W.A.I.V.

Wind Aided Intensified eVaporation

An Alternate Approach for the On-Site Management of Leachate

Presented by:

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LEACHATE MANAGEMENT SPECIALISTS, LLC

"Finding A Better Way"

Leachate Management Specialists

Today's Presentation

Topics

- "Natural Systems"

- W.A.I.V – **W**ind **A**ided **I**ntensified e**V**aporation
  - Technology Background
  - Worldwide Project Examples
  - FAQs
  - Costs

"Natural Systems" = ???

A new breed of technologies

Definition

"A ***Natural System*** is one that strategically takes advantage of and **leverages the ability of natural processes**…

- Evapotranspiration
- Wind movement
- Solar radiation
- Evaporation
- Plant and biological processes

…to solve practical problems."

Natural Systems

- Phyto-Utilization™ Systems
- Engineered Wetlands
- W.A.I.V.™

Natural Systems

- Trade space for “energy”
  - Energy = $$$ Money $$$
    - Electricity
    - Chemicals
    - Man power
    - Transport trucks
    - Mechanical complexity
    - O&M

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Natural Systems

"Phyto-Utilization™" Definition

The use of fast-growing (non-invasive), highly-tolerant plants to **CONSUME industrial wastewater** (leachate) to greatly reduce or eliminate the need for other disposal methods in a GREEN and sustainable way.

Landfill Leachate as a Resource!

Main Components are Water and Contaminants
(providing moisture and nutrients)

Natural Systems

Phyto-Utilization™ Systems

Tree-Based Phyto System

Vetiver-Based Phyto System

Natural Systems

Engineered Wetlands

Free-Water Surface (FWS) Wetland

Horizontal Subsurface Flow (HSSF) Wetland

Natural Systems

Wind Aided Intensified Evaporation

W.A.I.V.™

WAIV at a Landfill In Australia

Benefits of Natural Systems

- **GREEN, Sustainable Technology**
  - Reduced carbon footprint
  - Corporate sustainability reports / PR opportunities
- **Significant Cost Reduction (25-50%)**
- **Zero Discharge Potential**
  - Not dependent on POTW
    - Changing discharge limits
    - Blamed for their problems
    - Price increases
    - Can be cut off (more and more w/ UV disinfection)
- **Year-Round Leachate Management**

Benefits of Natural Systems

- Thousands of Fewer Miles Driven by Tanker Trucks
- **Less Truck Traffic through communities**
- **Reduced Liability**
- Less Wear on Local Roads
- Habitat for Wildlife
- Aesthetic Improvement for Area
- **National Award Winning Technology**
- Reduce Financial Assurance Premiums
- **New Alternative to Consider**

Environmental Benefits Example

Phyto-Utilization System

- 3 MGY System, over first 5 years
  - 15 million gallons total
  - Avoids 3,000 tanker trips
  - If 35 mi one-way, then **210,000 miles not driven**
  - 35,000 gal diesel not burned

2010 Republic Services corporate sustainability report… ***"We factor in that every trip we make and every mile of road we cover has an environmental impact of it's own."***

Benefits of Natural Systems

WIN x 3

Environment

Community

Industry

Leachate Management Specialists

Today's Presentation

Topics

- "Natural Systems"

- **W.A.I.V. – Wind Aided Intensified eVaporation**
  - Technology Background
  - Worldwide Project Examples
  - FAQs
  - Costs

WAIV™

Wind Aided Intensified eVaporation

A completely new evaporative technology

What it is NOT

- No Spray
- No Mists
- No Aerosols
- No Blowers or Fans
- No Drift
- **No Fuel**

WAIV™

Wind Aided Intensified eVaporation

What it is NOT

- No Sprays
- No Mists
- No Aerosols
- No Blowers or Fans
- No Drift
- **No Fuel**

What it IS

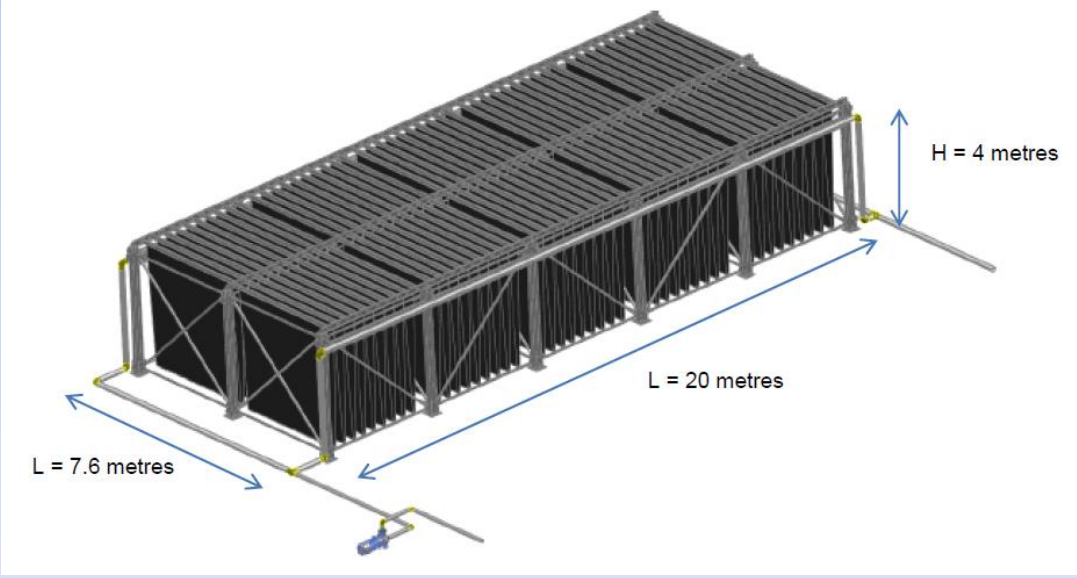
- The Newest Evaporative Technology
- Fundamentally Basic, Simple System
- Wind Driven
- Low O&M requirements

WAIV™

Wind Aided Intensified eVaporation

- Developed for the Desalination Industry
- Adapted for Other Industries

  - Solid Waste
  - Mining
  - Oil and Gas
  - Manufacturing
  - Food and Beverage
  - In lieu of Injection Well
  - Metals Finishing
  - Pharmaceuticals
  - Others



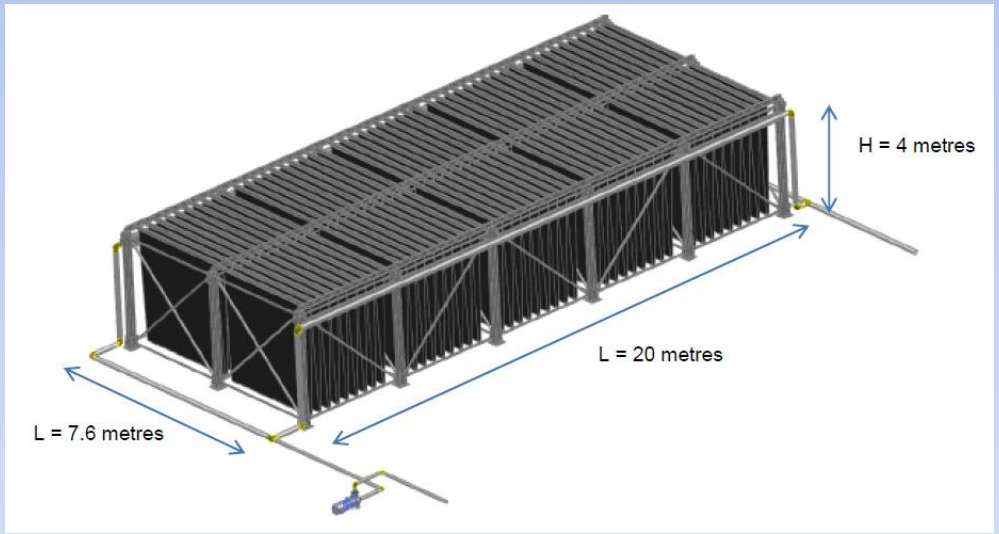
WAIV™

Wind Aided Intensified eVaporation

Explanation

- **High density of wetted surface area** within a **very small footprint**

- Wind causes enhanced, intensified evaporation



WAIV™ – Intellectual Property

What it is

- Fully patented
  - Numerous US and international patents
- Intellectual Property Rights are solid
- LMS has exclusive agreement with patent holders

WAIV™

Wind Aided Intensified eVaporation

WAIV™ – Main System Components

System Schematic

1. Controls (PLC)
2. Tank
3. Pump (circulation and sump)
4. Containment
5. WAIV Unit

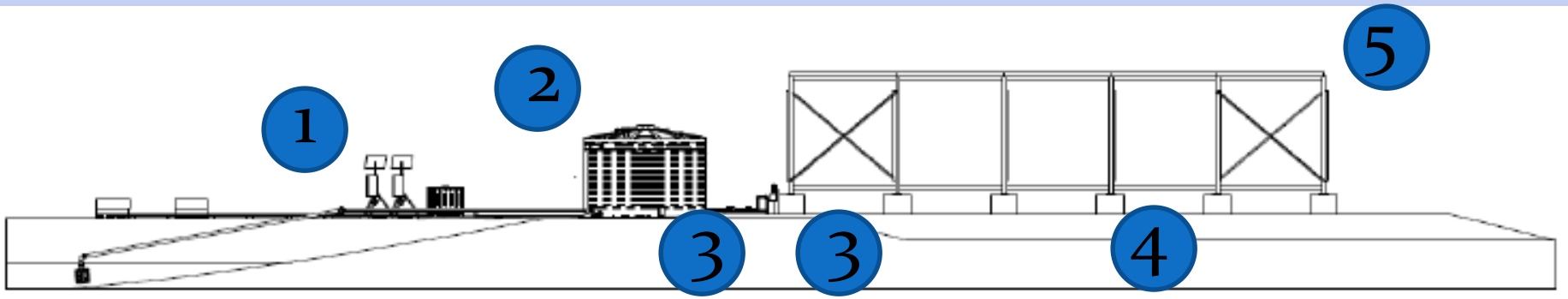
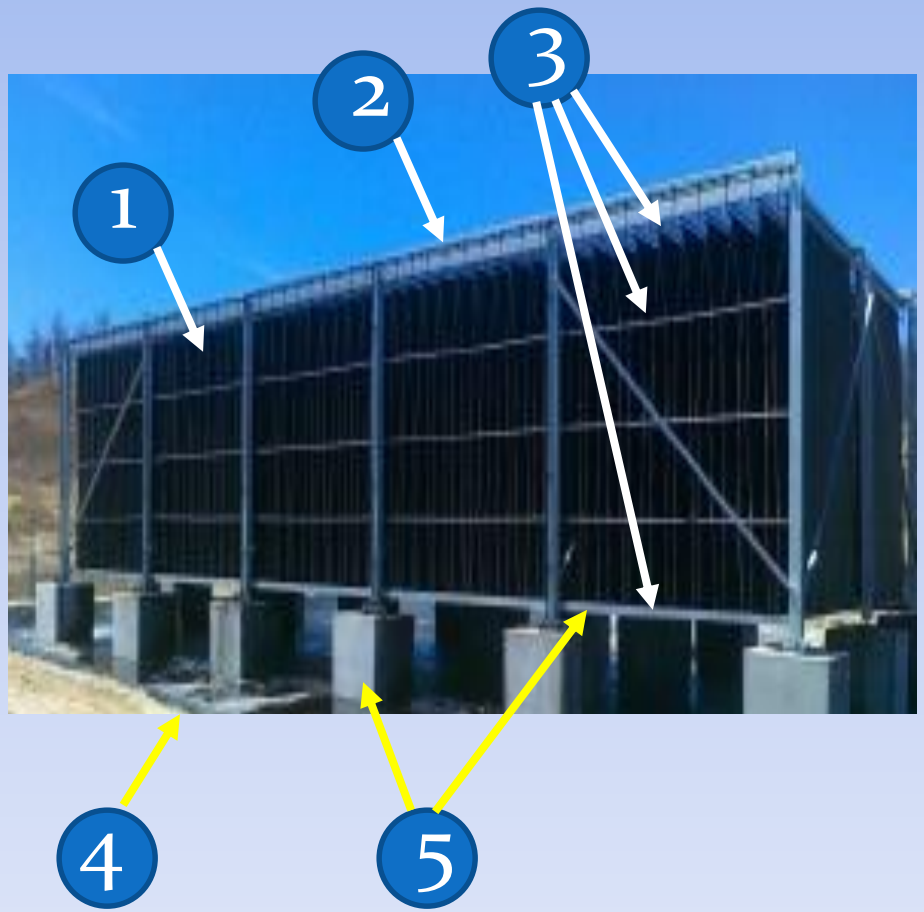


