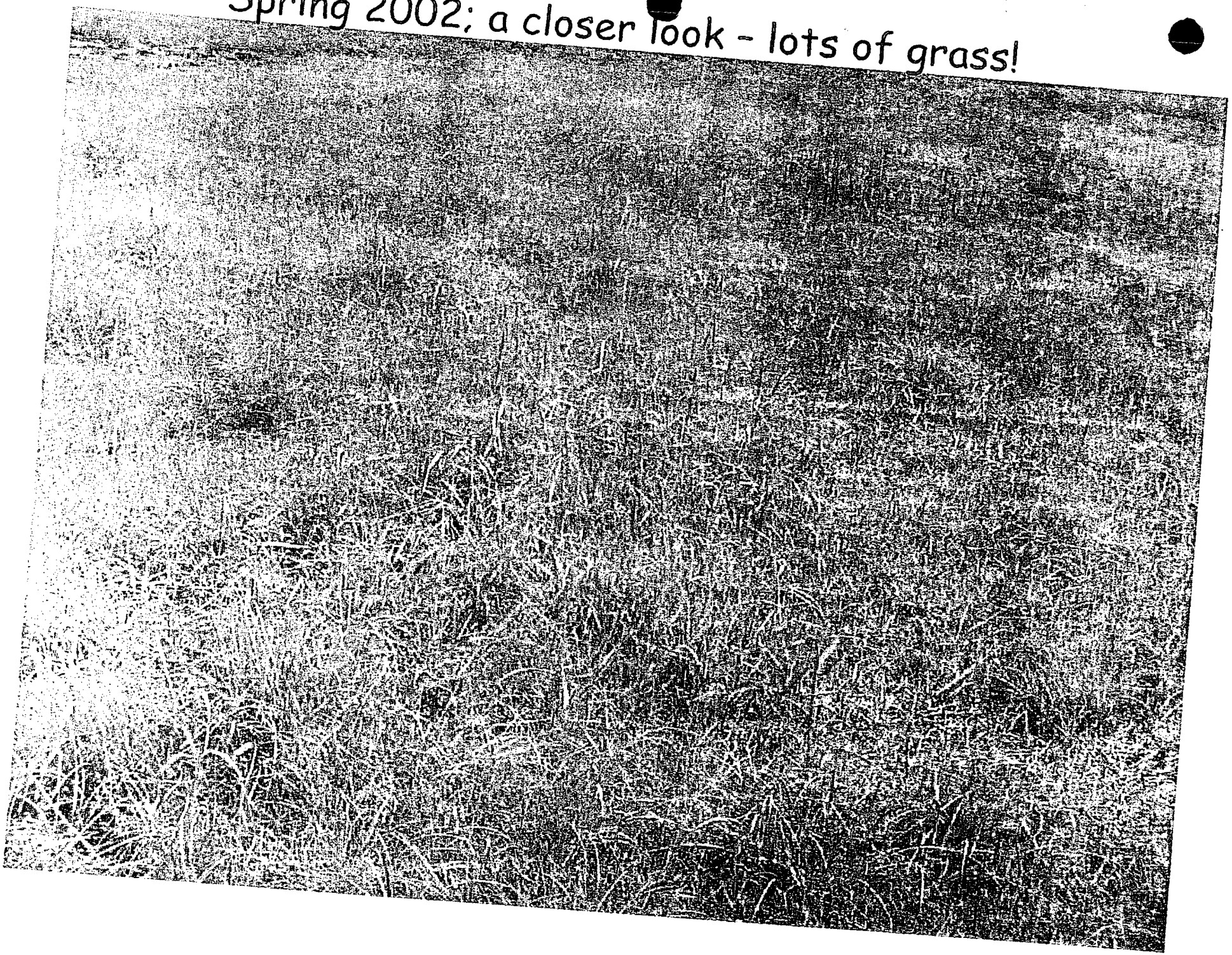
Spring 2000; lots of ragweed but lots of grasses too!



Spring 2002; buffalo now graze here!



Spring 2002; a closer look - lots of grass!



