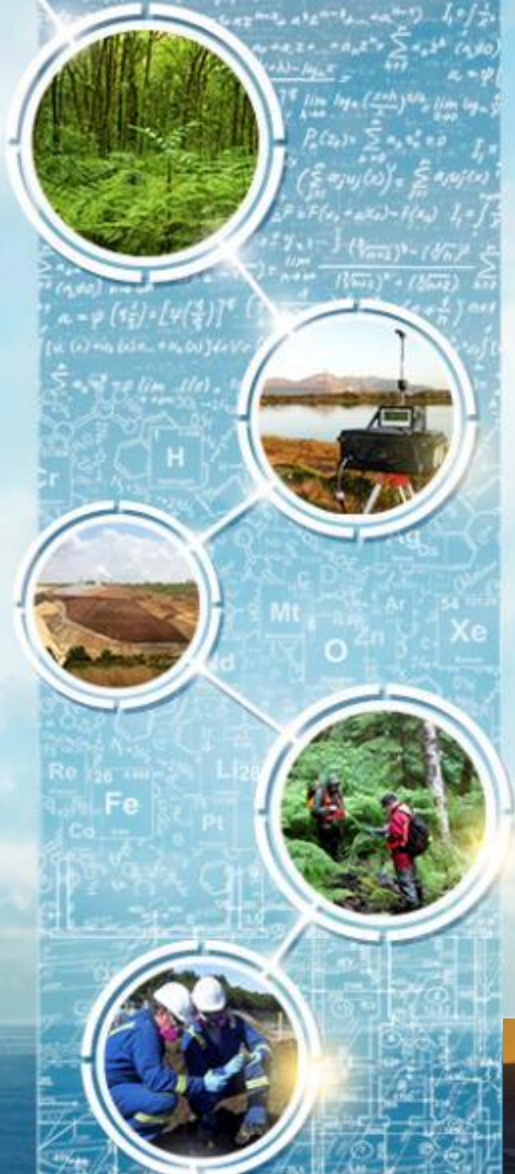

TETRA TECH

Halophytic Plant Establishment in Playa Settings to Promote Dust Control at the Salton Sea, CA

March 6, 2024

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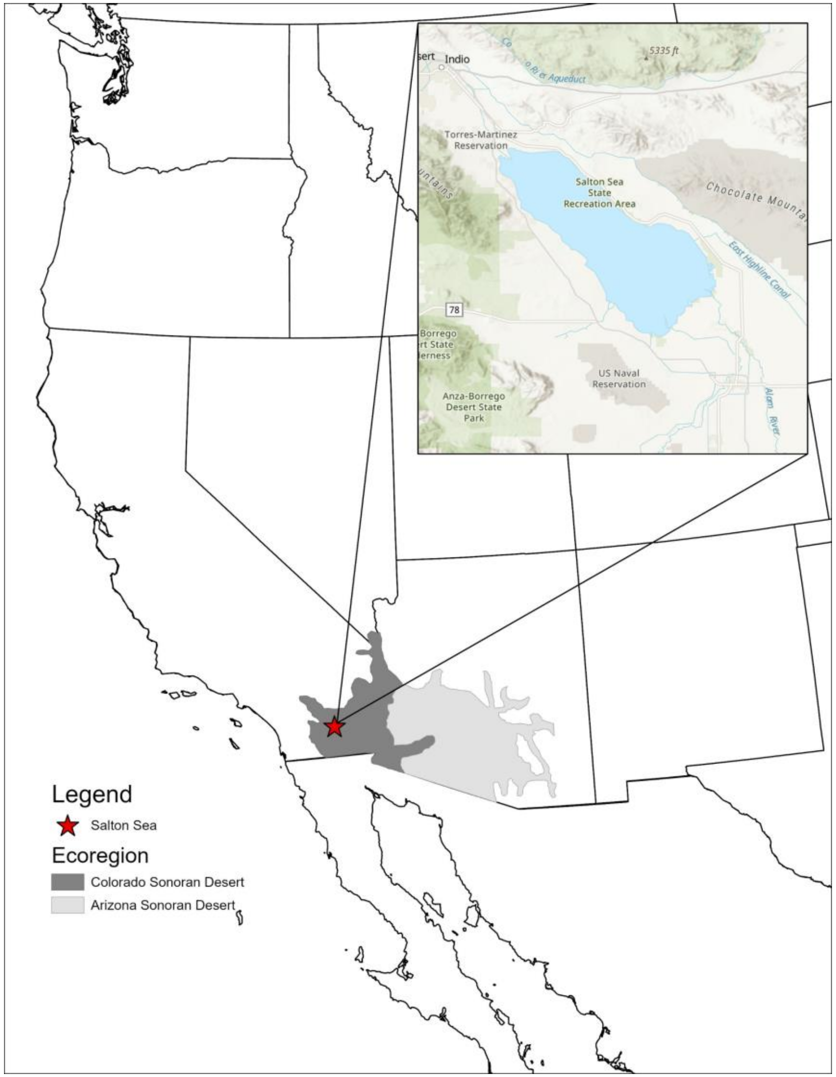
GRAND JUNCTION, CO
MARCH 5-7, 2024

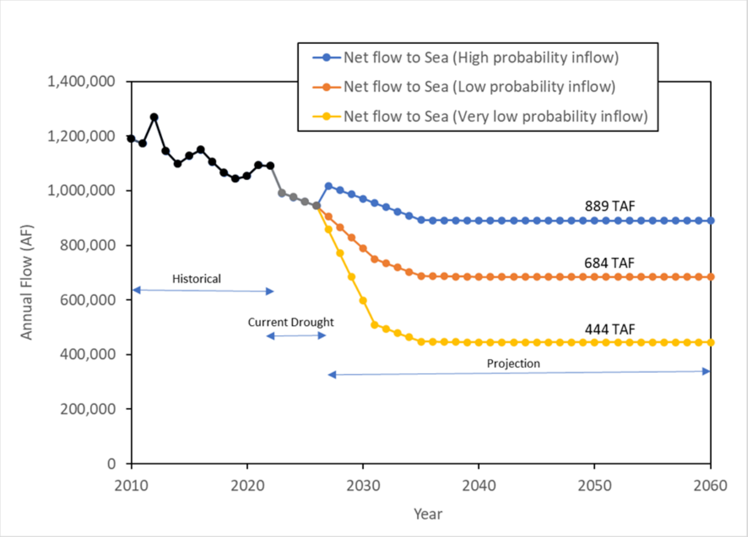
Environmental Setting

- Salton Trough within the Imperial Valley east of San Diego
- Within the Colorado Sonoran Desert, a subdivision of the Sonoran Desert
- Hyper-arid setting within the rain shadow of the Santa Rosa/San Jacinto Mountains (average rainfall is <3 inches per year)
- ~230 feet below sea level
- Declining lake surface elevation
- Exposed lakebed (playa)
  - Hyper-saline soils (average ~ 69 dS/m)
  - Near surface groundwater
  - Flat (limited seed entrapment)
  - Active aeolian transport zone
  - Dust emissions from exposed lakebed

