NAU NORTHERN ARIZONA UNIVERSITY

SRP EVAP

ME 476C Spring 2025

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Presentation Layout

- Project Overview
- Importance/Why
- Background & Benchmarking
- Customer & Engineering Requirements
- QFD
- Literature Review
- Mathematical Modeling
- Budget
- Gantt Chart
- Conclusion
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Project Overview

- The objective of this project is to research and implement an experimental apparatus to mimic a full-scale cover of a water canal equipped with solar panels.
- Sponsored by Dr. Tom Acker, Sr. Principal Engineer, Innovation and Development at Salt River Project. (SRP)
- Corporate Goal of SRP: reduce SRP's carbon emissions 82% by 2035, net zero by 2050.

Picture Credit: Tectonicus

Importance

Some Facts about SRP:

- Delivers 800,000 acre-feet of water to the greater Phoenix area - largest water supplier of region
- Manages seven storage reservoirs that are fed by the Salt River and Verde River
- Delivers water to customers via 131-miles of canals.
- One of the largest public power utilities in the U.S.
- Over 1.1 million electric service customers
- Peak load of over 8,000 MW in the summer

- Reducing evaporation in canals and using available space to generate electricity from solar panels will help SRP reach their Corporate Goal while maintaining customer satisfaction, high reliability, and energy affordability

- Little research has been done on the effectiveness of using solar panels over canals to reduce evaporation, so providing useful data on the subject can help SRP and their associate research team at ASU make informed decisions for their project development

Background & Benchmarking

- ❑ Casa Blanca Canal Solar Project:
  - ❑ Currently under construction on the Gila River
  - ❑ Combines renewable energy generation with water conservation
    - ❑ Half mile long
    - ❑ Reduces algae/aquatic plant growth
    - ❑ Decreases evaporation up to 50%
    - ❑ Increased water quality/quantity

Samantha Synk, 2/10/25, SRP

Background & Benchmarking

- Project Nexus:
  - Based in California
  - Covers various sections of the Turlock Irrigation District’s (TID)
    - Aims to study and build solar-over-canal technology
    - Determine water evaporation due to shading
    - Analyze how solar panel installations can reduced algae growth
    - Provide renewable power generation to local communities
    - Demonstrate scalability for potential statewide implementation

Background & Benchmarking

- Gujarat Canal Solar Project:
  - Located in India
  - The first to create solar-over-canal technology in 2012
    - Started with 1 MW test project over ½ mile strip of canal
    - Later expanded to 10 MW in 2015
    - Prevents 2 billion liters of water from evaporating annually
    - Solar power is primarily used for irrigation pumps.

Jorge Cesin, 2/10/25, SRP

Customer & Engineering Requirements

Customer Requirements	Engineering Requirements

• Agenda & Meeting Materials
• Scientific & Engineering Accuracy
• Design experiment & collect data to provide useful results for ASU research team
	• Parameters for experiment
	  ○ Relative Humidity
	  ○ Air Temperature
	  ○ Wind Speed
	  ○ Canal Width
	  ○ Water Depth
	  ○ Water Flow Speed
	• Provide how mass transfer is equal to heat transfer
	• Convective heat transfer coefficient should have transferable geometric similarity to mass transfer

QFD

Project: Captsone SRP QFD
Date: 2/10/2025

(Between 1 and 5, lowest rating to highest rating)
(3 = weak) (6 = moderate) (9 = strong)

System QFD

		Technical Requirements (0,3,9)							Competition (1-5)				
Customer Needs	**Customer Weights**	Evaporation Rate Measurement Precision	Enviromental Condition Monitoring & Control	Material Durability & Longevity	Geometric & Surface Area Optimization	Scalability & Adaptability to Different Environments	Economic Feasibility & Practical Implementation	Evaporation Suppression Effectiveness	*Casa Blanca Canal Solar Project*	*Project Nexus*	*Gujarat Canal Solar Project*		
Water Conservation	5	9	6	9	3	6	3	9	5	3	5		
Energy Efficiency	3	3	6	3	3	6	9	3	1	4	5		
Ease of Maintenance & Implementation	1	3	3	9	3	6	9	3	1	2	4		
Environmental Sustainable	3	9	6	9	6	9	3	9	4	5	5		
Scientific & Engineering Accuracy	5	9	9	3	3	6	3	9	2	5	3		
Adaptability to Different Environments	3	6	6	3	3	9	3	6	1	5	3		
Cost	3	3	3	6	6	3	9	3	2	3	3		
Technical Requirement Units		mm/day or L/m^2 /day	°C or (%)	Years	m^2 / m^3	Hours & m/s	$	%					
Technical Requirement Targets													
Absolute Technical Importance		54	39	39	30	45	36	51					
Relative Technical Importance		1st	5th	4th	7th	3rd	6th	2nd					