IPEC Guidelines for Remediation of Brine Spills

How long does it take to remediate a recent brine spill?

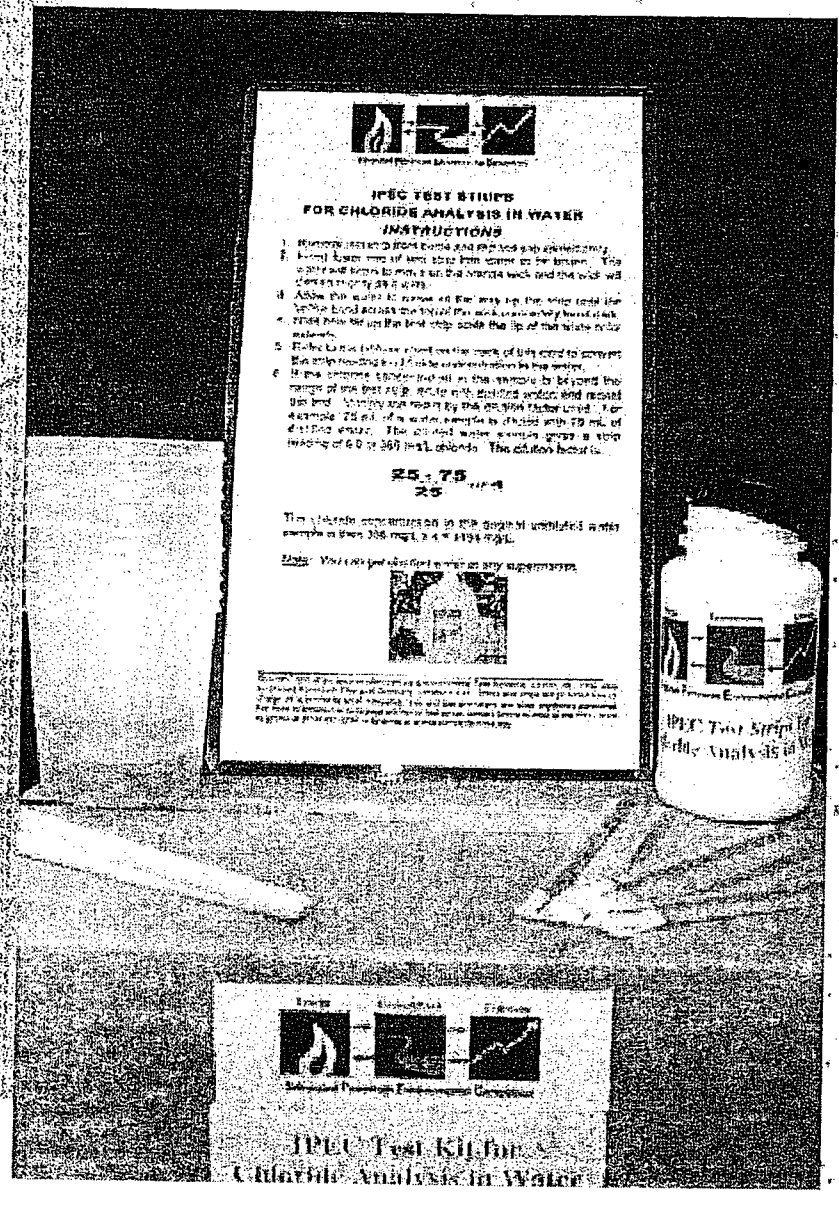
- 1-2 years for revegetation to begin; longer for restoration
- So keep the landowner in the loop!
- Be patient!

IPEC Guidelines for Remediation of Brine Spills

Monitoring drainage from your site

- Soil
  - If the salt leaches too quickly you can cause further damage - if so you may need a catchment (like a French drain and sump) for a while
  - Use the IPEC Soil Salt Analysis Kit to monitor soil downslope
- Surface waters
  - If brine components reach surface waters (or groundwater) you have violated the Clean Water Act

IPEC Test Kit for Chlorides in Water



- Monitor surface waters for brine impact
- Check rain water inside tank battery berm before discharge

IPEC Guidelines for Remediation of Brine Spills

Sometimes you might see new vegetation wither and die in dry weather when vegetation in unimpacted areas still looks OK!