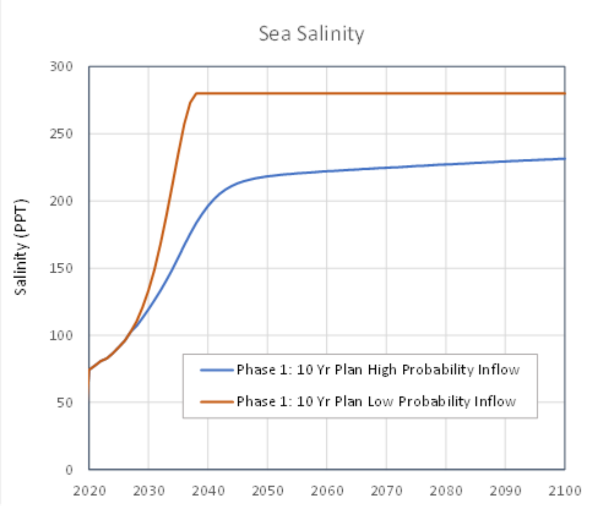


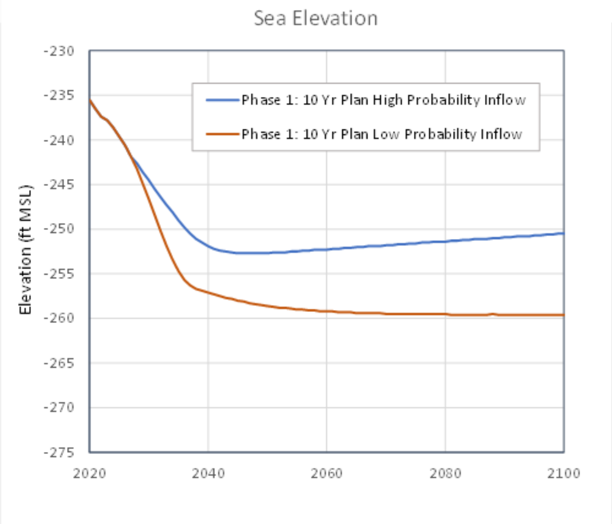
Receding Waters: Environmental Implications

- Lake surface elevation has declined 12 feet over the past 20 years
- An additional 18-foot decline in lake surface elevation expected over the next 20 years
  - By 2040 there will be 80,000 acres of additional exposed playa
  - Potentially significant air quality problems
  - Need for proactive dust control on exposed playa
- Dust control through increased surface roughness (engineered roughness) to reduce windspeed and lower soil emissions
- Halophytic vegetation establishment for long term surface roughness
  - *Allenrolfea occidentalis* (iodine bush)
    - Keystone species
  - *Atriplex lentiformis* (big salt bush)



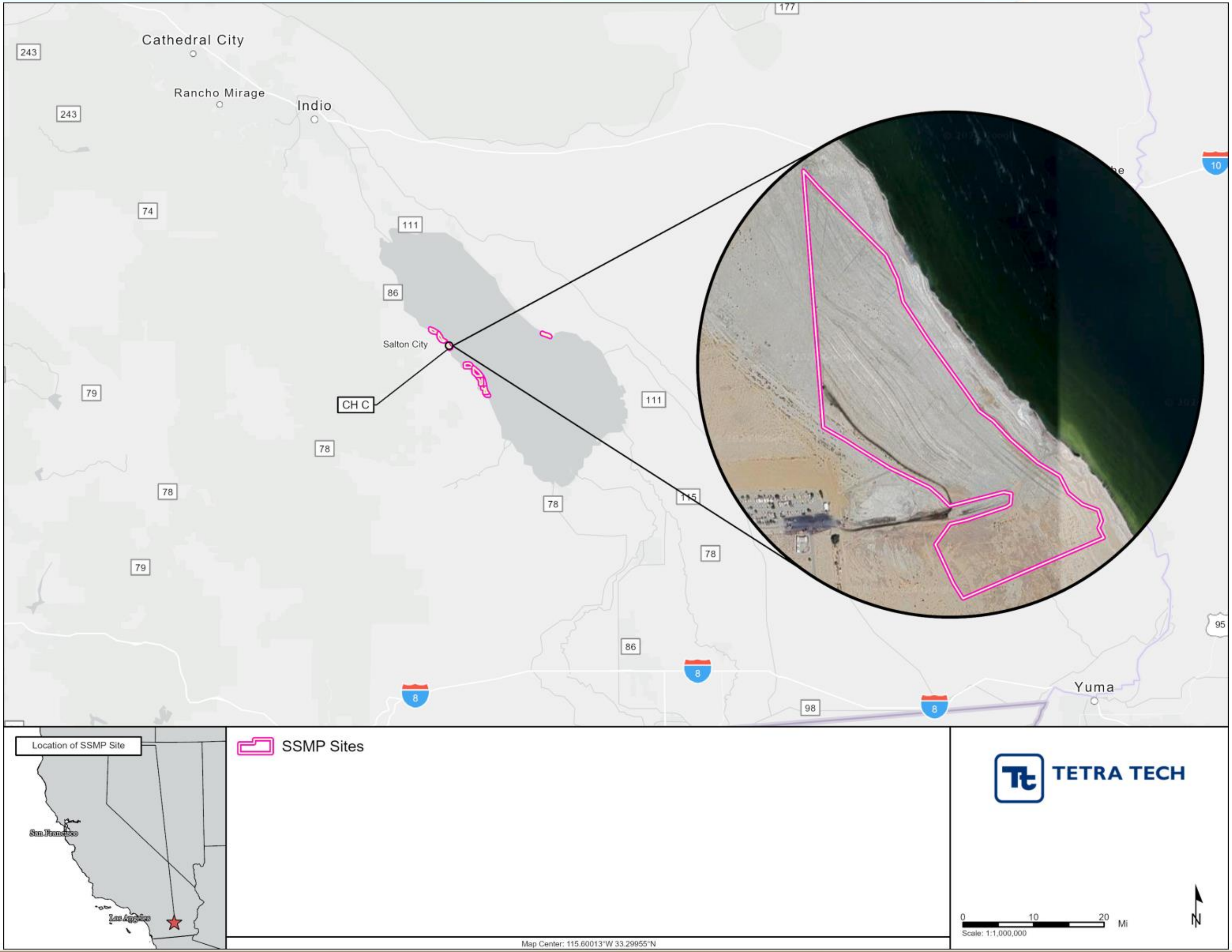
Salton Sea Management Program Long-Range Plan, 2024



