GUIDELINES FOR
ON-FARM
SUB-SURFACE ARTIFICAL
DRAINAGE SYSTEMS

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INTRODUCTION

This guide is a compilation of data from several references and is specifically for Coachella Valley crops and irrigation.

It will attempt to take the user from the request of a landowner wishing to install tile drains through the completed system.

BACKGROUND

The Indio F.O. has in its possession the records of the soil profiles determined during the development of the Coachella Valley Soil Survey. In most instances, these borings extend to a depth of 7 feet.

The borings are maintained in an orderly fashion in binders. The borings are grouped by Avenue, starting from Ave. 38 and proceeding South to the Salton Sea-Ave. 86. To further facilitate locating a particular point, the borings make reference to the Streets that run North to South. These Streets are named after U.S. Presidents in the order of their election to that office, (Washington, Adams, Jefferson, etc.) and go from West to East. Even numbered Avenues are 1 mile apart as are the Presidents.

Each boring is approximately 660 feet apart. This allows for at least 9 individual borings to fall on each 40 acre field. This works quite well, as the Coachella Valley Water District (CVWD) is designed on a 40-acre field system. This provides an irrigation meter at the corner of each field.

The CVWD also maintains the Master Drain System (Fig.1). The CVWD drains are usually concrete pipe set deep into the ground. They do, however, maintain several open drains. Most drains empty into the Whitewater River, which in turn empties into the Salton Sea.

This drainage system functions very well. More information concerning the CVWD drains can be obtained through the CVWD in Coachella.

STEPS IN THE DESIGN OF TILE DESIGN SYSTEMS

STEP 1 - The Indio F.O. is approached by a landowner who requests information on a possible drainage problem.

STEP 2a- The SCS technican consults the Coachella Valley Soil Survey to locate the property and determine the soil type. Soils which fall into the Capability Subclass of "W" or Capability Unit of "2" will require artifical subsurface drainage to sustain maximum production of agricultural crops.

STEP 2b- Consult the recent copy of the CVWD Coachella Valley Drainage and Stormwater Outlet System (Fig.1) This map will indicate if a drainage system exists on the land in question. A copy of the Tile system layout can be obtained from the CVWD.

STEP 3a- Consult the map located in the back of the Indio F.O. working copy of the CV Soil Survey Map binder. This map is a scale map of the CVWD irrigation delivery system. Printed inside each 40 acre block is the Weighted Average Permeability to a 7' soil depth. This number was determined by using the Soil Profile sheets.(Fig. 2),(step 3b) Locate the parcel in question and record the appropriate number. If no number, go to step 3b.

STEP 3b- If no Average Permeability number appears in the field in question and the soil is mapped as "Wet", refer to the Soil Profile books. Obtain a blank Design Summary Soil Permeability Chart CF-ENG-110. (Fig.3) Average each one foot increment through the profile sheet, excluding the top one foot. Place these average, weighted numbers in the appropriate spaces on SCS form CF-ENG-110. Follow the directions on the form to arrive at the weighted average permeability for the parcel in question.

STEP 4 - When the average weighted permeability has been determined, go to the inside back cover of the office Soil Survey Map book. On the cover is a graph of Weighted Average Permeability versus Spacing @7' tile depth. (Fig.4) This curve can be safely used as all on-farm drainage systems are at a 7' average depth. This curve has been determined by the formula:

$$S^2 = \frac{4P(b^2-a^2)}{.0065}$$

(See: Drainage Guide: Tile Drain Spacing - Appendix)

STEP 5a- Enter the graph on the Average Weighted Permeability side of the curve. Pivot the curve down to the spacing line. (Fig.4) This will give the average spacing between lateral lines in the field.

STEP 5b- Compare this proposed spacing with the actual spacing if a drainage system exists on the property. (from Step 2b) If the existing system is too wide, recommend placing new laterals between the existing laterals. (tile split) If the system is old and the field has been abandoned for years, advise the landowner that an entire new system may need to be installed, due to root encroachment of the envelope and tile line. A field investigation is needed to determine if the old system is functional, needs cleaning and repair, or should be replaced.

STEP 6 - Consult with the CVWD to determine what CVWD Main Drain that the field will drain into. Determine the "fall" of the land for placement of the drainage system.

STEP 7 - Refer to Fig. 5- Tile Design.
Set the field base line into the field ½ the tile spacing or more if conditions warrent. The outer most lateral lines are set ½ the tile spacing in from the property line or a minimum of 100' from an existing or planned Athel windbreak. Measure the distance between the two lateral lines and divide by the planned spacing. Adjust the spacing distance to install laterals at equal distances. It is better to install an extra line at closer than determined distance than further apart. Use an average pull-out at the end of each lateral of from 30'-50'. The pull-out is the distance from the end of the lateral tile line to the edge of cultivation or obstructions near the field boundary.

STEP 8 - Complete Construction Requirements No 606 Subsurface Drain (Fig.6)
Item 8. Special Requirements should note the following:

Envelope material / 1001.f tile

- 4" tile - 2.5 cy
- 5" tile - 3.0 cy
- 6" tile - 3.5 cy
- 8" tile - 4.0 cy

Artificial Fabric Filter Material is not recommended in the Coachella Valley due to the variation of fine material in the soils.