- This is caused by upward migration of salt during dry weather
- You might even see white salt crystals on the soil surface

IPEC Guidelines for Remediation of Brine Spills

What can you do when this happens?

Keep on:

- Tilling
- Adding organic matter
- Adding gypsum when necessary

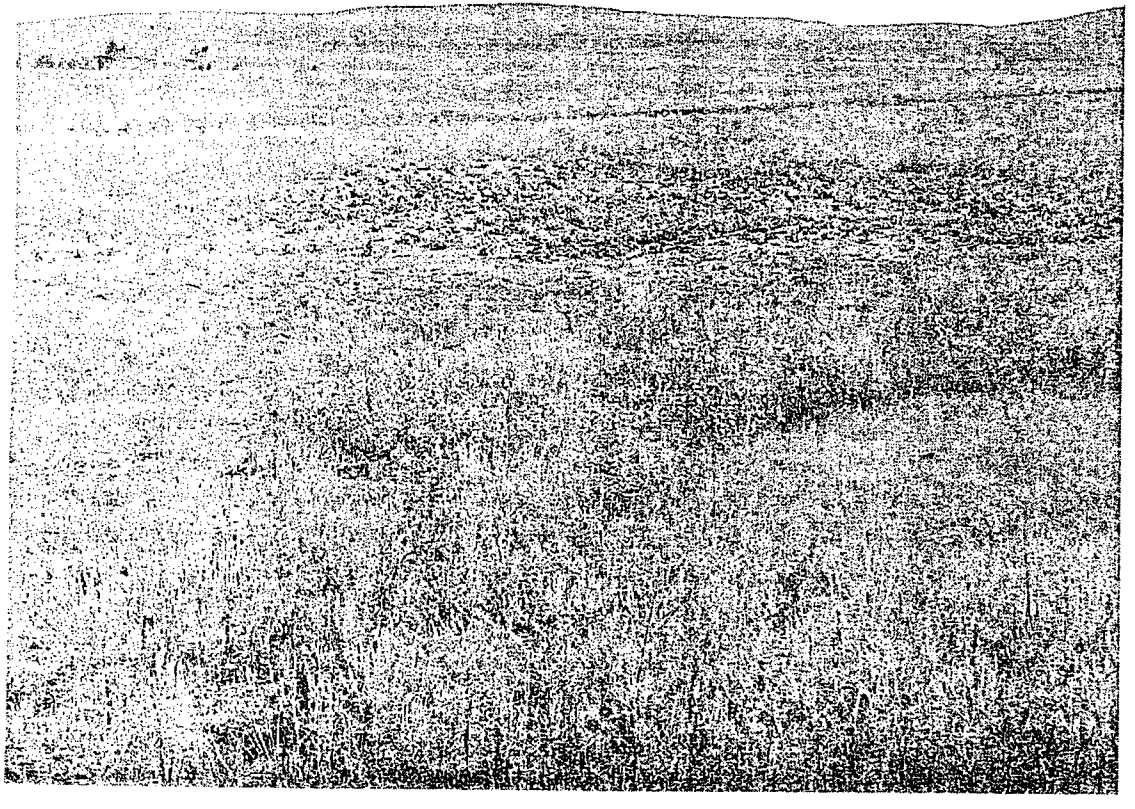
Until vegetation returns to the site and remains healthy! The deeper the salt has penetrated the longer this will take.

IPEC Guidelines for Remediation of Brine Spills

A bare spot that doesn't revegetate but has

- acceptable chloride concentrations and
- no sodicity problem

Probably needs fertilizer!