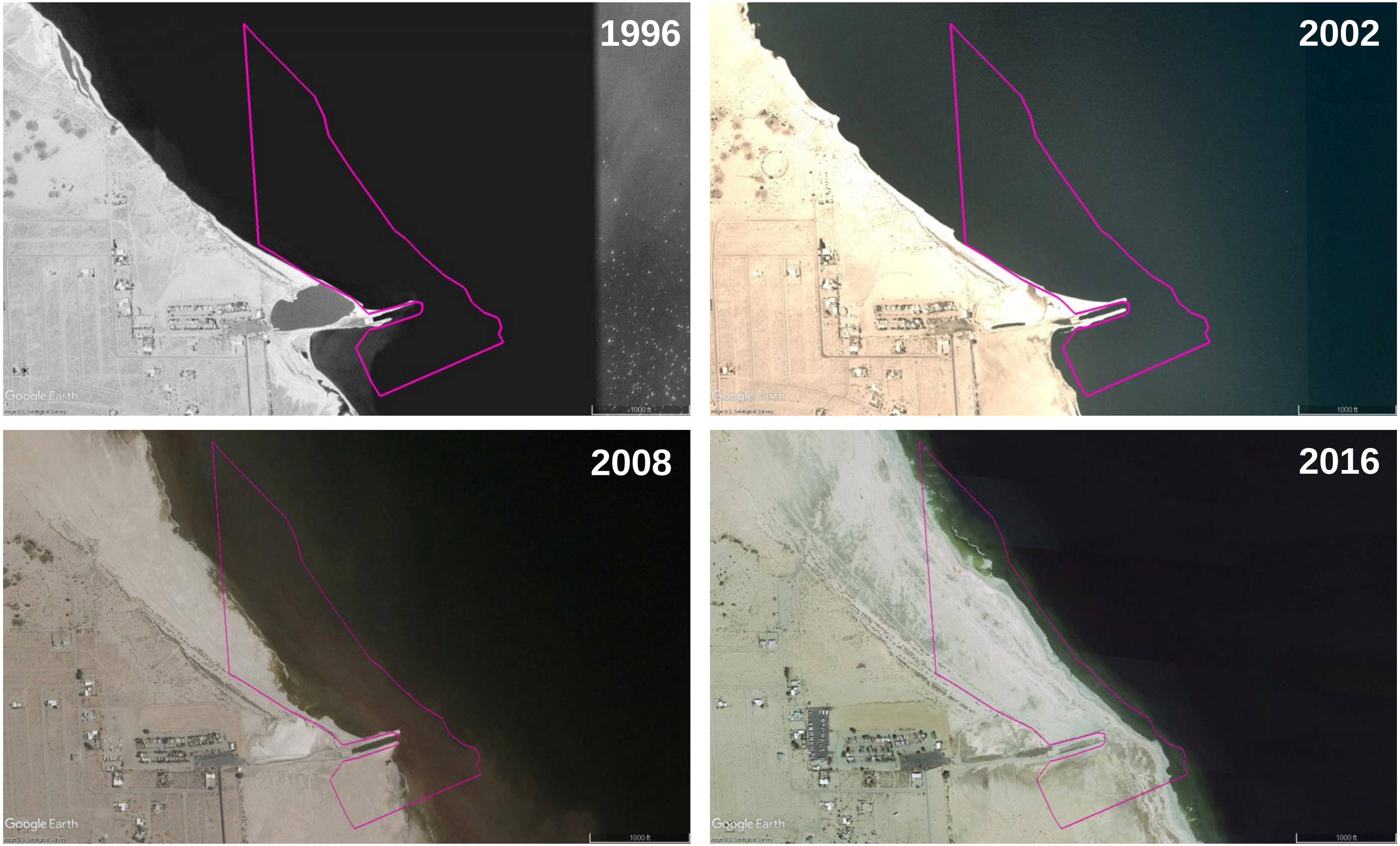


Salton Sea Management Program Long-Range Plan, 2024

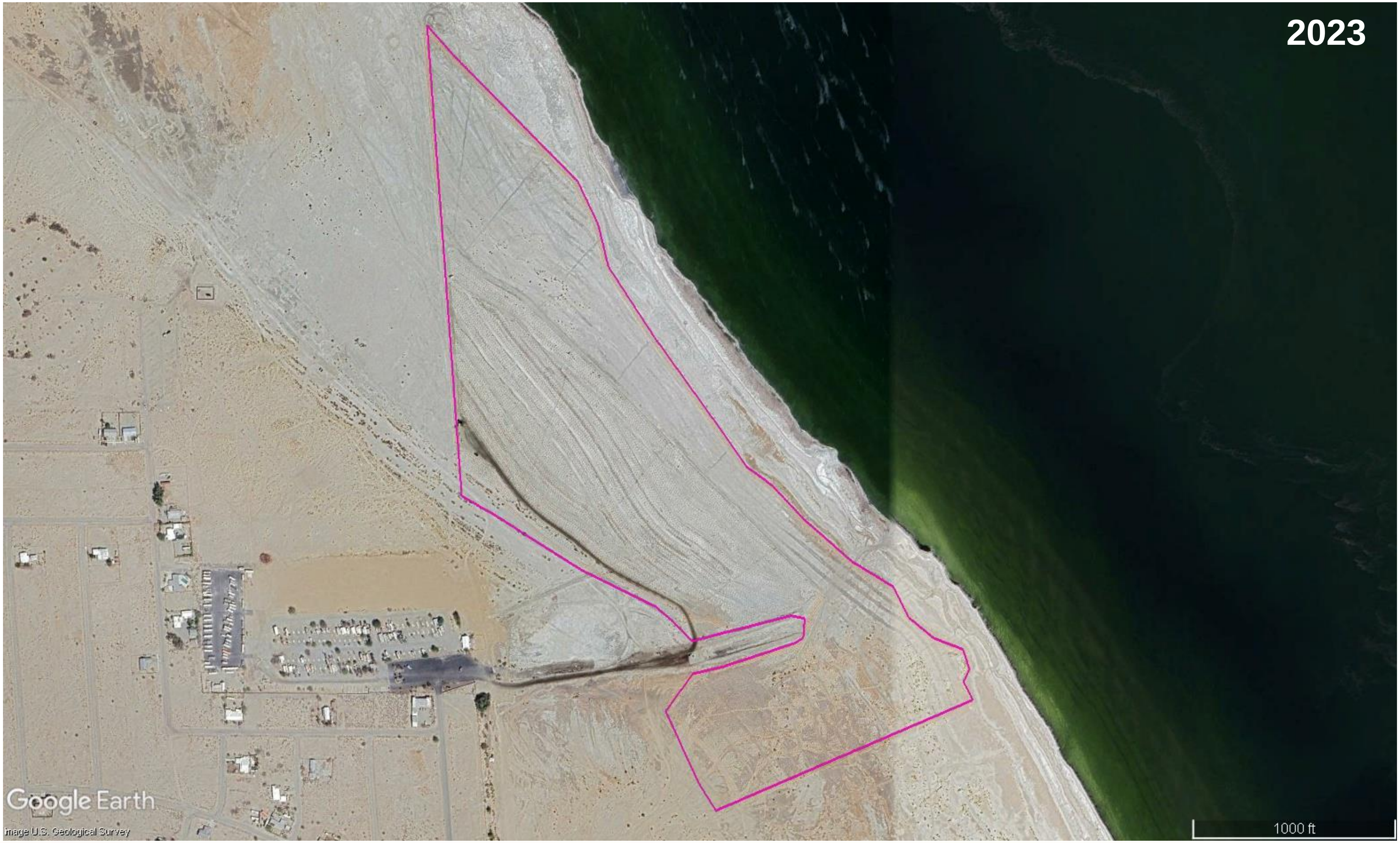
Clubhouse C Location



Receding Waters: Environmental Implications

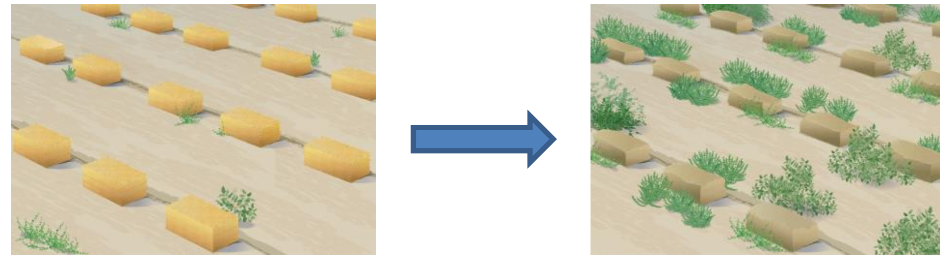


Receding Waters: Environmental Implications



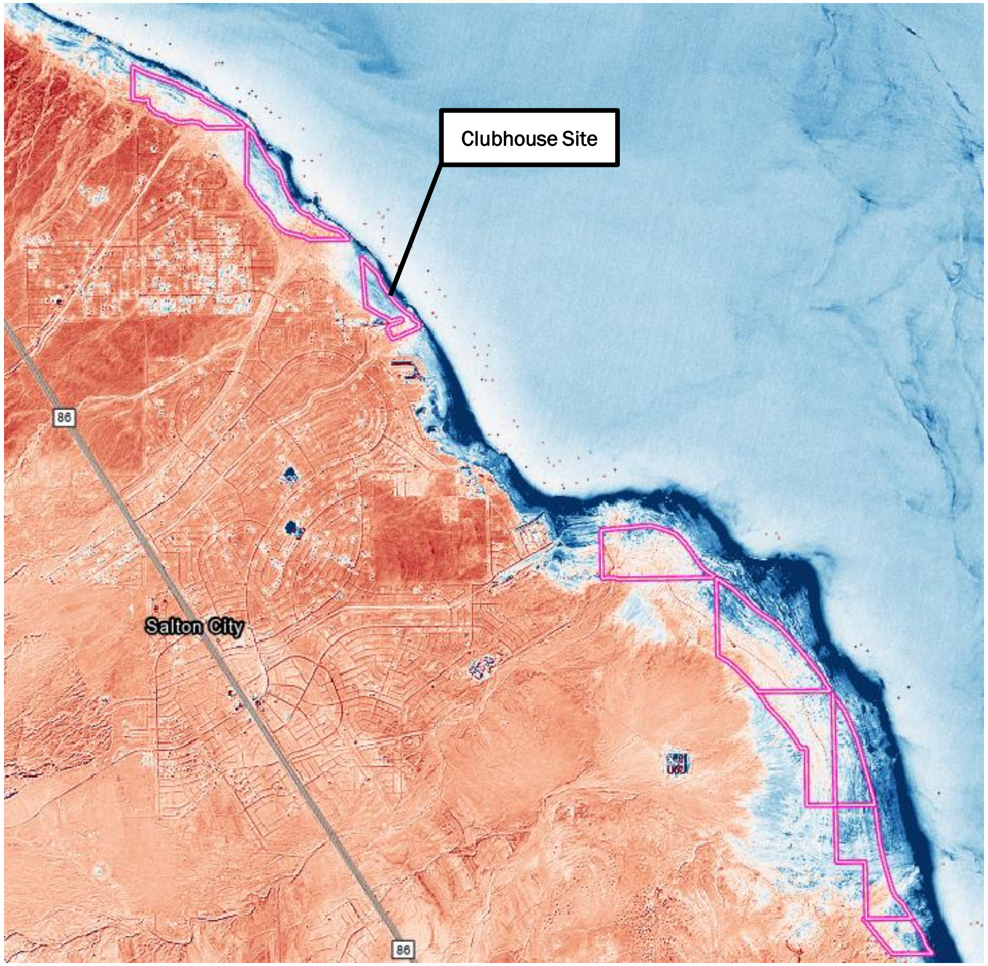
Ecological Dynamics and Landscape-Scale Design

- Design philosophy: Promote synergistic landscape-scale interactions between hydrologic flow regimes, plant establishment dynamics, dust suppression, and continuing vegetative colonization of the playa
- Immediate increase in surface roughness
  - Placement of straw bales
    - Reduce wind and suppress dust
    - Abiotic "nurse structures" to provide microhabitats and promote natural vegetation recruitment
- Long term increase in surface roughness through native vegetation establishment and expansion of current stands
  - Seeding, planting, and natural recruitment
  - Establish seed banks and increase seed dispersal over wide areas
  - Introduce additional plant species diversity over time
  - Promote wildlife habitat
- Direct surface water runoff events to promote vegetation establishment
- Determine optimal irrigation techniques