(Suitable envelope material is available from:

- Massey Sand & Rock
- Oasis Pit
- Vans Filter Rock
- La Bolsa-Westmorland Pit Run)

Refer to No 606 for more information on construction requirements.

STEP 9 - The tile design is now complete except for approval by the field office engineer or someone who has the delegation of authority to approve the design. Most tile designs in this office will be Class 1.

STEP 10- Present and explain the design and requirements to the landowner. Document all work on appropriate forms.

Plastic tile systems are recommended because they are less expensive than concrete systems. They can be easily attached to an existing concrete baseline if present. Plastic lines are also easily cleaned when necessary. Life expectance is 20+ years.

The most important aspect of any tile system is to obtain suitable envelope material. A poor envelope surrounding the tile line will decrease the effectiveness of that system and not give adequate drainage.

SOIL PROFILE CHART

For Drainage Investigation

2 - Silty clay, Clay
3 - Silty clay loam, Clay loam
4 - Silt loam, Loam, Very fine sandy loam
5 - Sandy loam, Loamy fine sand, Loamy very fine sand
6 - Fine sand
7 - Sand

Property EXAMPLE

Boring No. 55,5-Jack, 875 Land Use D... Crop Condition ...

Technician ... Date Survey 6/... Symbol 11.4.4.6

P=1.22

Depth in Feet	Texture	Special Features
0.0	LVFS	
1.0	VFSL	.75
2.0		.55
3.0	SiL	
	VFSL	.75
4.0		.55
5.0	SiL	
	FSL	.9
6.0	LFS	
	water	2.5
7.0		2.5
8.0		
9.0		
10.0		

Permeability Mapping Symbol: 2 | 3 | 4 | 5 | 6 | 7

Permeability Rate - inches per hour: .05 | .07 | .08 | .10 | .15 | .20 | .25 | .50 | 1.0 | 2.5 | 3.3 | 4.2 | 5.0 | 5.7 | 6.3

M-1228

Fig. 2 7-L-11351

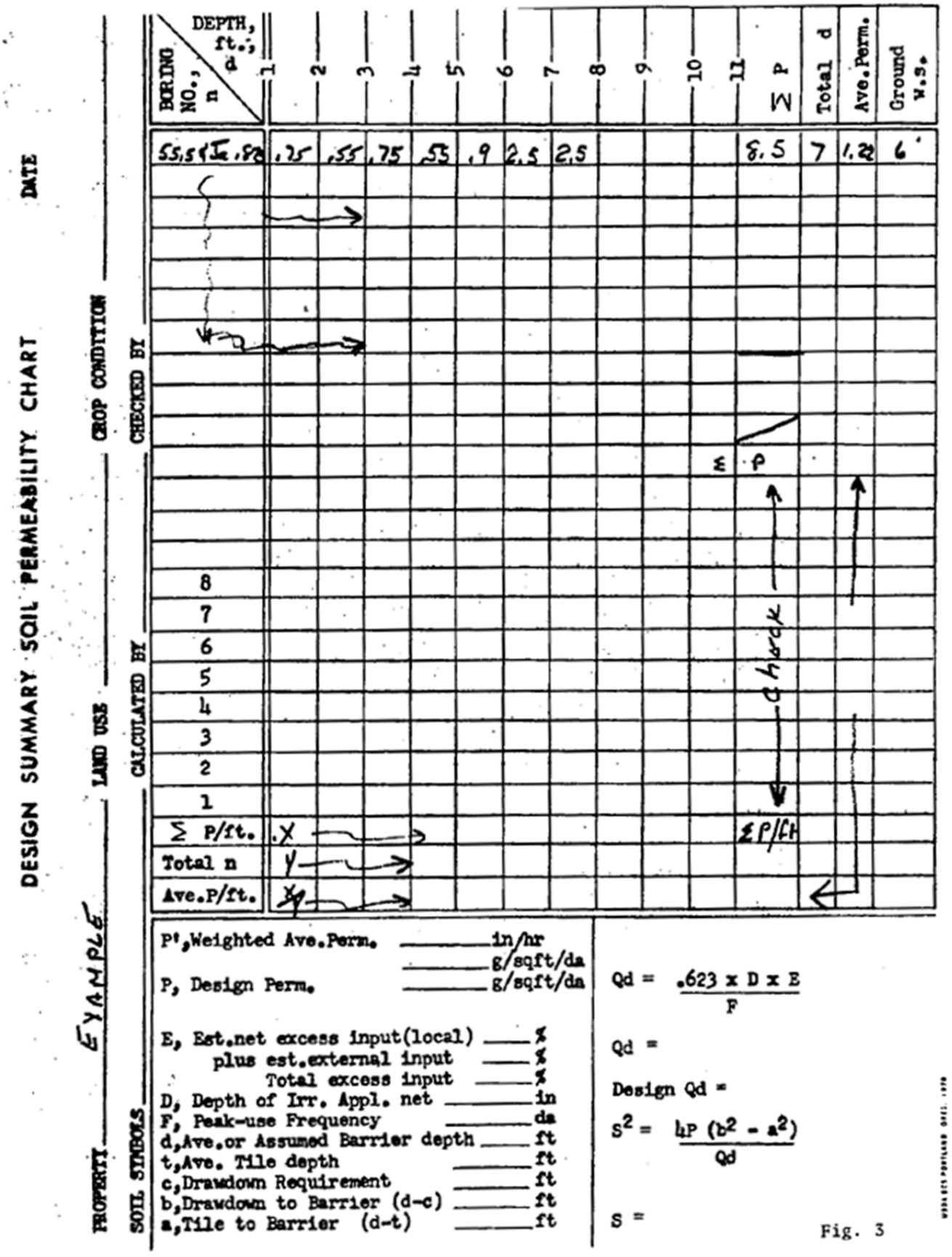

Fig. 3

(Rev 7/5/13)

