Managing Water Quality
in
Potable Water Tanks / Reservoirs

Management / Hydraulic / Design Considerations pertaining to:

Mixing Potable Water Tanks

and

THM Removal Systems

SolarBee®

Water Quality Challenges in Potable Tanks

AWWA estimates 65% of all potable tanks have water quality problems:

- Inlet / outlet design
- Short-circuiting
- Water age issues

- Temperature stratification
- Stagnation / dead zones
- Biofilm build up

- Loss of residual
- Nitrification events
- Risk of ice damage
- DBP Formation (TTHM's)

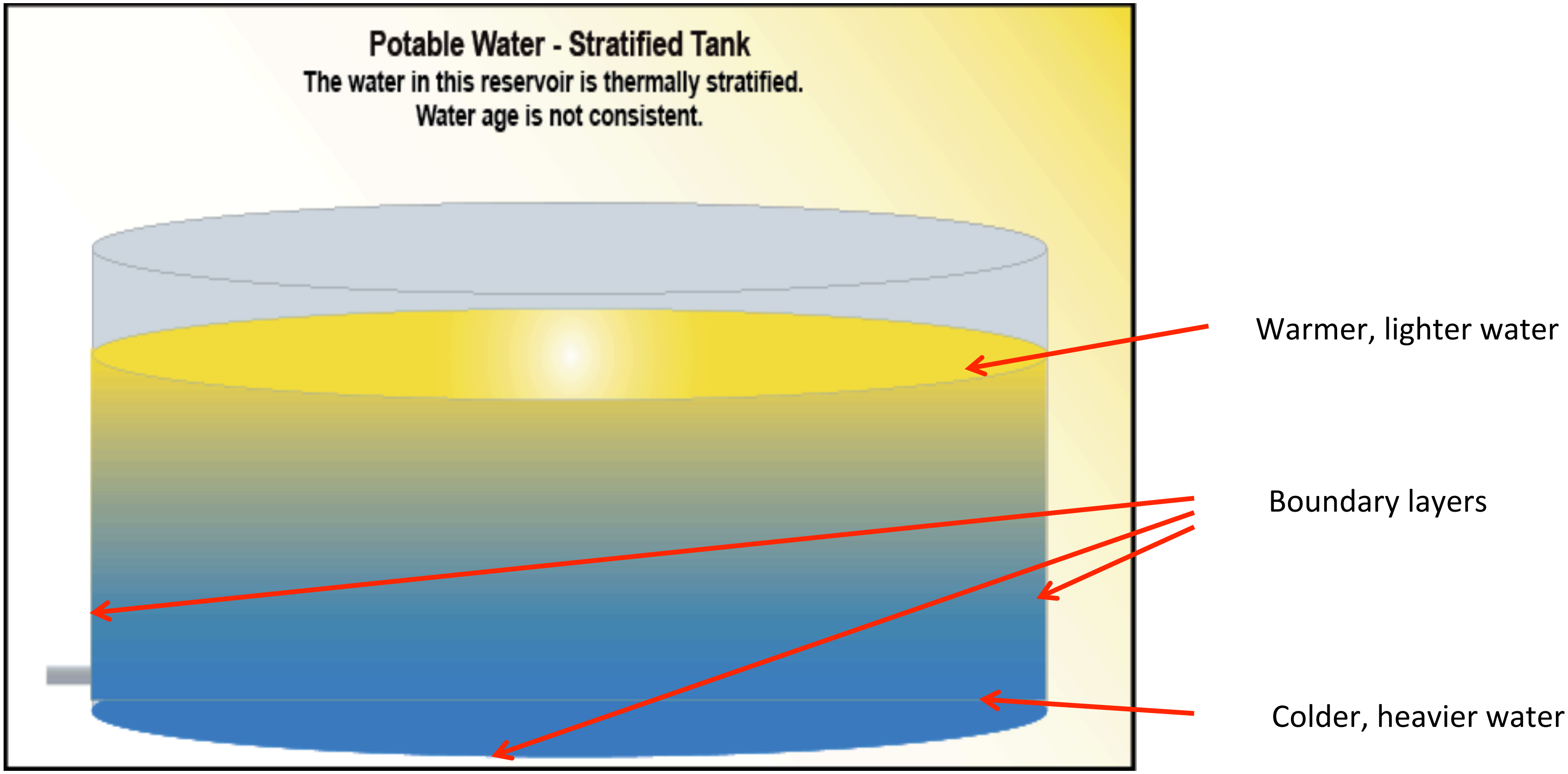
SolarBee®

- **Chlorine Systems, main problems:**
  - Loss of residual, warm weather, rapid bacteria growth
  - THM's and HAA's if source water was surface water

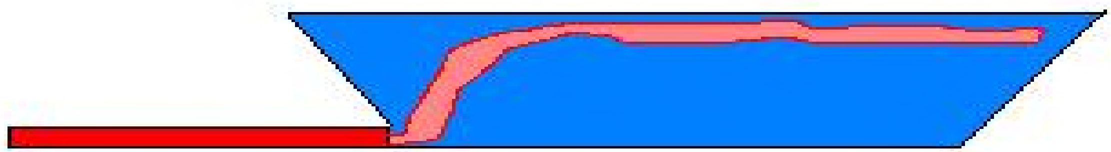
- **Chloramine Systems, main problems:**
  - Loss of residual, can occur very rapidly, 1-2 days, caused by chemistry, best to keep chlorine to ammonia ratios 4:5 to 1
  - Free Ammonia can nitrify, formation of Nitrite and Nitrate
  - Also can have THM's if source water was surface water, if chlorine used to achieve CT at the plant