Ecological Design Review

- Vegetation review (51 species)
  - Germination requirements
  - Salinity tolerance (germination/maturity)
  - Soil needs
- Hydrologic analysis
  - Mean annual and 2-year storm events
  - Estimate area that could be irrigated
- Remote Sensing
  - Sentinel-2 scenes timed to runoff events
  - Sentinel-2 NDMI = (B08 - B11) / (B08 + B11)
- Field
  - Soils (152 samples)
    - Vegetation
    - Sample depth
      - Surface
      - 16”
      - 24”
      - Composite
    - Soil salinity reported as (dS/m)



Sentinel-2 Normalized Difference Moisture Index (NDMI), February 14,2024

Halophytic Plant Selection

Family	Species	Common Name	Published Germination Soil Salinity Upper Limit (dS/m)	Published Mature Plant Soil Salinity Upper Limit (dS/m)
Chenopodiaceae	*Allenrolfea occidentalis*	iodine bush	60[1]	80[1]
Chenopodiaceae	*Atriplex lentiformis*	big saltbush	65-100[2]	65-100[2]
Chenopodiaceae	*Atriplex canescens var. macilenta*	four wing saltbush	8-14[2]	100[2]
Chenopodiaceae	*Atriplex polycarpa*	allscale	-	15.4[3]
Chenopodiaceae	*Suaeda nigra*	bush seepweed	-	69.4[3]
Asteraceae	*Isocoma acradenia* var. *eremophila*	alkali golden bush	-	9.6[3]
Poaceae	*Distichlis spicata*	saltgrass	15[4]	45.7[3]