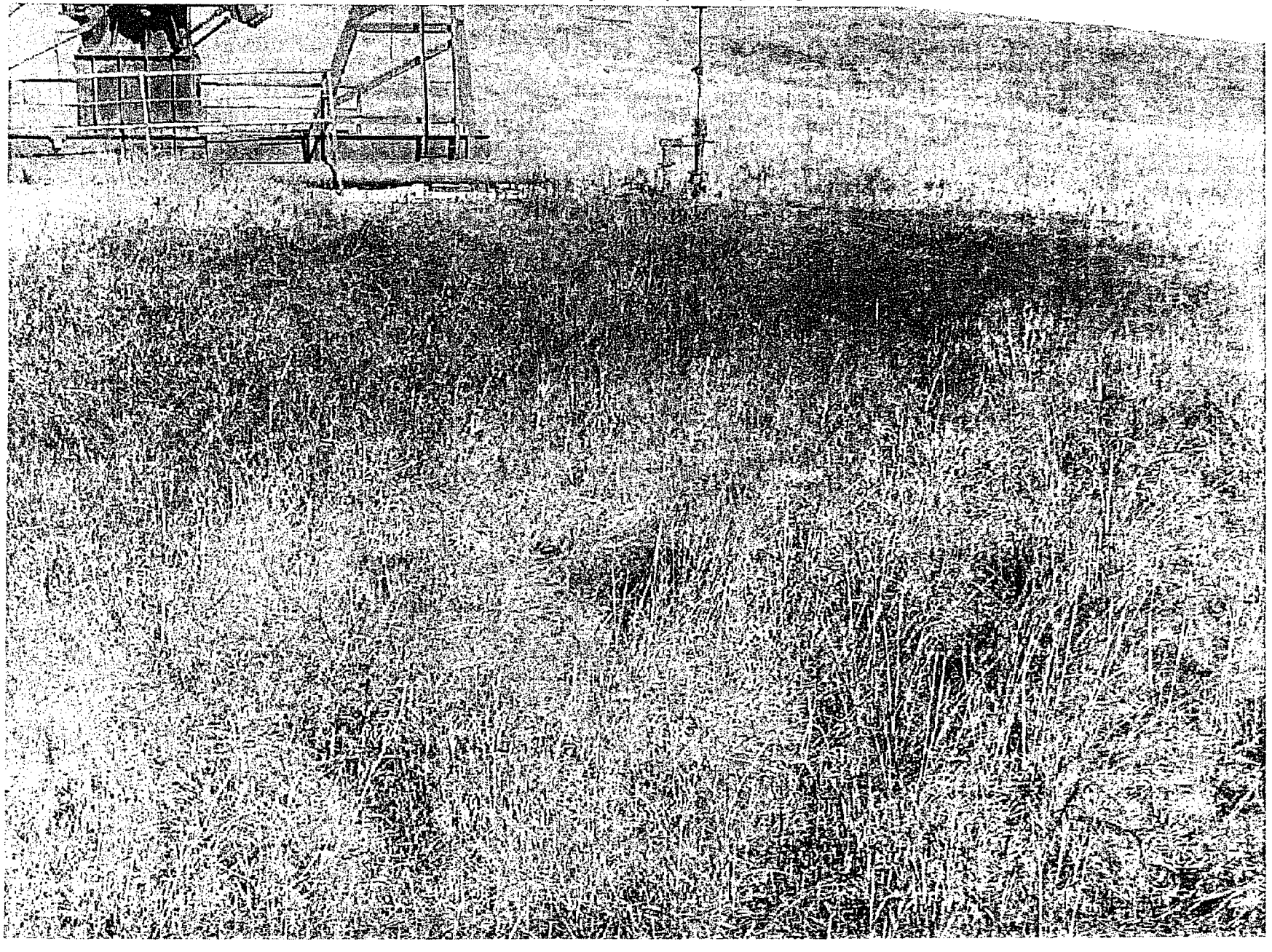
Here is an example. This is an old brine spill (>10 yrs old) that was sort of remediated using gypsum. This is the only area that is not at least partially revegetated. When the soil was tested it was found that there is very little residual salt - so why has the spot not revegetated? This is the lowest area in the site where water ponds when it rains. Rainwater has washed nutrients out of the topsoil here.

IPEC Guidelines for Remediation of Brine Spills

Remember you don't have to remediate what doesn't get into the soil

Look for ways to prevent salt damage!