Thermal Stratification Inhibits Mixing

The Boundary Layer is the Most Important Part



Thermal Stratification Can Be Caused by Inlet Temperature Differences

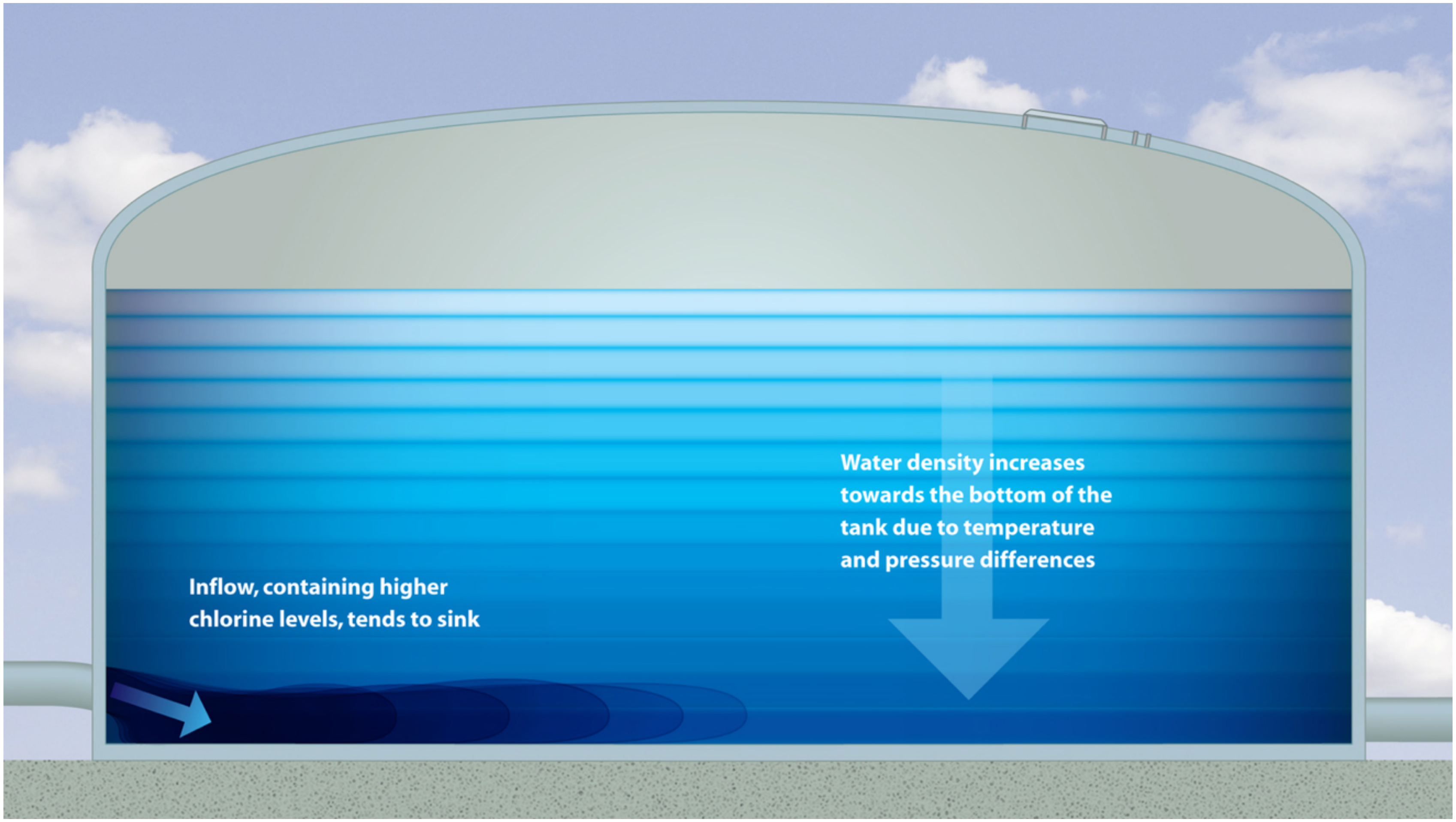


Positive Buoyancy

Negative Buoyancy

Charlotte Smith

Water Layering in a Potable Water Tank

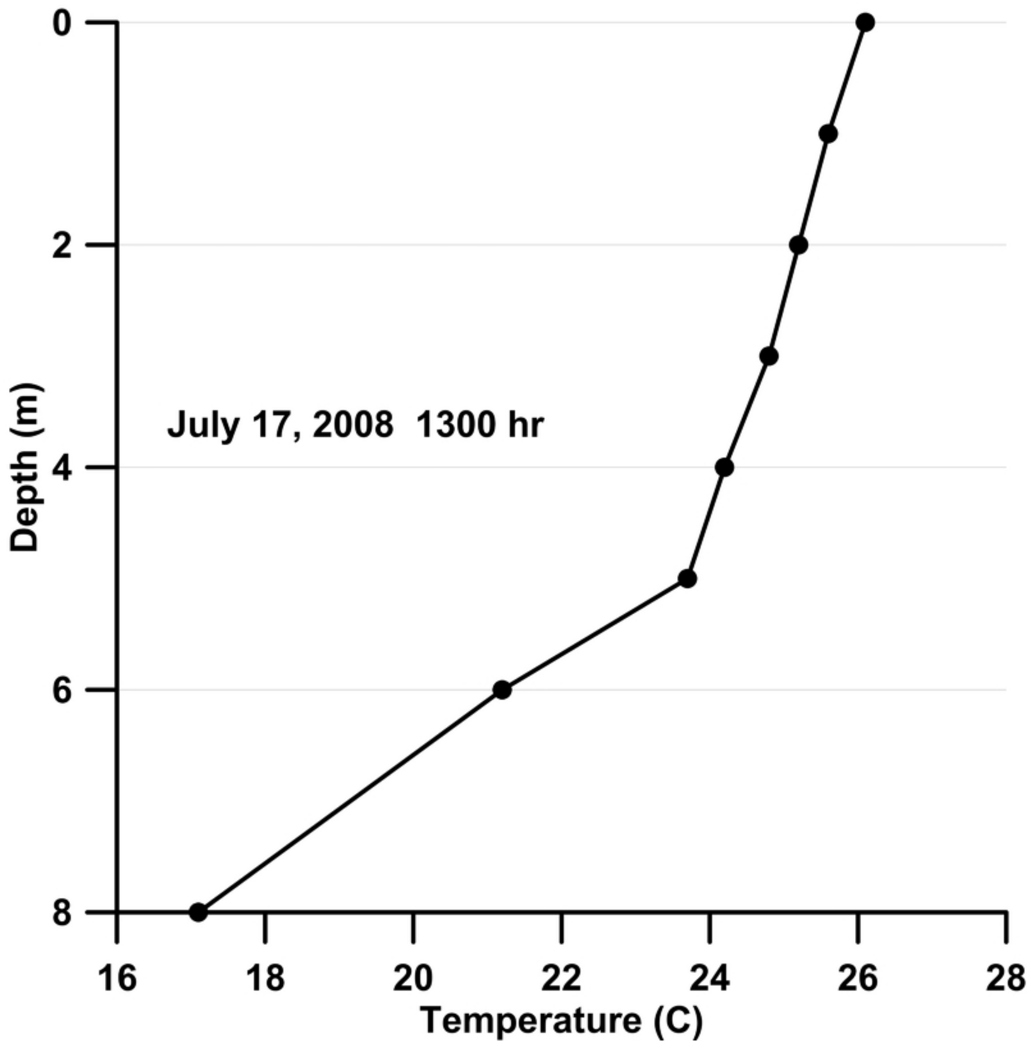


Water in reservoirs forms thin horizontal layers due to density differences of temperature and pressure.
Inflow water, with its higher chlorine concentrations, usually plummets to the bottom of the tank.

Temperature Stratification Example

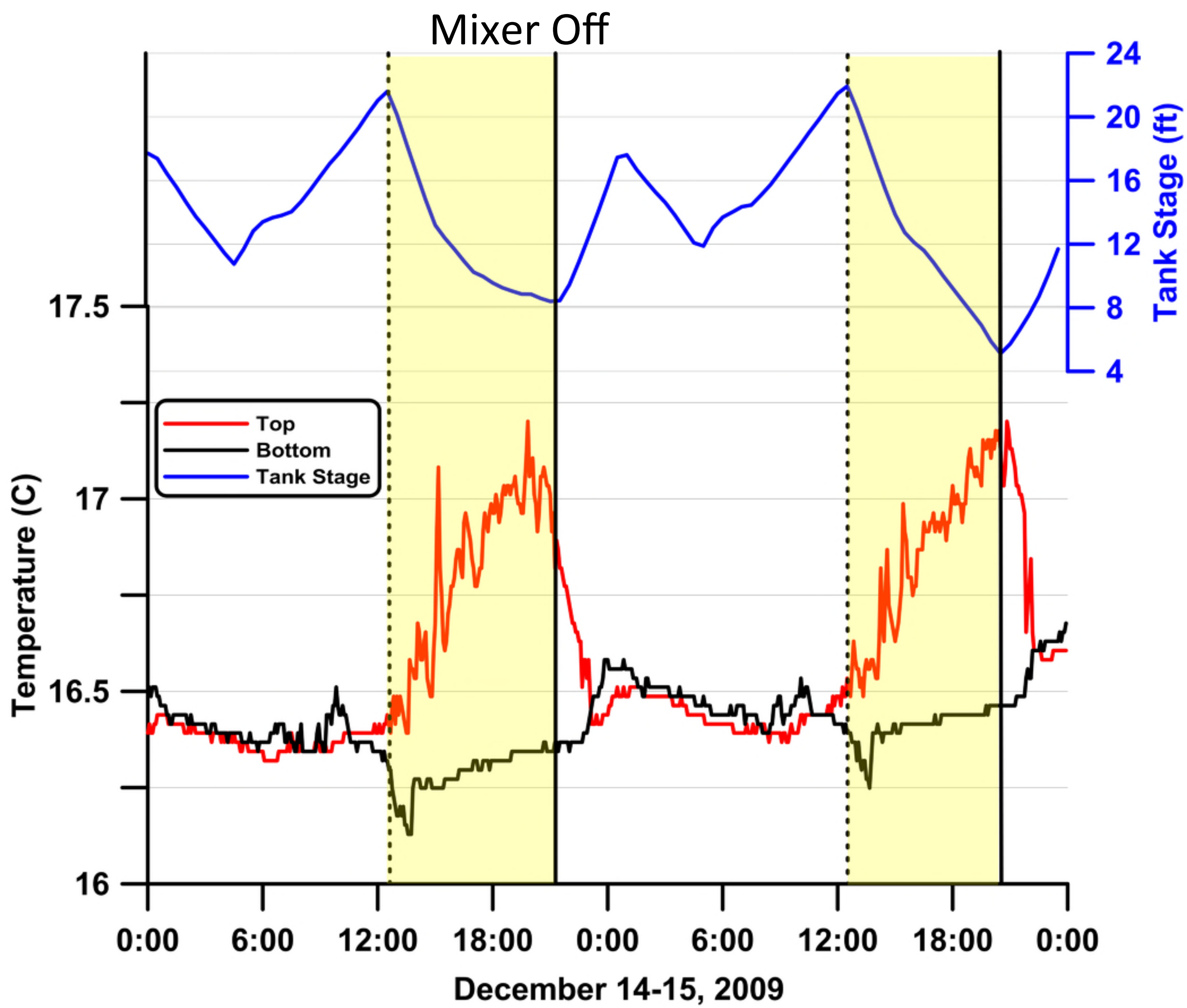
5 MG
Above
Ground
Steel
Tank

Not Mixed
And
Highly
Stratified



Temperature and Tank Level Examples

Tan Columns highlight temperature differences during daily draw and fill cycles



SolarBee

Determine whether the problem may be lack of mixing

<u>3 ways</u> to gauge potential water age problems.

Usually all 3 use temperature as a surrogate predicting chlorine residual and other problems, and range from:

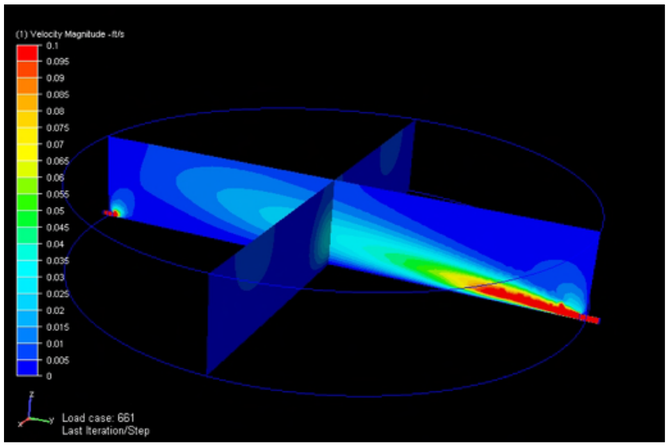
a) CFD Modeling, highest cost

b) Hobo loggers, mid range cst

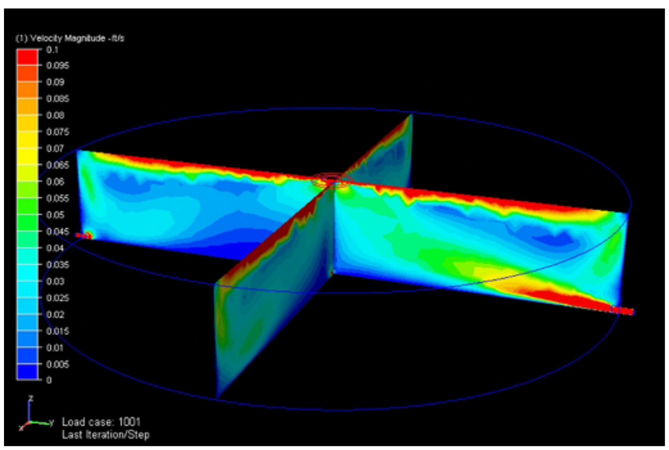
c) Manual temperature indicators, lowest cost