Figure 3-2 WAIV™ Unit

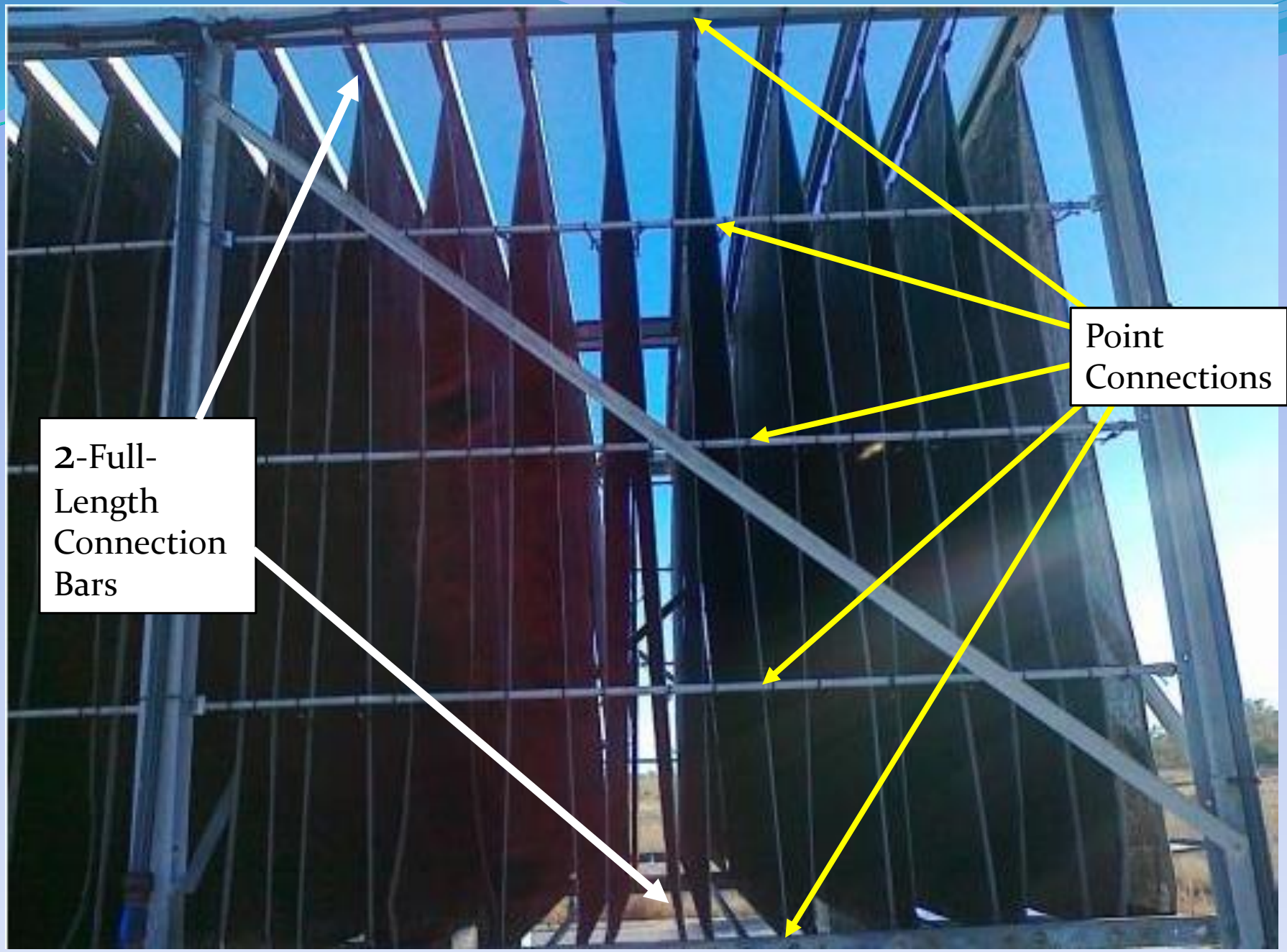
WAIV™

Wind Aided Intensified eVaporation



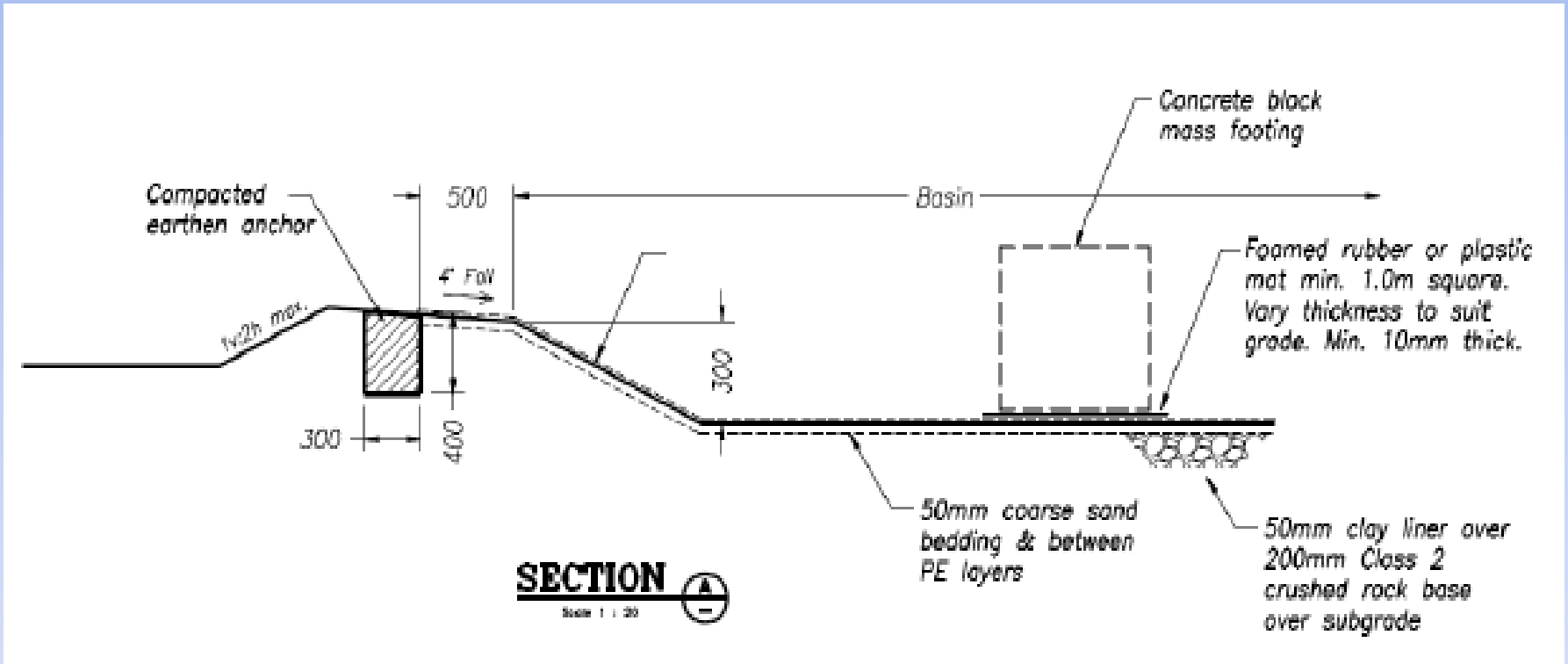
Unit Components

1. Specialized Wetted Surfaces (“Sails”)
2. Liquid Distribution
3. Tensioning System
4. Containment
5. Support Blocks and Framing



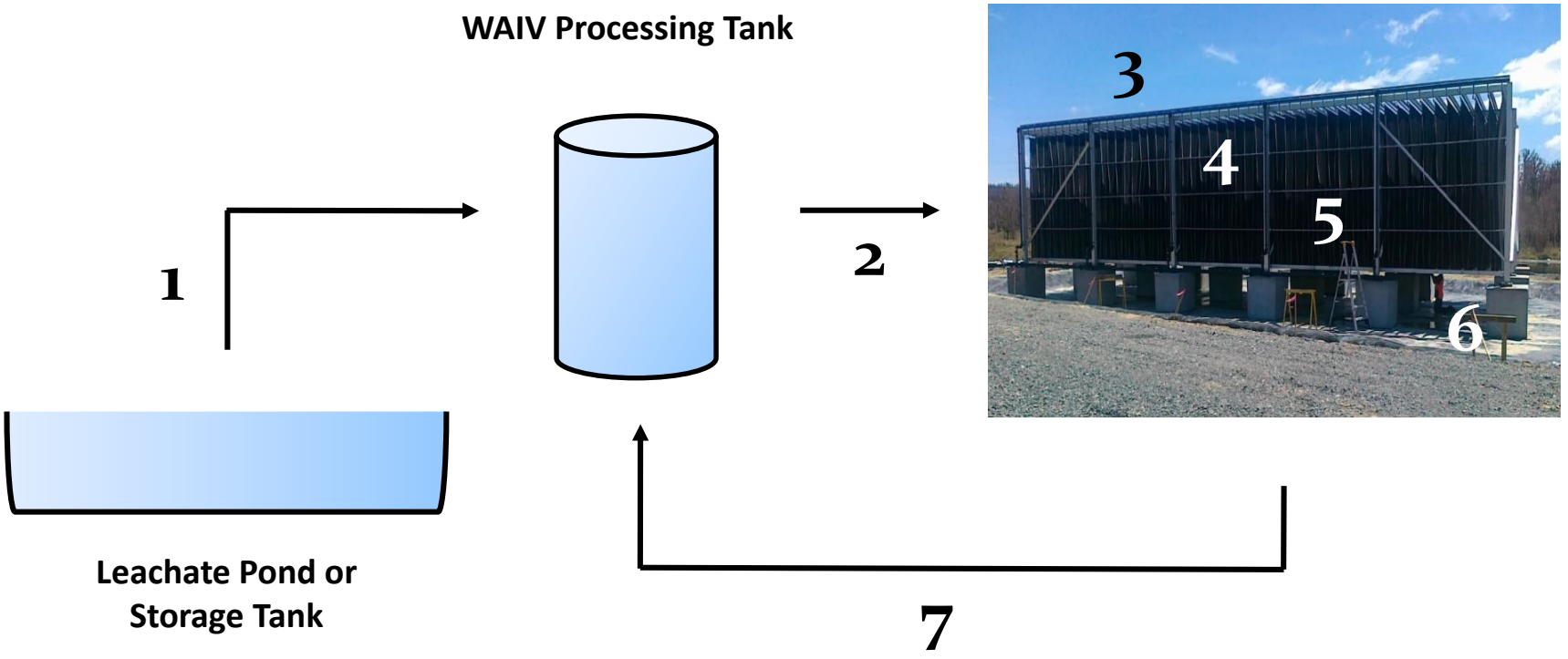
New Tensioning System

Containment Cross Section



Designed to meet requirements of facility type and State requirements

Simplified Process Flow



1	=	Supply
2, 3, 4	=	Distribution
5	=	Wind / Evaporation
6, 7	=	Circulate

Repeat

WAIV™

Wind Aided Intensified eVaporation

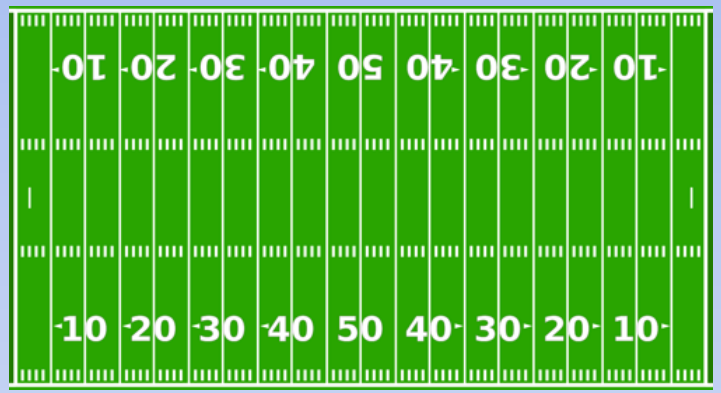
"Unit" Information:

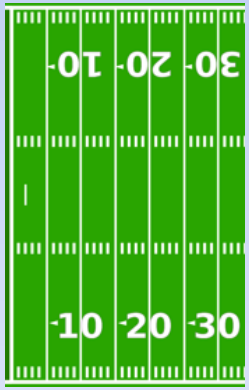
- Modular, scalable
- ~25' x 65' footprint/unit
- >62,000 ft^2 of surface area
- 1.4 acres of surface area