A high pressure leak of oil and brine sprayed a large area near this wellhead in December 2000



What was the first response to this spill?

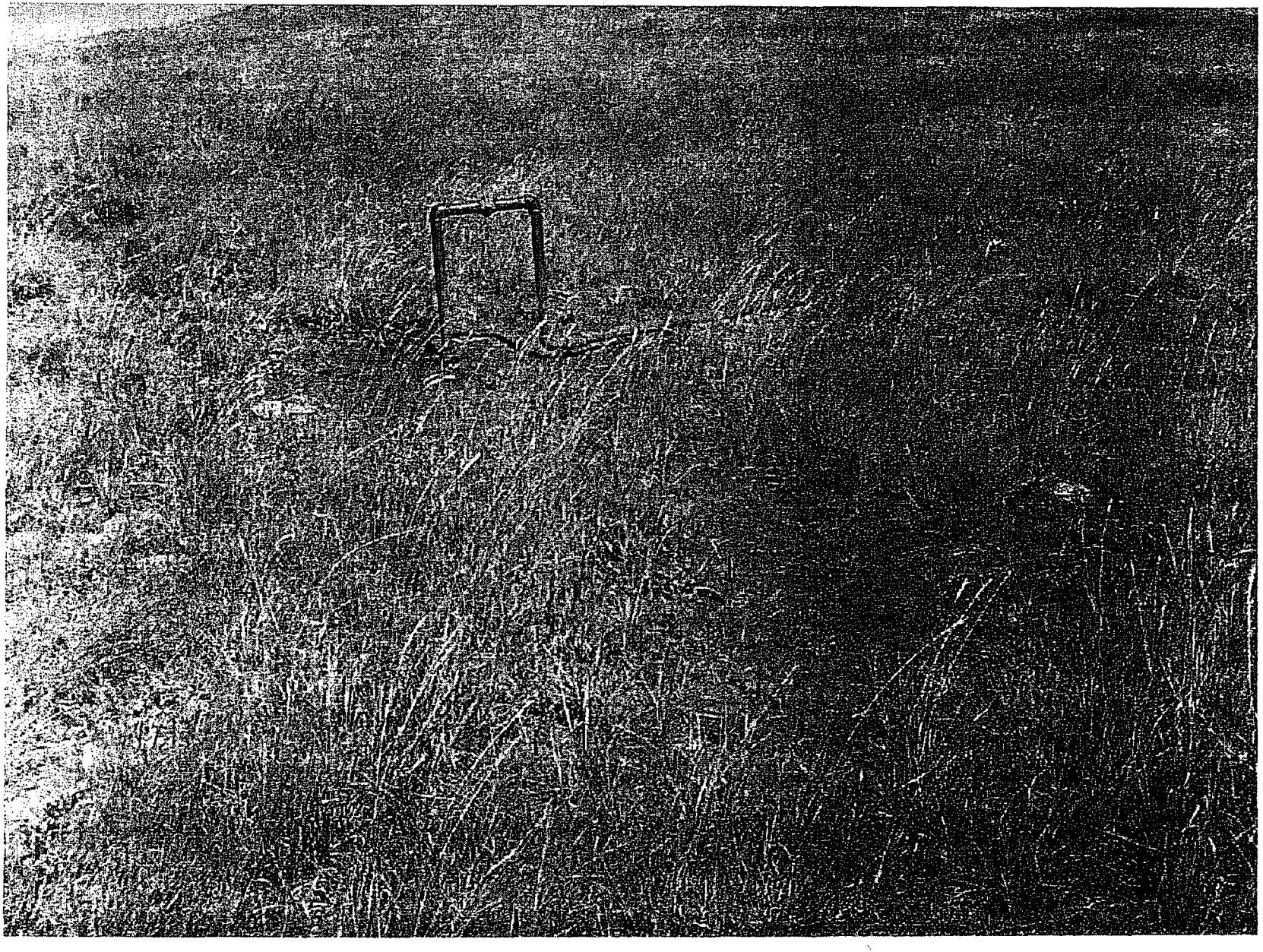
- Harvesting of oil-stained vegetation
- Why?
  - To limit the amount of oil reaching the soil and requiring remediation
  - Extent of brine contamination would not be known until spring

