DELTA CROPS & SALT WATER INTRUSION WITH TWIN TUNNEL OPERATION

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Introduction

- Lower than normal Sacramento River flows allow deeper inland penetration of:
  - Tidal influences
  - Saltwater
- With *California Water Fix* tunnel operation, Sacramento River flows will continuously be below normal
- Thereafter, unceasing saltwater intrusion will affect the quality of riparian waters in the Delta

Introduction

- Seawater & brackish blends of sea & fresh water are rich in dissolved minerals, which are also known as salts
- High levels of sodium & chloride are among the minerals in seawater
- Seawater & brackish waters are, at the same time, saline, sodic, & high in chloride
- Saline, sodic, & high chloride waters harm crops in several ways

Introduction

- Woody perennial (tree & vine) crops are of particular concern with saline waters due to:
  - High initial capital costs for development
  - Long-term return investment expectations
  - Tree & vine sensitive to salinity
  - Long-term exposure over many years
  - Increasing orchard & vineyard acreage in the Delta

IRRIGATION WITH SALINE WATER

Soils & Irrigation

- The soil solution = the liquid in soils
- Soil solutions have little capacity to resist chemical changes
- Irrigation water passing through soils easily change soil solution chemistry
- Saline, sodic, & high chloride irrigation waters very rapidly make soil solutions similarly saline, sodic, & high in chloride

Saline Water & Plant Stress

- High salt concentrations in soil solutions create energy (osmotic) gradients
  - EC ≥ 1.5 to 2.5 dS/m
- Trees & vines have to work against energy gradients in soil solutions to take up water

Irrigation Water Salinity Effects on Grape Yields*

Irrigation Water Salinity (dS/m)	1.0	1.7	2.7	4.5
Estimated Grape Yield	100%	90%	75%	50%

Source: Gratton, SR. 2002.

*Pears & cherries, the most common tree crops in the north Delta, are more sensitive to salinity than grapevines.

SALINE-SODIC WATERS HARM SOILS PHYSICALLY

Saline Water & Soil Degradation

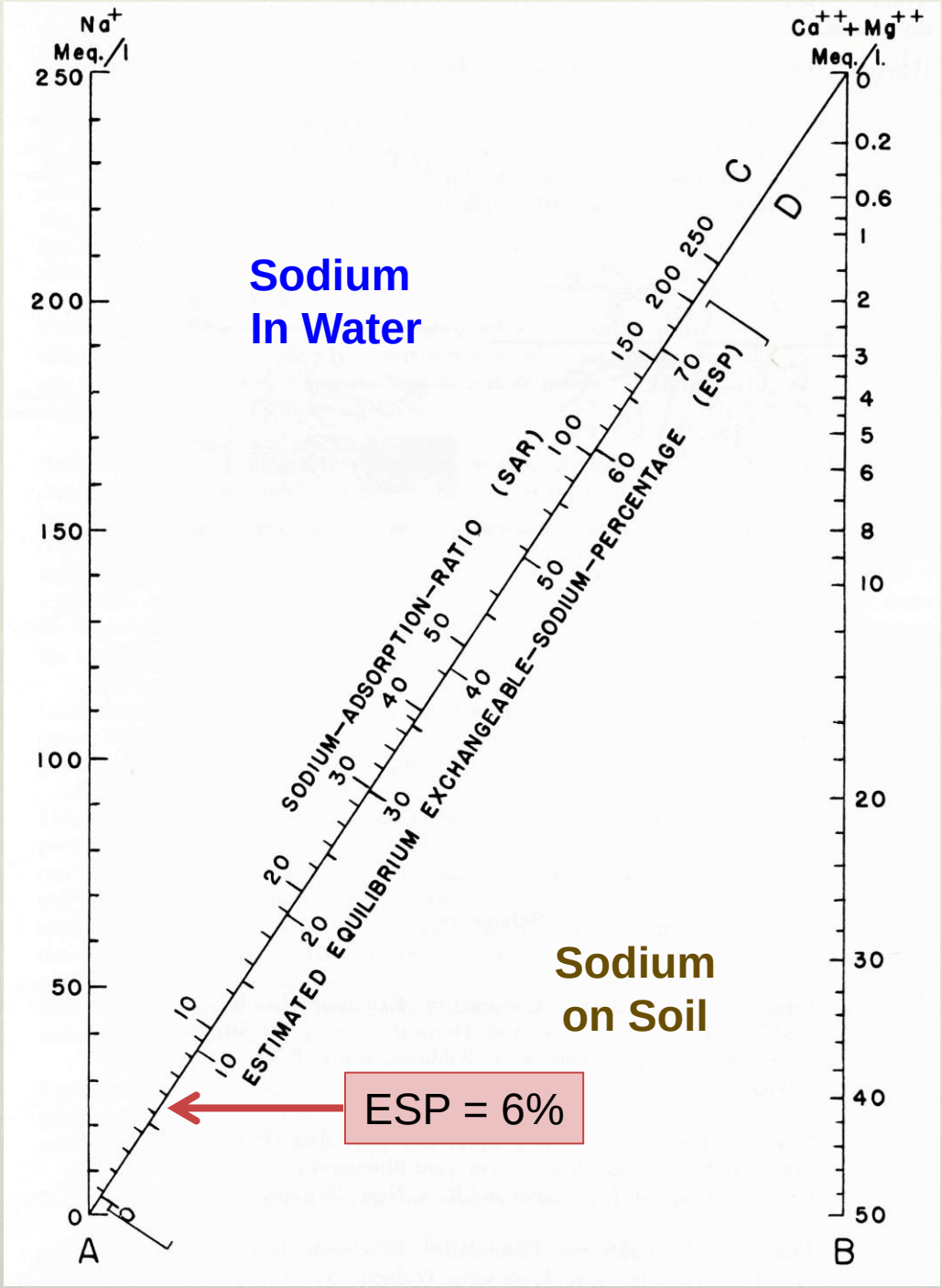
- Salts are electrically neutral associations of positively & negatively charged ions
  - Positively charged ions = cations
  - Negatively charged ions = anions
- Sodium is the most prevalent cation in river water-seawater mixtures
- Sodium markedly increases in soils receiving these waters for irrigations

Saline Water & Soil Degradation

- Soils are negatively charged
  - Charge in soils resides mainly on the surfaces of clay & organic matter particles
  - Cations adhere to soil particle surfaces
- Sodium displaces other cations on soil particle surfaces after sodic water is applied
  - The exchangeable sodium percentage (ESP) increases

Saline Water & Soil Degradation

- As the ESP approaches 6%, soil particles disperse rather than aggregate
  - Soil porosity decreases
  - Soil permeability to air, water, & plant roots substantially declines
  - The root environment is prone to waterlogging & increased plant pathogens
  - Plant growth & productivity diminishes
  - Crop water use efficiency erodes



Source: Neja, RA; Ayers, RS, Kasimatis, AN. 1978.