[1] (Gul & Weber, 1999), [2] (GeoSystems Analysis, 2011), [3] (Calfora, 2021), [4] (Castelán-Fentanes, et al., 2023)

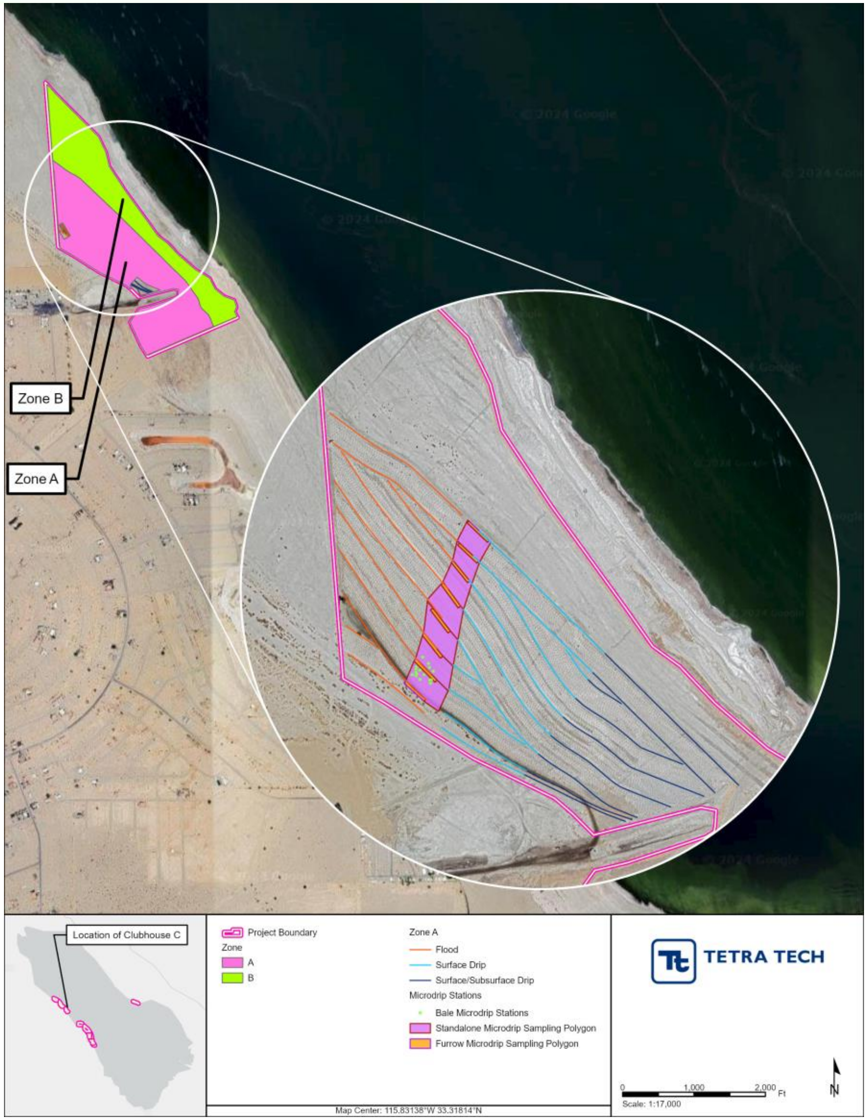
Depth (inches)	Minimum Depth Soil Salinity (dS/m)	Maximum Depth Soil Salinity (dS/m)	Average Depth Soil Salinity (dS/m)
surface	11.5	137.2	76.7
0-2	3.5	181.8	67.3
0-16	7.3	138.9	27.3
16	6.1	84.8	35.4
24	11.2	114.7	53.7

Surface soil sampling

Soil sampling at 24-inche depth

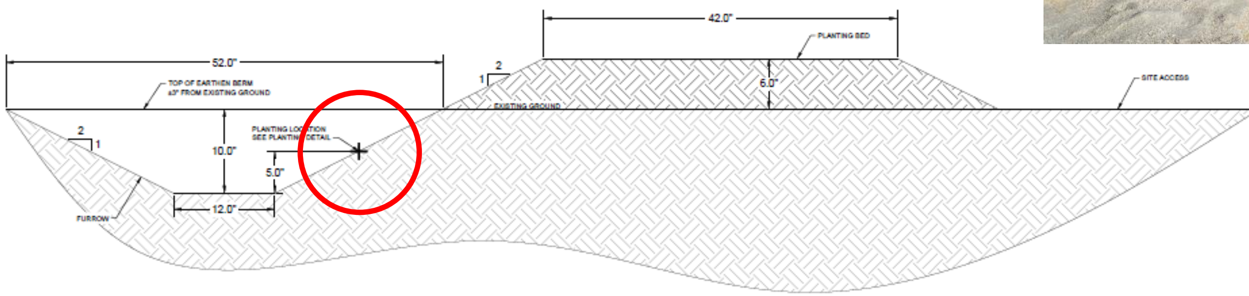
Vegetation Establishment and Irrigation Methods

- Bale placement for immediate surface roughness (2021)
- Furrow installed along topographic contours between straw bales lines (**Spring 2022**)
  - 12” wide, 10” deep with a 2 to 1 slope providing a 52” wide feature
  - Live plantings every 8’
  - Seed broadcast in the furrow and on excavated material
  - All plantings occur on the east side of the furrow
  - Excavated material placed on east side of furrows to allow surface flows to enter from western edge
- Stormwater spreading for the opportunistic diversion of water flow into lateral features to irrigate seeded and planted areas
- 4 irrigation methods (types) arranged on similar gradient profile
  - Furrow Irrigation
    - Furrow pulse (F)
    - Surface drip (SD)
    - Surface and subsurface drip (SSD)
  - Microdrip Irrigation (3)
    - Standalone
    - Furrow
    - Bale

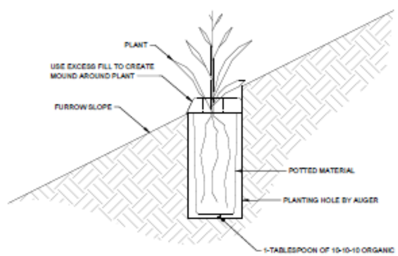


Irrigation Type 1: Furrow Pulse Flood (F)

- Plants installed 5” from bottom of furrow
- Furrow flooded to 9” depth via water truck
- Irrigation schedule
    - Day 1: Deep pulse
    - Every other week, side spray 125 gallons over 50’ segments