Computational Fluid Dynamics Modeling for Tank Mixing

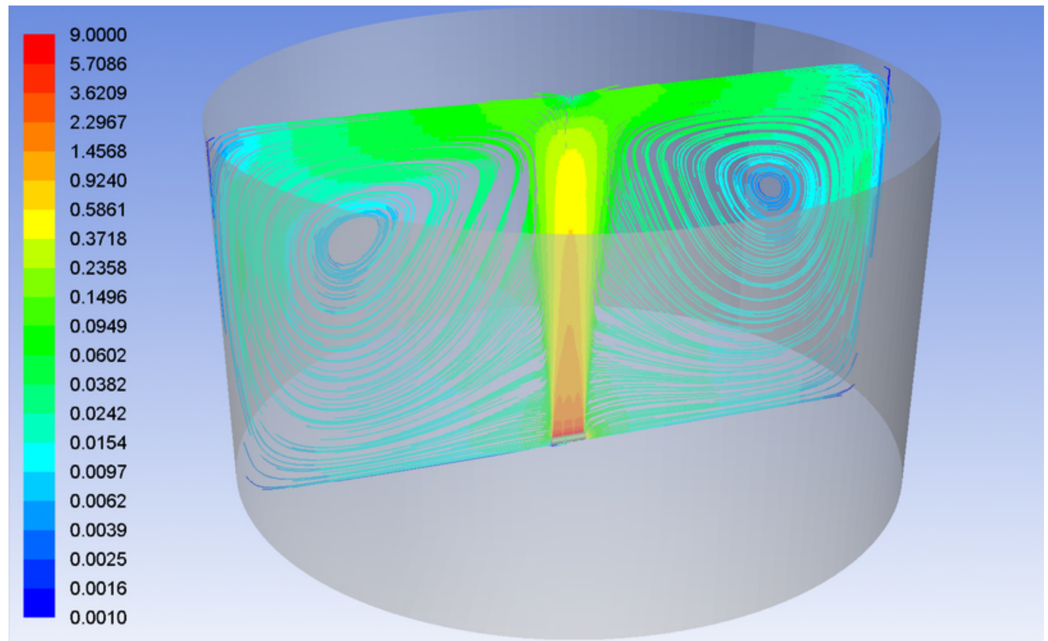
Commonly used, but there many variables and assumptions made



5 MG Tank, No MIxer

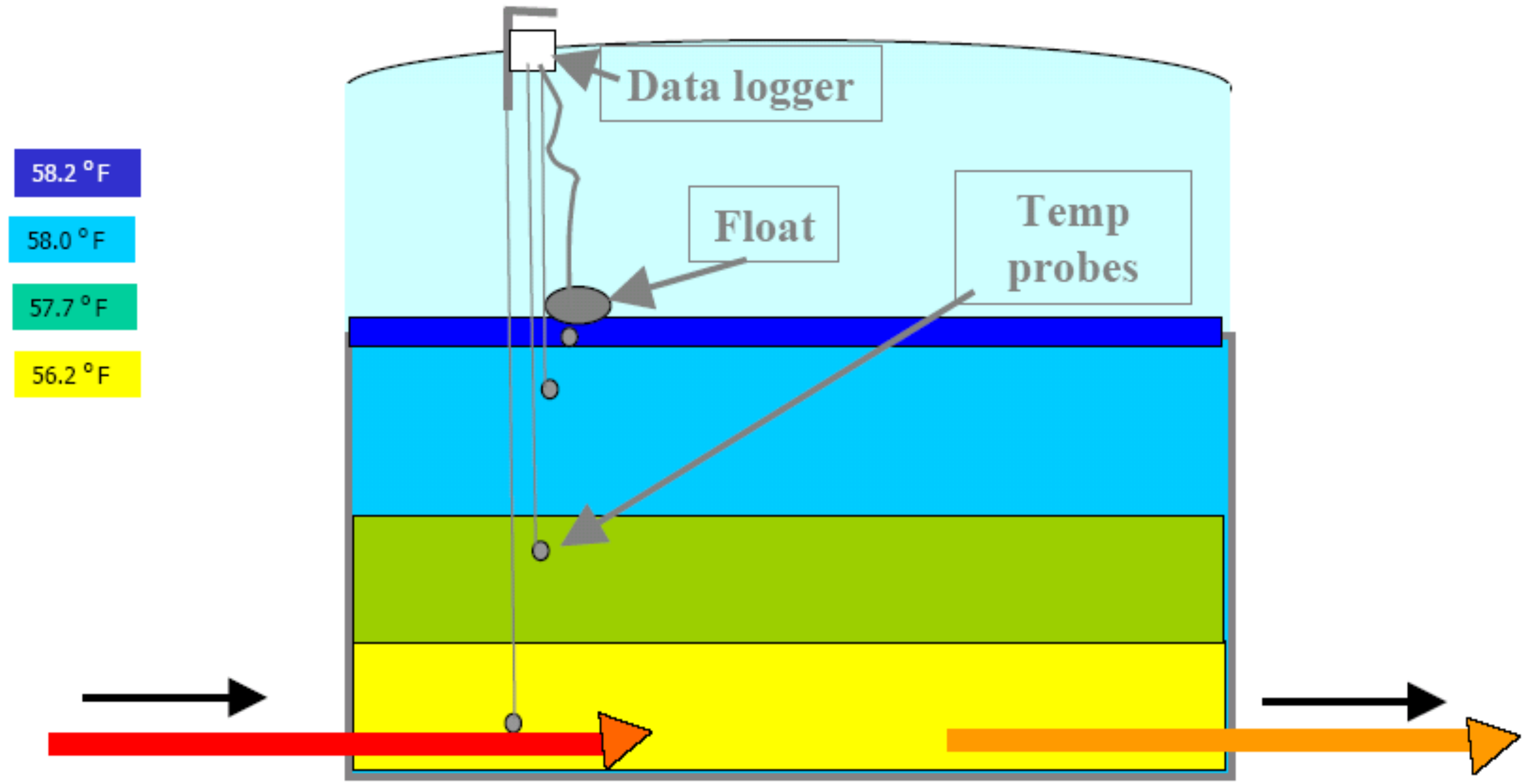


5 MG Tank, with Mixer



- Strong direct flow leaving the broad side of the mixer
- Model shows tank completely mixed

Consider Deploying a Data Logger ("Hobo") String



Temperature Stratification Tools

Temperature probes, HOBO brand

Or. . . use these tools to manually get a profile

AquaCal ClineFinder from Cabela's to 50' depth

Fish Hawk to 200' depth

Biofilm Build-up at Diffused Boundary Layer

Montana State University, Center for Biofilm Engineering

Plan to prevent major problems

- **Periodic cleaning of reservoir**
- **Reduce water age by cycling** the tank as much as possible without causing problems for other departments, such as fire department or Factory Mutual insurance underwriters
- **Install a mixer** for constant mixing to boundary layers
- **Do more-frequent testing in warm weather** (>55F water):
  - Test temperature stratification, and chlorine residual
  - With chloramines, test free ammonia and nitrite
  - The problems are worse in the summer, but can occur year-round in warm states