WAIV™

Wind Aided Intensified eVaporation

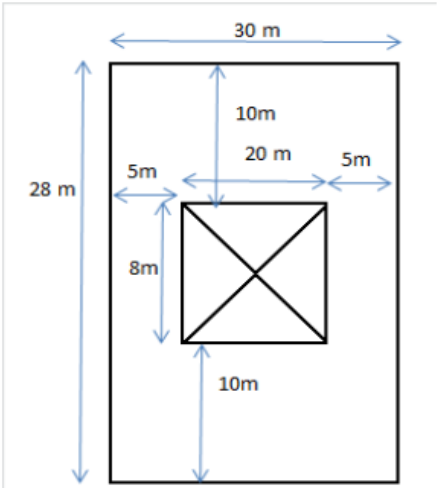
=



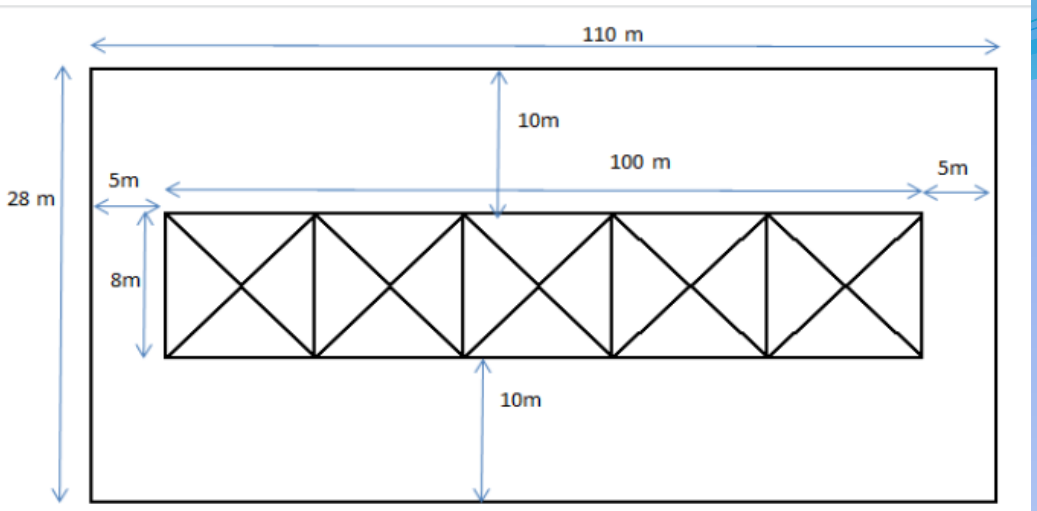


~62,000 sf (1.4 acres) of surface area
in ~62 x 25' footprint

~1.3 football fields of surface area

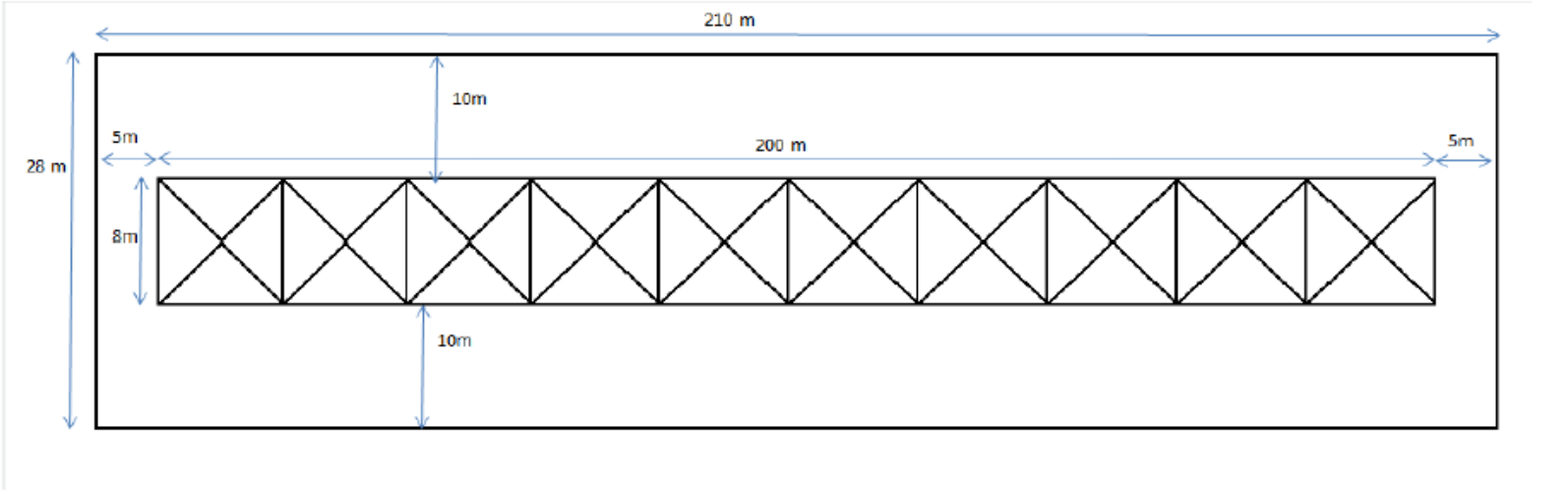


1 x WAIV Unit



5 x WAIV Unit

Modular, Scalable



10 x WAIV Unit

WAIV™

Wind Aided Intensified eVaporation

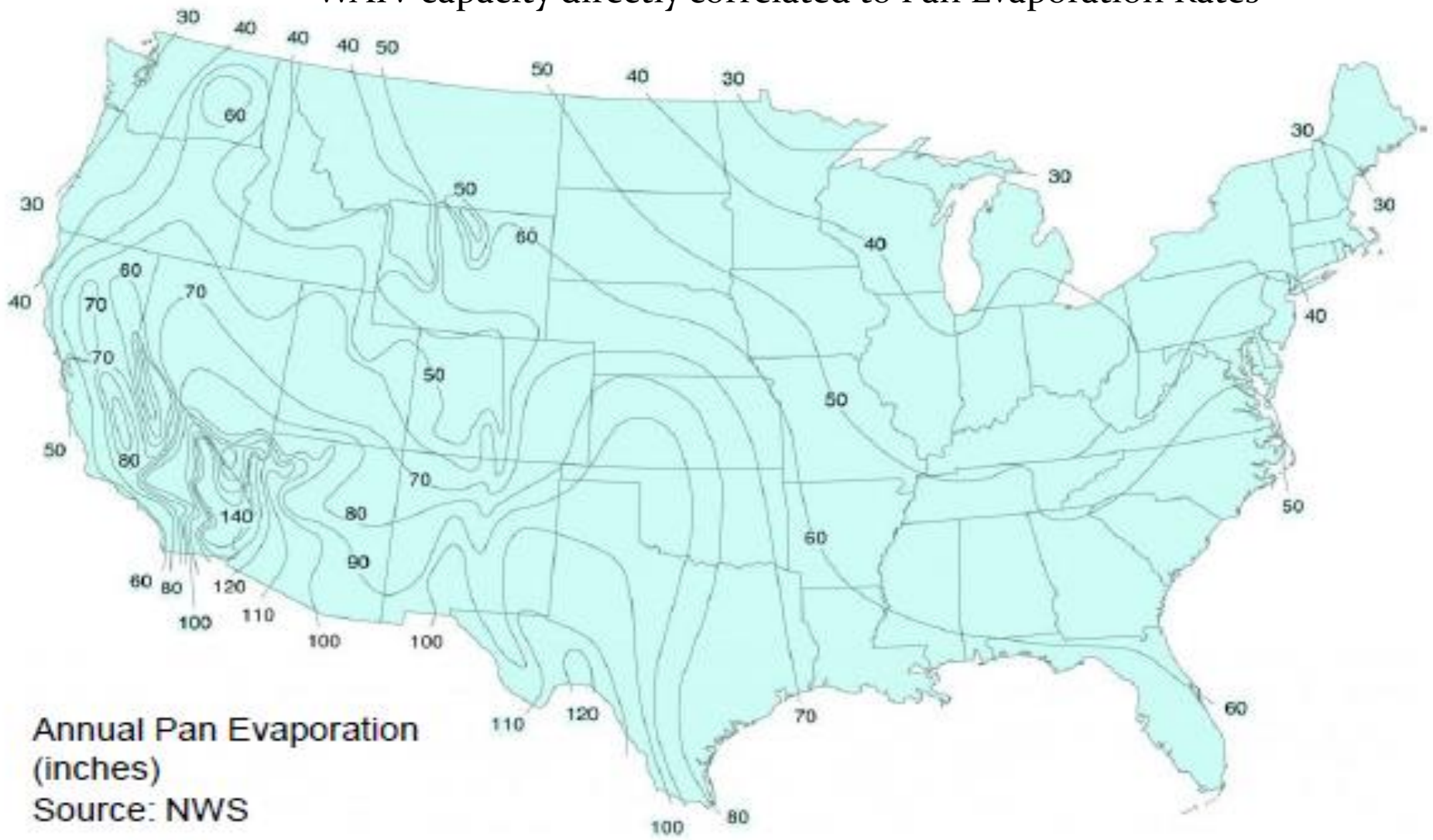
<u>"Unit" or "Pod" Info:</u>

- Modular, scalable
- ~50 x 50' footprint/unit
- 62,000 ft^2 of surface area
- 1.4 acres of surface area
- 0.8 to 1.8 MGY/unit
- **~2,500 to 5,000 gpd/unit**

