MANURE WASTE PONDING AND FIELD APPLICATION RATES

March 1973

PART I

Study Findings

&

Recommendation

University of California
Agricultural Extension
Stanislaus, San Joaquin and Merced Counties

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INTRODUCTION

Manure holding ponds are utilized to economically collect and store dairy and poultry waste waters. In most cases, the effluent from the ponds is used for irrigation. In others, the effluent is first recycled by re-using it for subsequent flushing. Whatever the mode of operation of the ponds, it is important to know how much, if any, deep percolation occurs; what is the fate of salts and nitrogenous substances; what are the changes in other chemical constituents; and what bacterial processes occur in the ponds.

OBJECTIVES OF THIS STUDY:

1. Water Quality of Ponds

   Manure holding ponds were studied to determine the salts, nitrogen status, biochemical oxygen demand (B.O.D.) and temperatures as a function of time and depth within ponds.

2. Seepage from Ponds

   The bottom of the ponds and the soil immediately beneath the ponds were studied for sealing time, salinity, nitrogen movement, and the depth of water movement.

   Soil solutions beneath the ponds were studied under shallow and deep water table conditions to determine manure ponding effects upon water tables.

   The potential for leakage with time after pond construction was studied under various soil and water table conditions.

3. Field Application of Manure

   Cropped soils were sampled to determine salt and nitrogen movement under various manure loadings.

Soil samples were taken after application of manure from two sources, pond effluent and dry manure. Manure was spread at various rates to determine crop usage of nitrogen and downward movement of salts and nitrogen with varying soil profile conditions.

CONCLUSIONS:

1. Water Quality of Ponds

Total dissolved salts (T.D.S.) in the ponds increase linearily with time and is a function of loading. Virtually no salt is lost from the ponds. Nitrogen is principally in the ammoniacal form. The ammonium increases with time, but not at the same rate as salts. The highest concentration of nitrate ever found was 40 ppm (NO_3^-). Most ponds contain 9 to 18 ppm NO_3^-. Ammonium N was found up to 1200 ppm.

Nitrogen input from animal waste was calculated. From pond water analyses, losses of ammonia and gaseous N were found to be from 20 percent to 50 percent of total inputs over a 12-month period. B.O.D. increases primarily with loading, but seems to vary greatly with water temperatures. Ponds have a B.O.D. stratification.

2. Seepage from Ponds

Manure ponds seal under all soil conditions. The time required for sealing varies with soil texture and loading.

Sandy loam, loams and clay loam soils seal under a reasonable manure loading rate equal to waste from 100 cows per ten-acre-foot pond size in less than 30 days.

Loamy sands seal in 30 to 60 days under reasonable loading. At a high rate equal to waste from 180 cows per ten-acre-foot pond size, sealing occurred in 30 days.

Ponds constructed in high water table conditions, that is water table at the pond bottom or above, sealed at the same rate as ponds with a deep water table. Nitrate and salt concentrations in soil solutions under ponds were found to be about the same under high water table conditions as under ponds with deep water tables.

The potential gradient to produce leakage, using tensiometer-type ceramic probes with mercury manometers, showed parallel results to the soil solution probes. Either type of instrumentation shows quantitative data.

Under high water table conditions, if the pond water is drawn below the water table level, an apparent upward gradient may occur and seepage may occur for 10 to 20 days following refilling with manured water.

Lateral movement from ponds seems not to exist. The maximum downward movement found, after manure sealing, was one millimeter per day under the coarsest soil conditions. The quantities of salt and nitrate moving through the soil profile are low.

3. Field Application of Manure

Summer corn and winter oats were used to test manure application rates. Permanent pastures were also examined.

a. Dry manure application rates of 10 to 20 yards per acre, resulted in low nitrogen and soluble salt measurements in the soil solution beneath the root zone. These constituents were about the same as when commercial fertilizers were applied at recommended rates. High manure rates (40 to 50 yards per acre) produced high nitrate and salt concentrations in the soil solution below the root zone.

b. Some soils studied had an impervious layer beneath the root zone, called a claypan or hardpan. The soil solution immediately above these layers was found to have low concentrations of nitrates, but high concentrations of salts.