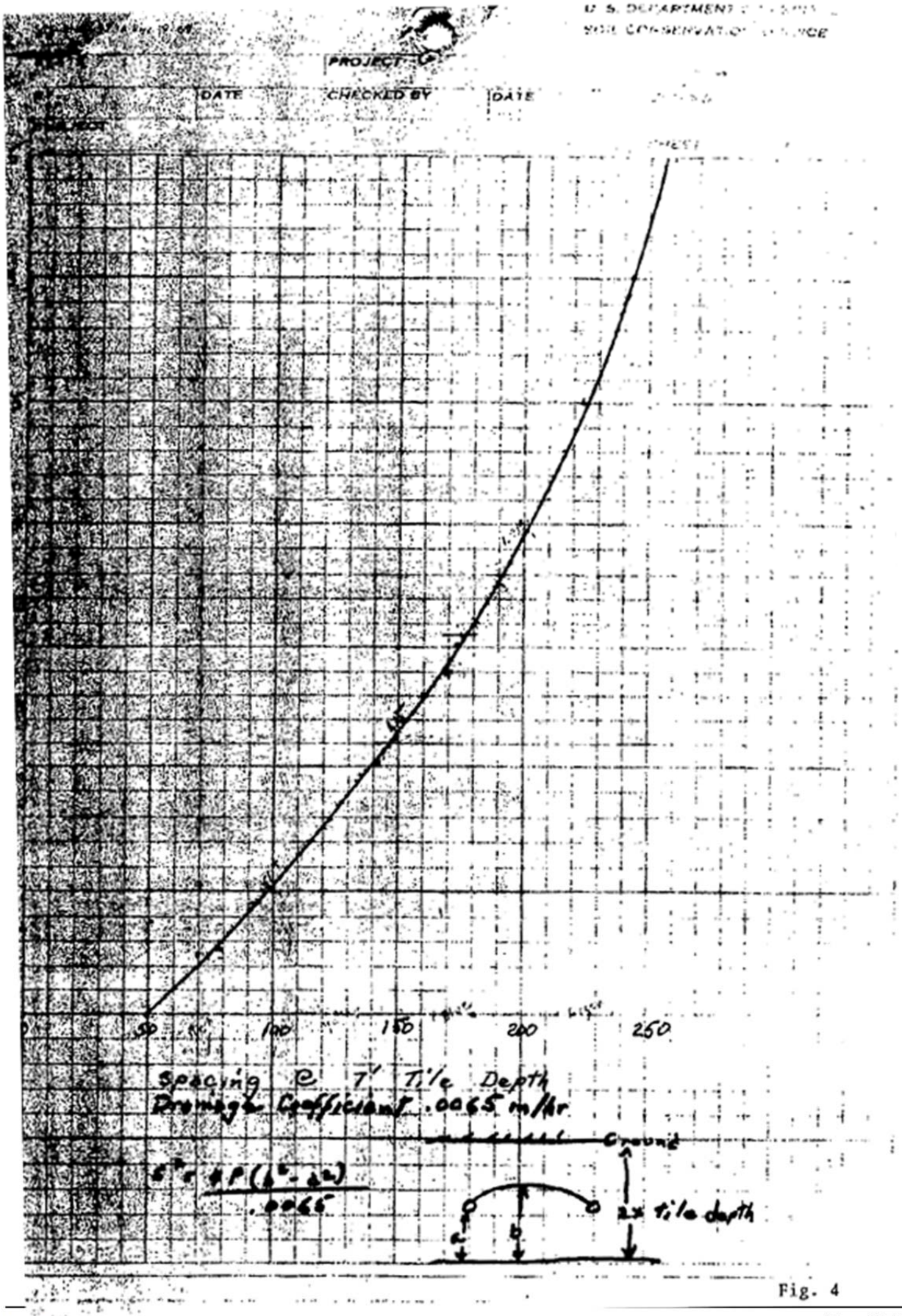

Fig. 4

(Rev 7/5/13)