Garet Bowles, 2/10/25, SRP

Literature Review

- **Books:**
  - Floating PV Plants [7]
    - This book explores the rapid growth and advantages of FPV technology, discussing integration into various environments and the environmental benefits of such systems.
  - Submerged and Floating Photovoltaic Systems [8]
    - This book covers the theoretical, numerical, and experimental aspects of water integrate PV systems, providing design-focused analyses and case studies.
- **Papers:**
  - The Impact of Floating Photovoltaic Power Plants on Lake Water Temperature and Stratification [4]
    - This paper quantifies Floating Photovoltaic (FPV) impacts on lake water temperature, energy budget, and thermal stratification through measurements of near-surface lateral wind flow.
  - Impacts of a Floating Photovoltaic System on Temperature and Water Quality in a Shallow Tropical Reservoir [5]
    - This paper found that areas beneath the solar panels experienced reduced temperature fluctuations, which can have implicationfor aquatic ecosystems.
  - The Impact of System Sizing and Water Temperature on the THermal Characteristics of Floating Photovoltaic Systems [6]
    - This paper examines how the size of FPV systems and the temperature of the water they are placed on, these factors influencethe temperature of the photovoltaic (PV) panels.
- **Other:**
  - Combined Effect of Wind Speed and Covering Irrigation Canals on water Quality Parameters [9]
    - This article Indicates that as wind speed increases, both water velocity and evaporation rates in canals rise.
  - Study of the effect of wind speed on evaporation from soil through integrated modeling of the atmospheric boundary layer and shallow subsurface [10]
    - This article will help compare the study's modeling to methods used for open water evaporation.

Literature Review

- **Books:**
  - Fox and McDonald's introduction to Fluid Mechanics [11]
    - The chapter from this textbook that I used as a source is chapter 7, Dimensional Analysis and Similitude, section 7.4, Flow similarities and model studies. This chapter gives a good introduction on non-dimensionalizing parameters and the requirements that prototypes and models must have in order to be effectively scaled to actual size. This is relevant for our research because the main objective of our project is to create a scale model with the correct parameters to accurately reproduce the conditions of a canal cover in solar panels to observe the effects on evaporation.
  - Similarity and Dimensional Methods in Mechanics [12]
    - This book provides a really good introduction on how to set up an experiment with the proper nondimensionalized parameters in order to accurately describe the natural phenomena in question. This source leads off of the first one in providing proficient background in setting up proper experimentation procedures for accurate modelling, as well as going into detail on how to go about this. This is going to be crucial for our project as we need to replicate the evaporation from the canal accurately in order to produce useful results.
- **Papers:**
  - Energy and water co-benefits from covering canals with solar panels [13]
  - Fundamentals of engineering thermodynamics [36]
  - Robust optimization of shading types to control the performance of water reservoirs [14]
- **Other:**
  - Evaporation, Condensation and Heat transfer [35]
  - Heat and Mass Transfer, Fundamentals and Applications [34]
  - Evaporation Rates, Condensation Rates, and Relative Humidity [37]
  - The thermodynamics of evaporation with emphasis on lake evaporation rates