Note: over 5,000 gpd observed on other sites, but do not want to overestimate

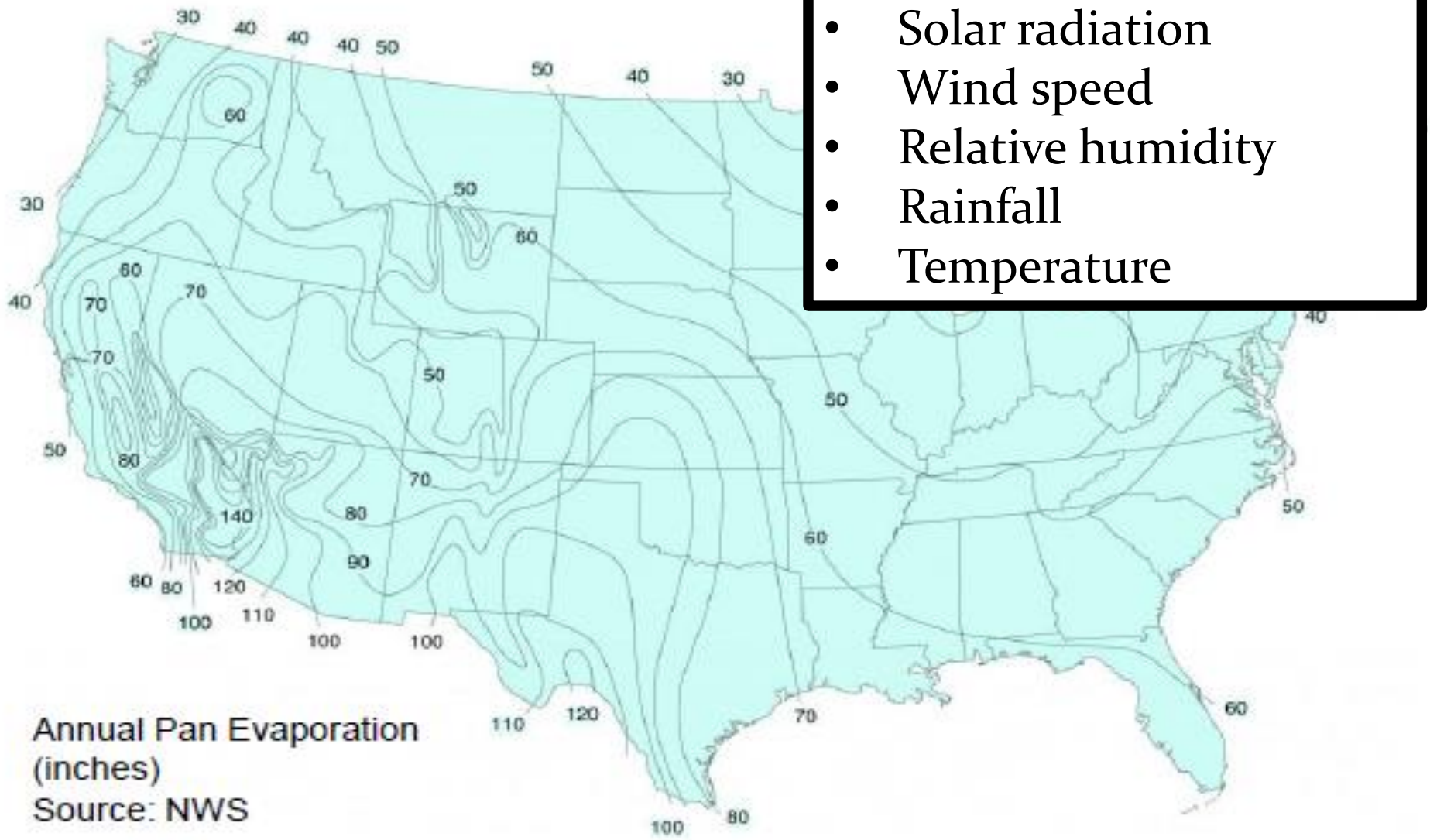
Annual U.S. Pan Evaporation

WAIV capacity directly correlated to Pan Evaporation Rates



Annual U.S. Pan Evaporation

- Solar radiation
- Wind speed
- Relative humidity
- Rainfall
- Temperature

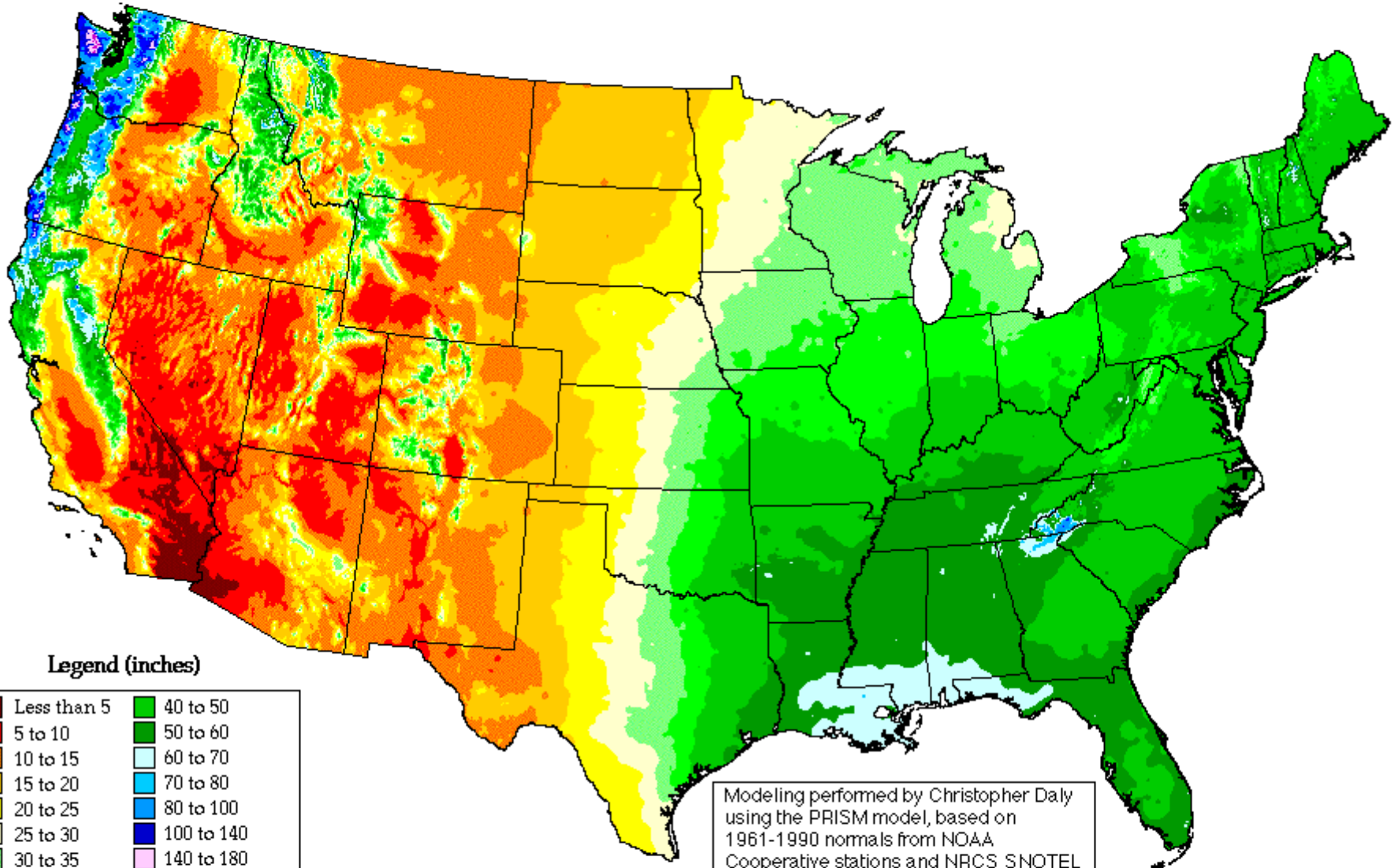


Annual Pan Evaporation (inches)
Source: NWS

Pan evaporation is a measurement that combines or integrates the effects of several climate elements: temperature, humidity, rainfall, drought dispersion, solar radiation, and wind.

Annual Average Precipitation

United States of America



Legend (inches)

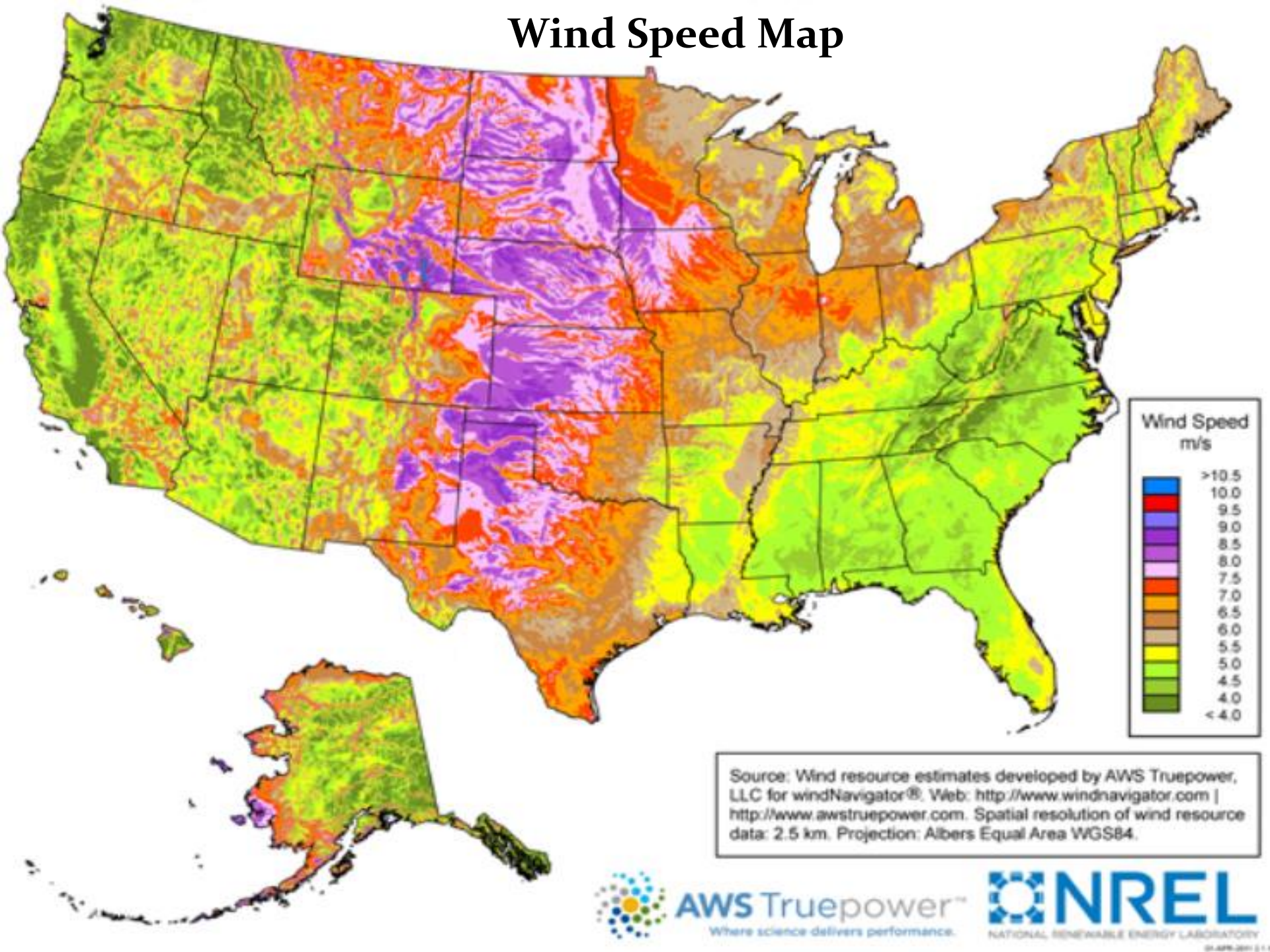
Less than 5	40 to 50
5 to 10	50 to 60
10 to 15	60 to 70
15 to 20	70 to 80
20 to 25	80 to 100
25 to 30	100 to 140
30 to 35	140 to 180
35 to 40	More than 180

Period: 1961-1990

Modeling performed by Christopher Daly using the PRISM model, based on 1961-1990 normals from NOAA Cooperative stations and NRCS SNOTEL sites. Sponsored by USDA-NRCS Water and Climate Center, Portland, Oregon.

Oregon Climate Service
George Taylor, State Climatologist
(541) 737-5705

Wind Speed Map



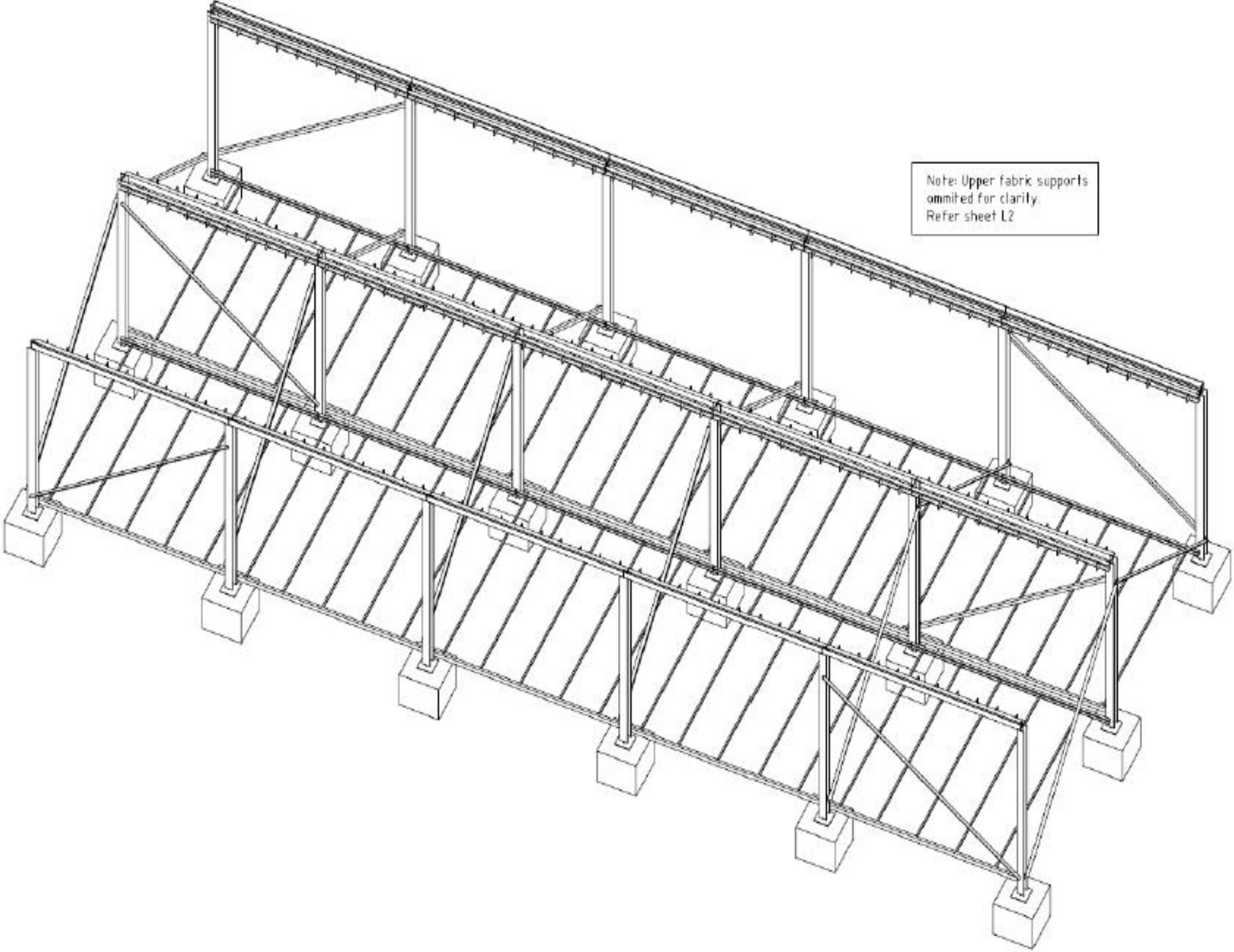
Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.

AWS Truepower™
Where science delivers performance.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

WAIV Construction

Copping Landfill - Australia


Note: Upper fabric supports
ommited for clarity.
Refer sheet L2

WAIV Construction

Berm, Liner and Concrete Blocks

WAIV Construction

Galvanized Steel Frame


coates
260 MRT
coates

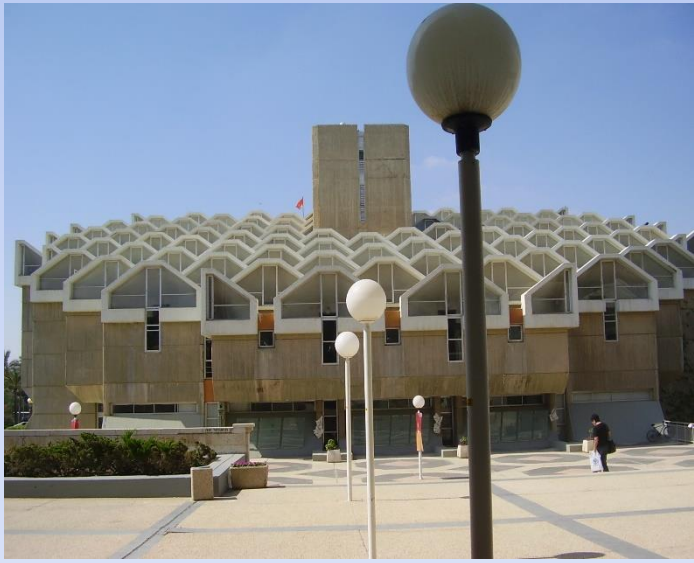
WAIV Surfaces and Distribution Piping Installed

WAIV Construction

Supporting equipment (tank, pumps, filter, PLC, etc.)