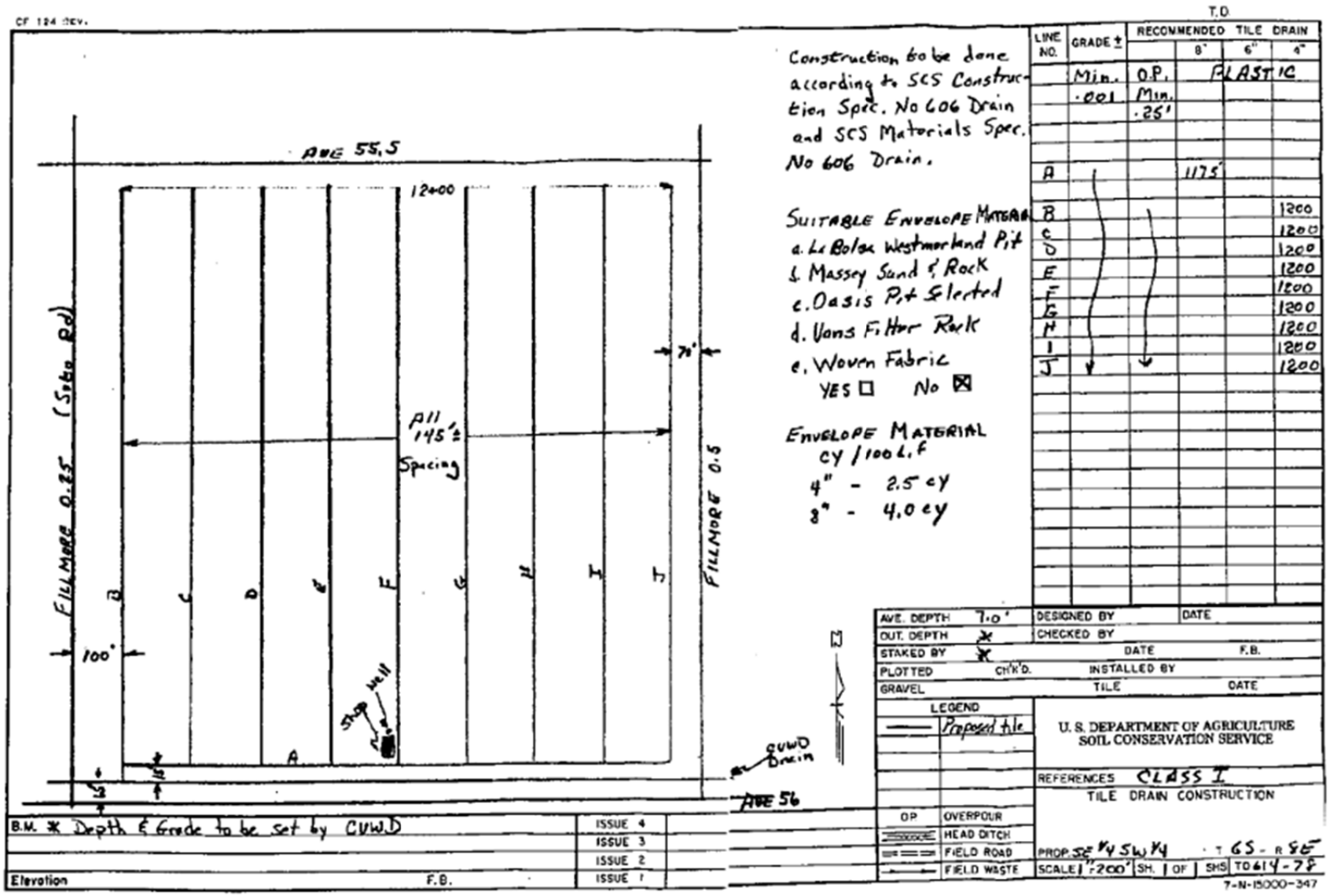
CF 124 Rev.
AVE 55.5
12+00
FILLMORE 0.25 (Sisto Rd)
FILLMORE 0.5
100'
70'
All 145'±
Spacing
A
B
C
D
E
F
G
H
I
J
Stock Well
CVWD Drain
AVE 56
N
Construction to be done according to SCS Construction Spec. No 606 Drain and SCS Materials Spec. No 606 Drain.
SUITABLE ENVELOPE MATERIAL
a. La Bolsa Westmorland Pit
b. Massey Sand & Rock
c. Oasis Pit Selected
d. Vons Filter Rock
e. Woven Fabric
YES ☐ No ☒
ENVELOPE MATERIAL
CY / 100 L.F
4" - 2.5 cy
8" - 4.0 cy
T.D
LINE NO.
GRADE ±
RECOMMENDED TILE DRAIN
8" 6" 4"
Min. .001
O.P. Min. .25'
PLASTIC
1175'
1200
AVE. DEPTH 7.0'
OUT. DEPTH
STAKED BY
PLOTTED
GRAVEL
DESIGNED BY
DATE
CHECKED BY
DATE
F.B.
CH'K'D.
INSTALLED BY
TILE
DATE
LEGEND
Proposed tile
OP OVERPOUR
HEAD DITCH
FIELD ROAD
FIELD WASTE
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
REFERENCES CLASS I
TILE DRAIN CONSTRUCTION
PROP. SE¼ SW¼ T 6S - R 8E
SCALE 1"=200' SH. 1 OF 1 SHS TO 614-78
7-N-15000-347
B.M. * Depth & Grade to be set by CVWD
Elevation F.B.
ISSUE 4
ISSUE 3
ISSUE 2
ISSUE 1

Fig. 5

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CALIFORNIA

CONSTRUCTION REQUIREMENTS

No. 606

SUBSURFACE DRAIN

For: Owner: _____

Job Location: _____

County: _____ RCD: _____

Farm No. _____ Date: _____ Prepared By: _____

IT SHALL BE THE RESPONSIBILITY OF THE OWNER TO OBTAIN ALL NECESSARY PERMITS AND/OR RIGHTS, AND TO COMPLY WITH ALL ORDINANCES AND LAWS PERTAINING TO THIS CONSTRUCTION.