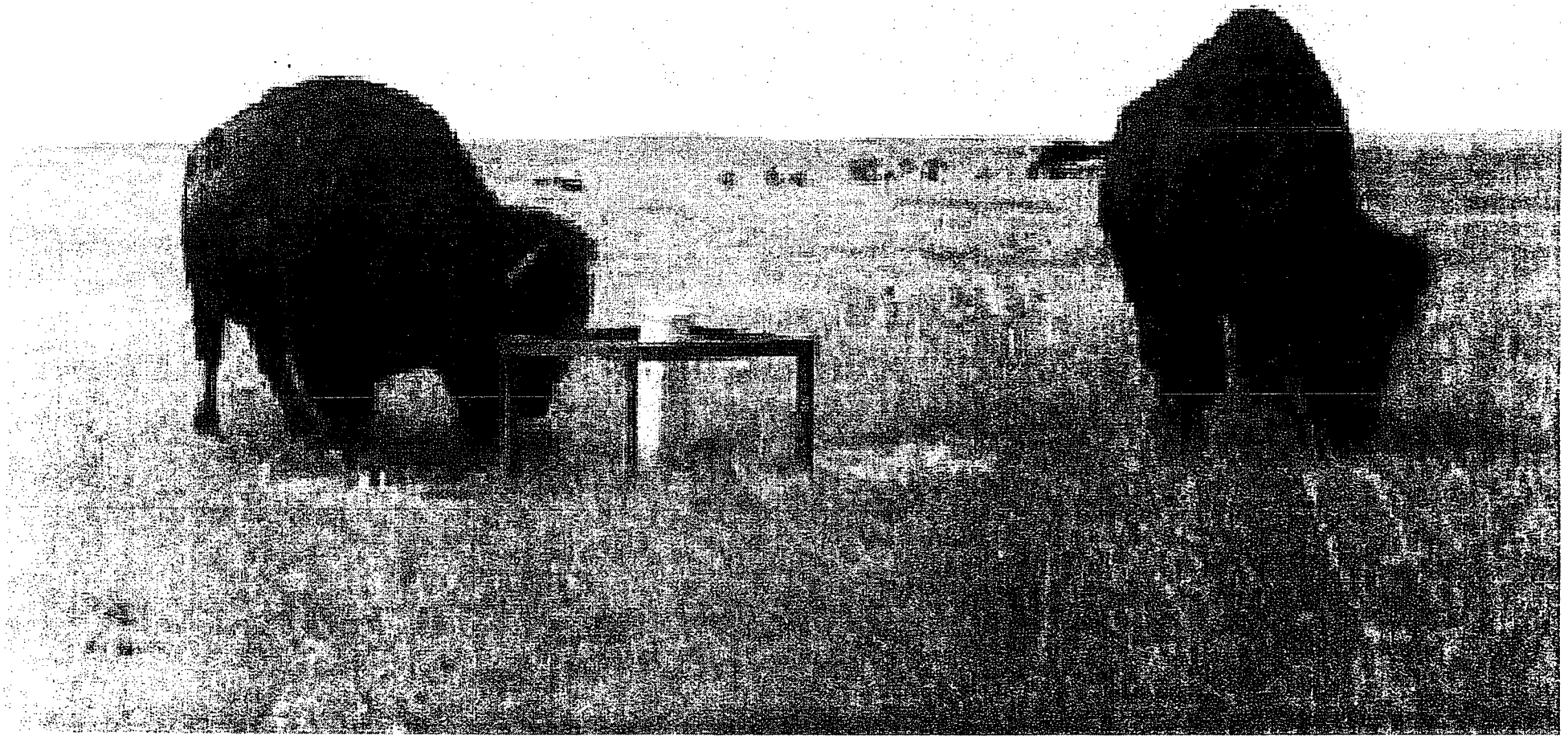
Spring 2001 brings a surprise! The only significant brine contamination detected is near the wellhead.