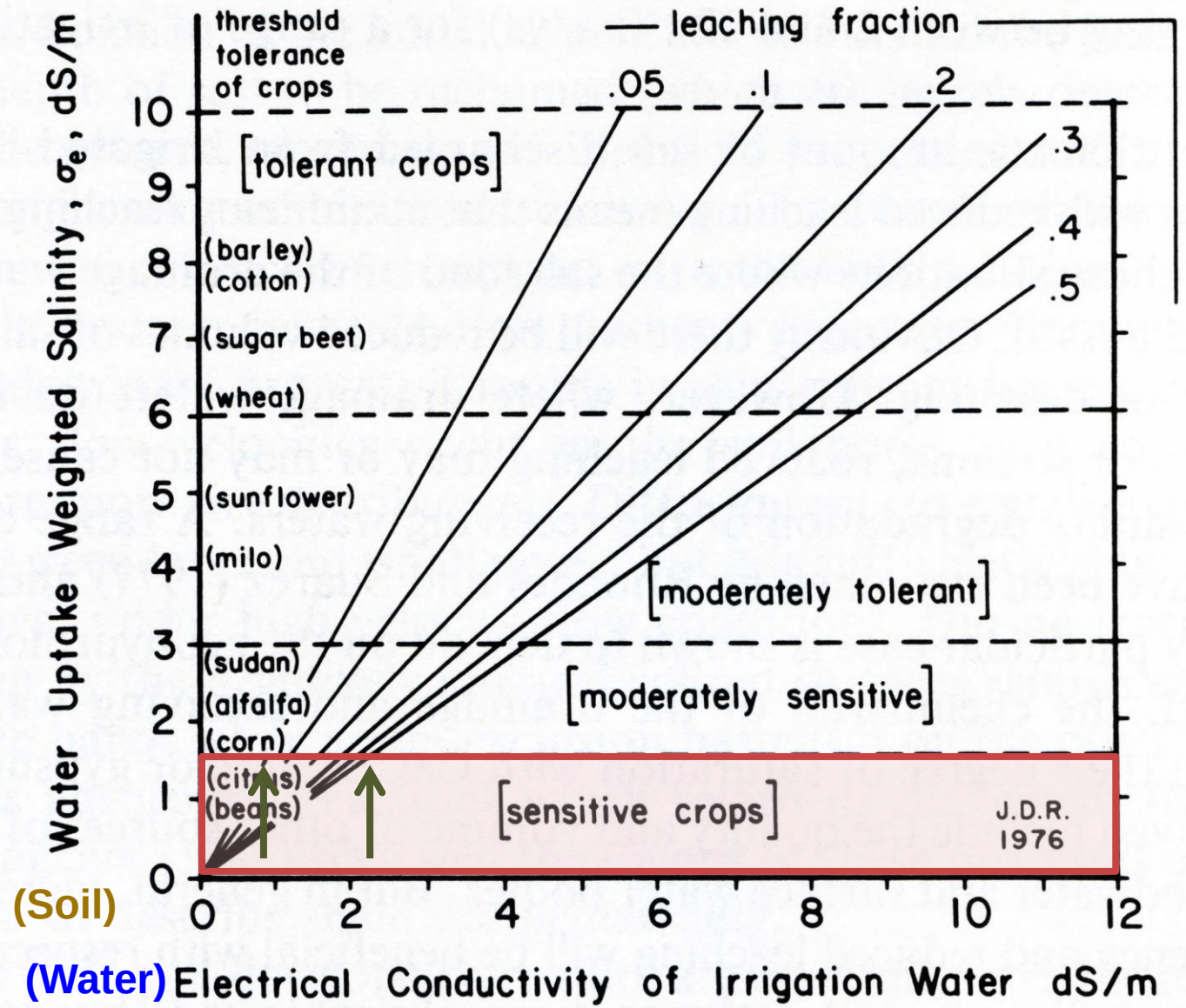
CROPS ON SALINE SOILS REQUIRE MORE WATER

Salinity Increases Water Needs

- To minimize water stress, crops irrigated with saline water need more water than when irrigated with Sacramento River water
  - To overcome salt induced water stress
  - To dilute & leach salts from root zones
- The extra water requirement = a leaching fraction (LF)

ASSESSING SALINITY HAZARDS

HIGH FREQUENCY IRRIGATION



Source: Rhoades, JD; Loveday, J. 1990.

Salinity Increases Water Needs

- Leaching fraction applications reduce:
  - The amount of applied water stored in root zones (application efficiency)
  - The amount of applied water beneficially used by crops (irrigation efficiency)
- Additional leaching fraction water also increases
  - Energy consumption for pumping
  - Labor, system maintenance, & other irrigation costs

SODIUM & CHLORIDE

Sodium & Chloride

- Sodium & chloride are the prominent ions in blends of intruded seawater & river water
- They readily associate due to their opposite charges (positive & negative, respectively)
  - However, they bond very weakly & sodium chloride salts are highly soluble
  - They readily dissociate
- Sodium & chloride readily move from soils into trees & vines as they take up water

Sodium & Chloride

- Sodium & chloride move with water as far as they can – the edges of leaves
- After accumulated sodium & chloride reach critical levels, tissues on leaf edges die
- In grapevines, critical concentrations are ≈ 0.25% sodium & 0.50% chloride

Late Season Chloride Toxicity in a Merritt Island Vineyard

Sample I. D.		MACRONUTRIENTS							MICRONUTRIENTS					POSSIBLE EXCESS	
Year	Block	Total N	NO3	P	S	K	Mg	Ca	Fe	Mn	Cu	Zn	B	Cl	Na
		%	ppm	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	%	%
10/26/10	P. Sirah weak	*NA*	581	0.15	0.15	0.3	1.06	3.6	470	137	3	151	145	1.2	0.02
10/26/10	P. Sirah good	*NA*	349	0.11	0.17	0.7	0.36	3.0	463	133	3	151	60	0.2	0.00
10/26/10	Cab Sauv weak	*NA*	242	0.19	0.16	0.6	0.79	3.3	519	38	3	150	264	1.6	0.03
10/26/10	Cab Sauv good	*NA*	230	0.10	0.22	0.9	0.41	3.4	526	45	3	130	64	0.2	0.00

1. Values highlighted in **light blue** are low and those highlighted in **light red** indicate high based on Progressive Viticulture guidelines. *NA* = not analyzed. ND = not detected.