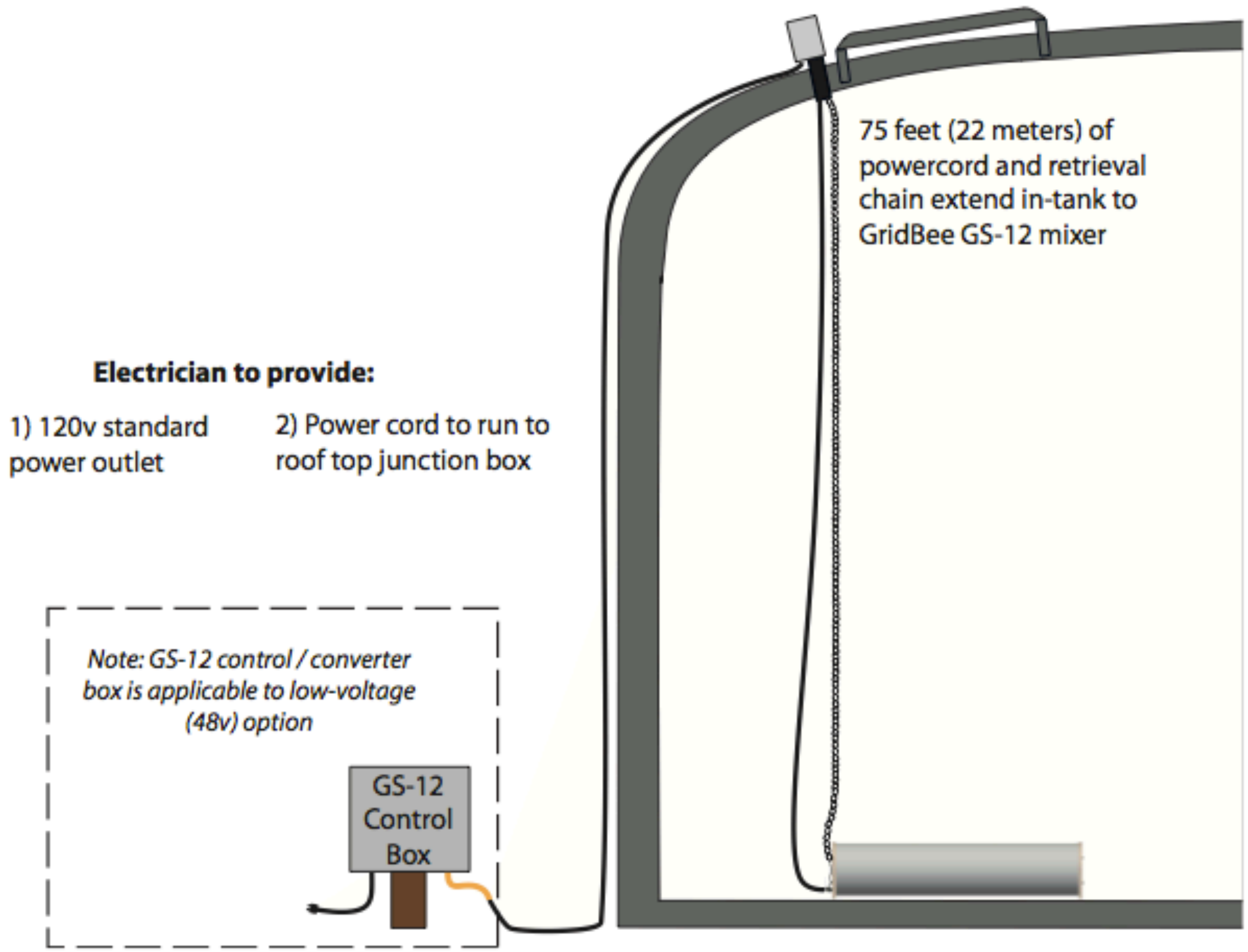
Plan to solve water quality problems

- **Have a mixing system in place.**
- **Have chlorine boosting system in place.**
- **Try Fast Response Early Boost** (FREB) first.
  - 1-10 gallons of boost, early, may be all that is needed

- These steps can avoid the need for crisis management meetings, dramatic drawdowns, fire protection problems, wasting of water, taking tank offline
- As a last resort, be prepared to breakpoint chlorinate the tank

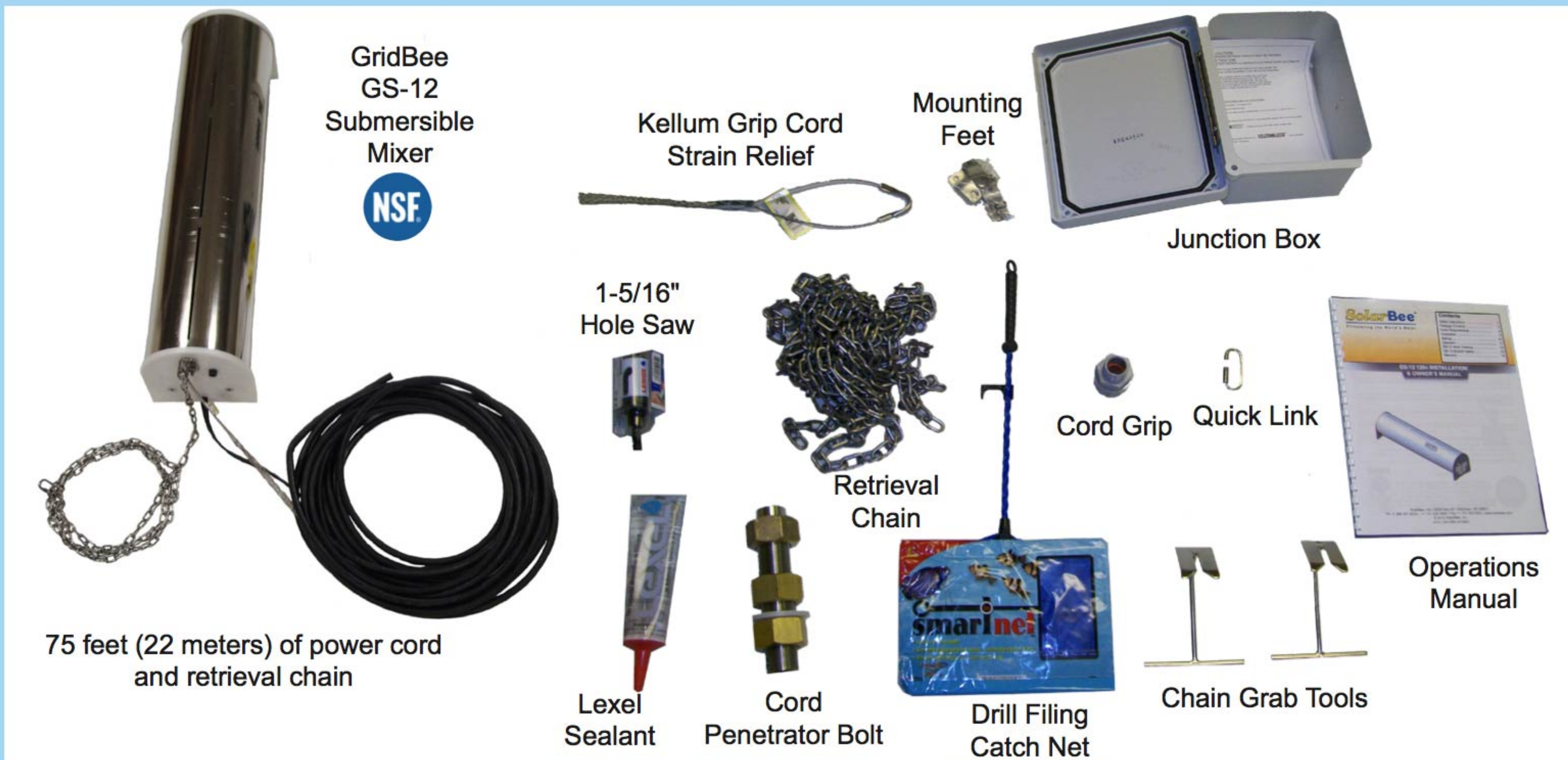
If power is available, consider installing an energy efficient, electric-powered mixer certified ANSI/NSF 61-G