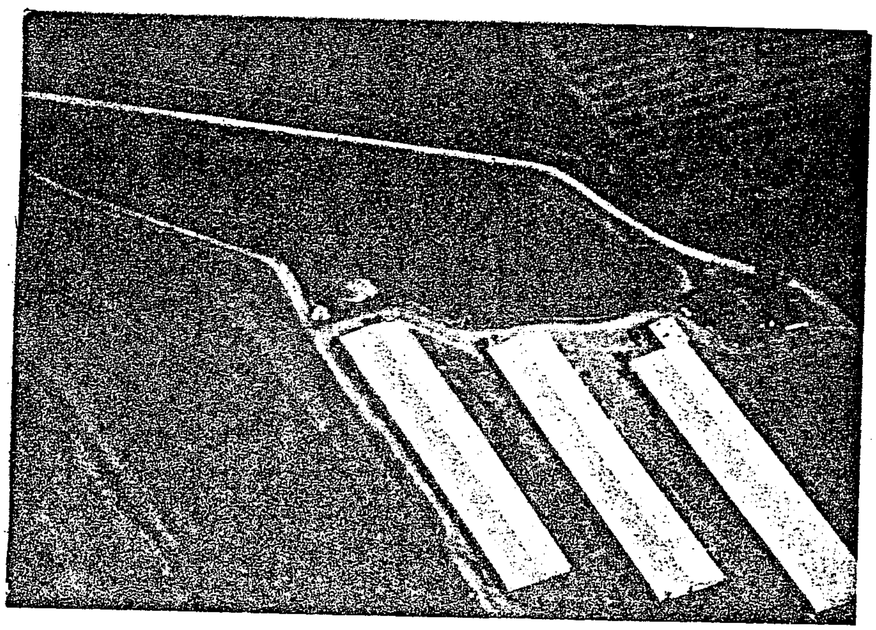
MANAGEMENT PRACTICES DEVELOPING

in the

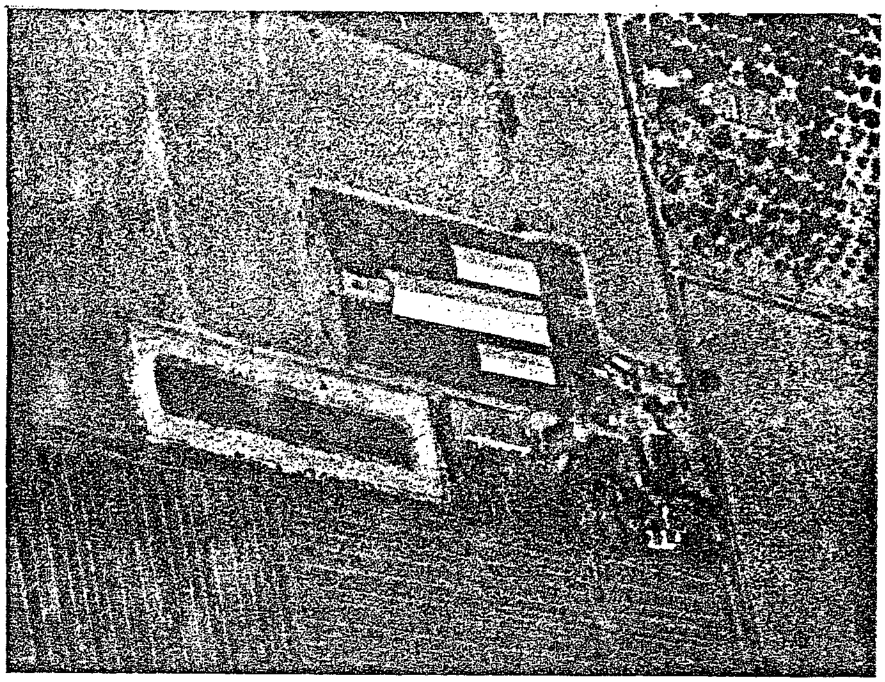
SAN JOAQUIN VALLEY

Poultry and Dairy Ponds

Poultry and dairy holding ponds are usually close to animal housing. Pond effluent is spread on the adjacent farm land.

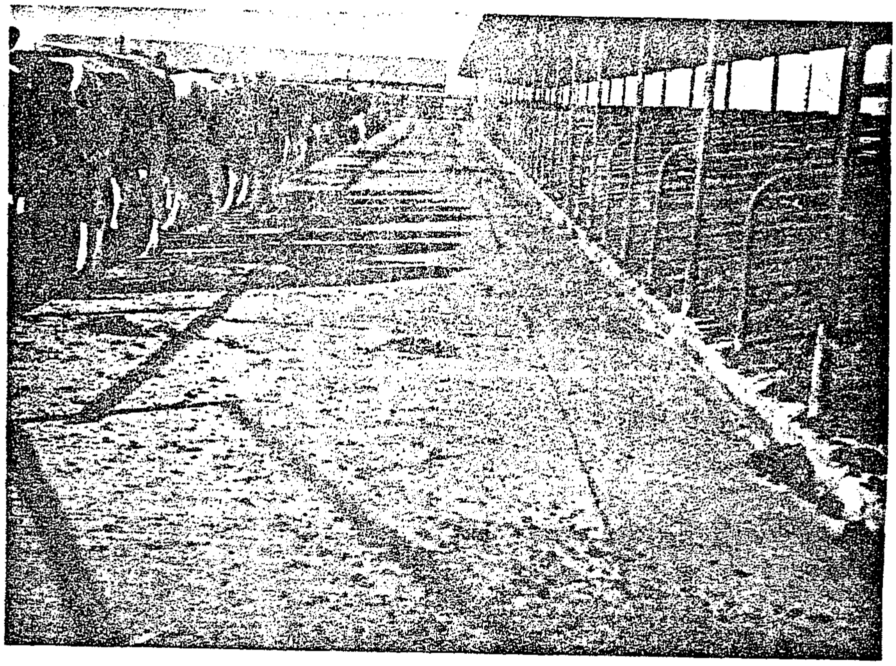


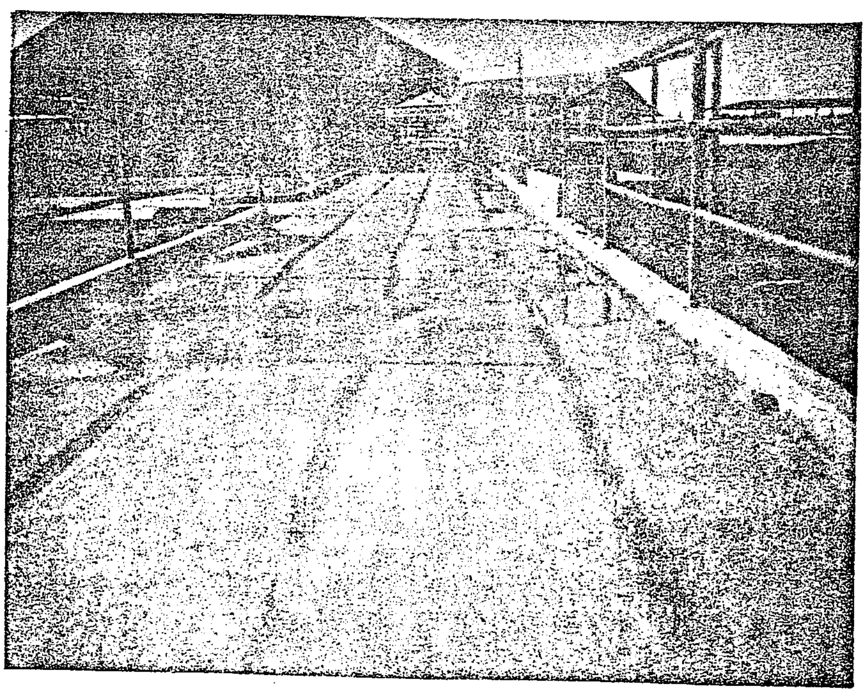
Poultry housing, pond, and adjacent farm land.



Dairy lot, pond, and adjacent cropland

Dairy feeding areas and paved lanes may be flushed with recycled manure pond water.