Late Season Chloride Toxicity in a Merritt Island Vineyard

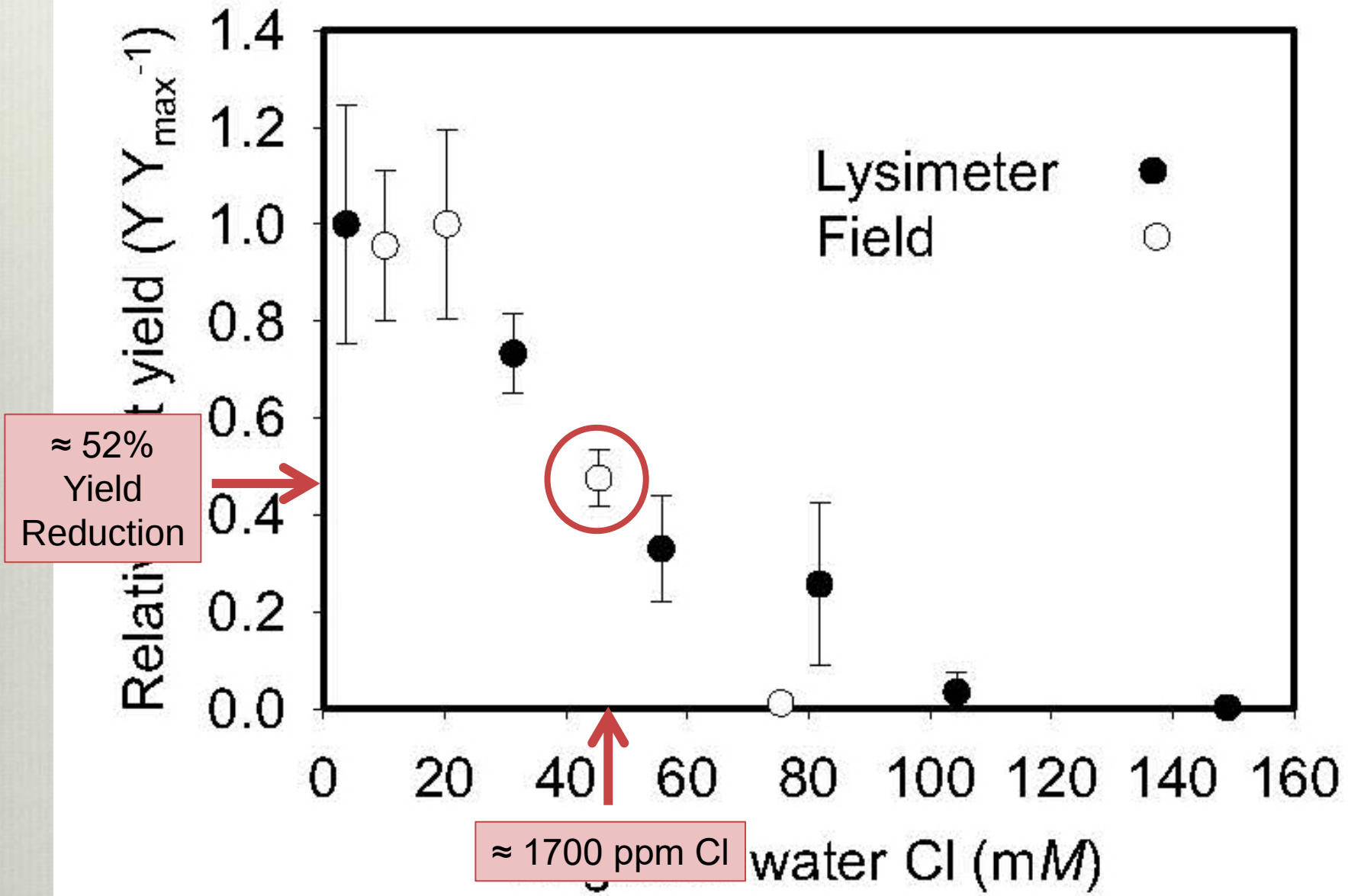
Sample I. D.	EC	CEC	O. M.	Exch. Na	ESP	Cl
	dS/m	meq/100 g	%	ppm	%	ppm
PS Weak 0"-15"	1.3	33	1.3	55	1	174
PS Weak 15"-39"	6.3	42	0.4	189	2	1802
PS Weak 39"-63"	6.9	30	0.3	316	5	2131
CS Weak 0"-15"	4.8	37	1.4	185	2	1308
CS Weak 15"-39"	5.7	29	0.3	268	4	1684
CS Weak 39"-63"	7.9	26	0.3	459	8	2444

1. Values highlighted in **light blue** are low and those highlighted in **light red** indicate high based on Progressive Viticulture guidelines. *NA* = not analyzed.

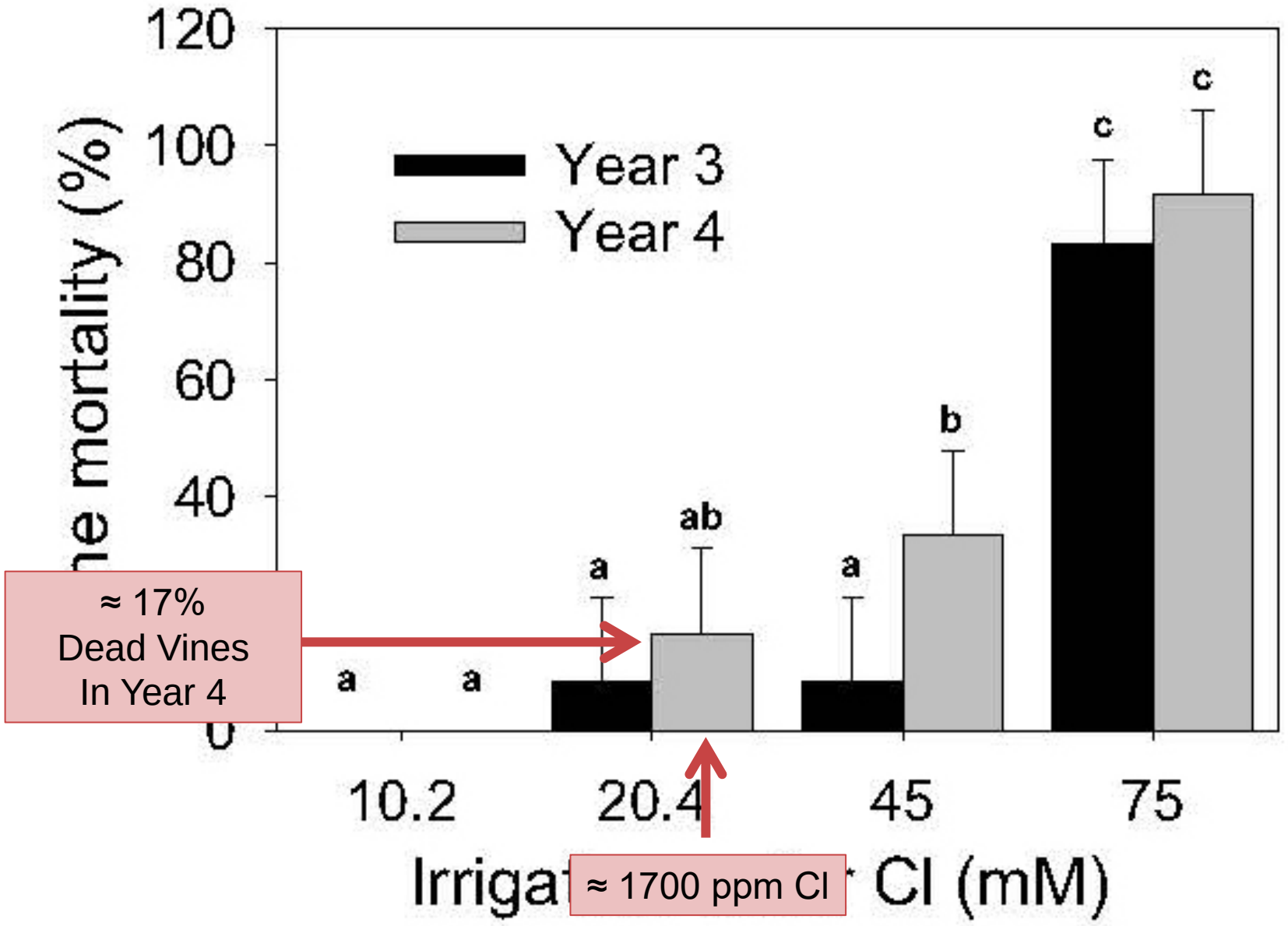
≥ 350 ppm

Sodium & Chloride

- Leaf tissue death due to toxicity limits a plants capacity to
  - Photosynthesize
  - Grow
  - Develop & ripen fruit
  - Ripen woody tissues
  - Survive