Installation Overview

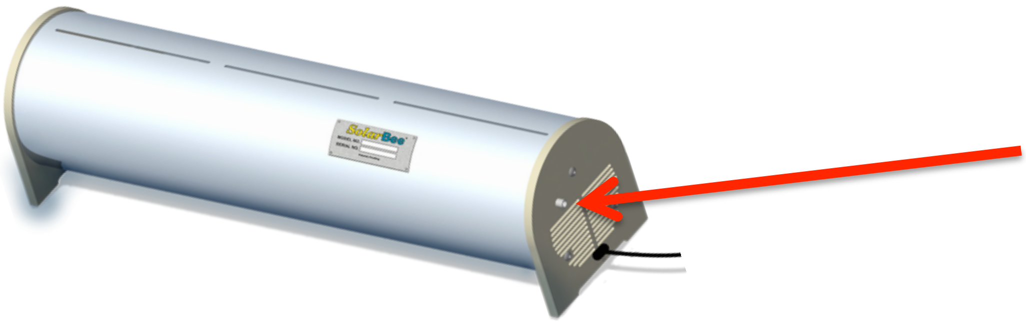


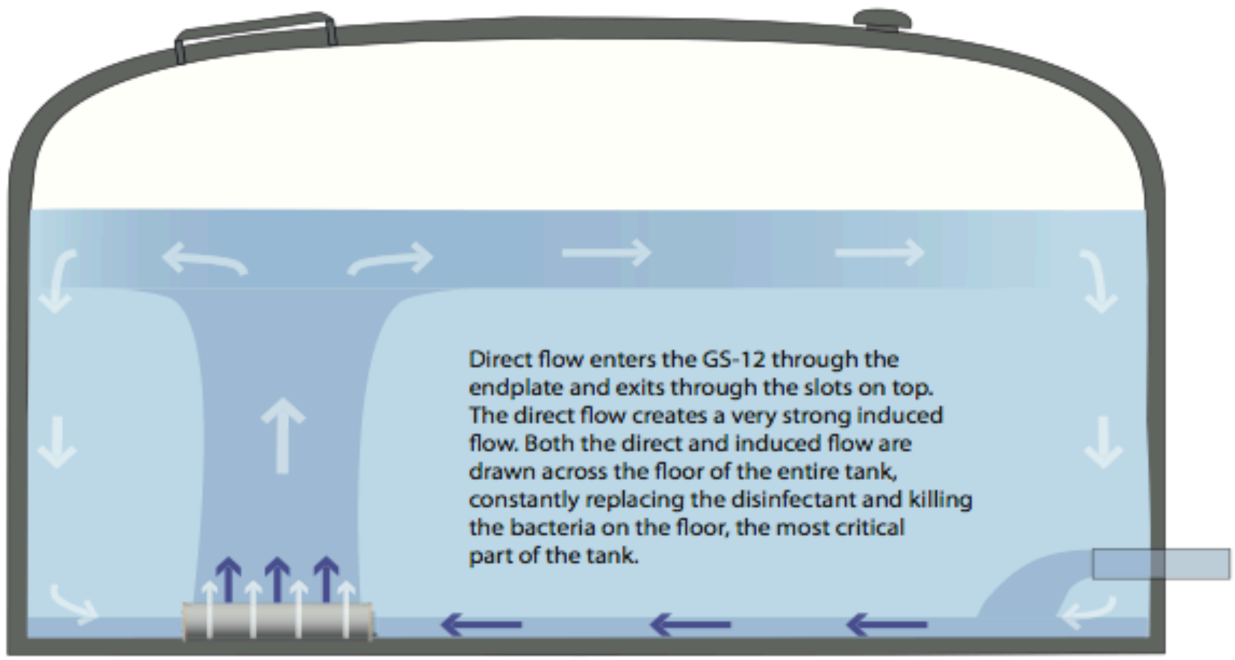
Electric Submersible Mixer

Submersible Electric Mixer
Package Contents

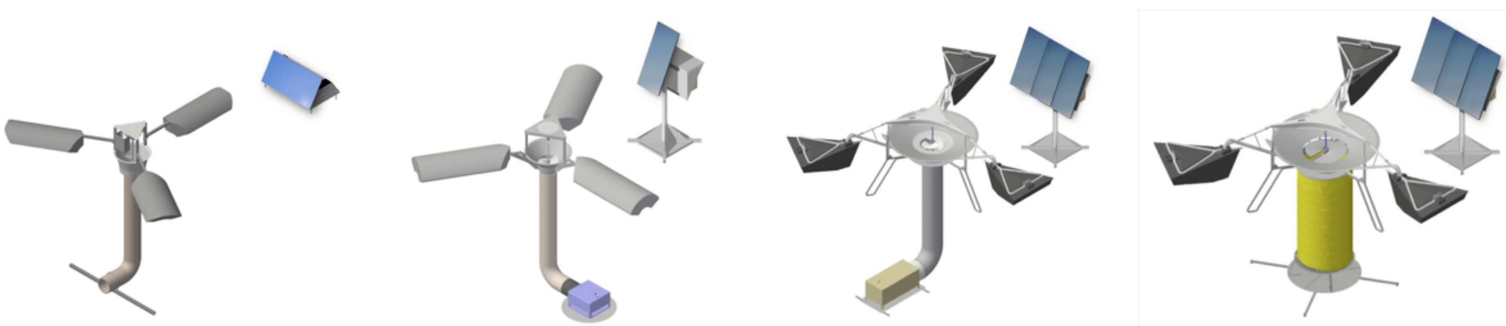


If boosting, it is best to inject into or near the mixer



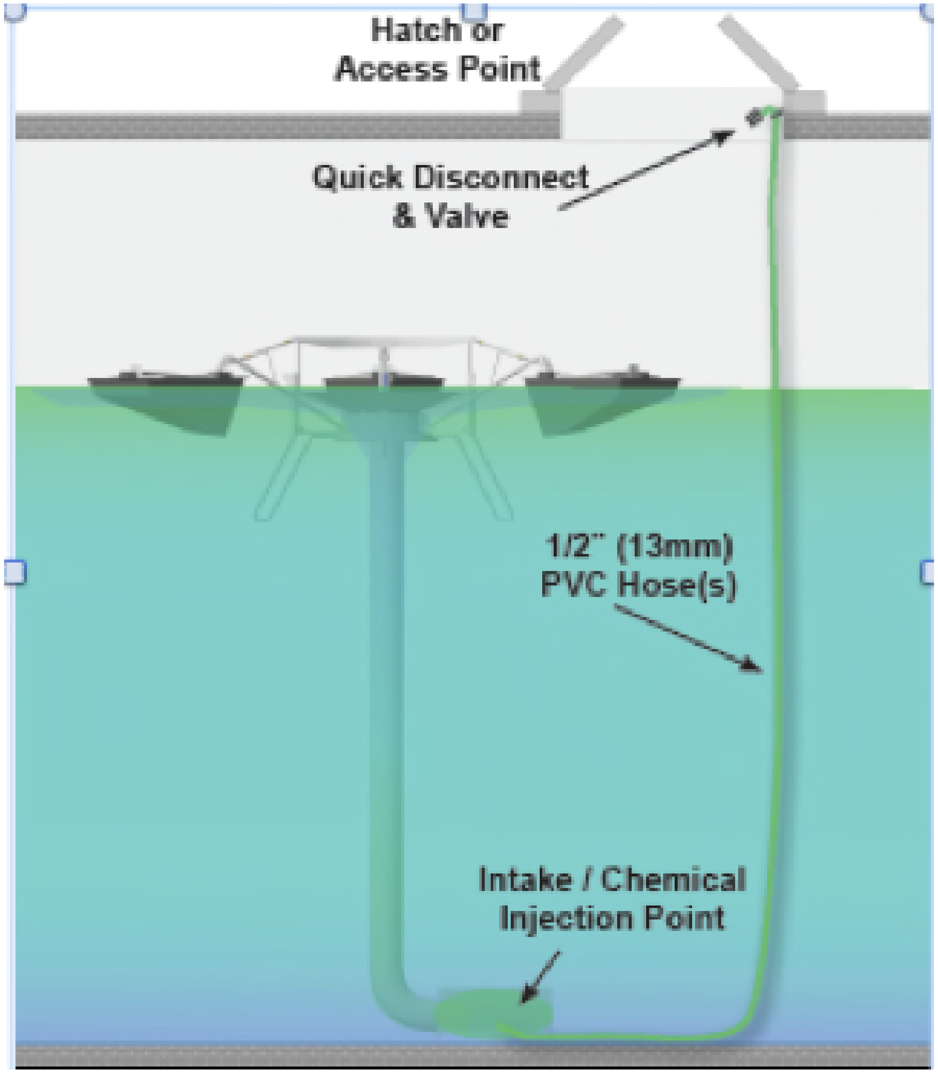


If power is <u>Not</u> available,
consider installing a NSF 61-G certified solar-powered mixer



Different mixer sizes, intake designs, and solar panel designs dependent on customer needs

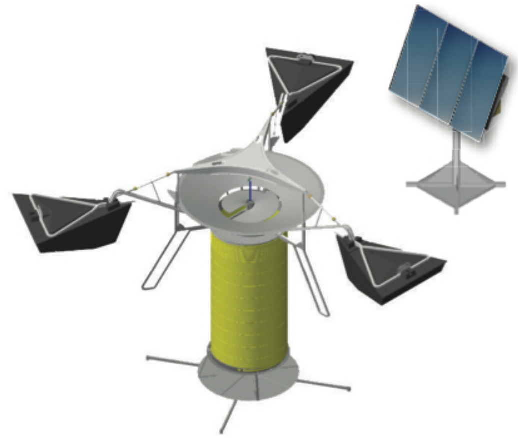
If boosting,
it is best to inject into a solar-powered mixer



Potable Water Mixers

Passive Mixer

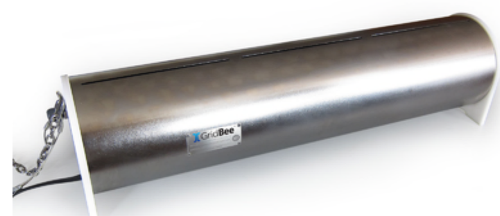
Solar-powered Mixer (Small / Medium Tanks)



Solar-powered Mixer (Large Tanks, one mixer in 30MG tank)