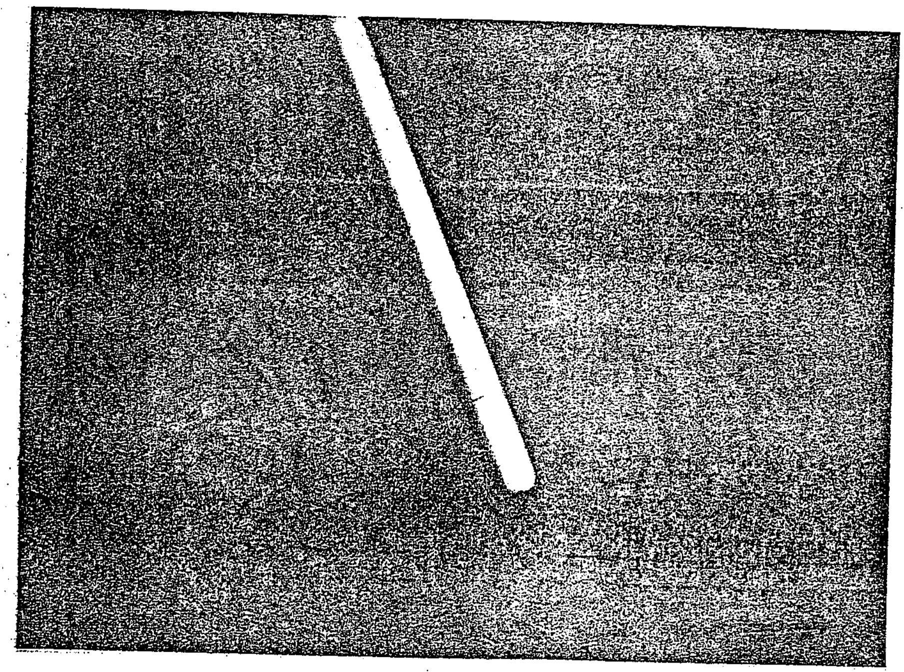




Recently flushed lanes

For this study, soil solutions under the ponds were extracted with suction devices using porous ceramic cups. The soil solution was drawn into the cup for sampling. Ceramic cups can also be used to monitor soil moisture potential gradients.

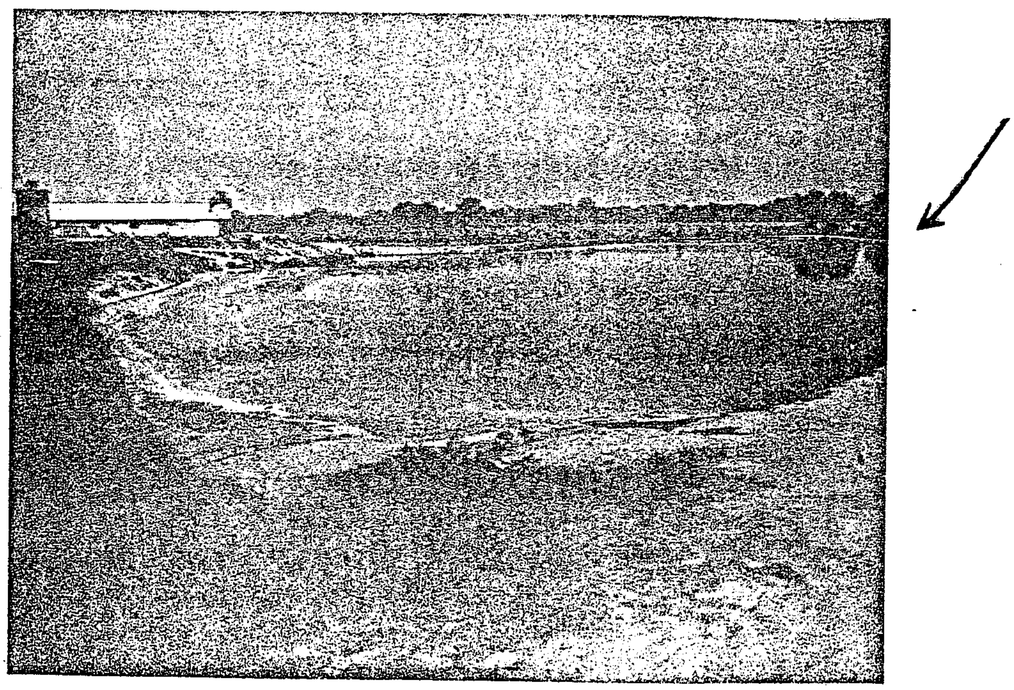
Soil sampling under ponds can be accomplished when ponds are emptied. Soil sampling can then be used to verify soil solution values.



Ceramic cups for placement under ponds for monitoring purposes

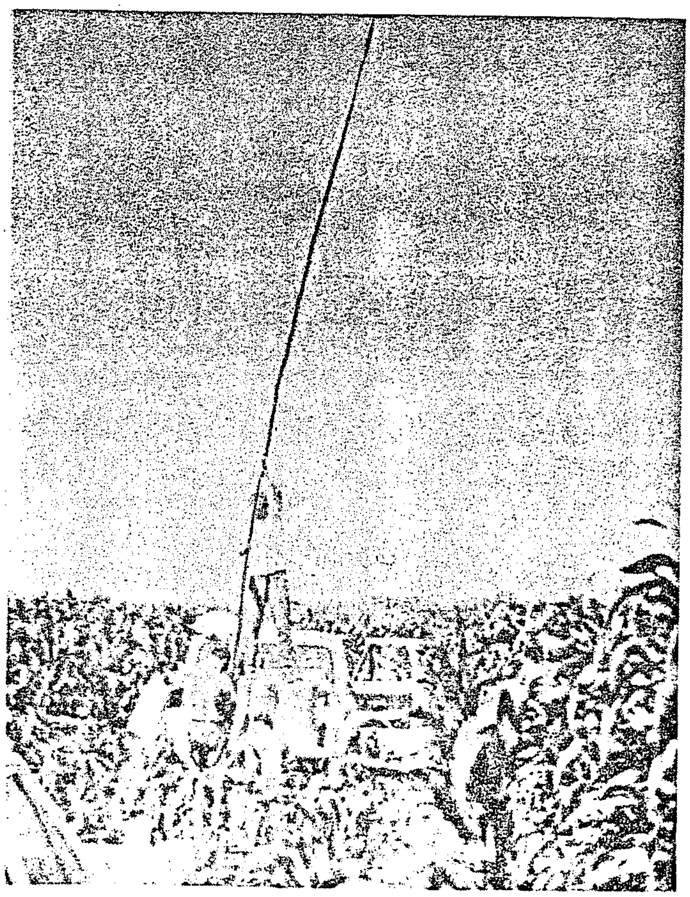
Mercury manometers for measuring soil moisture pressure and tubes for extracting soil solutions.

Pond management includes the use of ducks for scum control. Inlet from buildings upper left. Ducks in foreground and outlet pump (arrow) in upper right.