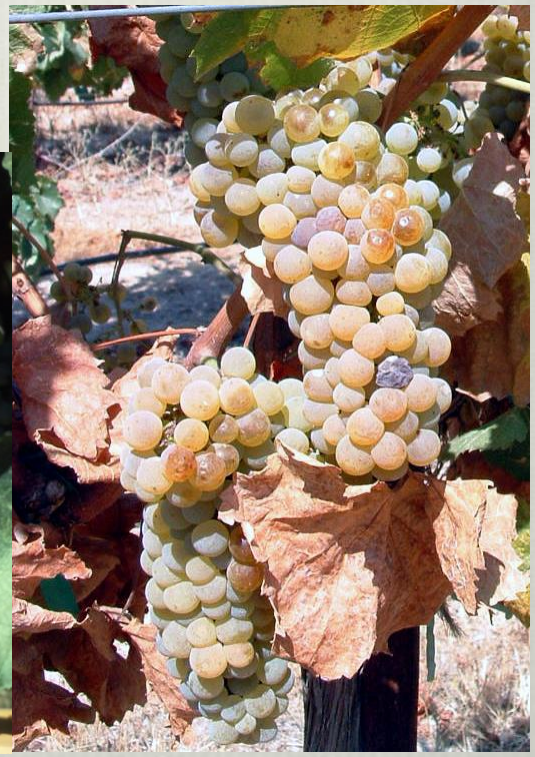
Source: Shani, U; Ben-Gal, A. 2005.



Source: Shani, U; Ben-Gal, A. 2005.

Sodium & Chloride

- Grape berries are also a final destination for sodium & chloride taken up from soils
- When berry concentrations are sufficiently high, sodium & chloride are sensible in wine as salty flavor
- Other descriptors: flat, dull, soapy, seawater-like, & brackish



Sodium & Chloride

- As with salinity, extra irrigation water is required to dilute & leach excess sodium & chloride
- Again, the extra water required for leaching decreases the efficiencies of applied water
- In soils, sodium negatively interacts with potassium & magnesium, while chloride negatively interacts with nitrate
- More fertilizer than normal may be needed for plants on sodic & high chloride soils

ONE MORE THING – DRAINAGE

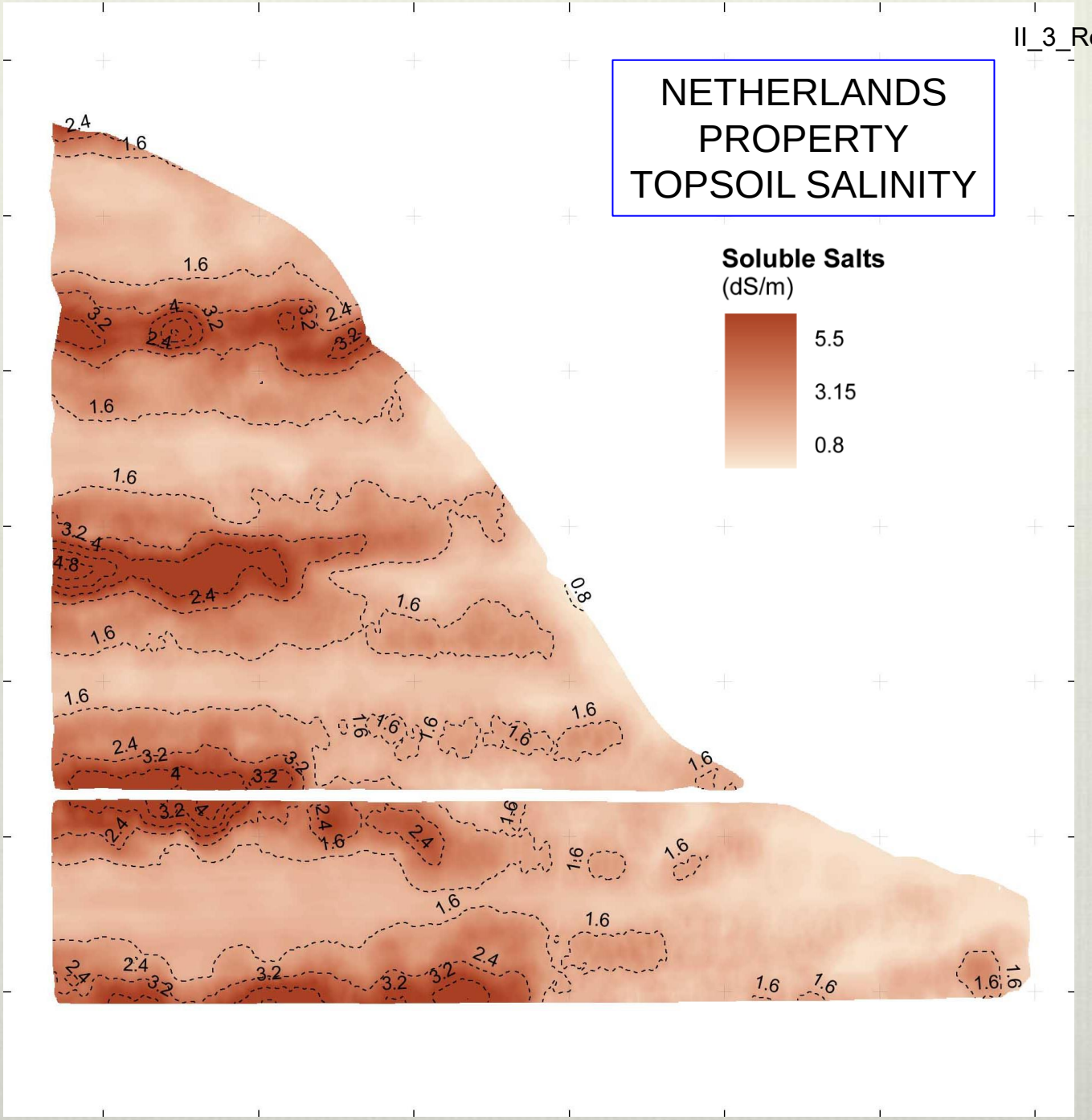
One More Thing - Drainage

- As we have seen, agricultural salt water intrusion problems require leaching
- However, leaching is effective only when salt laden water percolating below root zones has somewhere to go
- Therefore, adequate subsurface drainage is a second requirement for salt water intrusion induced problems on farm land