Construction shall be in accordance with the following requirements, Construction Specification No. 606 attached, other listed and attached construction specifications, and as shown on the listed and attached drawings and/or as staked in the field:

1. Type of drain conduit material: _____
2. ASTM or other Specifications: _____
3. Filter or Envelope Material: _____
4. Type of drainage outlet: _____
5. Structures required (such as man holes, junction box, or sump):

   _____

6. Other specifications, No's: _____, _____, _____, _____,

   _____, _____, _____, _____, _____, _____, _____.
7. Drawings, No's: _____, _____, _____, _____.
8. Special Requirements: Filter material 1100 L.F. T/C

   4" = 2.5 C.Y.; 5" = 3.0 C.Y.; 6" = 3.5 C.Y.; 8" = 4.0 C.Y.

   _____

Fig. 6

2/78

CONSTRUCTION SPECIFICATION

SUBSURFACE DRAIN

I. Scope

The work shall consist of installing a subsurface drain including the filter materials to the lines, grades, and elevations as shown on the drawings or as staked in the field.

II. Inspection and Handling of Materials

Material for subsurface drains shall be given a careful inspection before installation. Where applicable, clay and concrete tile shall be checked for damage prior to installation. Bituminized fiber and plastic pipe and tubing shall be protected from hazards causing deformation or warping. Plastic pipe and tubing with physical imperfections shall not be installed. A damaged section shall be removed and a suitable joint made connecting the replaced and retained sections. All material shall be satisfactory for its intended use and shall meet applicable specifications and requirements.

III. Placement

All subsurface drains shall be covered with the specified blinding, envelope, or filter material to a depth of not less than 3 inches around the drain. If the option to install an impervious sheet over the drain is used, at least 3 inches of blinding material must cover the sheet. No reversals in grade of the conduit shall be permitted.

Where the conduit is to be laid in rock trench, or where rock is exposed at the bottom of the trench, the rock shall be removed below grade enough that the trench may be backfilled, compacted, and bedded; and when completed, the conduit shall be a minimum of 2 inches from rock.

Joints between drain tile should not exceed 1/8 inch except in sandy soil where the closest possible fit should obtained. In organic soil where some the more fibrous types make it desirab to increase the space between the tile slightly.

Flexible conduits, such as plastic pip or tubing and bituminized fiber pipe, shall be installed according to the requirements in ASTM-F-449, "Standard Recommended Practice for Subsurface Installation of Corrugated Thermoplast Tubing for Agricultural Drainage or Water Table Control."

Earth backfill material shall be placec in the trench in such a manner that displacement of the conduit will not occur and so that the filter and beddin material, after backfilling, will meet the requirements of the plans and speci fications.

When a filter is specified, all opening in the subsurface drain shall be protec by the filter, or the bottom and sides of the conduit are to be protected by the filter and top of conduit. Part of the side filter material which is to be covered by a sheet of impervious plasti No portion of the conduit containing openings shall be left exposed when the use of a filter is specified.

If sand-gravel filter material is used, the trench shall be over excavated 3 inches and backfilled to grade with filter material. After placement of th conduit on the filter material, addi- tional filter material shall be placed over the conduit to fill the trench to depth of 3 inches over the conduit. A plastic sheet and friable soil can be used in lieu of filter material as the backfill over the subsurface drain when specified.

IV. Filter Material

Unless specifically excepted in these specifications, filter shall consist of a blend of clean sand and gravel, which is not subject to decomposition in air or water and is free from roots and other foreign materials. The size gradation limits shall be as specified on the drawings or as listed on the "Construction Requirement" sheet.

V. Envelope Materials

Envelope material shall consist of sand-gravel material, all of which shall pass a 1 1/2 inch sieve, 90 to 100 percent shall pass a 3/4 inch sieve, and not more than 10 percent shall pass a No. 60 sieve.

VI. Artificial Fabric Filter Material

The filter material may be fiberglass, knitted polyester or nylon, spun bonded nylon or plastic filter cloth. Fiberglass material shall be manufactured from borosilicate type glass and the manufacturer of the material shall certify that it is suitable for underground use. The fibers shall be of a variable size with some larger fibers intertwined in the mat in a random manner.

All tears or other areas where the blanket continuity is terminated, except at the ends of lines, shall be spliced with a minimum overlap of 4 inches.

VII. Corrugated Thermoplastic Tubing

A. Trenching. The recommended minimum cover in mineral soil to protect the tubing from crushing due to live loads is 2 feet. The minimum in organic soils is 2.5 feet.

In unstable trenches, means must be provided to protect the tubing from deformation oir floating until it has been properly liad and blinded. Provisions for safety during trenching operations shall be in compliance with the applicable safety and health regula tions for construction.

Bedding. The trench bottom shall be smooth and free of clods, loose or exposed rock. Where a gravel envelope is not specified, the bottom of the trench shall be shaped to conform to th pipe. The groove may be semicircular, trapezoidal shaped or a 90° V and shall be of such dimensions that the bottom one quarter of the pipe is in contact with undisturbed soil.

In unstable soils a firm foundation shall be provided by over excavation ar backfilling with processed stone or gravel, suitably graded so as to act as a mat into which the unstable soil will not penetrate. Where stabilizer materials do not provide adequate support, tubing shall be placed in a 90° rigid V prefabricated foundation cradle. The cradle must provide rigidity and furnis continuous support throughout the entire length.