Elevated Impeller Mixer

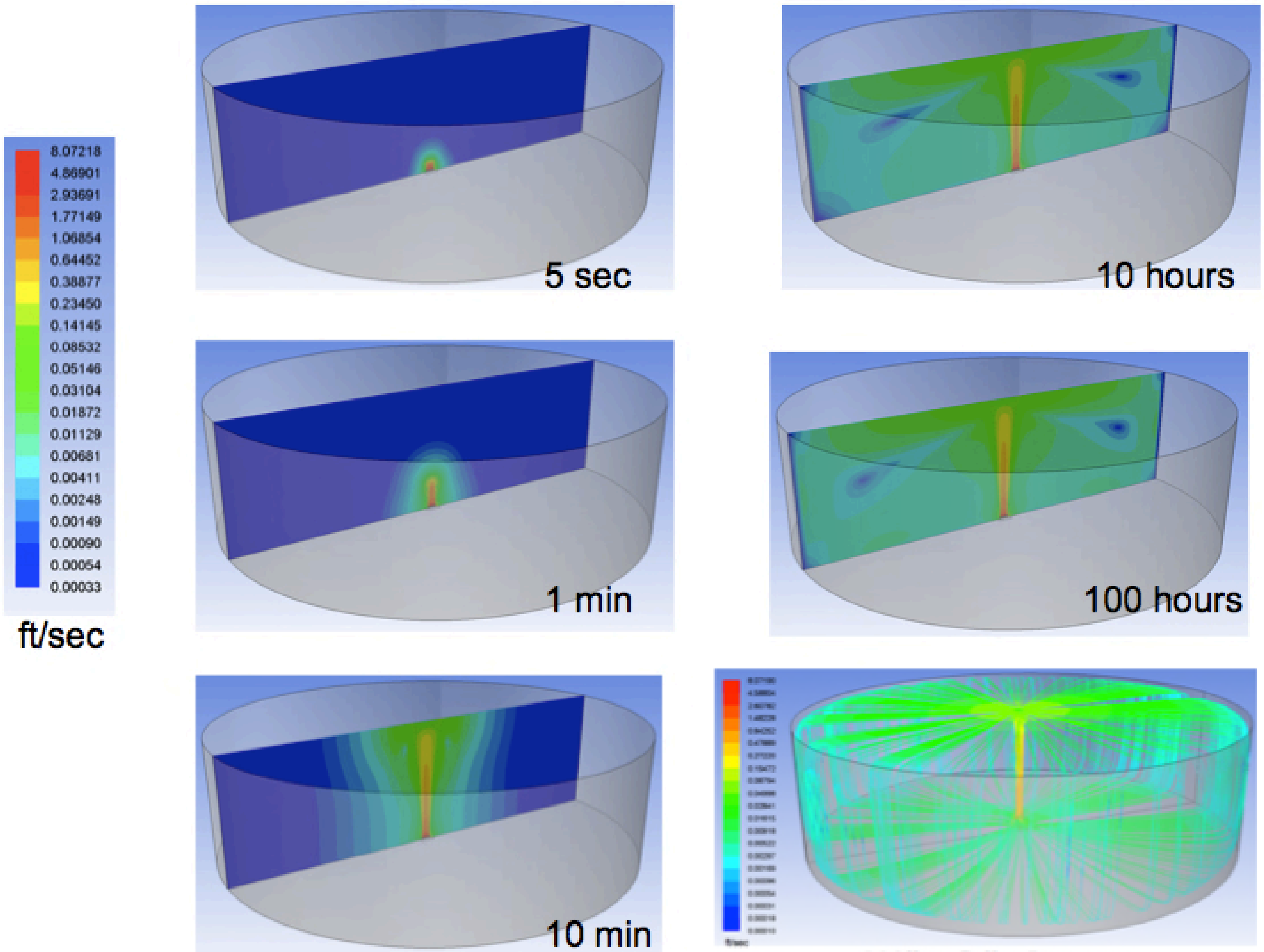
Elevated Nozzle Mixer



Submersible (floor) Sheet-flow Mixer

Mixer Modeling / Data

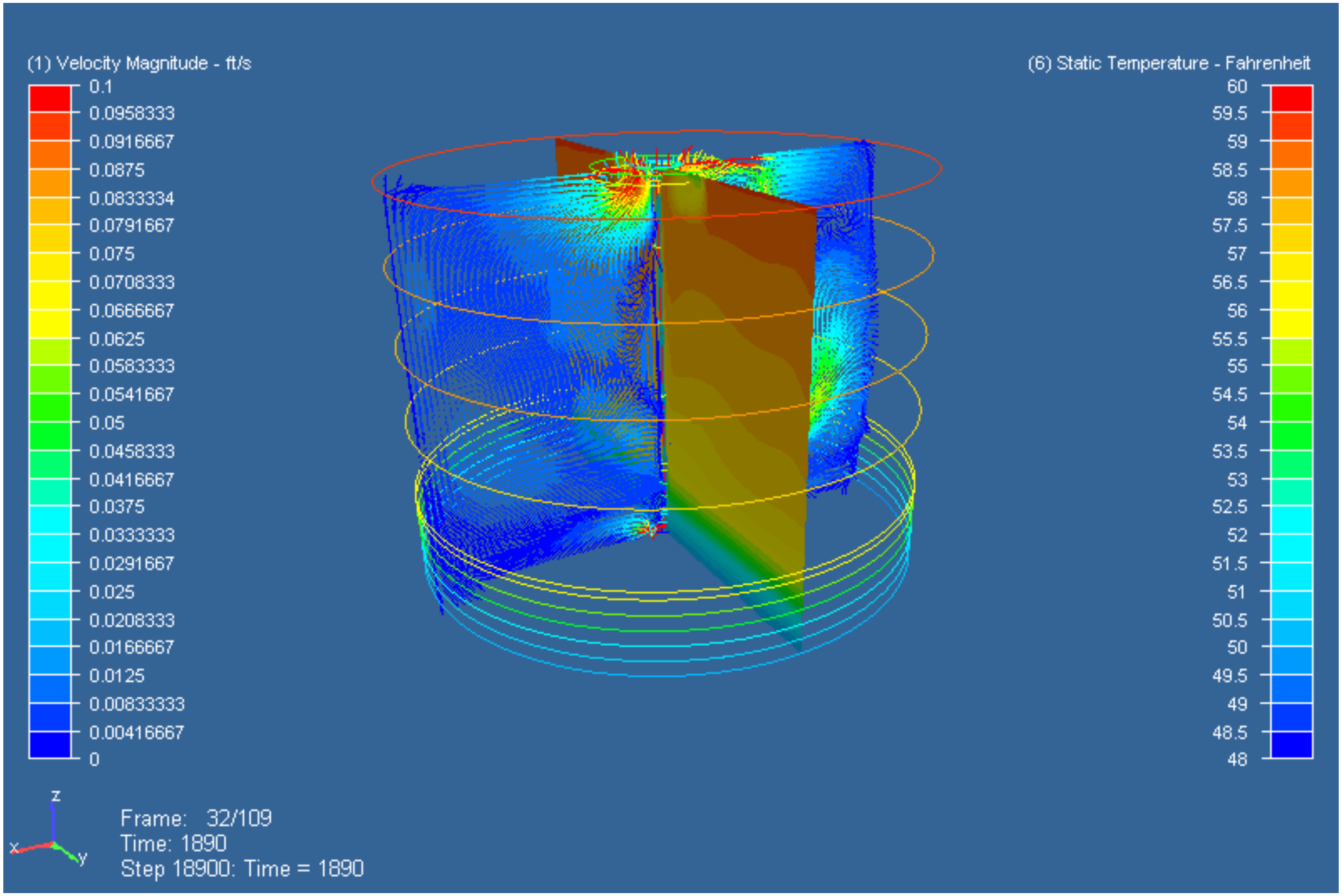
Computational Fluid Dynamics (CFD) Flow Modeling