Why was there not more brine damage?

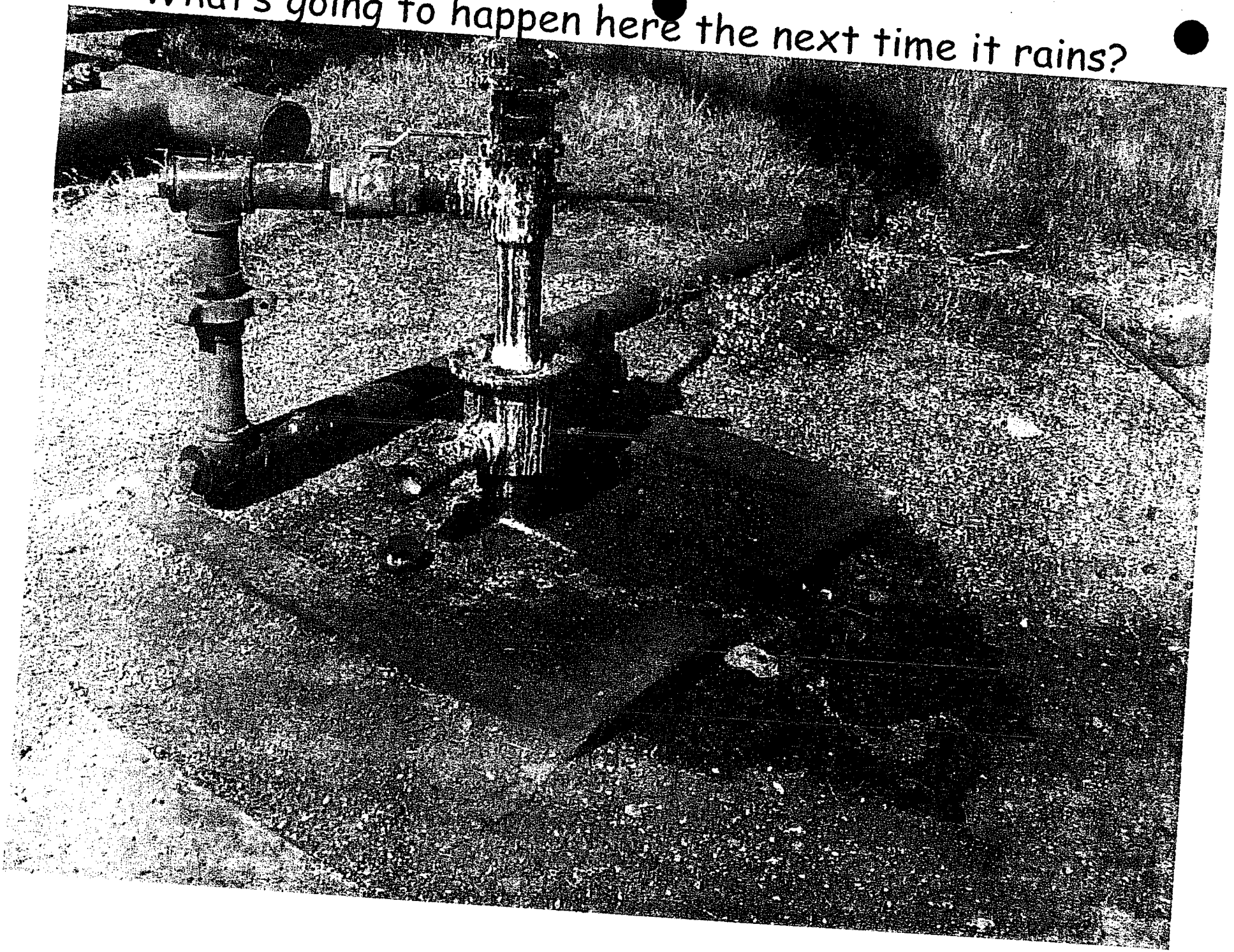
- Grass was harvested before any rain occurred
- Brine was recovered along with the oil!