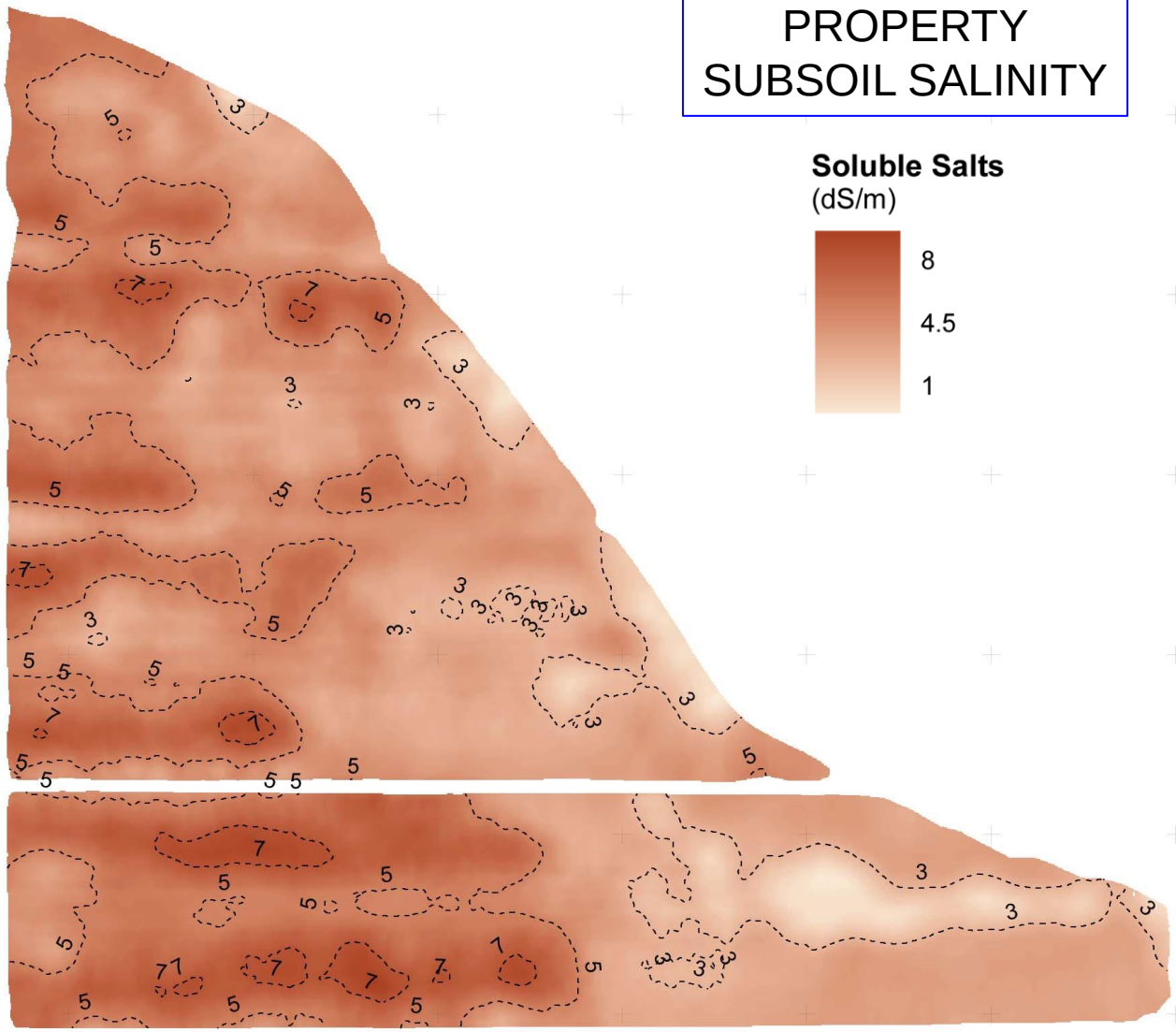
One More Thing - Drainage

- Unfortunately, naturally well drained soils are somewhat uncommon in the Delta
- Rather, most Delta soils are subject to high water tables that restrict drainage
- Costly drainage systems will be required for managing salt water intrusion induced problems