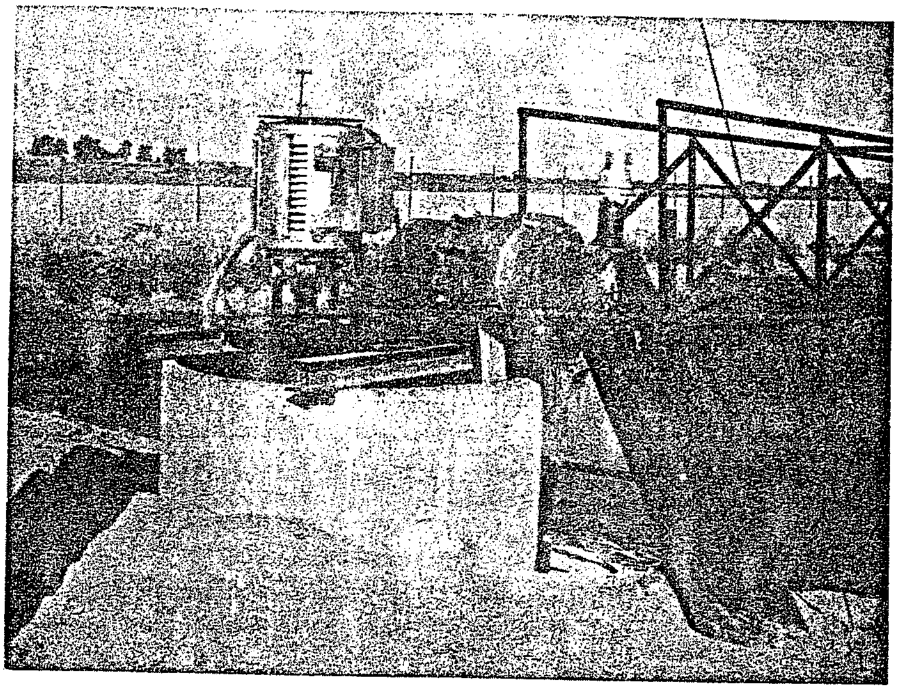


Reasonable rates of manure to apply to crops are determined by nutrient requirements of the crop. Maintenance of a favorable salt balance is extremely important to the long-term survival of California agriculture. Field sampling was used to study soils for nitrates and salinity under varying conditions.

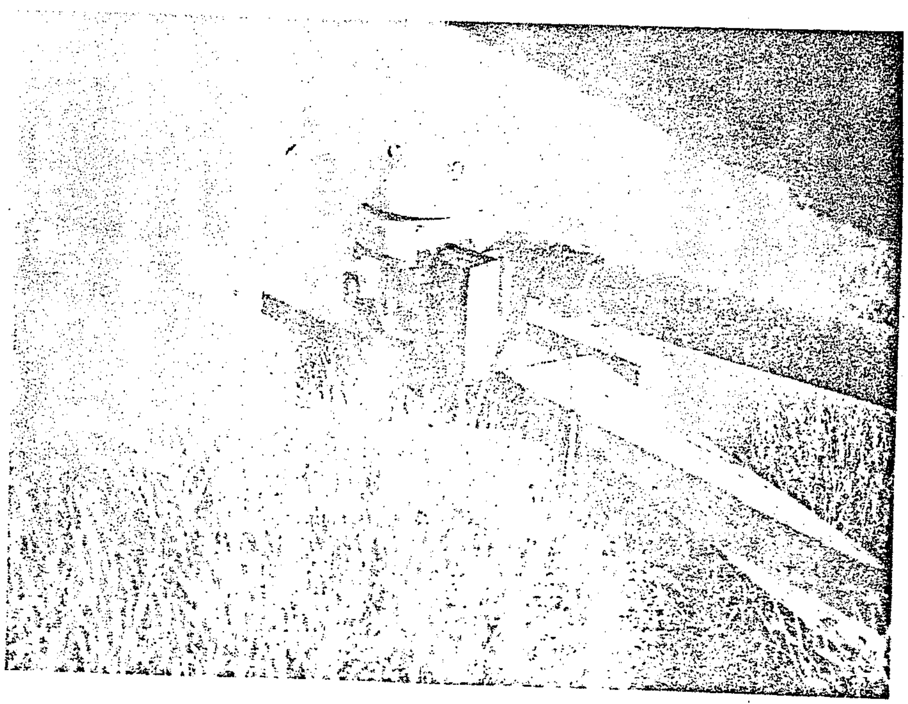
Deep, open soils with considerable depth were compared to shallow claypan and hardpan soils which have restrictive layers, a short depth beneath the crop roots. Soil augers were used in the study of this corn field.



Both manure pond effluent and dried manure are used as fertilizer in most parts of California. Pond water may be recycled for washing down feeding and other paved areas before it is used for irrigation.



Recycle - Pump



Similar pump for manure delivery to irrigation system

EXPERIMENTAL SITES

Twenty-five manure holding ponds were studied. The ponds were located in Merced, Stanislaus, San Joaquin and San Bernardino counties. These areas have some of the highest animal and poultry populations in the state of California. Ponds were selected to represent the range of soil textures from sands to clay loams, water table depths, and the varying age of ponds generally found in these areas. Fifteen of these ponds were instrumented with porous ceramic cups for measuring the rate of seepage and the concentration of nutrients. Ten ponds were used for determining changes in the pond water during use.

In one case, a ten-year-old manure pond was emptied, and sampling was conducted under the pond to a depth of ten feet to determine the fate of salts and nutrients.

Ten cropped fields were sampled which had a known manure fertilizer history, ranging from 10 to 20 years. These fields represented soils with restrictive layers and soils without such layering. Soil samples, at one-foot increments, were sampled to a restricting layer (claypan or hardpan). The open soil sites without restricting layers were sampled to a depth of 40 to 50 feet.

DISCUSSION

The Porter-Cologne Water Quality Control Act charges the State Water Resources Control Board (SWRCB) with the responsibility for regulating waste water quality from agricultural operations. Included among these waste waters are those coming from poultry and dairy husbandry. In the past, some waste waters from the poultry and dairy operations flowed into nearby stream beds where they either became part of the surface stream or percolated into gravelly stream beds and commingled with ground waters. Such waste waters were often high in B.O.D.; nitrates and related compounds; total dissolved solids; various esthetically offensive constituents; and miscellaneous organisms, such as bacteria. For the protection of nearly every beneficial use, therefore, it is imperative that improved practices be adopted.