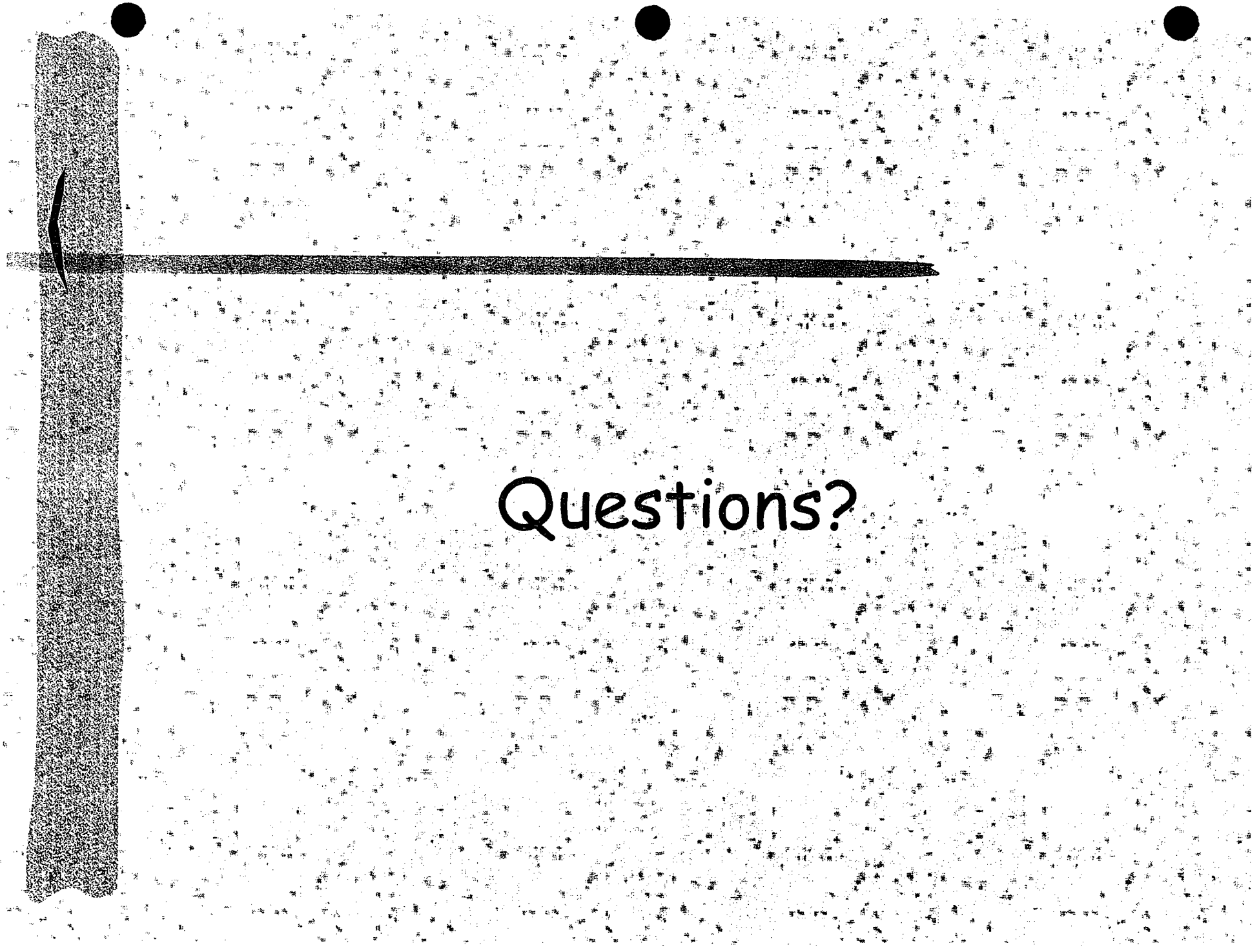
But, about 30 yds away and in the direction of the high pressure spray we find these bare spots. Is this brine damage? Soil testing says no. So what caused this?





What's going to happen here the next time it rains?




Questions?

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