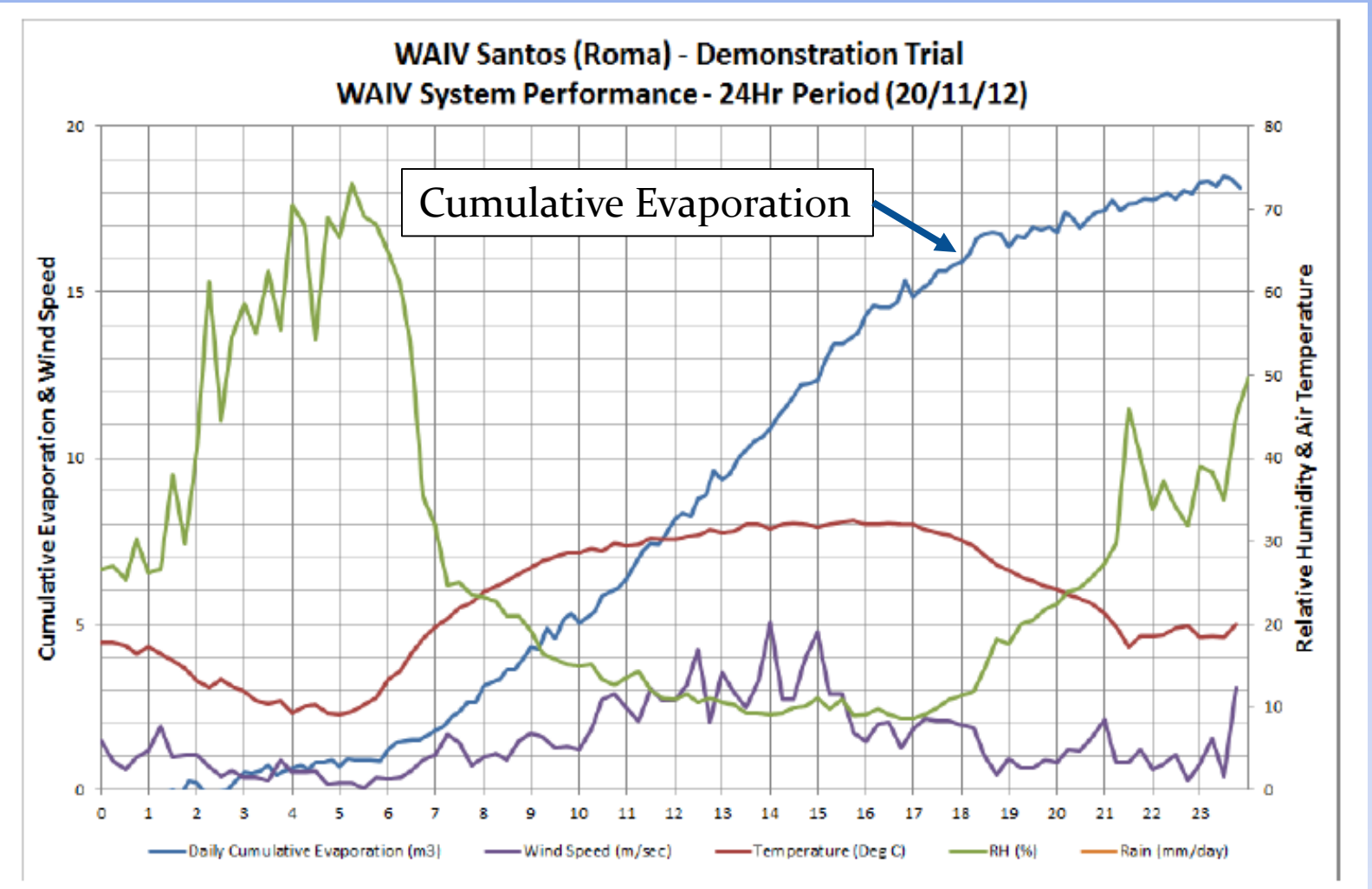
Extensive Research and Validation

Ben-Gurion University of the Negev



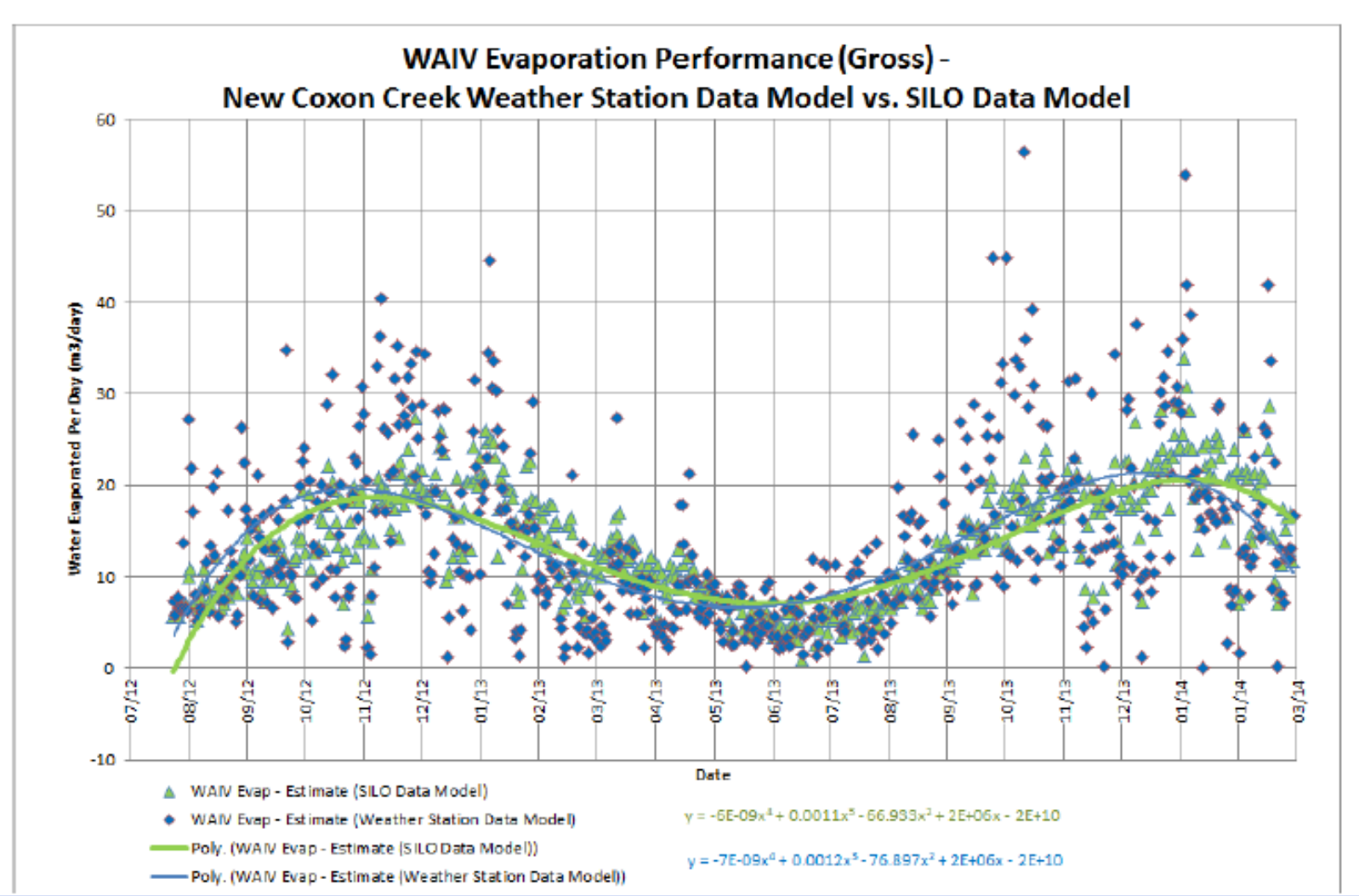
Backed by Science

Extensive Research and Validation



Daily data logging of: Cumulative Evaporated, Wind Speed, RH, Temp., Rainfall

Extensive Research and Validation



Validation of Evaporation Modeling with Actual Evaporation Data

Examples of WAIV™ Systems Around the World

1. **Leachate: Copping Landfill - Tasmania, Australia**
2. **Produced Water - Coal: Santos - Queensland, Australia**
3. **Concentrated Brine: GM– Ramos Arizpe, Mexico**
4. **Desalination: Pettavel Winery – Victoria, Australia**
5. **Desalination: Mekorot – Ketziot, Israel**

1 – Copping Landfill in Australia

for Leachate Evaporation

Copping Landfill in Australia

Site: Southern Waste Solutions (SWS) Copping Landfill

Location: Tasmania, Australia (latitude ~42 deg S)

Purpose: Leachate Evaporation

Operation: 2013 - Present

Key Results:

- Initial problems (i.e. strong winds, component strengths, scaling of calcium carbonate on the surfaces, etc.)
- Lessons learned and improvements made
- In the winter months, the system evaporated 5,500 gpd

Copping Landfill in Australia

- April 2016 – working reliably
- Adding WAIV capacity for their secured (hazardous) waste cell

2 – Santos Coxon Creek Facility in Australia

for produced water from coal seam gas operations

Santos Coxon Creek Facility in Australia

Site: Santos Coxon Creek – Coal Seam Gas Facility

Location: Queensland, Australia

Purpose: Mining RO Concentrated Brine Reduction from Produced Water

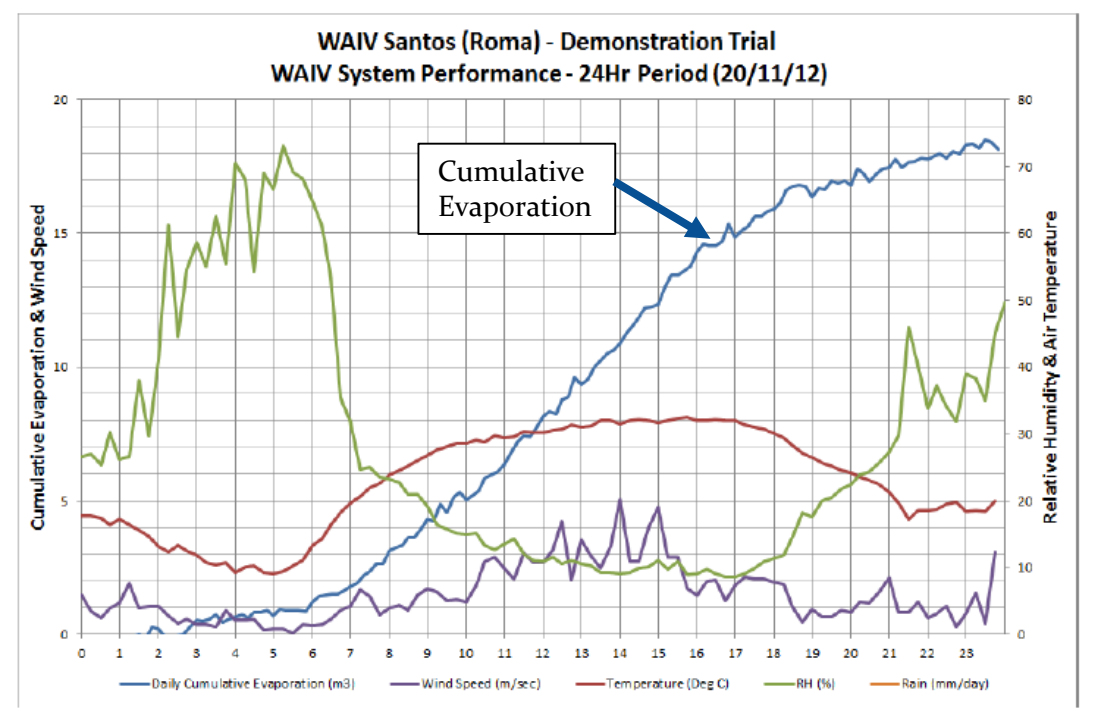
Operation: August 2012 –

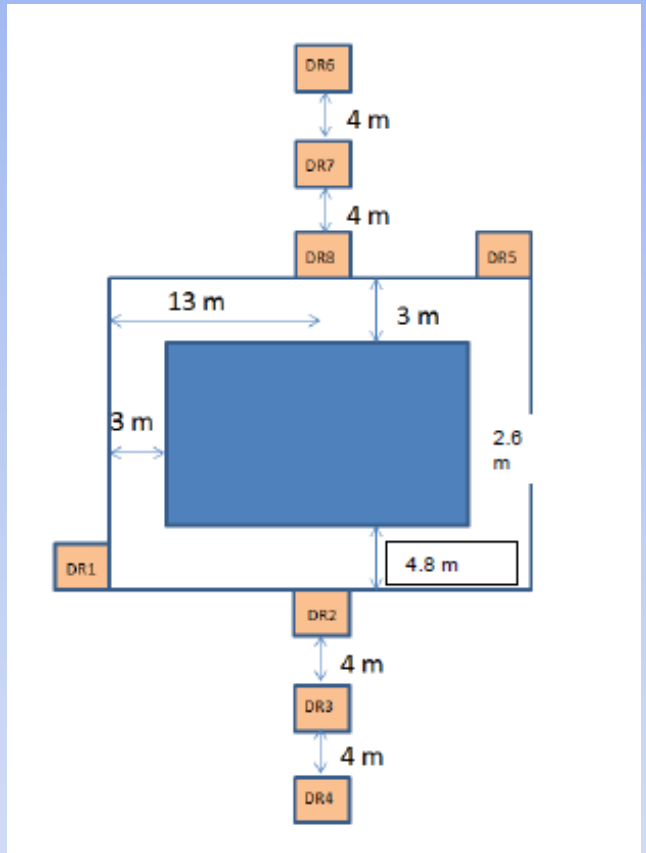
Key Results:

- 3,100 gpd average initially
- 5,200 gpd after improvements
- The system consistently evaporated more than 10X the volume of an evaporation pond.