If the bottom of the trench contains stones in excess of 1 1/2 inches in diameter or is in rock cut, the trench shall be over excavated 6 inches and refilled to grade under and around the tubing with a 6-inch cushion of acceptable gravel envelope will be completed to 3 inches above the tubing unless a plastic sheet is placed at the top of the tubing.

The envelope or filter material shall be carefully placed to form an even firm bedding without disturbing the tubing grade and alignment. When artificial fabric filter material is used, all open joints and perforations will be protected. If fabric filter materia is damaged during installation, it sha be repaired before backfilling with a minimum 4-inch overlap.

B. Placement. Additional care is nee when installing tubing on hot bright days or days when the temperature is l

The tubing should not be stretched more than 5 percent under any circumstances. When installing the tubing on hot days, backfilling shall be delayed until tubing temperature cools to the soil temperature.

Fitting shall be installed in accordance with manufacturer's instructions. Couplers shall be used at all joints and fittings, at all changes in direction, changes in diameter, junction with another line, and at the end of lines. All fittings shall be compatible with the tubing. Where certain fittings are not available, hand cut holes are acceptable provided care is taken not to create a means of obstructing flow, catching debris or allowing soil to enter the line, when making the connection.

Use nonperforated tubing when passing through areas where root growth may create an obstruction in the line. Nonperforated tubing will also be used where small pockets of noncohesive soil are encountered unless special envelopes or other means are used to stabilize the soil.

Place select bedding material containing no hard object larger than 1 1/2 inches in diameter in the trench to a recommended depth of 6 inches over the tubing.

Place the backfill material so that displacement or deflection of the tubing will not occur. This is preferably on an angle, so the material flows down the front slope. Avoid large stones, frozen material, and dry clods. The trench should be backfilled as soon as possible after blinding.

Corrugated thermoplastic tubing installed by mole plow will meet same requirements stated above for envelopes and filter material.

VIII. Outlet Pipe and Guard

Outlet pipe will be installed as shown on the drawings with adequate rodent guard.

IX. Drain Pipe

The pipe shall conform to the specification listed on the "Construction Requirement" sheet. Prior to purchase the owner should check with the Engine to determine if the manufacturer of th pipe is listed on the "Prequalified" list of suppliers.

X. Basis of Acceptance

The acceptability of the drain shall b determined by inspections to insure compliance with all the provisions of this specification with respect to the design of the line, the pipe and pipe markings, the appurtenances, and the minimum installation requirements.

XI. Vegetative Cover

Unless otherwise specified, a protecti cover of vegetation shall be establishe on the disturbed area. The planting o vegetative materials shall conform to the requirements of Construction Specification 342, Critical Area Planting.

XII. Special Measures

Measures and construction methods shall be incorporated as needed and practical that enhance fish and wildlife values. Special attention shall be given to pro tecting visual resources and maintainir key shade, food and den trees.

XIII. Construction Operations

Construction operations shall be done i such a manner that erosion and air and water pollution are minimized and held within legal limits. The owner, operat

contractor or other persons will conduct all work and operations in accordance with proper safety codes for the type of construction being performed with due regards to the safety of all persons and property.

The completed job shall be workmanlike and present a good appearance.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
COACHELLA WORK UNIT

DRAINAGE GUIDE: TILE DRAIN SPACING

This guide is a compilation of data from several references and is specifically for Coachella Valley crops and irrigation.

Spacing of tile drains should be based on the salt tolerance of the crop, quality of irrigation water, soil permeability, and amount of water to be drained.

The salt tolerance of many crops has been studied and the reductions in yields measured. 2/ 3/ This guide assumes that salt tolerance of a crop to be the soil salinity at which one gets 50 percent yield decrease for the crop in question. 3/ The salt tolerance of the (fruit) crop is generally about 1½ times greater than the (soil) salinity level at which small (10%) decreases in yield of the crop occur. 2/

The quality of irrigation water determines the amount of water in addition to the consumptive use of the crop that will be needed to maintain a favorable salt balance. This guide is based on the use of Colorado River water which has an Electrical Conductivity (EC) of 1.2 Millimhos per centimeter.

Soil permeability is the weighted average permeability of the soil to a depth of at least 7 feet and preferably 9 feet. The first foot of soil is excluded. This value is obtained by use of the Soil Profile Chart or the Design Summary Permeability Chart. 1/

The amount of water to be drained is called Design Qd and is determined by comparing the depth of Drainage Water (Ddw) required to maintain a favorable salt balance and the Depth of Deep Percolation Water (Dpw) resulting from irrigation inefficiency.