Literature Review

- **Books:**
  - *Weather and Water* [24]
    - Explores the interactions between atmospheric conditions and hydrological processes, emphasizing the impact of weather pattens on water distribution, evaporation, and resource management.
  - *Water in Confining Geometries* [25]
    - Explores how water behaves when restricted in small spaces, highlighting its unique thermal, structural, and dynamic properties and their significance in science and engineering
- **Papers:**
  - Design and analysis of a canal section for minimum water loss [19]
    - Explores strategies for optimizing canal design to reduce water loss, focusing on structural efficiency and hydraulic performance.
  - Water Losses from Irrigation Canals and their Modern Sustainable Solutions [20]
    - Provides an overview of the causes of water loss in irrigation canals and examines contemporary engineering solutions to enhance water conservation and efficiency.
  - Characterization and control of Irrigation Canal seepage losses: A review and perspective focused on field data [21]
    - Reviews field data on seepage losses in irrigation canals and discusses practical methods to mitigate water loss for improvedagricultural water management.
- **Other:**
  - Impact of covering irrigation canals on evaporation rates in arid areas
    - Investigates how covering irrigation canals in dry climates reduces evaporation, offering insights into water conservation strategies for arid regions.
  - Review of factors affecting canal water losses based on a meta-analysis of Worldwide Data
    - Synthesizes global research on canal water losses, identifying key environmental and structural factors that influence efficiency and sustainability in irrigation systems.

Literature Review

- **Books:**
  - Humidity, Evaporation, and Boiling[19]
    - This engineering talks about the humidity levels with vapor pressure and shows how it will effect the evaporation and how hotter water can increase into boiling increases the evaporation
  - A Review of Evaporation Reduction Methods from Water Surfaces
    - This paper reviews various methods for reducing water evaporation from open water surfaces, including physical, chemical, and biological techniques. It highlights the effectiveness of floating and suspended covers, chemical monolayers, and biological solutions like aquatic plants and windbreaks, evaluating their advantages, limitations, and efficiency in minimizing water loss
- **Papers:**
  - Wind Effect on the Evaporation Rate[18]
    - This paper examines how wind speed affects evaporation rates by developing a resistance-based model for an evaporating surface, considering heat and vapor flow interactions
  - Effects of the Wind Speed–Evaporation–SST Feedback on the El Niño–Southern Oscillation.[16]
    - They used a modified delayed oscillator model to include heat flux processes, introducing chaotic behavior and phase-locking to the seasonal cycle. The study finds that this thermodynamic feedback that differs from the usual zonal wind stress-SST feedback.
- **Other:**
  - PV to reduce evaporative losses in the channels of the São Francisco's River water transposition project[17]
    - This paper explores the use of photovoltaic (PV) panels to cover water channels in the São Francisco River Integration Project (PISF) in Brazil, aiming to reduce evaporation losses and generate renewable energy.

Literature Review

- **Books:**
  - Evaporation of Water with Emphasis on Applications and Measurements [31]
    - This book gives and in depth look into evaporation for both large bodies of water, and droplets of water. The book also talks about temperature and humidity gradients, as well as surface temperature and much more relating to water properties and evaporation.
  - Hydraulics of Open Channel Flow [28]
    - This book gives an very in depth look on open channel flow and hydraulics of water. The book gives examples and equations relating to the flow of water as well as example problems to solve.
- **Papers:**
  - Evaporation from three water bodies of different sizes and climates: Measurements and scaling analysis [30]
    - The flow statics of heat and water vapor were observed and noted in three different bodies of water, in different climates and parts of the world.
  - Evaporation and Surface Temperature [29]
    - This segment of a book gives very important data like tables on relative humidity, experiments, and observations on evaporation and surface temperature of water.
  - Effect of Solar Canals on Evaporation, Water Quality, and Power Production: An Optimization Study [27]
    - Discusses how covering bodies of water can be beneficial, as well as explains the tests that were ran and the mathematical modeling
- **Other:**
  - The Water Cycle and Climate Change [32]
    - This article is about how climate change affects the evaporation and precipitation in different areas of the world, including how plants can affect the humidity
  - Evaporation Rates, Condensation Rates, and Relative Humidity [33]
    - This course goes over an experiment done to help test the evaporation rate of water, the course also talks about net condensation and net evaporation.