5 Million Gallon Reservoir

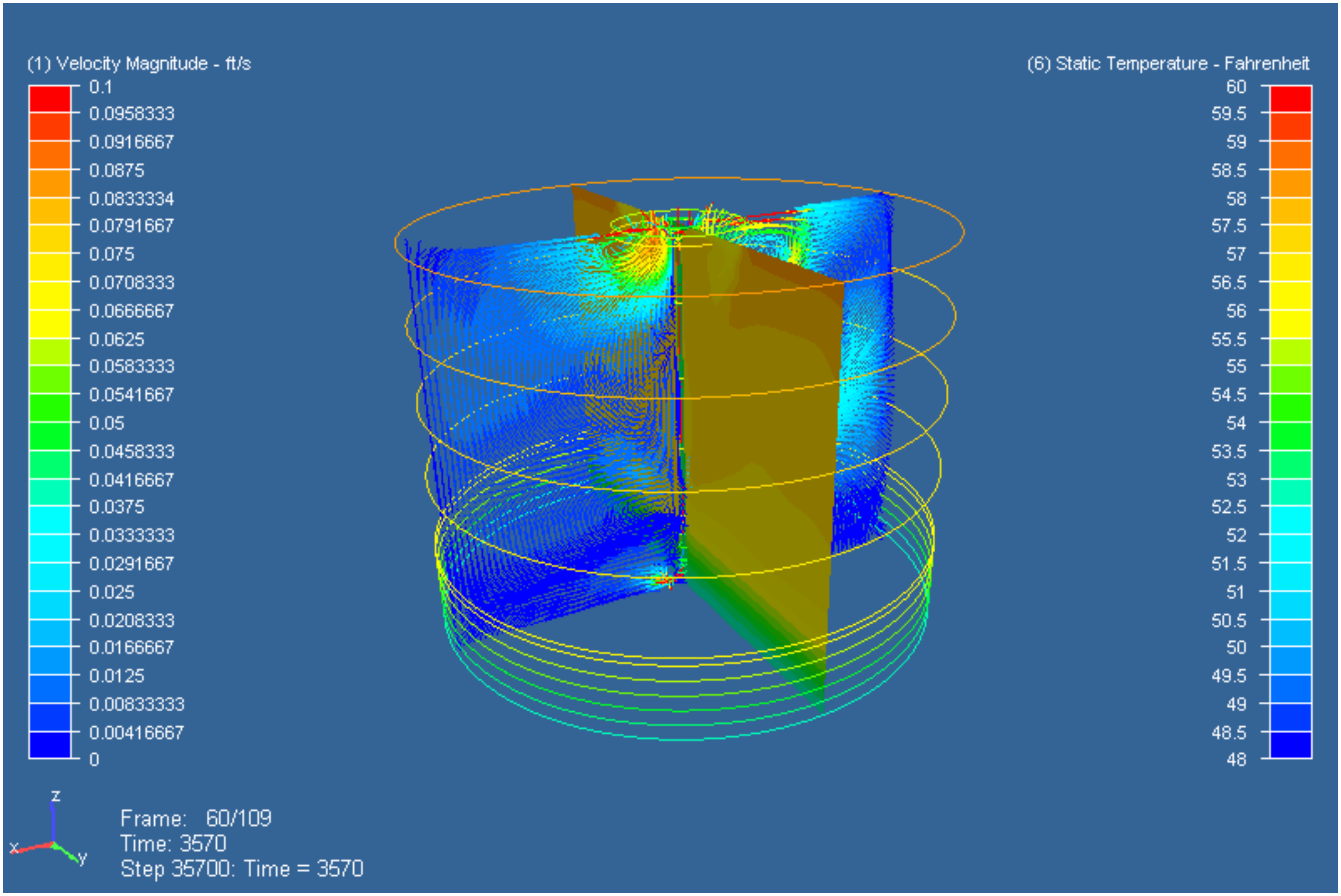
Slide A, prior to mixer being turned on

5 MG Tank, 30 ft tall, 170 ft diameter, above ground steel tank



Slide B   mixer on for 28 minutes

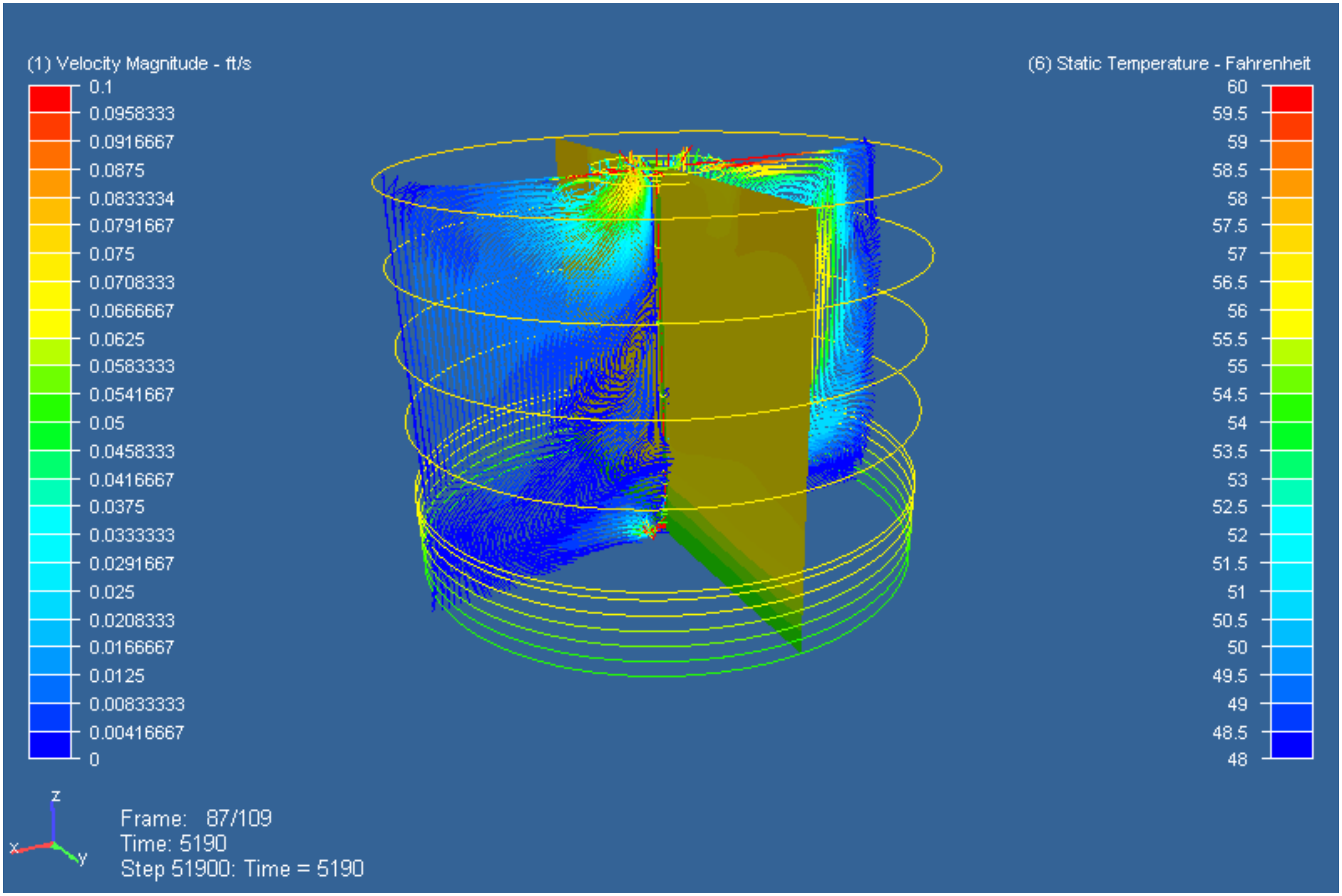
5 MG Tank, 30 ft tall, 170 ft diameter, above ground steel tank



SolarBee

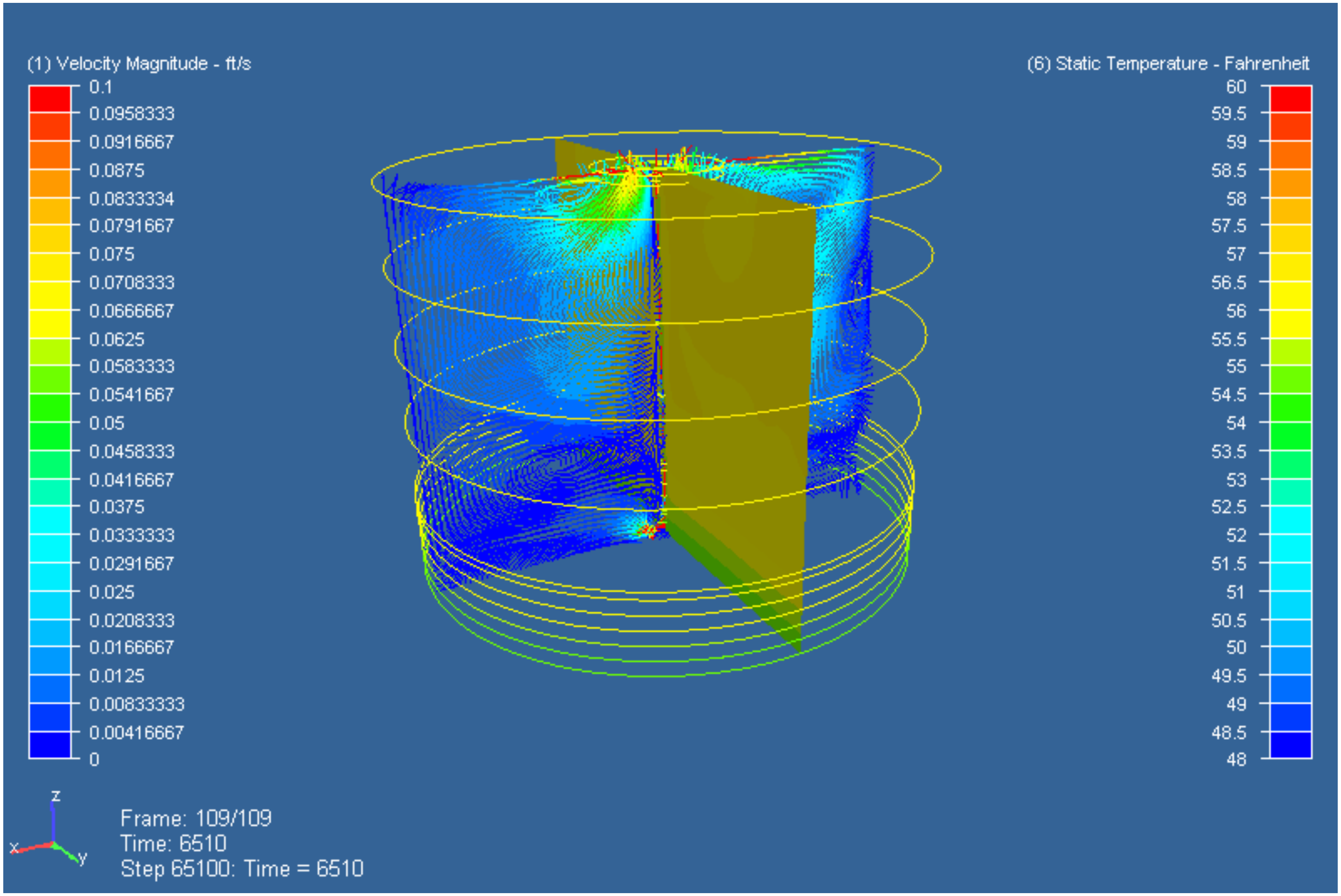
Slide C mixer on for about 1 hour

5 MG Tank, 30 ft tall, 170 ft diameter, above ground steel tank

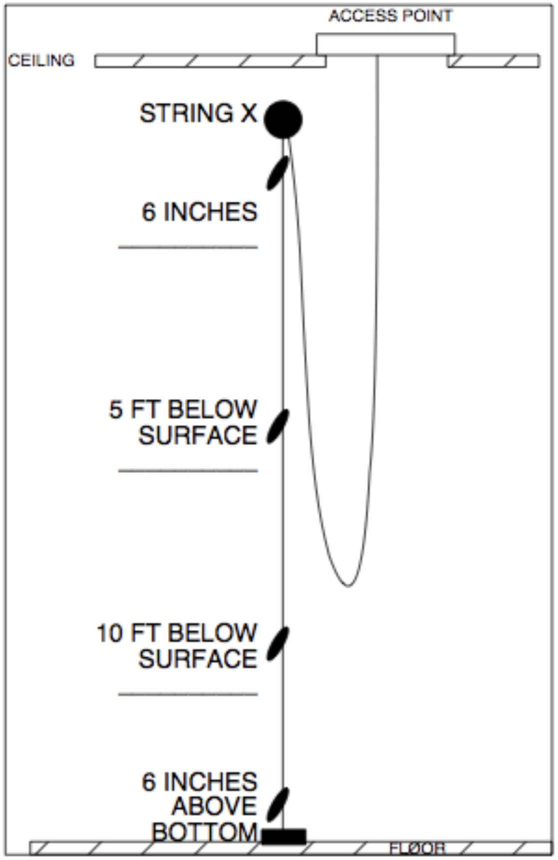


Slide D   mixer on for ~ 1.3 hours

5 MG Tank, 30 ft tall, 170 ft diameter, above ground steel tank



Test Data



6 HOBO STRINGS (3 PER TANK BASIN)
SET TO BEGIN 5 MIN TEMP SAMPLES ON 6/17/2011, 6:00 AM EASTERN

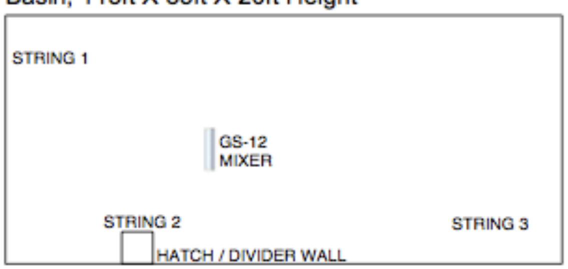
2.5 MG RECTANGULAR BASIN:
STRINGS 1 THROUGH 3