The recycling and land disposal of manure waters is one of a number of alternatives available for handling of animal wastes. Other alternatives include combustion, spreading, composting and feeding.

Waste holding ponds have a number of desirable characteristics. They are esthetically inoffensive, having very little odor. They facilitate fly and mosquito control. The manure wastes can be readily applied to surrounding cropland by blending with irrigation water. Overflow of manure to adjacent water courses is eliminated. Seepage from ponds contains low concentrations of nitrate. In addition, the technology is currently available to effectively monitor the performance of ponds.

Seepage of water from manure-laden ponds in loamy sand to clay soils was studied and is in the order of one millimeter per day after 30 days. The gradients indicative of moisture movement were nonexistent after 60 days under all ponds studied. Lateral movement does not occur. The maximum movement found was about one millimeter depth of water per day under the coarsest soil conditions. The quantities of salt and nitrate that are moving through the soil profile are extremely small.

After thirty months, the soil solutions below the manure ponds have a lower concentration of all nutrients than adjacent well waters. No observable changes have occurred in nearby well and ground water during this period.

Significant stratification of nitrates and B.O.D. within the waste ponds appears to exist with increased anaerobic activity, and a lowering of nitrates occurring with depth.

RECOMMENDATIONS

Total salinity (T.D.S.) within the ponds increases linearily fairly rapidly according to loading. Because of salt increases, at present loadings of 15,000 chickens or 100 dairy cows per acre of surface, it is recommended that the ponds be emptied at 2- to 3-week intervals, or when T.D.S. approaches 1000 ppm. Irrigation blending and disposal to cropland is a suggested use for the effluent. Irrigation blending is usually a necessity after winter storage between irrigation seasons.

From the result of these studies, it does not appear necessary to recommend any artificial seal inside the manure holding reservoirs.

When double cropping is practiced (winter cereals and summer field corn or summer sorghum) or where irrigated permanent pasture is grown, manure loadings up to 10 to 20 yards per acre did not materially increase nitrates or salinity (T.D.S.) in percolating waters. Studies on several different soils, and with varying depths to an impermeable layer, indicate a reasonable manure loading is one consistant with crop needs for nitrogen.

The salts (T.D.S.) available under the suggested 10 to 20 yards per acre "reasonable" manure-loading rate did not show a higher T.D.S. or nitrate level in the soil solution than in adjacent well waters. These rates (10 to 20 yards per acre) will supply about 200 pounds of nitrogen and 2000 pounds of salts per acre.

MANURE WASTE PONDING AND FIELD APPLICATION RATES

March 1973

Part II

Technical Report

University of California
Agricultural Extension
Stanislaus, San Joaquin, and Merced Counties

MANURE WASTE PONDING AND

FIELD APPLICATION RATES

TECHNICAL REPORT

The technical data in Part II of this study is the result of nearly three years of intensive field investigations and laboratory analyses on the part of many Agricultural Extension and County laboratory personnel.

The objectives were to investigate many animal manure and commercial fertilizer trials and observe the fate of the fertilizer materials and salts on cropped soils.

In order to meet these objectives, the State Water Resources Control Board cooperated with the University of California, Agricultural Extension, and the Kearney Foundation in field research studies in the San Joaquin Valley.

Funds were made available to Agricultural Extension on a contractual basis and the staff of the State Water Resources Control Board provided technical assistance in delineating those parameters pertinent to SWRCB.

Technical assistance in soil physics was furnished by the staff of the Department of Water Science and Engineering, University of California, Davis. Technical expertise concerning soil and water chemistry, animal husbandry, etc., was provided by Agricultural Extension personnel.

EXPERIMENTAL METHODS

1. Nitrogen and Salt Content of Manure Pond Waters

Manure water from holding ponds that is reused to flush additional manure from production areas contains progressively higher nitrogen and salt contents. The rate of such a build-up and its concomitant effects upon fertilized crops are important to both livestock producers and to SWRCB in protecting the waters of the state.

Irrigation water movement rates were studied before filling ponds with manured water. As ponds were being filled, sealing time was determined. In addition, reference stakes were located within some ponds to measure depth changes with time to further measure rate of water loss from the ponds.

4. Manure Disposal Areas and Commercial Fertilizer Trials

Soils were examined for movement of nutrients and salts where known manure history could be documented.

Soils with crops of winter cereals followed by corn for silage were examined where manure had been the principle fertilizer used. A commercially fertilized apricot plot and a commercially fertilized permanent pasture plot were sampled and analyzed.

RESULTS

1. Nitrogen and Salt Content of Pond Waters

Cows excrete approximately 0.4 pounds of nitrogen per day, and chickens excrete about 0.003 pounds of nitrogen per day in the form of nitrogenous materials.

These nitrogenous materials are oxidized, under aerobic conditions, to nitrates--the most soluble form of nitrogen--and can move readily through the soil with water. In an anaerobic aquatic movement, nitrates are converted to nitrogen gas, a process commonly known as denitrification. Periodically, pond waters were analyzed for nitrate and ammonium-nitrogen and compared to calculated amounts of manure input. At the end of a 22-month period, total dissolved nitrogen content of a manure pond was determined.

During this period, a typical pond (Table 1) had received the waste from 43,000 chickens. This loading rate corresponds to total nitrogen additions equivalent to 1950 mg/l nitrogen, but only 450 mg/l nitrogen was found in the ammonium form, and 4.3 mg/l in the nitrate-nitrogen form.

Table 1.

Changes in nitrate-nitrogen, salt content, and B.O.D. at the one-foot depth of a typical manure pond during a 22-month period.

Dates	Nitrate-Nitrogen mg/1	Salt Content, mg/1 *	B.O.D., ppm **
12/8/70	1.1	448	76
2/6/71	1.7	1645	--
3/8/71	2.3	1632	400
7/21/71	3.6	1696	580
8/20/71	4.0	2816	480
8/23/71	4.8	2880	400
8/31/71	5.1	2944	380
6/27/72	4.4	3084	650
8/9/72	5.2	3178	235
10/5/72	4.3	3392	450

* Salt measurements were EC_e (mmho's/cm) and calculated to salt content, mg/1 using factor of 640.