Literature Review

- **Books:**
  - Fundamentals of Heat and Mass Transfer By T. L. Bergman [41]
    - Chapter 7 of Heat and mass transfer goes into detail on external flow when dealing with heat transfer, more specifically in 7.2.2 discusses how to account for turbulent flow, due to it being inherently unsteady. This chapter explains that by using Reynolds numbers up to 10^8 that the local friction factor for flow can be accurate within 15%. This will be crucial to our research when it comes to determining our fluid velocity boundary layer thickness.
  - Evaporation of Water With Emphasis on Applications and Measurements By Frank E. Jones [42]
    - Chapter 6 deeply goes into detail for surface temperature, temperature differences between surface and bulk, temperature gradients, and humidity gradients above a water surface which will directly apply to findingout standards for the canals local climate.
- **Papers:**
  - Variation of Relative Humidity as Seen through Linking Water Vapor to Air Temperature: An Assessment of Interannual Variations in the Near-Surface Atmosphere [43]
    - Explains how humididty directly correlates to temperature, and applies to gradient humidity over water
  - Relative Humidity vs. Absolute Humidity: Key Differences [44]
    - Describes differences of relative vs. absolute humidity and provide definition
  - Temporal Analysis of Long-Term Atmospheric Moisture Levels in Phoenix, Arizona [45]
    - Long term monthly average dew points in Pheonix
- **Other:**
  - Cooling affect of canal and temp change around canals in UK [46]
    - Reasrch done on the evniormental impact of canals or rivers directly correlating to the near by environment temperature
  - Average weather in Pheonix Arizona year round [47]
    - Provides detailed information on Pheonix dewpoint throughout the year
  - Evaporation from a Water Surface [48]
    - Provides equations for open water sources
  - ASHRAE Design conditions for Pheonix area [49]
    - Provies information for the wet bulb and dry bulb for the larger Phoenix area

Mathematical Modelling

1. Relative Humidity is one of the main parameters we will be using to measure the changes in evaporation rates on the canal underneath solar panels. It is a ratio of the partial pressure of water vapor present in the atmosphere, divided by the vapor pressure present on the surface of the water in the canal.

$$\phi = \frac{p_{v,h_2o}}{p_{g,h_2o}} \times 100\%$$

$\phi = Relative\ Humidity$

$p_{v,h_2o} = partial\ pressure\ of\ water\ vapor$

$p_{g,h_2o} = P_{sat\ @\ Temp}\ found\ in\ steam\ tables$

2. A theoretical partial pressure value calculated from monthly averages in the phoenix area is given:

$$p_{v,h_2o} = 0.007439\ bar$$

3. The water temperature on the surface of the canal is used to find the vapor pressure[36]. The relative humidity above the water surface is then calculated.

$$When\ T = 18°C \rightarrow \phi = \frac{0.007439\ bar}{0.02064\ bar} \times 100\% = 36\%$$

$$When\ T = 20°C \rightarrow \phi = \frac{0.007439\ bar}{0.02339\ bar} \times 100\% = 31.8\%$$

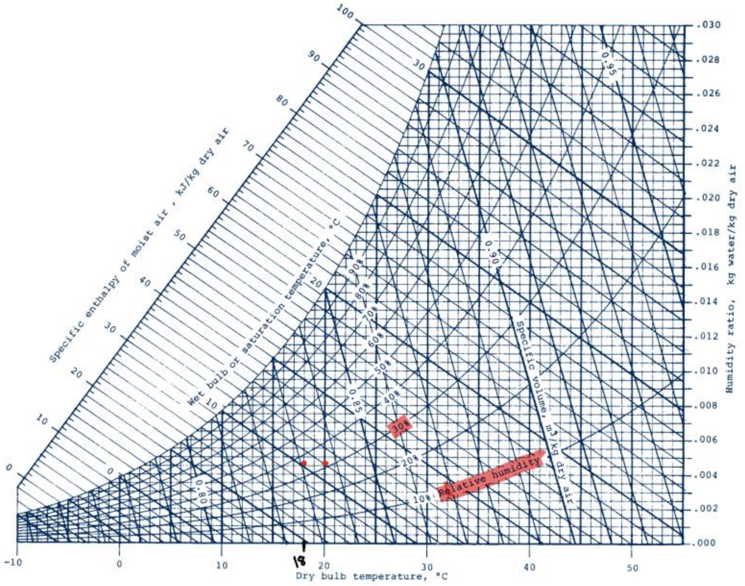
4. The ratio of the relative humidity can be used to indicate whether evaporation or condensation is occurring, and its value can be used to solve for the rate of evaporation of water in the canal under different surface temperatures.