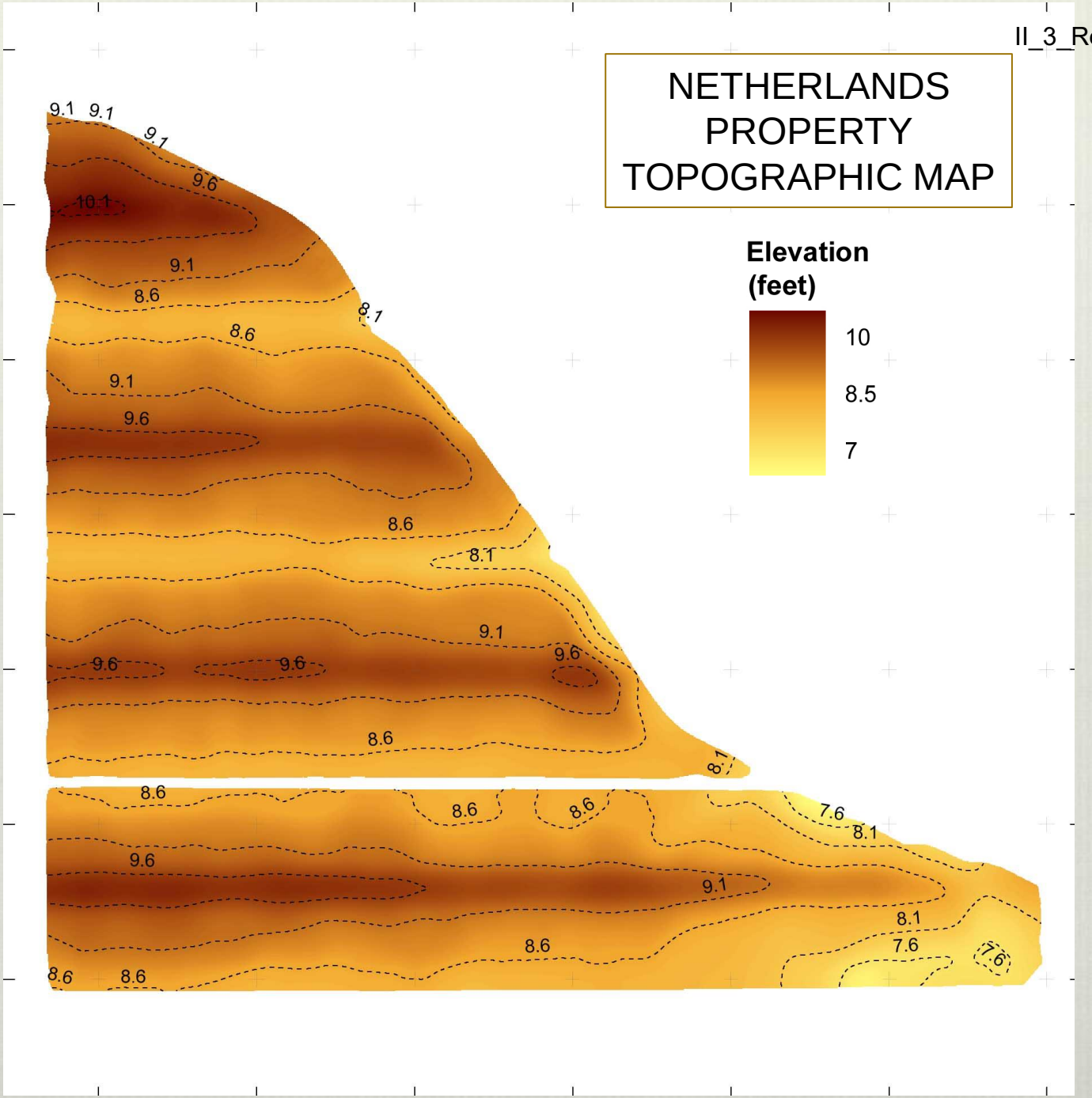
NETHERLANDS PROPERTY TOPSOIL SALINITY



NETHERLANDS PROPERTY SUBSOIL SALINITY

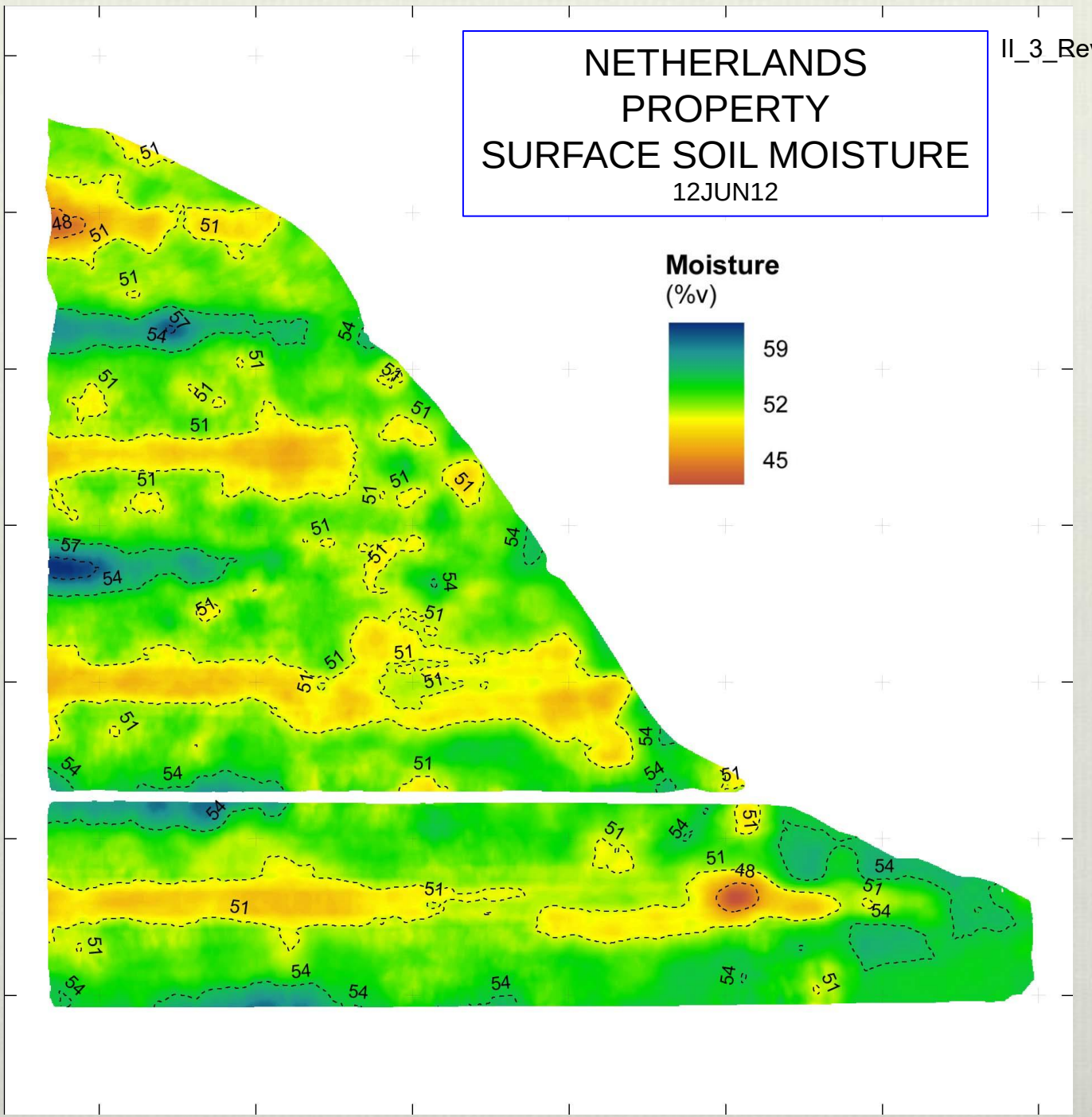


NETHERLANDS PROPERTY TOPOGRAPHIC MAP