Santos Coxon Creek Facility in Australia

The project included extensive research and validation of WAIV's effectiveness.





Extensive research to prove no drift

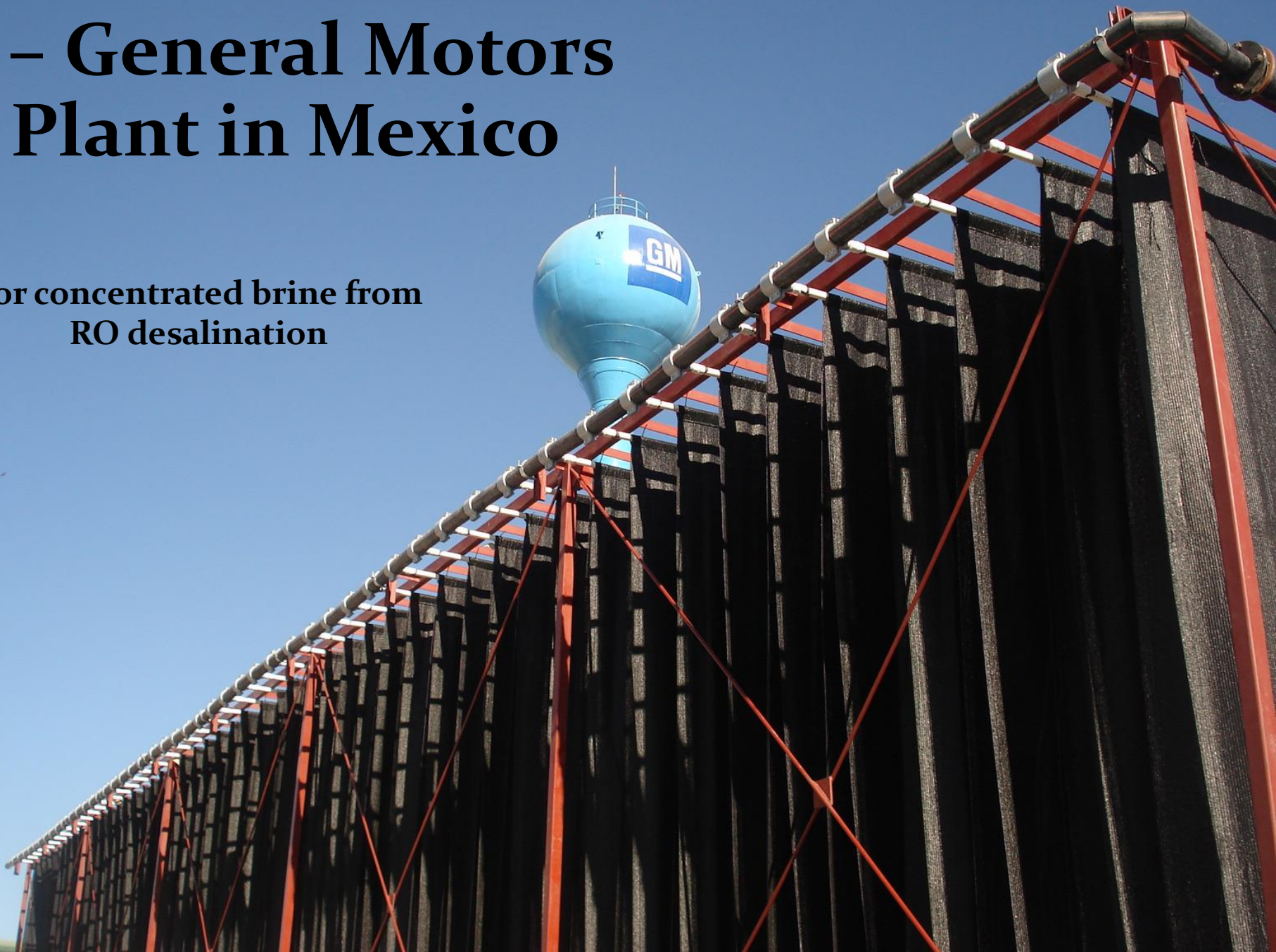
An 89 page technical document was produced from the extensive research conducted at this site.

Santos Coxon Creek Facility in Australia

The system was deemed a success and a good demonstration of WAIV's effectiveness to enhance evaporation.

3 – General Motors Plant in Mexico

For concentrated brine from RO desalination



General Motors Plant in Mexico

Site: General Motors Automobile Plant

Location: Ramos Arizpe, Mexico

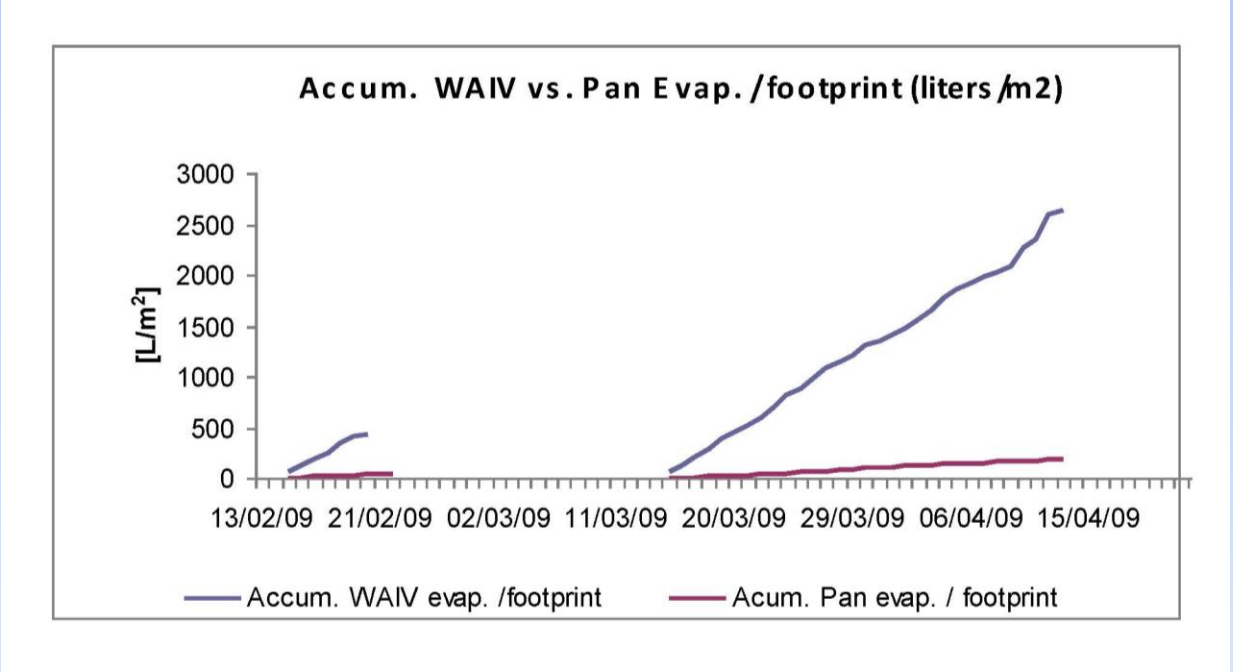
Purpose: RO Concentrated Brine Reduction

Operation: 2009 – shut-down of entire facility by GM

Key Result:

Additional process water required and GM was looking for alternate to evap ponds for RO brine disposal.

The system evaporated more than 10X the volume of an evaporation pond.



Initial Installation of the WAIV System

WAIV – Lessons Learned

WAIV

- Tested in the field for over a decade
- Numerous improvements have been made to the system as a result of **practical field operational experience**

Lessons learned regarding:

- Fabric selection
- Mineralogical and biological fouling
- Frame construction
- Dealing with high winds
- Preventing drift
- Diff pumps used to find most effective
- Desired flow rate (circulation rate) tested for optimization

WAIV – Lessons Learned

(continued)

Lessons learned regarding:

- Algae growth blocking pump intake screen
- Access to equipment and WAIV surfaces for maintenance
- Water distribution improvements
- WAIV sail tensioning
- Control panel high temperatures
- Fabric dimensions
- Sail spacing (not too close or too far apart)
- Size of concrete support blocks
- Weather station installation to monitor performance vs conditions
- Other…

Wind Aided Intensified eVaporation

FAQ's

- Landfill Types - Applicability
- Fouling – Mineralogical
- Climate –
  - Humid Environments
  - High Rainfall
- Processing capacity of a WAIV system

Wind Aided Intensified eVaporation

FAQ's

What types of landfills can use WAIV for leachate evaporation?

- Open landfills
- Closed landfills
- MSW
- C&D
- Industrial or other mono-fill landfills
- Even hazardous waste landfills
- Ash Ponds

Wind Aided Intensified eVaporation

FAQ's

What about mineralogical fouling of the WAIV surfaces?

- Developed for desalination industry (which has high TDS in RO reject)

- Leachate TDS typical concentrations
  - Closed = low 1,000's mg/L
  - Open = 7-18,000 mg/L
  - Open extremely high = 30,000+ mg/L

- Maintenance = periodic acid flush

Brine Crystallization

Harvesting Desirable Minerals with WAIV

Operates Under Supersaturated Conditions

30% (300,000 mg/L) Dissolved Solids

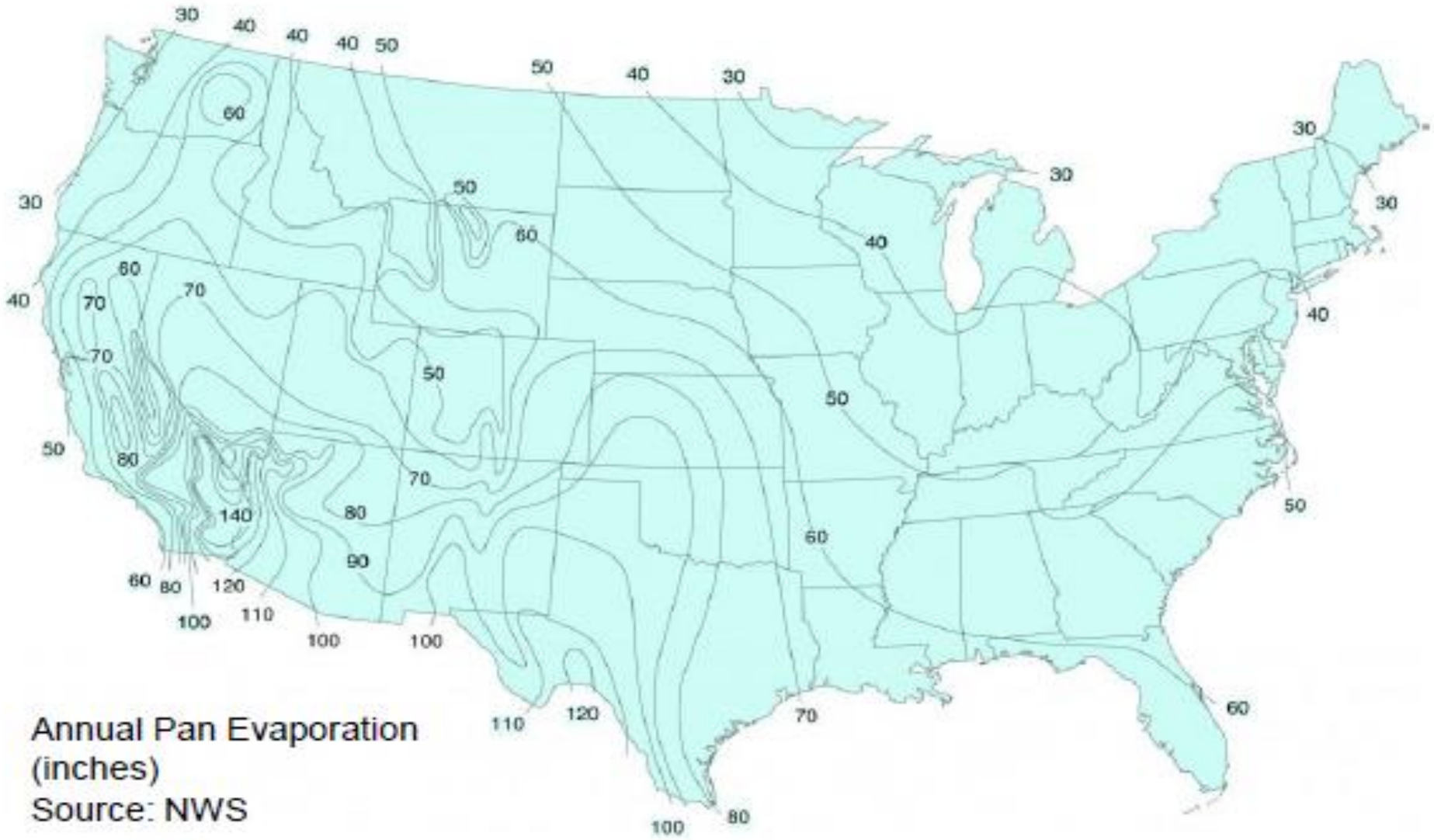
Wind Aided Intensified eVaporation

FAQ's

What about operating in very humid environments like those in Florida and all along the Gulf Coast?