$p_{v,h_2o} < p_{g,h_2o}$: evaporation occurs

$p_{v,h_2o} = p_{g,h_2o}$: equilibrium

$p_{v,h_2o} > p_{g,h_2o}$: condensation occurs

Figure A-9 Psychrometric chart for 1 atm (SI units). *Source:* Z. Zhang and M. B. Pate, "A Methodology for Implementing a Psychrometric Chart in a Computer Graphics System," *ASHRAE Transactions*, Vol. 94, Pt. 1, 1988.



$$\omega = 0.004627\ kg/kg$$

Lilliana Hadik-Barkoczy, 2/10/25, SRP

Mathematical Modelling

Use the convective mass transfer equation to determine the mass flux of water vapor due to evaporation from the canal surface [38] [39].

$$N''_A = h_m\left(C_{A,s} - C_{A,\infty}\right) = 0.0019\left(0.0289 - 0.0093\frac{kg}{m^3}\right) = 3.724 * 10^{-5}\frac{kg}{m^2 * s}$$

$$N''_A = Mass\ flux\ of\ water\ vapor\left(\frac{kg}{m^2 * s}\right)$$

$$h_m = Convective\ mass\ transfer\ coefficient\ (\frac{m}{s})$$

$$C_{A,s} = Water\ vapor\ concentration\ at\ the\ canal\ surface\ (\frac{kg}{m^3})$$

$$C_{A,\infty} = Water\ vapor\ convection\ in\ ambient\ air\ (\frac{kg}{m^3})$$

Use the Sherwood equation to find the rate at which mass transfer occurs due to convection.

$$sh = \frac{h_m L}{D_{AB}}\ rearrange\ equation\ to\ solve\ for\ h_m = \frac{sh * D_{AB}}{L} = \frac{1088.84*(2.5*10^{-5}\frac{m^2}{s})}{14.12m} = 0.0019$$

$$sh = Sherwood\ number\ (Resembles\ Nusselt\ number\ in\ heat\ transfer)$$

$$L = Characteristic\ length\ (m)$$

$$D_{AB} = Diffusivity\ of\ water\ in\ air\ (\approx 2.5 * 10^{-5}\frac{m^2}{s})$$

Since wind affects evaporation use the empirical equation for forced convection [40].

$$sh = 0.664 * Re^{\frac{1}{2}}Sc^{\frac{1}{3}} = 0.664 * \left(3.78 * 10^6\right)^{\frac{1}{2}} 0.6^{\frac{1}{3}} = 1088.84$$

$$Re = \frac{\rho VL}{\mu} = \frac{(1.1007\frac{kg}{m^3})(3.3\frac{m}{s})(20m)}{19.2*10^{-6}(Pa*s)} = 3.78 * 10^6$$

$$\rho = Air\ density\ (\frac{kg}{m^3})$$

$$V = Wind\ speed\ (\frac{m}{s})$$

$$L = Canal\ width\ (m)$$

$$\mu = Air\ viscosity\ (Pa * s)$$

$$Sc = \frac{V}{D_{AB}} = 0.6$$

Finally solve for total evaporation rate

$$\dot{m} = N''_A * A = (3.724 * 10^{-5}\frac{kg}{m^2 * s})(20 * 50\ m^2) = 0.03724\ \frac{kg}{s}$$

$$\dot{m} = Total\ evaporation\ rate\ (\frac{kg}{s})$$

$$A = Surface\ area\ of\ the\ canal\ (m^2)$$

Mathematical Modelling

Average rate of surface evaporation for the month of June in a Phoenix Canal for a length of 1 mile. (assuming unshaded)

gs = Θ A (xs - x) / 3600

Where gs = amount of evaporated water per second (kg/s)

Or

gh = Θ A (xs - x)

Where gh = amount of evaporated water per hour (kg/h)

Θ = (25 + 19 v) = evaporation coefficient (kg/m2h)

v = velocity of air above the water surface (m/s)

A = water surface area (m2)

xs = maximum humidity ratio of saturated air at the same temperature as the water surface (kg/kg) (kg H2O in kg Dry Air)

x = humidity ratio air (kg/kg) (kg H2O in kg Dry Air)

For Phoenix:

[48]

Θ = (25 + 19(3.21)) – **85.99 kg/m^2h**
v= 7.2mph – **3.21 m/s** (Avg. for June)
A = 22ft x 5280ft – 6.7m x 1609.3m –**10782.3 m^2** (avg width assumed 22ft)
xs = 0.62198 pws/ (pa - pws) – **6.62%**
x = **0.4627% kg/kg** (Avg. for June)
Pa = 30.02 inHg × 3386.39 Pa/inHg – **101,877.5 Pa** (Avg. for June)
Pws= e^(77.3450 + 0.0057 T - 7235 / T)/ T^8.2 – **9804.3 pa**
Pw = ρw/0.0022(T) **746.57 Pa**
T = 113.8 f – 45.5C – **318.65 K** (Avg. Peak temp for June)