NETHERLANDS PROPERTY SURFACE SOIL MOISTURE

12JUN12



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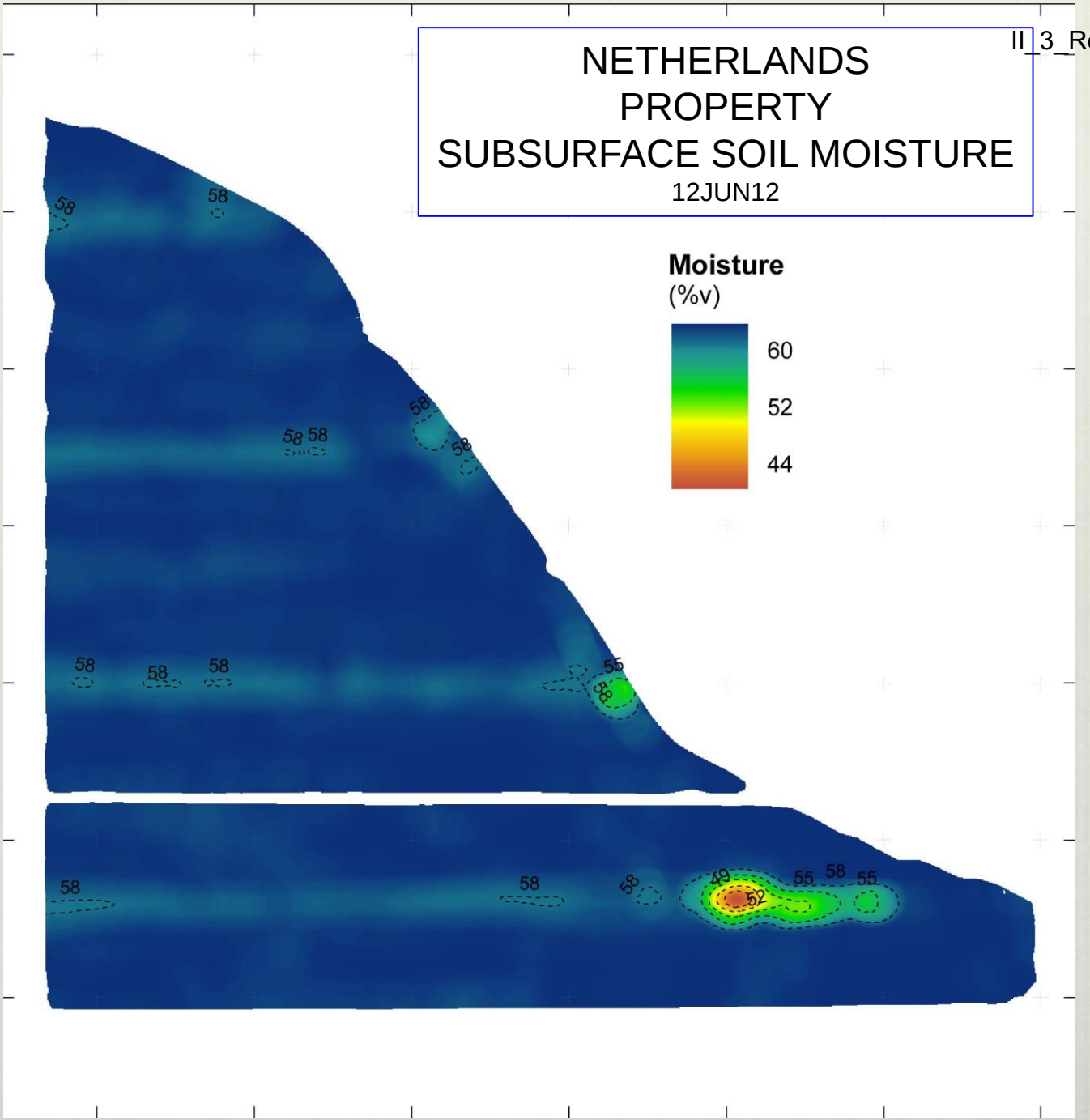
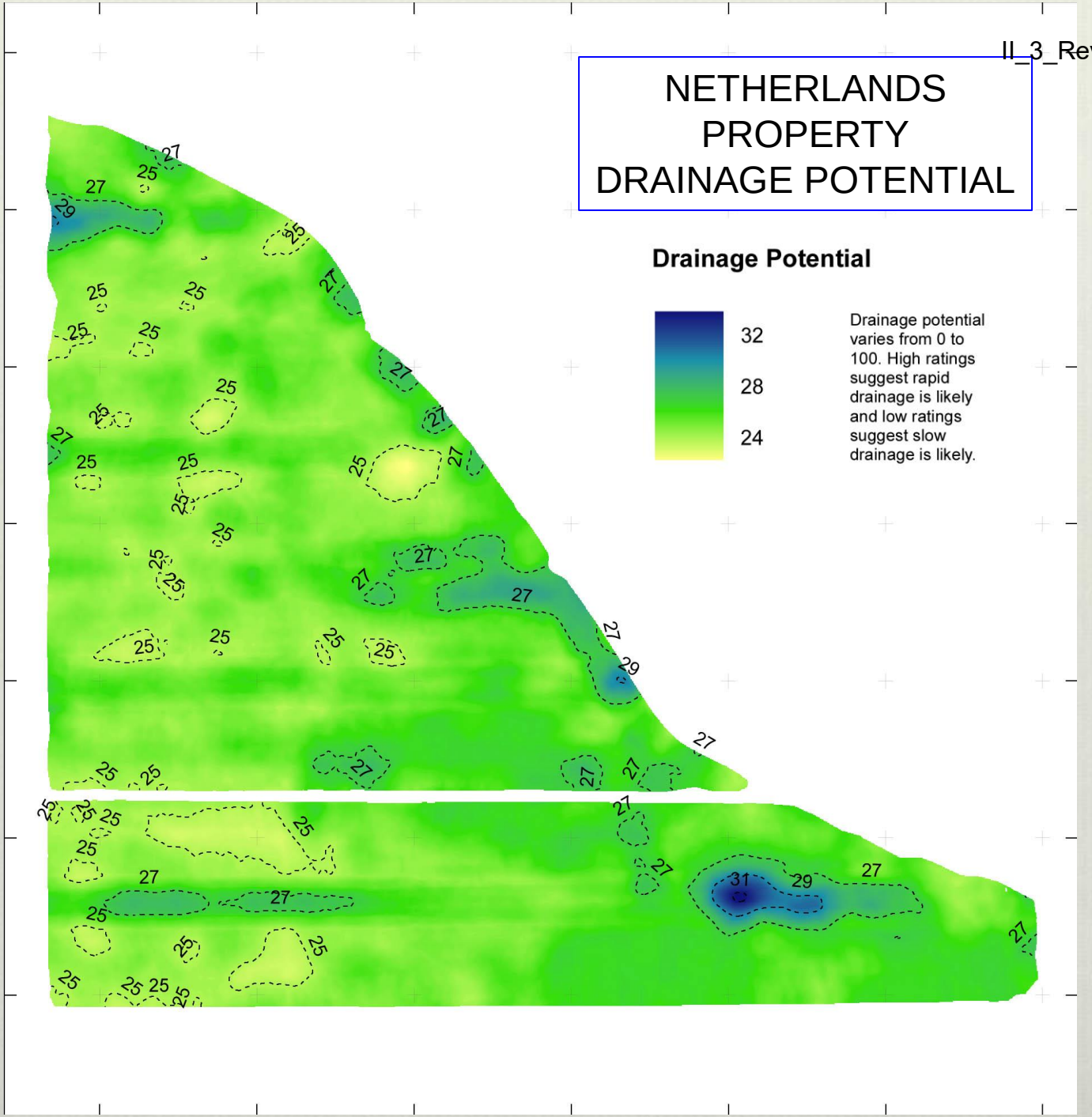
NETHERLANDS PROPERTY SUBSURFACE SOIL MOISTURE