The Depth of Drainage Water (Ddw) tells us the amount of water to be drained during the peak irrigation season in order to maintain a salt balance favorable for that crop. The amount of this extra water can be computed by using the formula:

$$Ddw = \frac{EC\ iw}{EC\ dw - EC\ iw} \times Dow \quad 1/$$

Where Ddw = depth of drainage water
Dow = depth of consumptive use
ECiw = electrical conductivity of irrigation water
ECdw = electrical conductivity of drainage water or tolerance of the crop

Given ECiw = 1.2 Millimhos per centimeter for Colorado River irrigation water in Coachella Valley

ECdw =
- 16.0 for Cotton 3/
- 12.0 for Sorghum 3/
- 12.0 for Date Palm 2/
- 8.0 for Alfalfa 3/
- 6.0 for Sweet Corn 3/
- 6.0 for Grapes 2/
- 4.5 for Oranges, Grapefruit 2/
- 4.0 for Carrots 3/
- 3.75 for Lemons 2/

Then

	ECdw	ECiw	ECiw / ECdw-ECiw	Dcw inches/day	Ddw inches/day
Cotton	16.0	1.2	.081	.33	.027
Sorghum, Date Palm	12.0	1.2	.111	.33	.037
Alfalfa	8.0	1.2	.176	.33	.058
Sweet Corn, Grapes	6.0	1.2	.250	.31	.078
Oranges, Grapefruit	4.5	1.2	.364	.33	.120
Carrots	4.0	1.2	.429	.31	.133
Lemons	3.75	1.2	.471	.33	.155
Grapes 5/	6.0	1.2	.250	.80	.200

Drainage water also comes from Deep Percolation Losses during irrigation. The on-farm irrigation efficiency in Coachella Valley is estimated to be 65% with losses of 5% by evaporation and 30% by Deep Percolation. The amount of Deep Percolation water during the peak irrigation period can be computed by:

$$D_{pw} = \frac{D\,P_x}{I\,E} D_{cw}$$

Where
- Dpw = depth of deep percolation water
- D P = % of irrigation lost by deep percolation
- I E = % of irrigation efficiency
- Dcw = Depth of consumptive use during peak period

Given
- D P = 30%
- I E = 65%
- Dcw = 0.31 inches/day for grapes, sweet corn, carrots
  0.33 inches/day for cotton, dates, sorghum, alfalfa, oranges, grapefruit, lemons.
  0.80 inches per day for grapes 5/

Slope Ft/Ft	Inside Diameter of Pipe Corrugated Plastic (n = 0.016) 3	4	6	8	10
.001	10	22	65	140	255
.0015	12	27	80	170	310
.002	14	32	92	200	360
.0025	16	35	103	220	400
.003	18	38	112	240	440
.004	21	44	130	280	500
.005	23	50	145	310	560

Example Problem #1:

At what distance downstream will a 5 inch I.D. concrete drain pipe on a slope of 0.001 feet per foot need to be changed to a larger diameter pipe if the Design Qd is 0.152 inches per day and the tile spacing is 144 feet.

Given : Design Qd = 0.155 inches per day = 3.0 gpm (Table I) per acre (43,560 sq.ft.)

: Tile spacing = 144 ft.

: 5 inch ID concrete drain pipe on slope of 0.001 Ft/Ft has a design capacity = 49.1 gpm (Table II)

Then : $\frac{49.1 \text{ gpm}}{3.0 \text{ gpm/acre}}$ = 16.4 acres drained

16.4 acres x 43,560 sq.ft./Ac = 714,384 sq. ft. drained

$\frac{714,384 \text{ sq. ft.}}{144 \text{ ft. width}}$ = 4961 feet downstream

Example Problem #2:

What is the maximum drainage area an 8 inch ID concrete drain pipe on a slope of 0.001 feet per foot can serve if the Design Qd is 0.152 inches per day?

Given: Design Qd = 0.155 inches per day = 3.0 gpm per Acre (Table I)

Design capacity of 8 inch ID concrete pipe or s = .001 is 172 gpm (Table II)

Then: $\frac{172 \text{ gpm}}{3 \text{ gpm/ac}}$ = 57.3 ac.

Answer = 57.3 ac.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

COACHELLA WORK UNIT

DRAINAGE GUIDE: DESIGN CAPACITY OF TILE DRAIN PIPE

This guide is specific to Coachella Valley crops and irrigation.

The design capacity of drain pipe is taken at full flow. This is based on the fact that full flow will occur for only short periods after irrigation. The only other possible time that tile lines could flow full is during leaching. The leaching period generally lasts about 30 days.

Four (4) inch inside diameter pipe is the minimum acceptable size. For concrete and clay tile drains, five (5) inch inside diameter pipe is the minimum size recommended because of installation hazards in wet soils.

The distance "downdrain" that any size pipe will serve is based on the amount of water to be drained (Design Qd), the area being drained, and the capacity of the drain pipe.

The amount of subsurface water to be drained (Design Qd) has been calculated for the peak irrigation period and is presented in Table I.

TABLE I: CALCULATED PEAK SUBSURFACE DRAINAGE FLOWS

DESIGN Qd	DRAINAGE FLOW IN GALLONS PER MINUTE	
	Per Acre	Per 40 Acres
0.37 inches/day	7.0 gpm	280 gpm
0.155 inches/day	3.0 gpm	120 gpm

* Grapes
** Cotton, Date Palms, Sorghum, Alfalfa, Oranges, Grapefruit Lemons, Sweet Corn, Carrots.

Use the tile spacing to calculate the area drained by a length of drain pipe. Multiplying the area drained by the drainage flow per unit of area, we can calculate the expected flow at the downstream end of that length of drain pipe.

Pipe size is increased at the point where the expected flow equals the design capacity of the drain pipe.