Gs = 85.99 x 10782.3 (0.0662 - 0.004627) / 3600 = **15.85 kg/s**

Gh = 85.99 x 10782.3 (0.0662 - 0.004627) = **57088.64 kg/h**

Brendan Steele, 2/10/25, SRP

Mathematical Modelling

- Evaporation has a ton of variables in a real-world scenario. To understand what affects evaporation we need to break down each components of the evaporation rate. One variable the effects evaporation a lot is the flow speed of water

Surface temp(which is a key factor in evaporation) is affected by the heat flux, the body temp, and heat transfer coefficient

$$q'' = h_w(T_b - T_s)$$

- q″ = heat flux from the bulk water to the surface (W/m^2) about 494.1W

With qsolar, q rad , and qevap

- hw = convective heat transfer coefficient inside the water (W/m^2·K) about 164.7
- Tb = bulk water temperature (∘C) winter = 12*c
- Ts = surface water temperature (∘C) around

The heat transfer coefficient hw can be estimated using the Nusselt number correlation for turbulent flow

$$Nu = CRe^m Pr^n$$

$$h_w = \frac{Nu \cdot k}{L}$$

- Nu = Nusselt number (dimensionless) = about 1372.5
- Re =[UL/v]Reynolds number (depends on water velocity U)

Low speed (5m/s) = 813,333 high speed(1.5m/s) = 2,440,00

- Pr=[cpμ/k] Prandtl number (depends on water properties)

Varies to 13.44 at 0*C to 1.75 at 100*c

- C,m, n= empirical constants based on flow conditions

C = .026 m=.8 n=.33

- k=thermal conductivity of water (W/mK) = .6 W/m*k
- L = width canal = 24.4
- U = water flow velocity (m/s). .5m/s - 1.5m/s

Mathematical Modelling

Double-Deck Surface Air Layer Model (DSAL)

The DSAL model is used to estimate water evaporation from water's surface, particularly in irrigation canals. This is done by splitting the air above the water's surface into to parts, a relatively still lower layer, which gets its movement/flow from the flowing water under it (SAL-W) and a more turbulent upper layer, which gets its flow from the wind (SAL).

Lower Layer

$$E_{SAL\text{-}W} = AU_w\,(e_w - e_{a\delta})$$

$E_{SAL\text{-}W}$ = Evaporation of lower layer

A = (See Equation)

U_w = flow speed of water in the canal (m s^{-1})

e_w = saturated water vapor pressure for the temperature of water

$e_{a\delta}$ = the actual water vapor pressure of air temperature at height δ

Upper Layer

$$E_{SAL} = BU_a\,(e_{a\delta} - e_a)$$

E_{SAL} = Evaporation of upper layer

B = (See Equation)

U_a = wind speed (m s^{-1})

e_a = actual water vapor pressure of air temperature

Double-Deck Surface Air Layer Model Continued…

$$A = \frac{18k^2}{RT\{\ln(\delta/z_{w0})\}^2}$$

k = von Kármán constant (0.4)

R = gas constant, 8.314 J (mol K)$^{-1}$

T = absolute air temperature (K)

z_{w0} = roughness length of the running water surface (1×10^{-5} m)

δ = thickness of the SAL-W

$$B = \frac{18k^2}{RT\{\ln(z_a/\delta)\}^2}$$

z_a = measurement height of air temperature

Solving for A = $(18(.4)^2)/(8.134*310.22\ (\ln(.1065/1 \times 10^{-5})^2) = \boxed{1.327 * 10^{-5}}$

Solving for B= $(18(.4)^2)/(8.134*310.22\ (\ln(2/.1065)^2) = \boxed{1.326 * 10^{-4}}$

For T – Average Air Temperature Phoenix Summer 2024 = 37.222 C + 273 K = 310.22K

δ = .1065 m (based on values given in book)

z_a = 2m (based on values given in book)