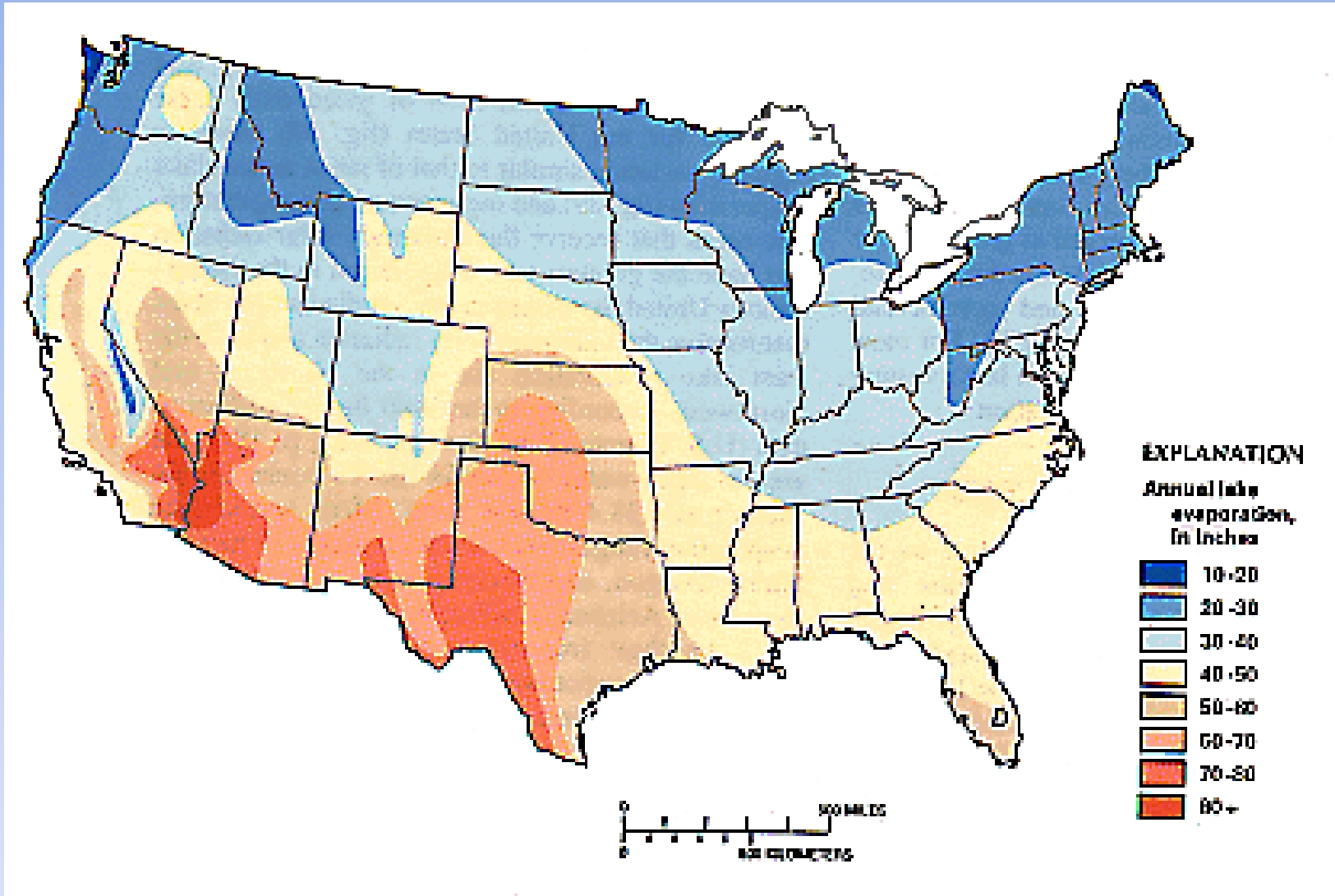
- Direct correlation with Pan Evaporation
  - High solar component
  - Sufficient winds
- Results are predictive (evaporation modeling)
- Operates 24/7 so take full advantage of 'available' evaporation capacity

Annual U.S. Pan Evaporation

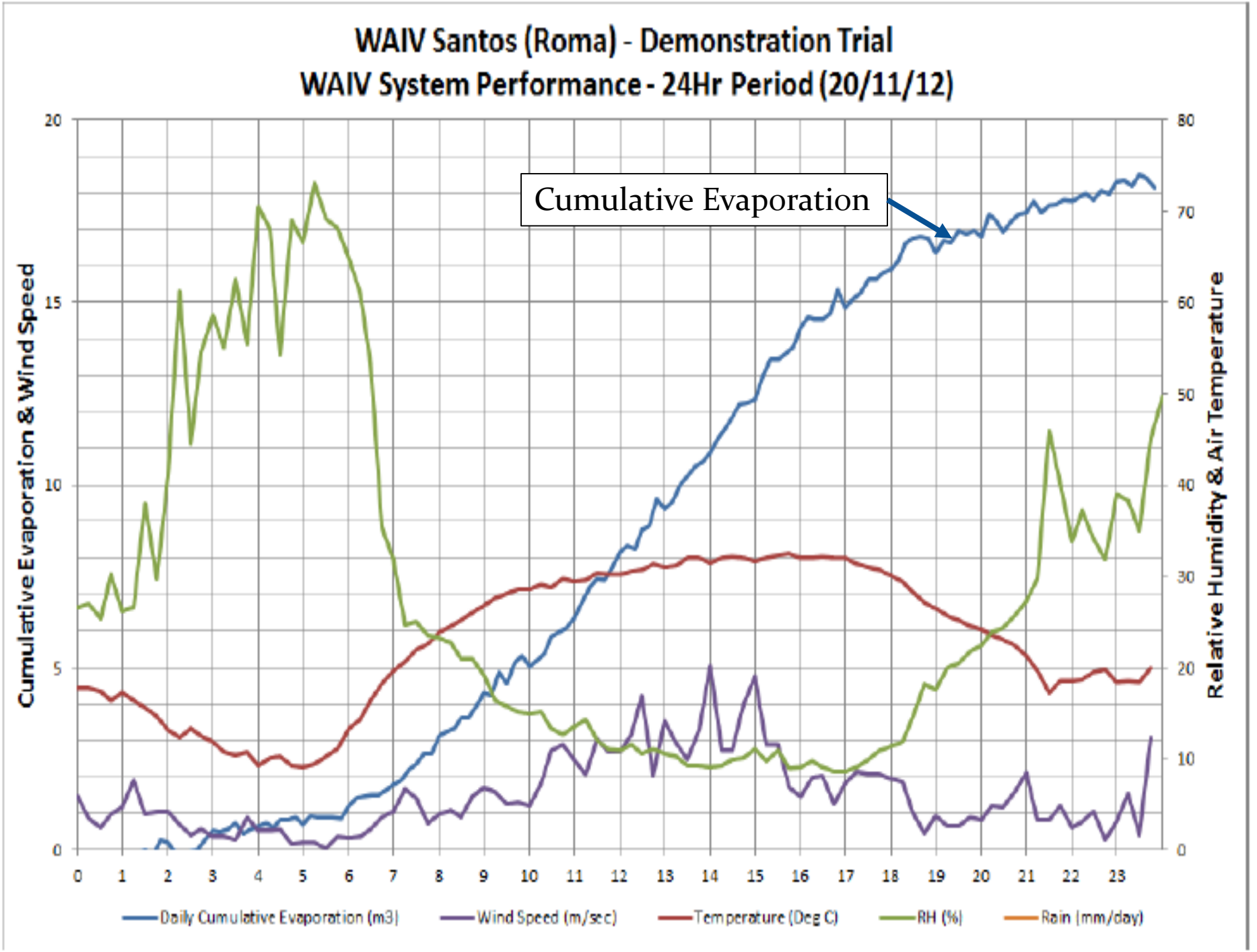


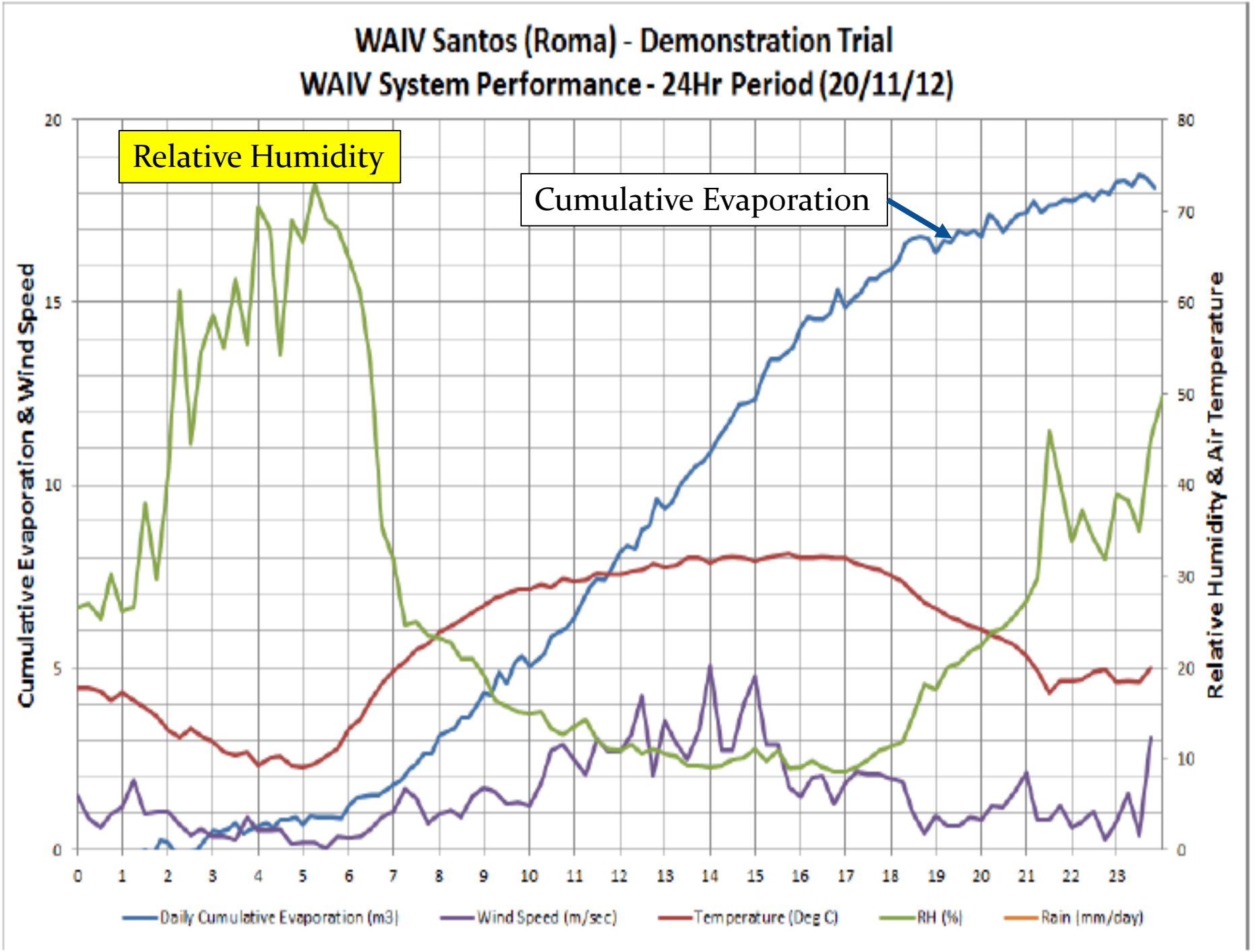
Annual Pan Evaporation
(inches)
Source: NWS

Lake Evaporation



(Source: Data from U.S. Department of Commerce via USGS website)


WAIV Santos (Roma) - Demonstration Trial
WAIV System Performance - 24Hr Period (20/11/12)
Cumulative Evaporation
Cumulative Evaporation & Wind Speed
Relative Humidity & Air Temperature
0
5
10
15
20
0
10
20
30
40
50
60
70
80
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Daily Cumulative Evaporation (m3)
Wind Speed (m/sec)
Temperature (Deg C)
RH (%)
Rain (mm/day)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0
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80
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Daily Cumulative Evaporation (m3)
Wind Speed (m/sec)
Temperature (Deg C)
RH (%)
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WAIV Santos (Roma) - Demonstration Trial