TYPICAL ELEVATION VIEW – FURROW W/ PLANTING BED



TYPICAL VIEW – PLANTING DETAIL

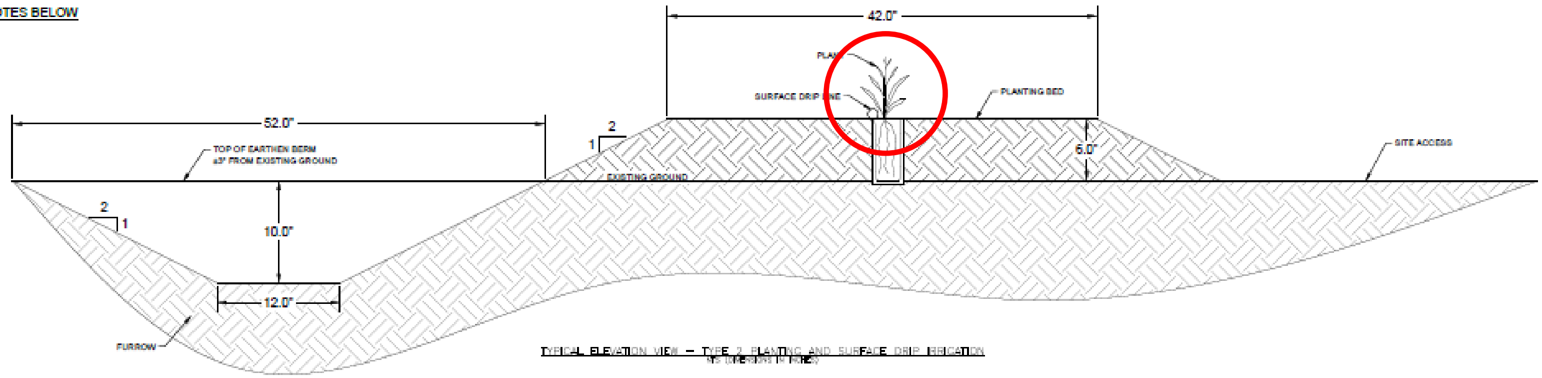
Irrigation Type 2: Surface Drip (SD)

- Planted location on top of excavated furrow material
- Surface dripline with emitters every 2’
- 0.4 GPH emitter
- Irrigation schedule
  - Week 1 everyday, 1hr
  - Week 2-4 every other day
  - Week 5-12, twice per week
  - Week 12 –tbd, once per week

SEE PLANTING AND SEEDING NOTES BELOW

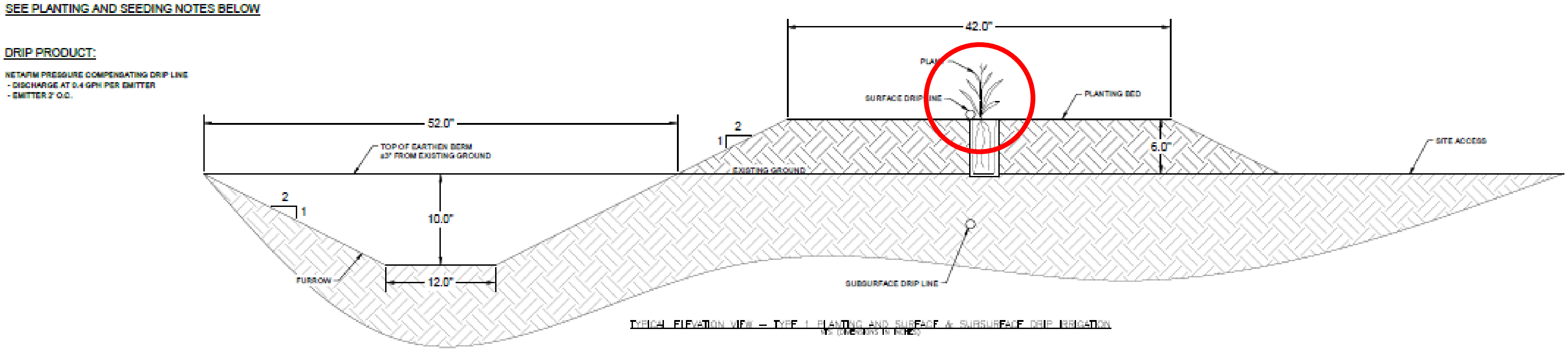
DRIP PRODUCT:

NETAFIM PRESSURE COMPENSATING DRIP LINE
- DISCHARGE AT 0.4 GPH PER EMITTER
- EMITTER 2' O.C.



Irrigation Type 3: Surface and Subsurface Drip (SSD)

- Planted location on top of excavated furrow material
- Surface dripline with emitter at planting site and every 2’ along line
- Subsurface dripline 12” below planting bed
- Discharge 0.4 GPH per emitter



Irrigation Type 4: Microdrip Stations

- **105 Standalone** microdrip stations containing solitary bucket locations and a seeded zone within the wetted area of the station, separated into seven sampling zones
- **185 Furrow** microdrip stations associated with the berm/swale features supporting planted iodine separated into eight sampling zones
- **16 Bale** microdrip stations containing buckets adjacent to grass bales and a seeded zone within the wetted area of the station with no sampling zones