$E_{SAL} = (1.326 * 10^{-4})(2.6)(6.28 - 6) = 9.65 * 10^{-5}$ mm/day

Average wind speed in Phoenix during summer = 5.8 mph or 2.6 m/s

Mathematical Modelling

- The effect of water evaporation as influenced by canal surface area and geometry can be expressed using the mass transfer equations below, which align with many of the team's calculations [19]:

$$E = (e_s - e_d) f_w$$

E = evaporation discharge per unit free surface area (m/s);
e_s = saturation vapor pressure of the air at the temperature of the water surface (Pa)
e_d = saturation vapor pressure of the air at the dew point (Pa)
f_w = wind function (m/s/Pa).
The difference between the saturation vapor pressure of the air at the temperature of water surface and at the dew point (e_s - e_d) in Pa was given by:

$$e_s - e_d = 610.78\left[\exp\left(\frac{17.27 * \theta_w}{237.3 + \theta_w}\right) - R_h \exp\left(\frac{17.27 * \theta_a}{237.3 + \theta_a}\right)\right]$$

θ_w = water surface temperature in °C
θ_a = mean air temperature in °C
R_h = relative humidity expressed as fraction.

The wind function for a flowing channel in m/s per Pa was given by Fulford and Sturm as:

$$f_w = 3.704x10^{-11}(1 + .25u_2)$$

where u_2 = wind velocity in m/s at 2 m above the free surface.

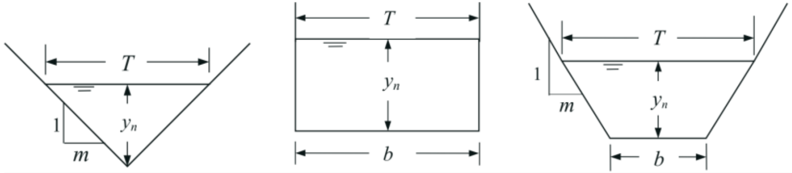
$$\Rightarrow E = 2.262 \times 10^{-8}(1 + .25u_2)\left[\exp\left(\frac{17.27*\theta_w}{237.3+\theta_w}\right) - R_h \exp\left(\frac{17.27*\theta_a}{237.3+\theta_a}\right)\right]$$

This shows that in the simplest form of mass transfer approach E is a function of the wind velocity over the evaporating surface, the water surface temperature, the air temperature and relative humidity of the air above the water surface, though it may be affected by many other factors.

⇨ **Evaporation Loss from a canal can be expressed as:**

$$\boldsymbol{q_e = E * T}$$

q_e = evaporation discharge per unit length of canal (m2 /s)
T = width of free surface (m)



Total Water Loss (Evaporation and Seepage) for trapezoidal canals:

$$\Rightarrow q_w = k y_n \left\{\left[(4\pi - \pi^2)^{1.3} + (2m)^{1.3}\right]^{\frac{.77+.462m}{1.3+.6m}} + \left(\frac{b}{y_n}\right)^{\frac{1+.6m}{1.3+.6m}}\right\}^{\frac{1.3+.6m}{1+.6m}} + (b + 2my_n)E$$

This is a Mass Transfer expression that combines the evaporation equation above and Swamee et al seepage equation:

$$q_w = k y_n F_s + ET$$

Example:
e_s= 2.06398 kPa Tetens Equation
e_d = .7430 kPa (given relative humidity from Liliana's of 36%)
u_2 = 3.3 m/s (Samantha's recorded wind velocity)
T ≈ $24m$ avg width of top of water's surface
$R_h = \frac{.007439\ bar}{.02064\ bar}$ (Liliana's relative humidity finding)

⇨ $E = (2.06398 - .7430)(3.704x10^{-11}(1 + .25(3.3))$
⇨ $E = 8.92956 \times 10^{-11}$
⇨ $\boldsymbol{q_e = E * T}$ ...... $8.92956 \times 10^{-11} \times 24m$
⇨ $\boldsymbol{q_e = 2.14309 \times 10^{-9}}\ m^2/s$ (evaporation loss)

From there we can incorporate seepage loss as well to calculate total water loss in the equation above.