** The City of Modesto, Water Quality Control Division, cooperated in B.O.D. determinations for this study.

Soil solutions were not obtained from the porous cups at the one-foot or two-foot depths below the pond bottoms (Table 5). This lack of extraction was not due to failure of the experimental apparatus, but was due to the extremely low water-conducting properties of the soil. This very reduced conduction confirmed the sealing of the pond bottoms. Moreover, auger samples (Table 7) indicated that the soils were blue-black, dense and not saturated.

Table 3.

The nitrate-nitrogen, salt content, pH, and B.O.D. of a typical dairy manure pond at one-foot intervals between the pond surface and the bottom.

Depth Feet	Nitrate-Nitrogen mg/l		Ammonium-Nitrogen mg/l	Salt Content mg/l		pH		B.O.D. ppm	
	1971	1972	1972	1971	1972	1971	1972	1971	1972
1	6.4	6.0	500	1523	2020	7.9	8.0	137	250
2	7.0	6.5	550	1728	2140	7.2	7.4	116	260
3	6.1	6.0	600	1561	2040	7.7	7.9	120	280
4	5.9	5.8	650	1504	2230	7.8	7.9	123	270
5	6.1	6.0	650	1523	2300	7.9	8.0	125	250
6	5.7	5.5	700	1600	2300	7.8	7.8	117	240
7	3.7	2.7	1000	----	----	Slurry	---	1040	150[illegible]

Table 5.

Typical nitrate and salt content values of the soil solution beneath ponds. Soil solution was extracted by ceramic cups.

DEEP WATER TABLE

Depth Feet	Nitrate-Nitrogen, mg/1 before filling	Nitrate-Nitrogen, mg/1 7 months after filling	Salt Content, mg/1** before filling	Salt Content, mg/1** 7 months after filling
2	--	--	--	--
5	1.3	1.6	2640	640
10	1.1	1.4	960	1624
14	1.3	1.9	1920	1344

Table 6.

Typical nitrate and salt content values of the soil solution beneath pond.*

SHALLOW WATER TABLE

Depth, Feet	Nitrate-Nitrogen, mg/1 (7 months before filling)	Ammonium-Nitrogen, mg/1 (7 months before filling)	Nitrate-Nitrogen, mg/1 (7 months after filling)	Ammonium-Nitrogen, mg/1 (7 months after filling)	Salt Content, mg/ before filling	Salt Content, mg/ aft
1	2.2	1.0	0.6	7.11	2560	1184
5	2.8	1.0	0.3	2.24	640	864
Water Table	2.8	1.0	0.3	2.24	384	864

* Water Table Depth 20 inches

**Salt measurements were EC_e(mmho's) and calculated to salt content, mg/1 using factor 640.

Table 8.

Typical nitrate-nitrogen and salt content values of the soil solution in soil immediately adjacent to a pond. A soil auger was used to remove samples for analyses nine months after filling.

Depth Feet	Nitrate-Nitrogen mg/1	Salt Content mg/1*
1	5.3	550
2	4.4	301
3	4.1	333
4	2.6	305
5	4.3	307
6	8.2	269
	Bottom of Pond	
7	5.0	371
8	3.8	371
9	3.4	250
10	2.6	243
11	5.3	243
12	3.4	275
13	2.4	256
14	2.9	192
15	2.7	211
16	2.9	210
17	3.4	282
18	2.9	281
19	2.7	282

* Salt measurements were EC_e (mmho's) and calculated to salt content, mg/l, using factor of 640.

Table 9.

Typical Manometer Readings in Centimeters of Mercury

Hydraulic Gradient $\Phi_2 - \Phi_1 / L$

Loamy Sand, 20 Inches to Water Table

		Depth	Readings	Gradient
	0	1 foot	5 feet	$\Phi_2 - \Phi_1/L$
Infiltration of Pure Water	29.0 (cm)	31.0 (cm)	32.5 (cm)	+4
Days Manure Added 1		32.8	33.2	+2
3		33.6	33.2	+1.1
5		33.5	33.2	+1
9		33.5	33.2	+1
15		33.5	33.2	+1
22		33.4	33.1	+1
24		33.3	33.2	+1
26		32.3	32.2	+1
31 Pond Full of Manure Water		32.1 Sealed	32.1 Sealed	0

Seal Complete 31 Days

WATER TABLE ANALYSIS

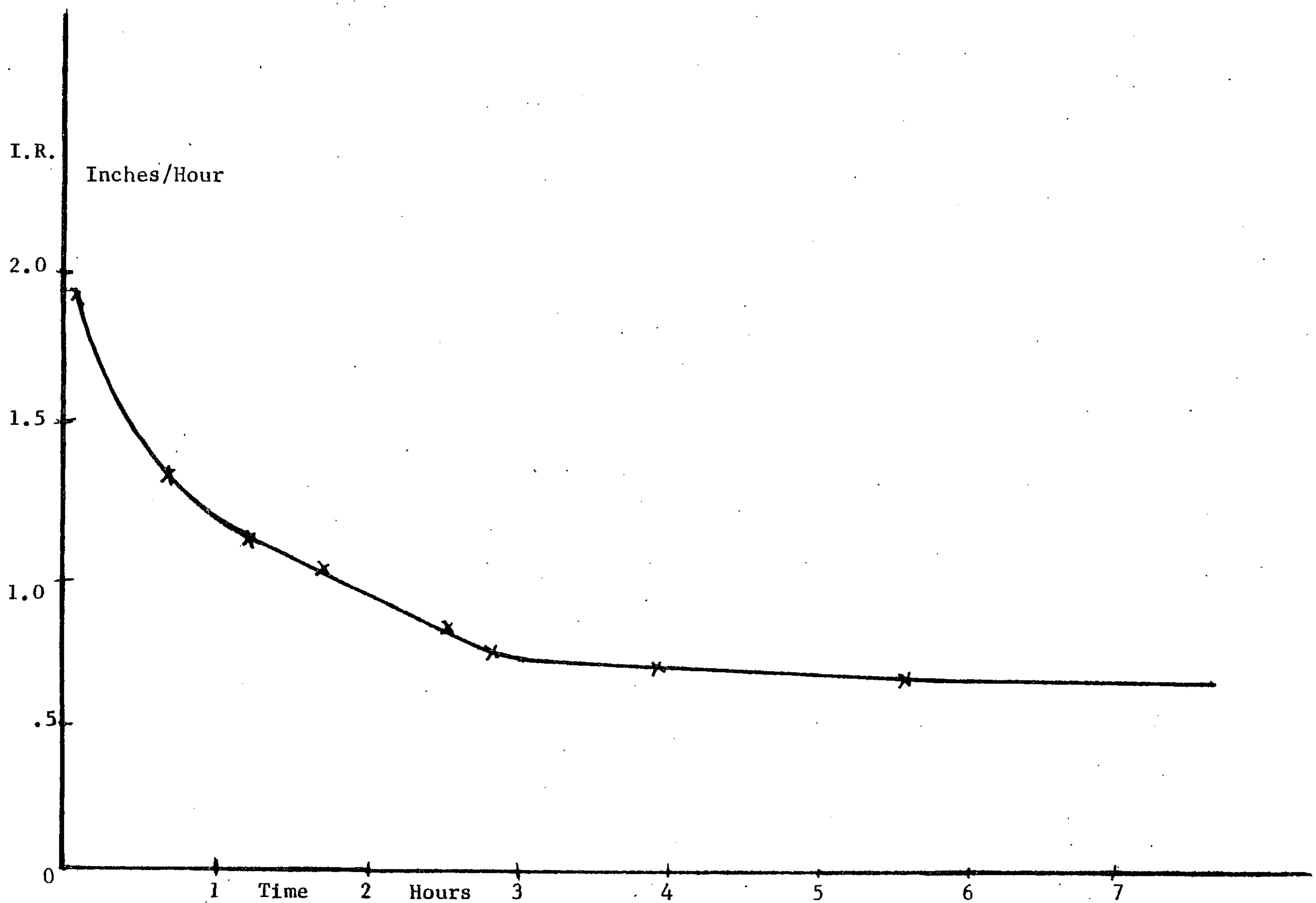
Time Days	pH	EC	Ca+Mg ME/1	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1
0	7.36	.24	6.2	3.5	80
31	7.36	.24	6.2	2.8	80