DRAINAGE GUIDE: DESIGN CAPACITY OF TILE DRAIN PIPE

Design capacity of drain pipe is taken as full flow and can be calculated by using Manning's formula for pipes:

$$Q = \frac{0.463}{n} d^{8/3} s^{\frac{1}{2}}$$ (Kings Handbook of Hydraulics, 3d Edition, Pg 188)

Where:

Q = Discharge in cubic feet per second
n = Roughness coefficient = .013 for concrete, clay, and bituminous fiber, and .020 for corrugated plastic pipe
d = Inside diameter of pipe in feet
(d_1 = inside diameter of pipe in inches)
s = Slope or hydraulic graident in feet per foot

Given:

d_1	d	$d^{8/3}$	$\frac{0.463}{.013}$	$\frac{0.463}{.020}$	s	$s^{\frac{1}{2}}$
					.0005	.0224
					.0007	.0265
4"	.333'	.0532	35.615	23.15	.0010	.0316
5"	.417'	.0972	35.615		.0015	.0387
6"	.500'	.1570	35.615		.0020	.0447
8"	.667'	.3398	35.615		.0025	.0500
10"	.833'	.6140	35.615		.0030	.0547
					.0040	.632
					.0050	.0707

Then:

Design capacity of tile - GPM

Slope	Inside Diameter of Pipe				
Ft/Ft	Concrete - Clay - Bituminized Fiber (n = 0.013)				
	5	6	8	10	12
.001	50	79	172	310	500
.0015	60	97	210	380	600
.002	69	112	243	439	700
.0025	78	125	272	491	790
.003	85	137	297	537	870
.004	98	159	343	620	1000
.005	110	177	384	694	1120

Then

	D P / I E	Dcw inches/day	Dpw inches/day
Cotton, Sorghum, Date Palm, Alfalfa, Oranges, Grapefruit, Lemons	.46	.33	0.152
Sweet Corn, Grapes, Carrots	.46	.31	0.143
Grapes 5/	.46	0.80	0.368

DESIGN Qd is the total amount of drainage water in inches to be removed each day and is used in the DONNAN FORMULA for tile spacing. For each crop, use of design Qd equal to the Depth of Deep Percolation water (Dpw) when it is greater than the Depth of Drainage Water (Ddw). Otherwise use the Ddw value for the DESIGN Qd.

	Dpw inches/day	Ddw inches/day	DESIGN Qd inches/day	Qd in/hr
Cotton	.152	.027	.152	
Sorghum, DatePalm	.152	.037	.152	
Alfalfa	.152	.058	.152	
Sweet Corn, Grapes	.143	.078	.143	
Oranges, Grapefrt	.152	.120	.152	
Carrots	.143	.133	.143	
Lemons	.152	.155	.155	
Grapes 5/	.368	.200	.368	→ .0153
			.155	→ .00645

TILE SPACING can now be computed using the Nomograph for Solution of Donnan's Formula 1/

$$S^2 = \frac{4 P (b^2 - a^2)}{Qd}$$

Where:
- S = spacing of the tile lines in feet
- P = coefficient of permeability of the soil in same unit as Qd (inches per day) from soil Profile Chart (CF-144) or Design Summary Soil Permeability Chart (CF - 110)
- b = distance from draw down curve to barrier stratum at the mid point between the tile lines in feet.
- a = distance from the average tile depth to barrier stratum in feet.
- Qd = Quantity of water to be drained (inches per day).

Given
- b = 9 feet (using tile depth at 7.0 ft) 1/
- a = 7 feet (using tile depth at 7.0 ft) 1/
- Qd = 0.152 inches per day for cotton, dates, sorghum, alfalfa, oranges, grapefruit
  0.155 inches per day for lemons.
  0.143 inches per day for sweet corn, grapes, and carrots.

The tile spacing for the Coachella Velley will be designed with Qd = 0.155 inches per day for all crops except grapes when they are border irrigated. When they are border irrigated tile spacing for grapes will be designed with Qd = 0.368 inches per day.

Soil Permeability in/hr	Qd = .155	Qd = .368
.25	70	45
.50	100	65
.75	122	80
1.00	141	92
1.50	173	112
2.00	199	130
2.50	223	145
3.00	244	160

Example: Recommend the tile spacing for a field of grapes with a soil permeability of 2.5 inches per hour.

Solution: Reading across to column Qd = .368 inches per day. Recommended spacing is 145 feet. With an 11 foot grape spacing the tile would spaced at 143 feet, if 12 foot grape spacing the tile would be spaced at 144 feet.

The type of filter material used in the Coachella Valley is based on the permeability of the soil being drained. The sources of filter material are selected Oasis Pit, LaBolsa Westmorland Pit, Vans Filter Rock, and Massey Sand and Gravel. The filter rock and pea gravel are not recommended for use when the permeability of the soil is less than 0.75 inches per hour.

References:

1/ "Procedures and Use of Donnan Formula in Imperial and Coachella Valleys" by Paul Koluvek in part 7.1 of Engr. Handbook for work unit staffs.

2/ Table 2 of Agriculture Information Bulletin No. 292 "Salt Tolerance of Fruit Crops" in Reference section of Engr. Handbook for work unit staffs.

3/ Agriculture Information Bulletin No. 283 " Salt Tolerance of Plants" in Reference section of Engr, Handbook for work unit staffs.

4/ Irrigation Guide in the Work Unit Tech Guide.

5/ The spacing figures for grapes are derived from the irrigation practices of several ranchers in the Coachella Valley.