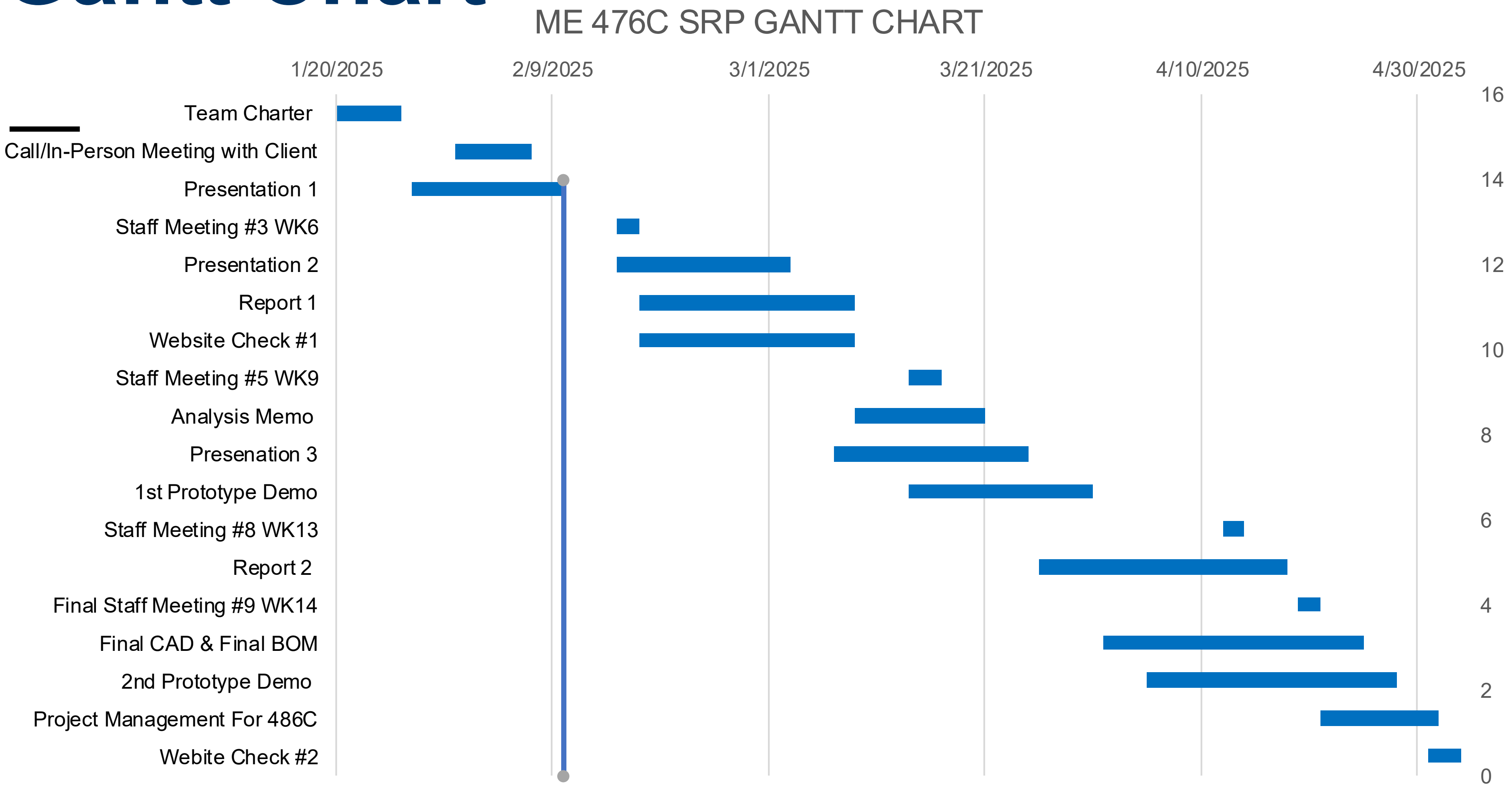
Garet Bowles, 2/10/25, SRP

Budget

Budget: $5,000

- The current budget is 5k with 10% of that money coming from the team via fundraising.
- The plan for the budget is to use the money to conduct tests. The tests would help the team discover which cases reduce evaporation the most.
- Due to the conditions in which the team was given, no real prototype needs to be created, meaning the majority of the budget will be put towards testing and research.

Gantt Chart



Garet Bowles, 2/10/25, SRP

Conclusion

Moving Forward:

- Stay ahead/ early start on key task
- Think/start design for testing apparatus
- Refine water evaporation research and quality data

Thank You!

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