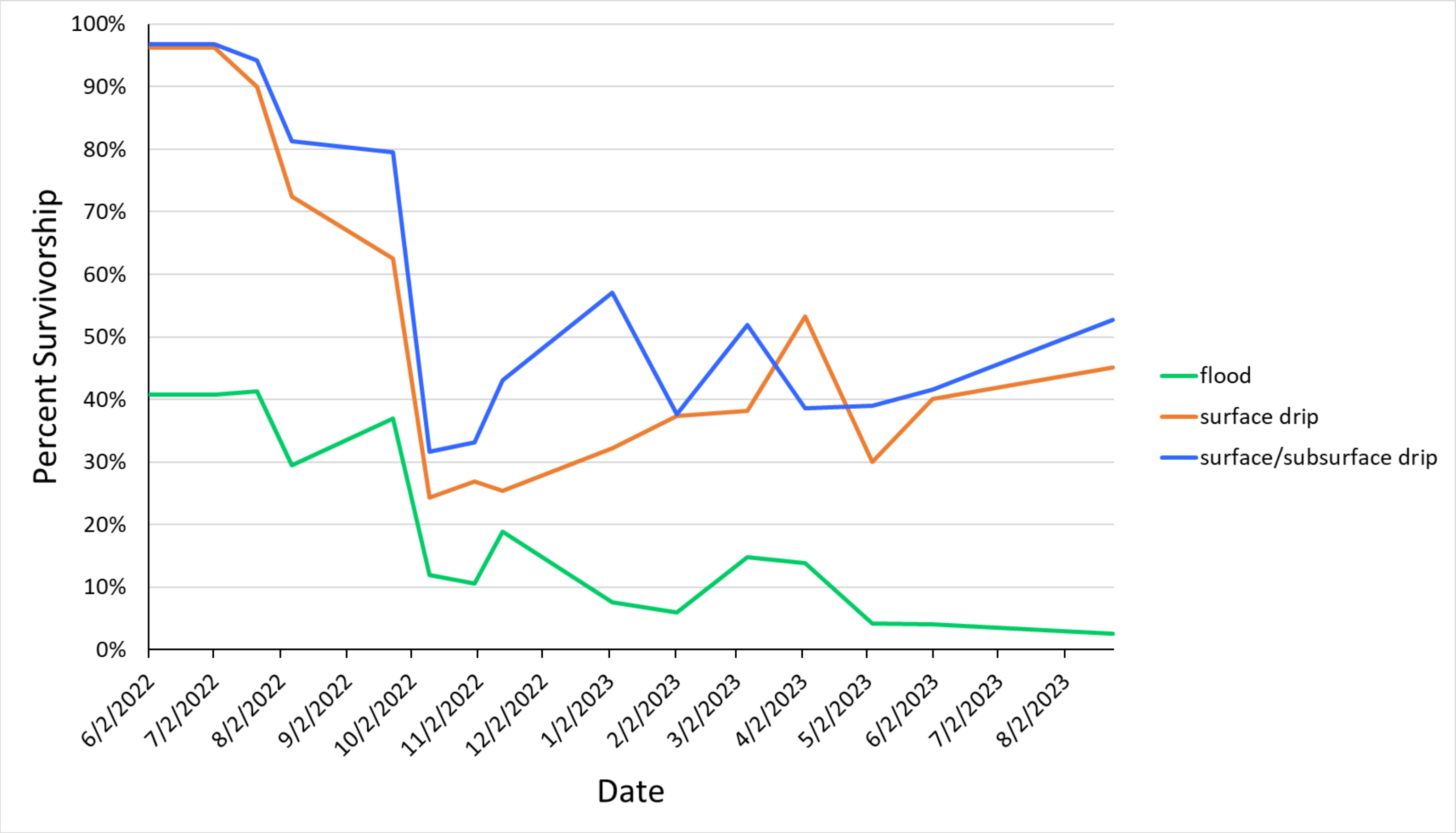
- 4-gallon buckets that provided water at a rate of approximately 0.1 GPH

Vegetation Sampling Methods

- ZONE A: Irrigation (Types: F, SD, SSD)
  - GIS split of each Zone and irrigation type and random transect selection
    - Planted Iodine Bush survivorship
    - Seed germination counts
    - Stem counts

- ZONE A: Microdrip Stations (Types: Standalone, Furrow, Bale)
  - Unique IDs assigned to each station and type
    - Planted Iodine Bush survivorship (Furrow)
    - Seed germination counts
    - Stem counts

CH C Zone A: Planted Iodine Bush Survivorship



CH C Zone A: Flood Irrigation Stem Density

Species	Common Name	Stems per 100 ft.	Species Proportion (%)
Allenrolfea occidentalis	**iodine bush**	**2.4**	**13.2**
Atriplex lentiformis	**big saltbush**	**5.7**	**31.8**
Atriplex canescens var. macilenta	four wing saltbush	0.2	1.1
Atriplex polycarpa	allscale	0.2	1.3
Suaeda nigra	**bush seepweed**	**3.6**	**20.2**
Isocoma acradenia var. *eremophila*	alkali golden bush	0.3	1.6
Distichlis spicata	saltgrass	0.1	0.6
other	-	5.5	30.2
	Sum	**18.1**	
N=852 **Seven sampling events (August 2022-August 2023)**			

CH C Zone A: Surface Irrigation Stem Density

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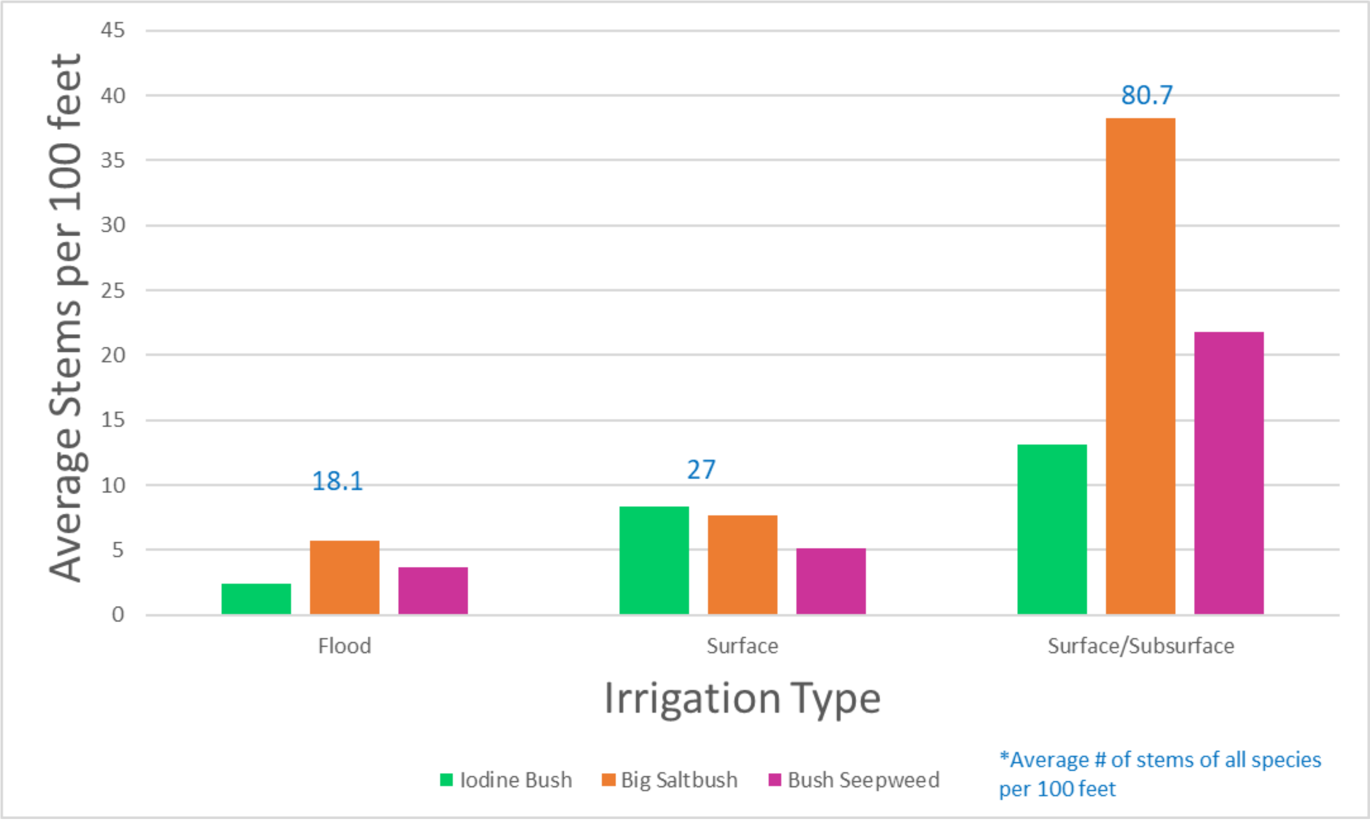
Species	Common Name	Stems per 100 ft.	Species Proportion (%)
Allenrolfea occidentalis	**iodine bush**	**8.4**	**30.9**
Atriplex lentiformis	**big saltbush**	**7.7**	**28.4**
Atriplex canescens var. macilenta	four wing saltbush	0.3	1.2
Atriplex polycarpa	allscale	0.1	0.2
Suaeda nigra	**bush seepweed**	**5.2**	**19.0**
Isocoma acradenia var. *eremophila*	alkali golden bush	0.0	0.0
Distichlis spicata	saltgrass	0.2	0.6
other	-	5.4	19.8
	Sum	**27**	
N=1,142 **Seven sampling events (August 2022-August 2023)**			