Graph 2

I.R. (Infiltration Rate) Before Manure

20" Water Table

Loamy Sand Soil



Manure Disposal on Cropped Soils

High Application Rates

The amounts of nutrients and salts available for leaching were studied when high manure rates were used on open, deep soils and soils underlain by restrictive layers.

High manure usage of 40 yards per acre on open soils showed salt and nitrogen movement toward the underground, Table 9. Forty yards per acre is equivalent to 24 dry tons of manure per acre and is equivalent to the manure from approximately 9 to 10 cows per acre. The downward movement of nitrogen (Graph 4) compares applications of 12 yards per acre to 40 yards per acre. The downward movement of T.D.S. (Graph 5) compares applications of 12 yards per acre to 40 yards per acre. The fluctuations in amounts of nitrogen and salt in about five-foot increments (Graphs 4 and 5) suggest annual movement due to the leaching fractions of irrigations.

High manure usage with restrictive layers is shown in Table 10. In this table, nitrate-nitrogen has accumulated on the pan to some extent, but the crops have used considerable amounts of the surface nitrogen. Salinity accumulation on the pan is shown in Table 11. The high application rate of manure preceded sampling by eleven months (Table 11).

Table 9. (cont'd)

Depth Feet	pH	EC_e	Ca+Mg ME/L	Nitrate-Nitrogen mg/1	Ammonium-Nitrogen mg/1	Total Nitrogen mg/1
24	7.1	0.32	1.8	17.5	-0-	Trace
25	7.2	0.39	3.0	18.0	-0-	Trace
26	7.0	0.37	2.4	18.5	-0-	Trace
27	7.1	0.37	1.6	18.0	-0-	Trace
28	7.1	0.29	2.0	21.0	-0-	Trace
29	7.2	0.46	2.4	21.6	-0-	Trace
30	7.0	0.47	3.6	22.5	-0-	Trace
31	7.2	0.32	1.8	16.0	-0-	Trace
32	7.5	0.36	3.2	19.5	-0-	Trace
33	7.0	0.31	3.2	17.2	-0-	Trace
34	7.2	0.41	2.6	26.0	-0-	Trace
35	7.3	0.51	3.2	38.0	-0-	Trace
36	7.1	0.57	3.6	40.0	-0-	Trace
37	7.4	0.38	2.2	24.0	-0-	Trace
38	7.4	0.41	2.4	25.0	-0-	Trace
39	7.2	0.53	3.8	44.5	-0-	Trace
40	7.0	0.62	3.8	37.0	-0-	Trace
WELL WATER ANALYSIS AT DAIRY						
	6.5	.25	2.0	3.5	-0-	-0-

Graph 5

Salinity Profile for Open Soil
CROP: 1960-1972 Corn-Oats
FERTILIZER: 12Yds/A Dairy Manure + 150#N/A
Versus
40 Yds/A Dairy Manure + 150#N/A