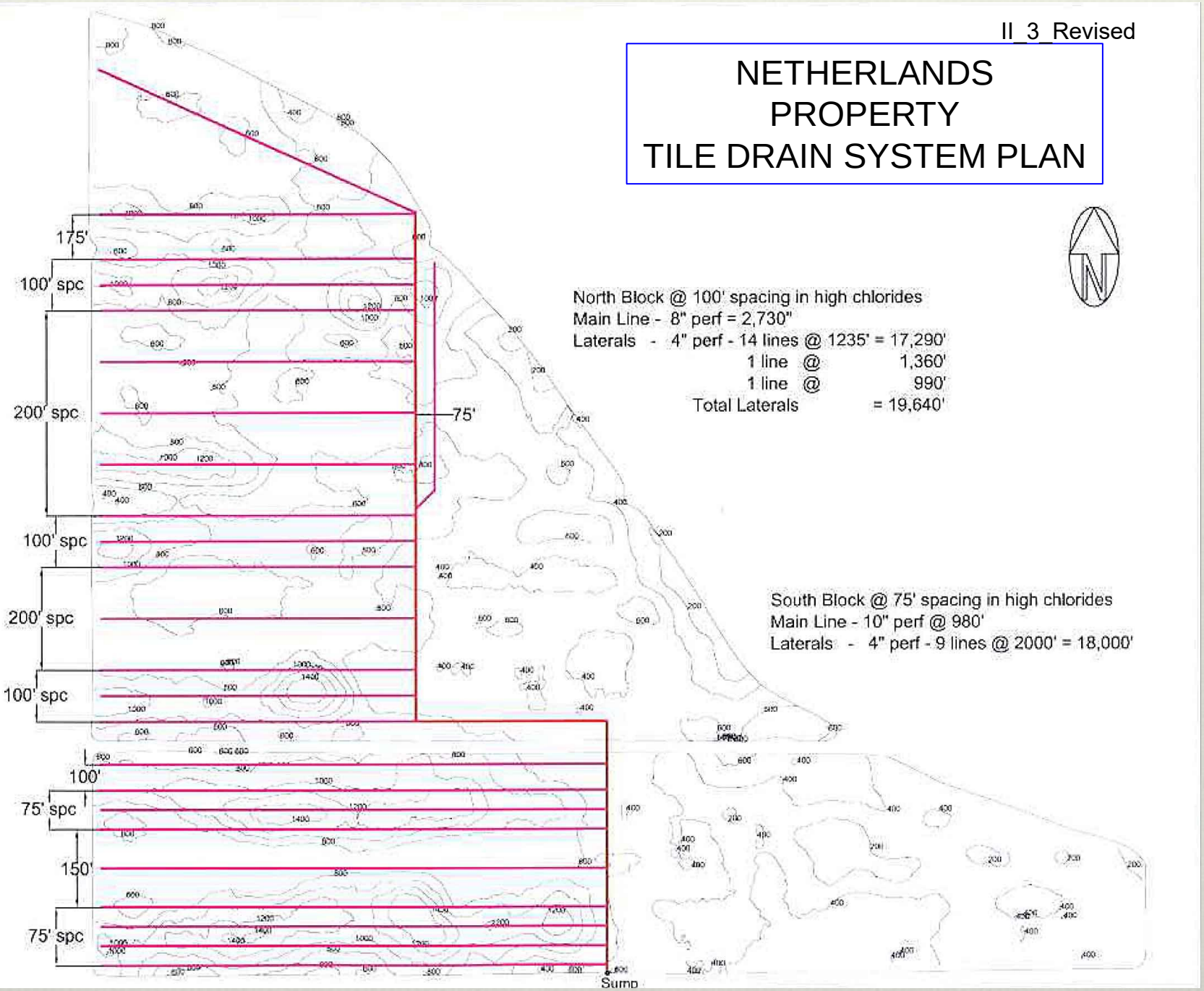
12JUN12



NETHERLANDS PROPERTY DRAINAGE POTENTIAL

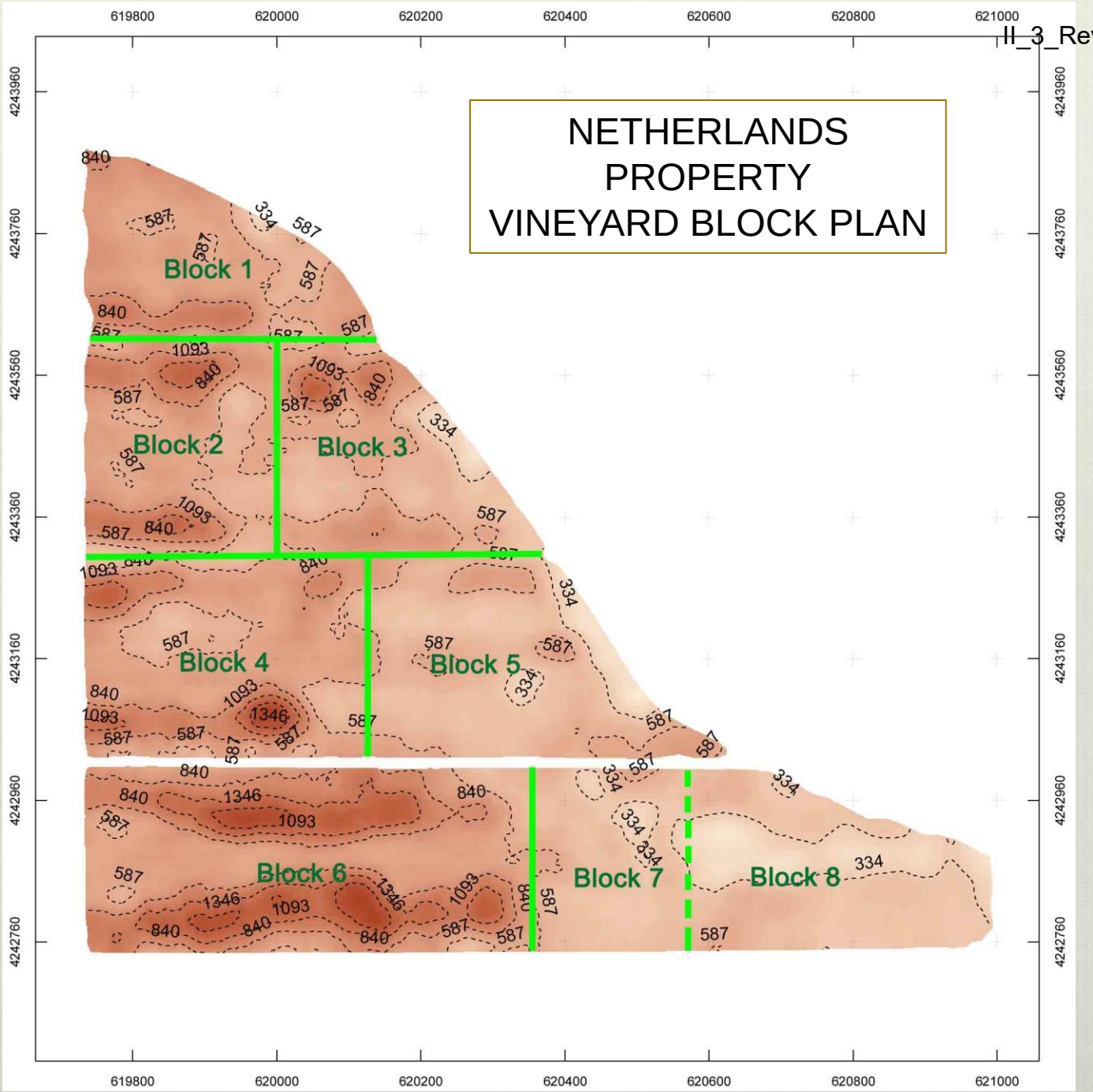


NETHERLANDS PROPERTY TILE DRAIN SYSTEM PLAN



North Block @ 100' spacing in high chlorides
Main Line - 8" perf = 2,730"
Laterals - 4" perf - 14 lines @ 1235' = 17,290'
1 line @ 1,360'
1 line @ 990'
Total Laterals = 19,640'

South Block @ 75' spacing in high chlorides
Main Line - 10" perf @ 980'
Laterals - 4" perf - 9 lines @ 2000' = 18,000'


NETHERLANDS
PROPERTY
VINEYARD BLOCK PLAN
Block 1
Block 2
Block 3
Block 4
Block 5
Block 6
Block 7
Block 8
619800
620000
620200
620400
620600
620800
621000
4243960
4243760
4243560
4243360
4243160
4242960
4242760


NETHERLANDS
VINEYARD
JULY, 2015
Source: Google Earth
Ryer Ave
84
Rd 160

One More Thing - Drainage

- Drainage waters are returned to rivers & sloughs, compounding the negative impacts of salt water intrusion
- As a result, leaching fractions increase
- The ultimate solution: low salt, Sacramento River irrigation water

Low Salt River Water Used to Irrigate a Grand Island Vineyard

Sample I. D.	Date	SALINITY		PERMEABILITY		POSSIBLE TOXICITY		
		EC	TDS	SAR-Adj.	EC	SAR-Adj.	Na	Cl
		dS/m	ppm		dS/m		ppm	ppm
Vyd Irrigation	May, 2013	0.0	160	1	0.0	1	13	31
Vyd Pump	May, 2012	0.4	265	1	0.4	1	25	20
River	Dec, 2007	0.1	114	0	0.1	0	6	5
Canal	Dec, 2007	0.2	174	1	0.2	1	14	8
Irrigation	Sep, 2007	1.4	909	5	1.4	5	93	94

1. Values in black indicate no problems, those in **yellow** indicate increasing problems, and those in **red** indicate severe problems.

CONCLUSIONS

Conclusions

- Current conditions in the Delta are the most sustainable
  - Ample high quality, low salt irrigation water is readily available in Delta rivers & sloughs
  - Salt water induced water stress & sodium & chloride toxicities are uncommon
  - Little extra water is required for leaching
  - On-farm water use efficiency is high
  - The Delta vineyards & orchard produce high quality fruit & wine for the US & beyond