CH C Zone A: Surface/Subsurface Irrigation Stem Density

Species	Common Name	Stems per 100 ft.	Species Proportion (%)
Allenrolfea occidentalis	**iodine bush**	**13.2**	**16.3**
Atriplex lentiformis	**big saltbush**	**38.3**	**47.4**
Atriplex canescens var. macilenta	four wing saltbush	2.7	3.3
Atriplex polycarpa	allscale	0.1	0.1
Suaeda nigra	**bush seepweed**	**21.8**	**27.0**
Isocoma acradenia var. *eremophila*	alkali golden bush	0.0	0.0
Distichlis spicata	saltgrass	0.6	0.7
other	-	4.2	5.2
	Sum	**90.7**	

N=2,744
Seven sampling events (August 2022-August 2023)

CH C Zone A: Total Stem Density

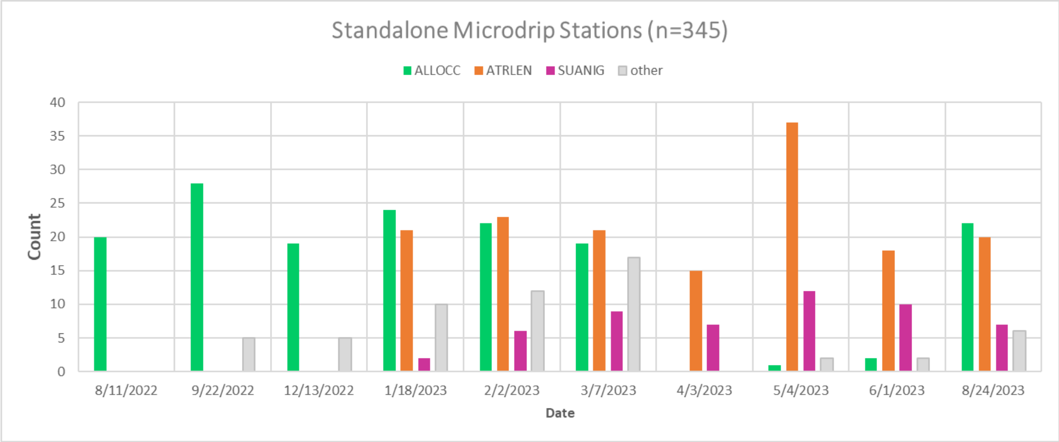


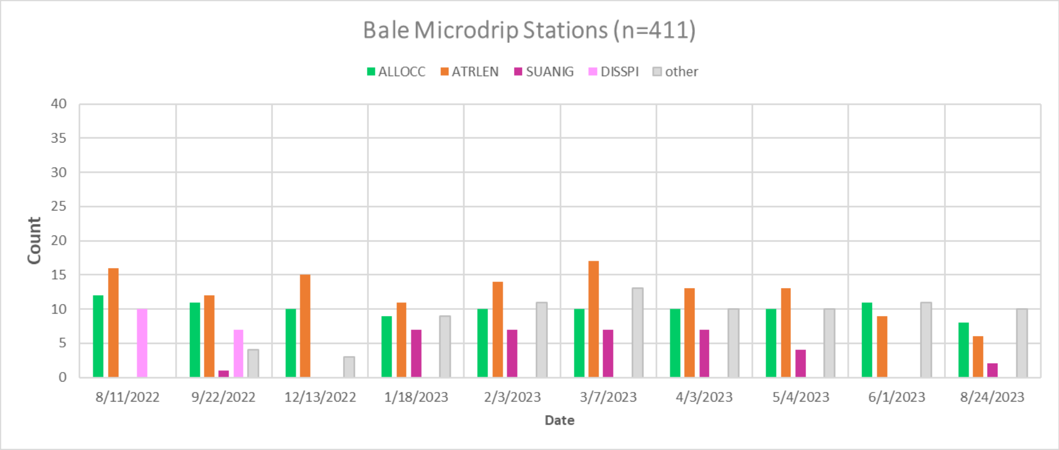
CH C Zone A: Standalone + Bale Microdrip Plant Establishment

Species	Common Name	Standalone Germination Rate (%)[1]	Bale Germination Rate (%)[2]
Allenrolfea occidentalis	**iodine bush**	**46.0**	**27.2**
Atriplex lentiformis	**big saltbush**	**27.9**	**37.3**
Atriplex canescens var. macilenta	four wing saltbush	0.3	0.9
Atriplex polycarpa	allscale	0.0	0
Suaeda nigra	**bush seepweed**	**8.4**	**9.6**
Isocoma acradenia var. *eremophila*	alkali golden bush	0.0	0
Distichlis spicata	**saltgrass**	**0.3**	**7.5**
ATRSPP	-	0.0	0
	Average	**11.1**	**11.1**

[1] n=287 germinated plants [2] n=228 germinated plants

CH C Zone A: Microdrip Plant Establishment





CH C Zone A: Summary

- Selected plant species demonstrated ability to germinate and establish in playa conditions
- Four “high performance” plant species
  - *Allenrolfea occidentalis*
  - *Atriplex lentiformis*
  - *Suaeda nigra*
  - *Distichlis spicata*
- Drip irrigation likely produces localized salt dispersal effect and improve soil chemistry in seedbed
- Plant germination and establishment at microdrip stations demonstrated that plants may grow under limited water conditions
- Plant selection and drip irrigation may be scaled up for application in other sites
- Significant reduction of dust emissions after the placement of bales and vegetation establishment activities
- Minimal apparent limitations related to soil salinity and plant establishment after germination period

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Special Thanks To

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