WAIV System Performance - 24Hr Period (20/11/12)

Relative Humidity

Temperature

Cumulative Evaporation & Wind Speed

Relative Humidity & Air Temperature

Daily Cumulative Evaporation (m3) | Wind Speed (m/sec) | Temperature (Deg C) | RH (%) | Rain (mm/day)

WAIV Santos (Roma) - Demonstration Trial

WAIV System Performance - 24Hr Period (20/11/12)

Relative Humidity

Temperature

Cumulative Evaporation & Wind Speed

Relative Humidity & Air Temperature

Daily Cumulative Evaporation (m3) | Wind Speed (m/sec) | Temperature (Deg C) | RH (%) | Rain (mm/day)

Relative Humidity

Temperature

Wind Speed

Cumulative Evaporation & Wind Speed

Relative Humidity & Air Temperature

Daily Cumulative Evaporation (m3)

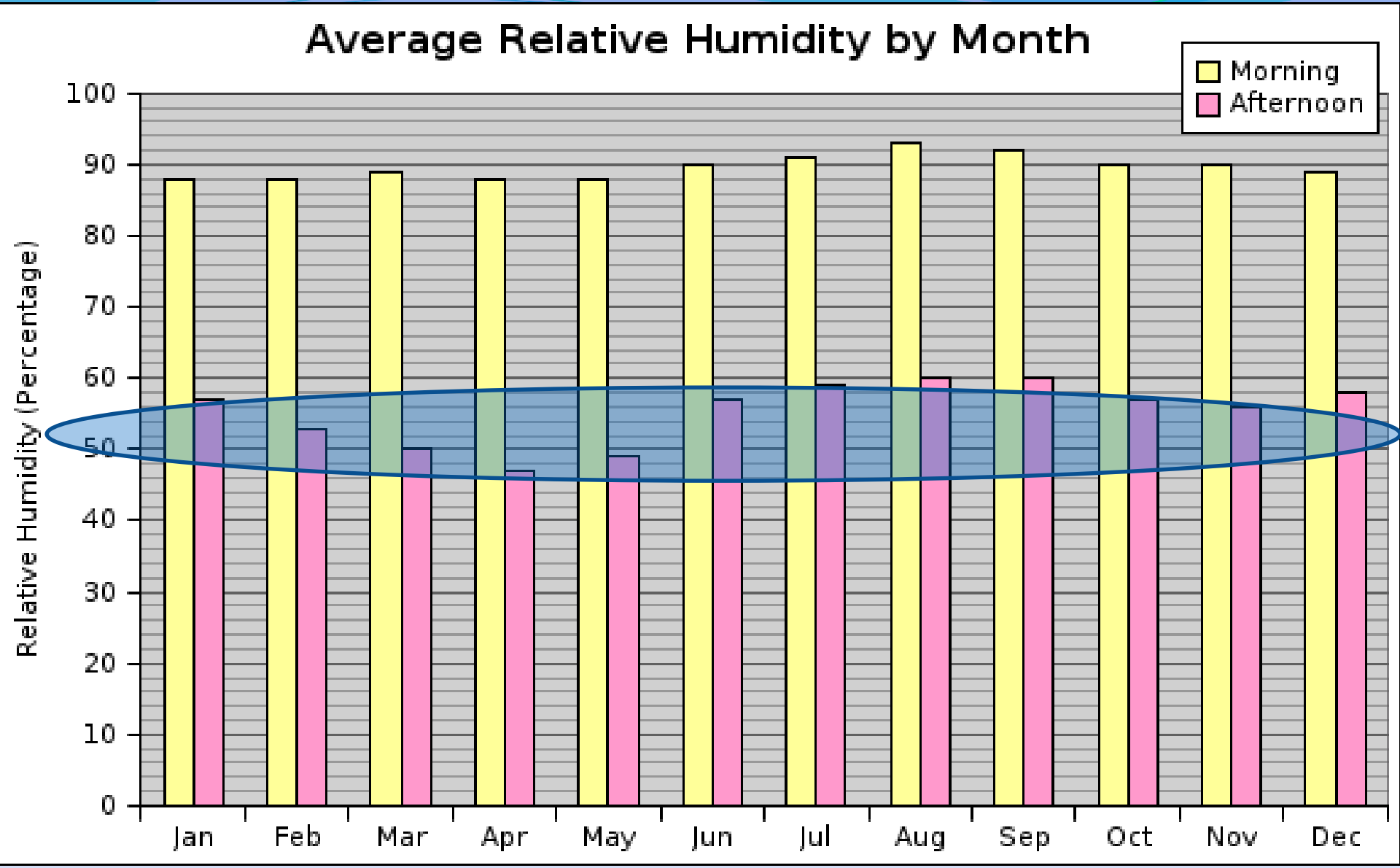
Wind Speed (m/sec)

Temperature (Deg C)

RH (%)

Rain (mm/day)

WAIV Santo al
WAIV System Pe (11/12)
Relative Humidity
Cumulative Evaporation
Wind Speed
Temperature
Cumulative Evaporation & Wind Speed
Relative Humidity & Air Temperature
0
5
10
15
20
0
10
20
30
40
50
60
70
80
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Daily Cumulative Evaporation (m3)
Wind Speed (m/sec)
Temperature (Deg C)
RH (%)
Rain (mm/day)


Average Relative Humidity by Month
Morning
Afternoon
Relative Humidity (Percentage)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Orlando, FL

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FAQ's

What about areas of high rainfall?

- Similar to 'Humid' FAQ
- Rainfall volume included in analysis

Leachate Storage Ponds
1” rain / acre = 27,100 gallons
55” / year / ac = 1.5 Million Gallons

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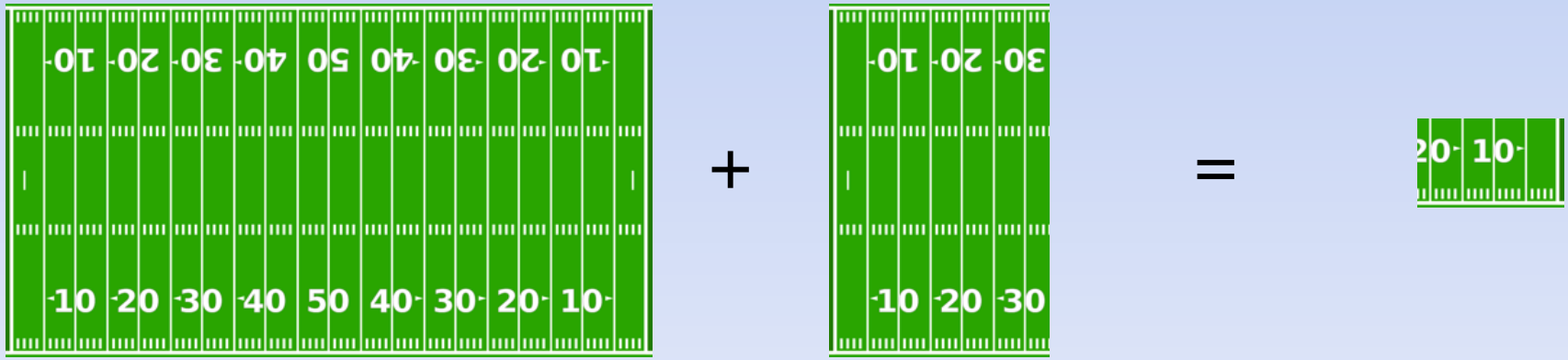
FAQ's

What about areas of high rainfall?

- Similar to 'Humid' FAQ
- Rainfall volume included in analysis
- Ratio of surface area to footprint = very favorable



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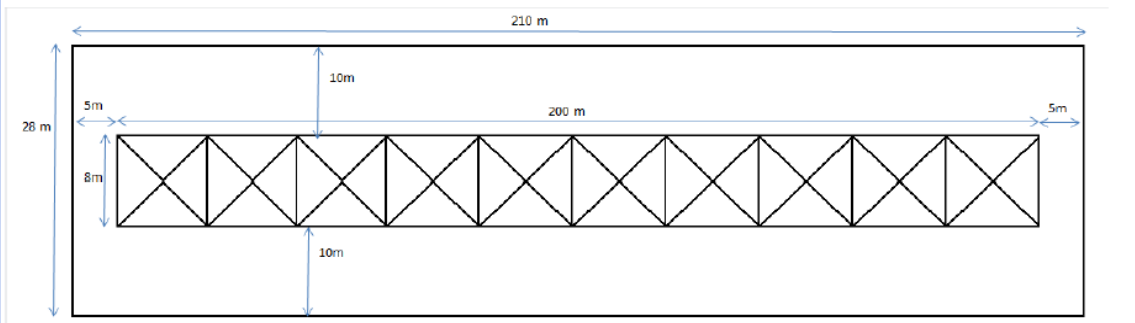
FAQ's

How much liquid can a WAIV system process?

- 0.8 – 1.8 MGY/unit
- 2,500 – 5,000 gpd/unit
- Modular - Scale up to desired gpd



10 x WAIV Unit

Rule of Thumb = ~1 MGY/unit

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FAQ's

- Space Requirements
- Costs
  - O&M
  - Capital
- Permitting
- Matching technology to a site
- Performance enhancement

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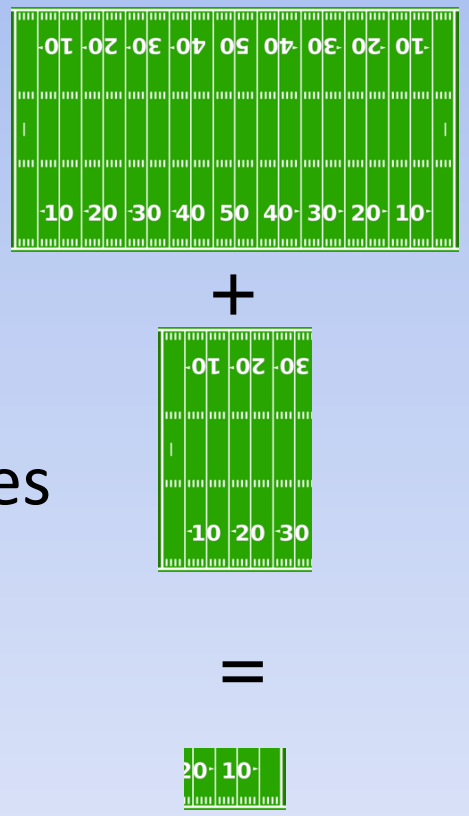
FAQ's

What are the space requirements?

- 1 WAIV Unit ~0.15 acres
- 2 WAIV Units ~0.25 acres
- 3 WAIV Units ~0.35 acres



- Additional WAIV Units each add ~0.1 acres

<u>Location</u>

- Near leachate source
- On TOP of landfill (↑ wind speeds)

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FAQ's

O&M?

- Facility staff very busy with other site responsibilities
  - Owner can focus on revenue-producing activities
- Primarily **hands-off system for Owners**
- Provide turn-key installation and **all the operational support included**
- Goal to **make your problems** with leachate go away

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FAQ's

O&M Costs

- **O&M is included in a per gallon cost**
  - Expect per/gal costs cut by 30-50% or more
  - Pay for performance
- Full service O&M included
  - Local approved technician to respond
- Owner expected to help with minor tasks, e.g.:
  - Restart system after power interruption
  - Visual inspections
  - Notify LMS if any concerns
  - Minor troubleshooting with LMS staff

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FAQ's

Capital Costs

- Affected by climate and processing capacity / unit
  - 5 MGY in different climates
- Affected by how much an owner wants to invest

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FAQ's

Capital Costs

<u>3 Primary Capital Options</u>

1. Most costs by owner (TBD per site specifics)
2. Shared costs (~$XY,000 / unit)
3. **No Cost to owner ($0 to LMS)**

- Pay for performance (reduce risk to Owner)
- Payback on capital investment **(ROI): ~1.5 – 2.5 years** typ
- Typical Owner investment ~$200-400k

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FAQ's

What about gaining regulatory approval for a new technology?

- Fundamental technology
- Easy to understand and explain
- Fewer risks than other technologies
- Protective of soil and groundwater
- Anticipate acceptance with thorough explanation

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FAQ's

How do I know if this is a match for my site?

- A No-Cost "Initial Site Data Assessment"
  - Look at key site parameters
  - Looking for fatal flaws
- Completed free of charge
  - We're picky!!
  - Too much invested for anything less

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FAQ's

Can we enhance performance?

- Install in areas of higher wind
  - e.g. top of closed cells

- High flow industrial fans
  - e.g. Install 3 industrial fans with 20,000 cfm each
    - Total flow = **31.5 billion cubic feet in a year**
    - Bound to enhance efficiency (straight physics)
    - Blowers are low hp, so ~$5-6k/yr electric total

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FAQ's

Final Comments

- High degree of applicability
- Developed with science
- Proven in field w/ many improvements
- Low to no cost options, O&M included
- Beneficial for the environment
- No risk to owner to take a look

'Natural Systems' are a new option for landfill owners to consider

Leachate Disposal Through WAIV™

THANK YOU

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LEACHATE MANAGEMENT SPECIALISTS

"Finding a Better Way"

Old Way

New Way