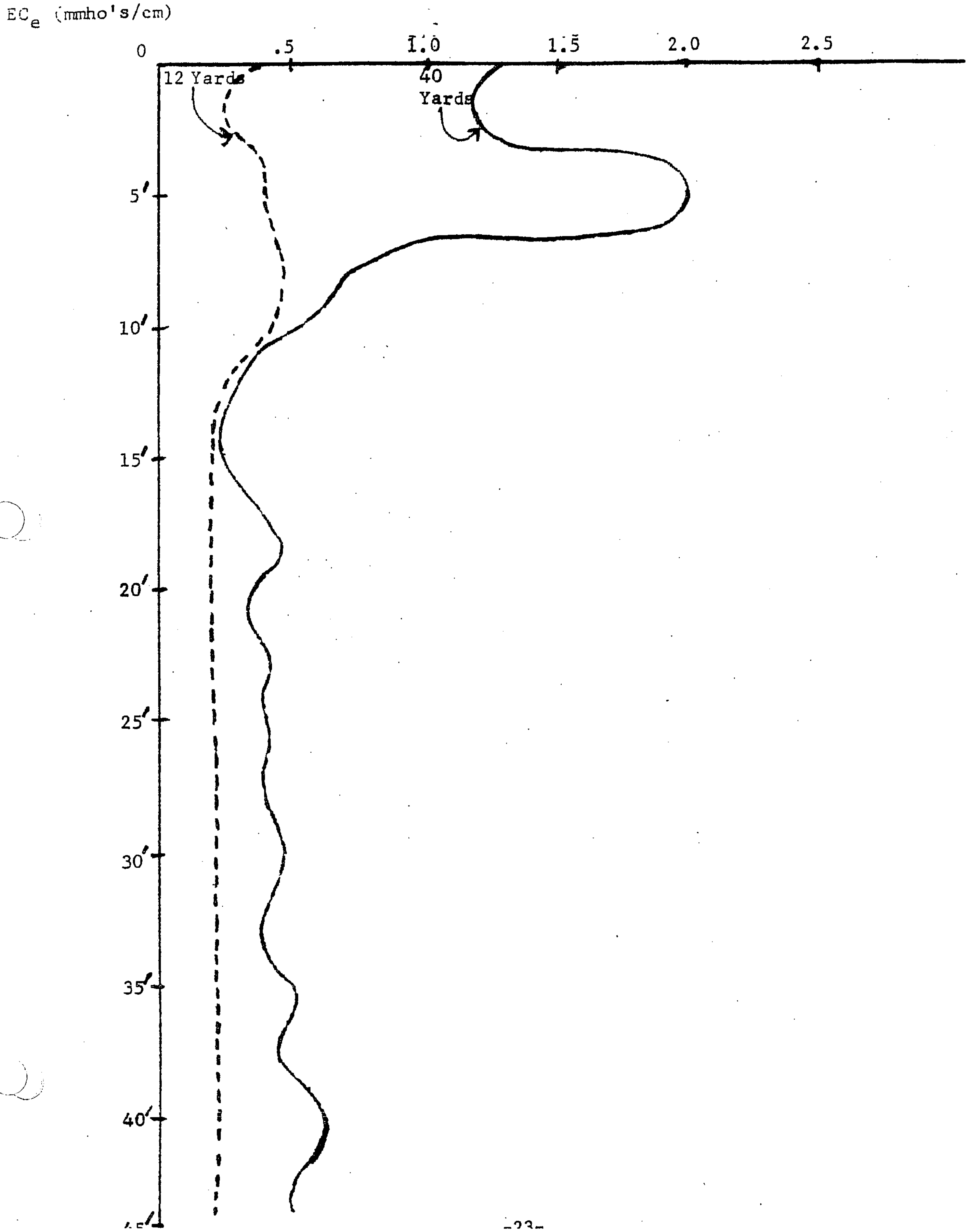


Table 11.

Typical soil analysis of cropland: 15 years corn-oats, 10 years 40 yards per acre manure plus 150 pounds nitrogen applied to corn.

Sampled in May, 1972 Previous to Annual Manure Application.

Depth Feet	pH	EC_e	Ca+Mg ME/L	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1
0-1	6.97	.28	2.2	4.8	740
1-2	6.95	.35	3.2	.7	200
2-3	7.00	.32	2.4	.4	80
3-4	7.00	.32	2.4	.5	120
4-5	7.00	.24	1.4	8.5	60
5-6	7.10	.36	1.4	7.7	40

Hardpan at 6 Feet

Table 12.

Soil analysis September 1972,(end of corn season). 1960-1972 corn oats: 150 pounds nitrogen (commercial), 12 yards manure 1971: 3 irrigations barn wash water,1972.

Depth Feet		pH	EC_e	Ca+Mg ME/L	Ammonium-Nitrogen mg/l	Nitrate-Nitrogen mg/l	Total Nitrogen mg/l
0-1		6.3	0.28	1.2	-0-	0.5	540
2		6.5	0.25	1.6	6.12	0.26	200
3		6.4	0.30	1.2	-0-	0.33	140
4		6.4	0.30	1.4	-0-	0.48	140
5		6.8	0.31	1.8	-0-	0.77	140
6		6.7	0.34	1.2	-0-	1.17	140
7		6.6	0.35	1.9	-0-	1.53	140
8		6.5	0.36	2.0	-0-	1.66	100
9		6.4	0.41	2.6	-0-	2.10	140
10		6.5	0.38	2.4	-0-	2.28	80
11		6.5	0.29	1.8	-0-	1.60	40
12		6.7	0.25	1.4	-0-	1.08	20
13		6.4	0.25	1.6	-0-	0.96	60
14		6.4	0.22	1.4	-0-	0.96	60
15		6.6	0.20	1.4	-0-	0.65	20
16		6.6	0.20	1.2	-0-	0.66	60
17	HP	6.6	0.36	2.4	-0-	1.22	80
18	HP	6.7	0.30	1.8	-0-	0.74	80

Table 13.

Soil analysis of cropland 1972. History: Pasture, liquid manure only. *

Depth Feet	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1
0-1	20	860
1-2	100	240
2-3	82	200
3-4	24	180
4-5	23	80
5-6	27	60
6-7	3.8	60
7-8	25.5	50

Hardpan at 8 Feet

* 800 cows per 120 acres
Milk barn water approximately 10 percent of total manure produced = total manure from 80 cows per 120 acres or 2 cows per 3 acres.

Table 14.

Commercial fertilizer only, soil analysis 1972. History: Pasture, commercial nitrogen only, (100 pounds of nitrogen per year).

Depth Feet	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1
0-1	9.5	860
1-2	6.0	420
2-3	5.8	140
3-4	3.4	160
4-5	2.9	160
5-6	2.8	100
6-7	18.4	60
7-8	2.2	60

Hardpan at 8 feet

Table 15.

Soil analysis 1972. History of an eight year commercial nitrogen apricot fertilizer plot. (50 N/A/Yr. versus 400 N/A/Yr.)

	50N		400 N	
Depth Feet	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1	Nitrate-Nitrogen mg/1	Total Nitrogen mg/1
0-1	5.3	700	142	980
1-2	12.0	520	175	600
2-3	12.0	440	23	300
3-4	3.7	300	24	220
4-5	6.3	300	54	300
5-6	2.9	380	57	460
6-7	3.4	240	16.3	300
7-8	4.8	180	10.0	200

lower and B.O.D. is higher. All factors of stratification appear to be favorable for rapid sealing with low losses of nutrients and salts.

Manure disposal to cropped lands needs further investigation However, under San Joaquin Valley cropping of corn silage (summer) and cereal oats (winter), "reasonable" manure rates seem to be in the range of 10 to 20 yards (6 to 12 tons) per acre per year. The results in this report indicate that these rates are not contributing significant salts for leaching through either deep, open, permeable soils or restricted soil profiles.

This study does indicate, under stratified soil conditions, large manure application rates based solely on nitrate-nitrogen can be safely used. Denitrification probably accounts for the losses in stratified soils. Salts, however, do accumulate on pan layers in greater amounts under heavy manure loading.

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