LOCATION	STRING 1	STRING 2	STRING 3
6 IN BELOW SURFACE	9947109	9947104	9947099
5 FT BELOW SURFACE	9947110	9947106	9947100
10 FT BELOW SURFACE	9947111	9947107	9947101
6 IN ABOVE BOTTOM	9947112	9947108	9947102

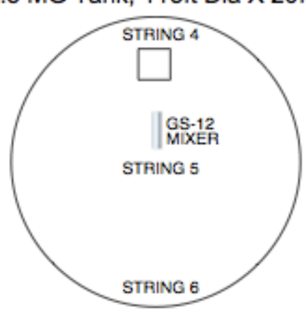
2.5MG CIRCULAR BASIN:
STRINGS 4 THROUGH 6

LOCATION	STRING 4	STRING 5	STRING 6
6 IN BELOW SURFACE	9947095	9947103	2028445
5 FT BELOW SURFACE	9947096	9923850	2028436
10 FT BELOW SURFACE	9947097	9933293	2028431
6 IN ABOVE BOTTOM	9947098	2419909	2028451

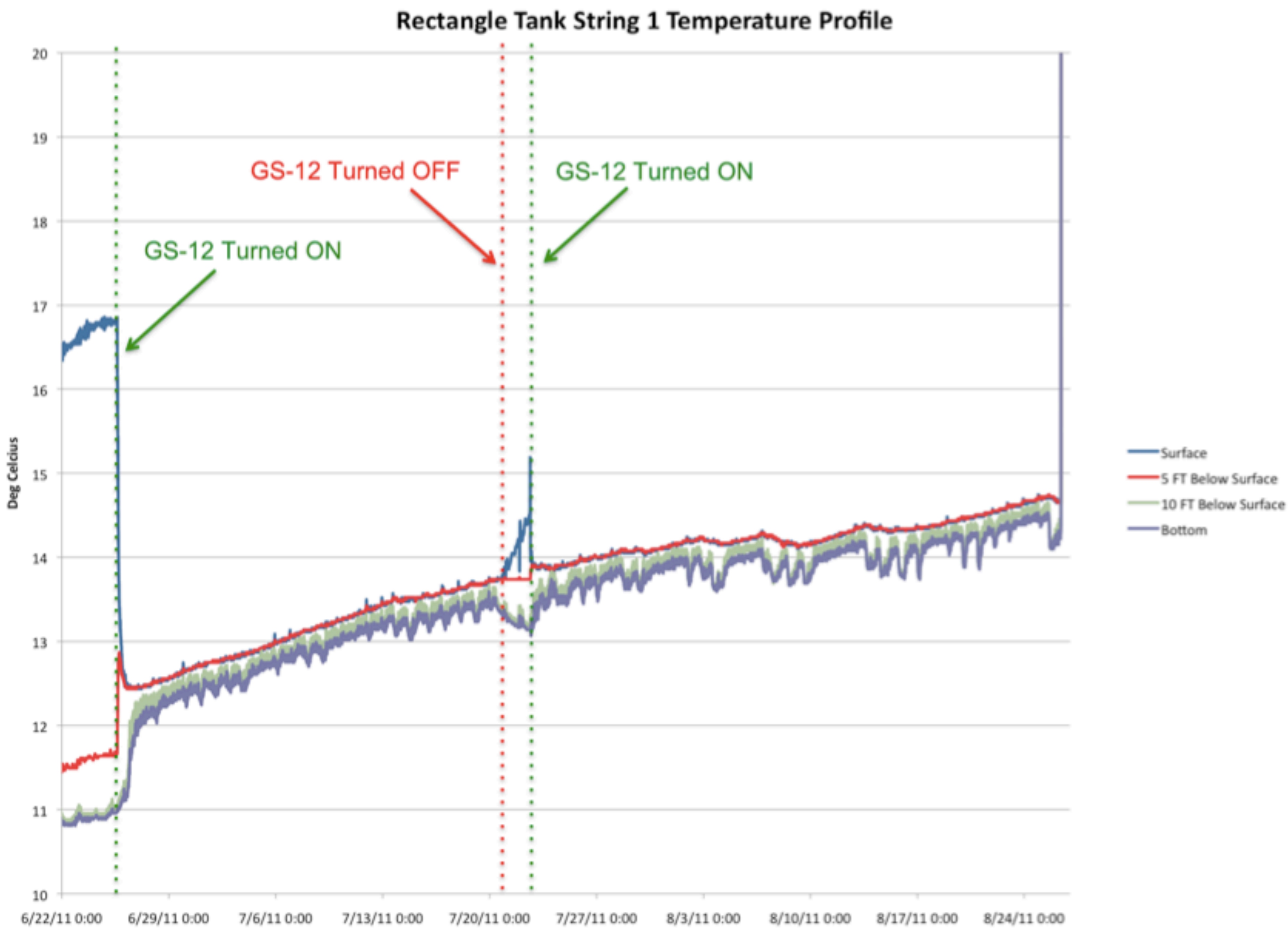
Rectangular, Underground, Concrete 2.5 MG Basin, 115ft X 85ft X 20ft Height



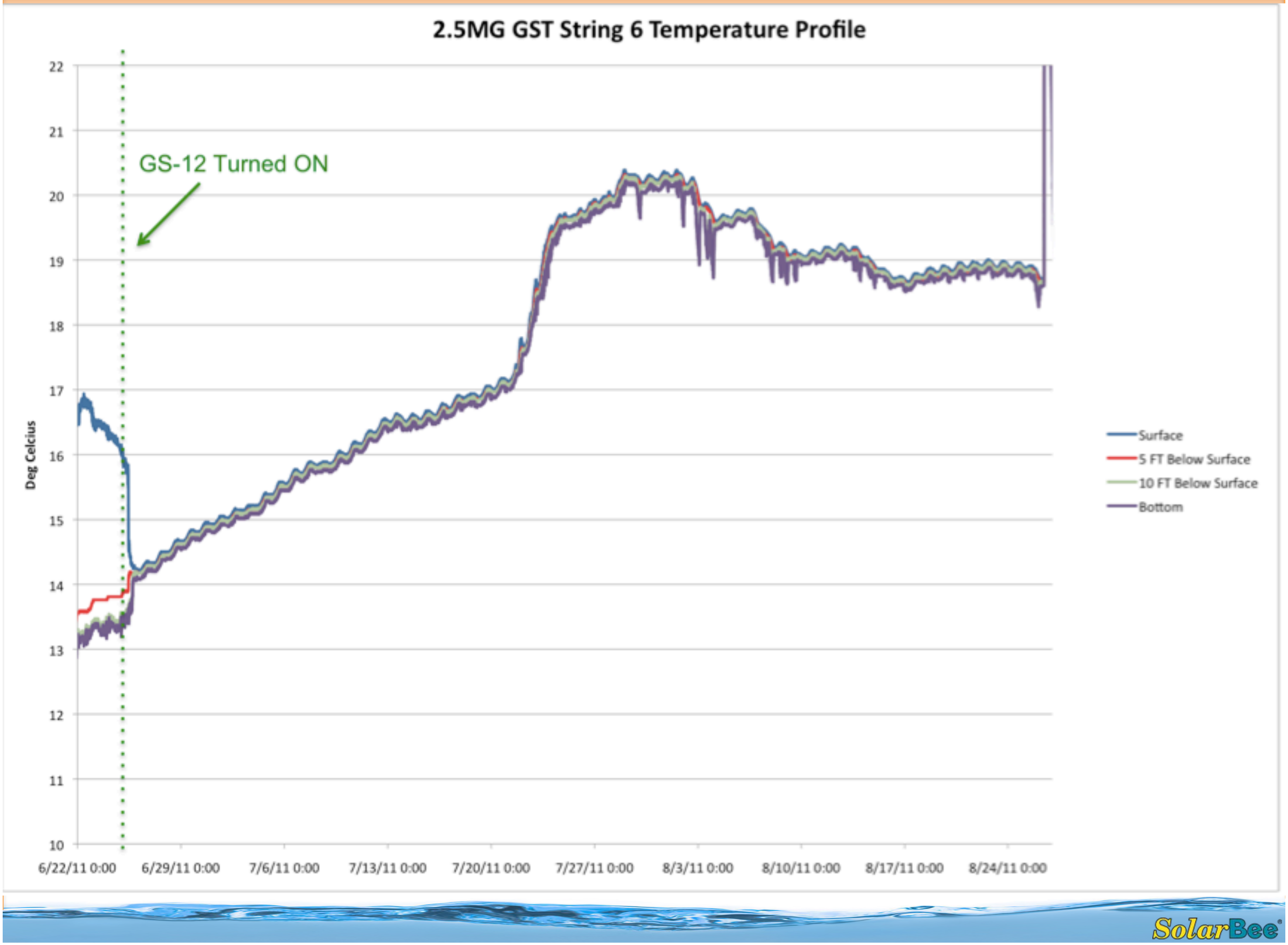
GST, Partially Buried, Concrete 2.5 MG Tank, 115ft Dia X 20ft Height

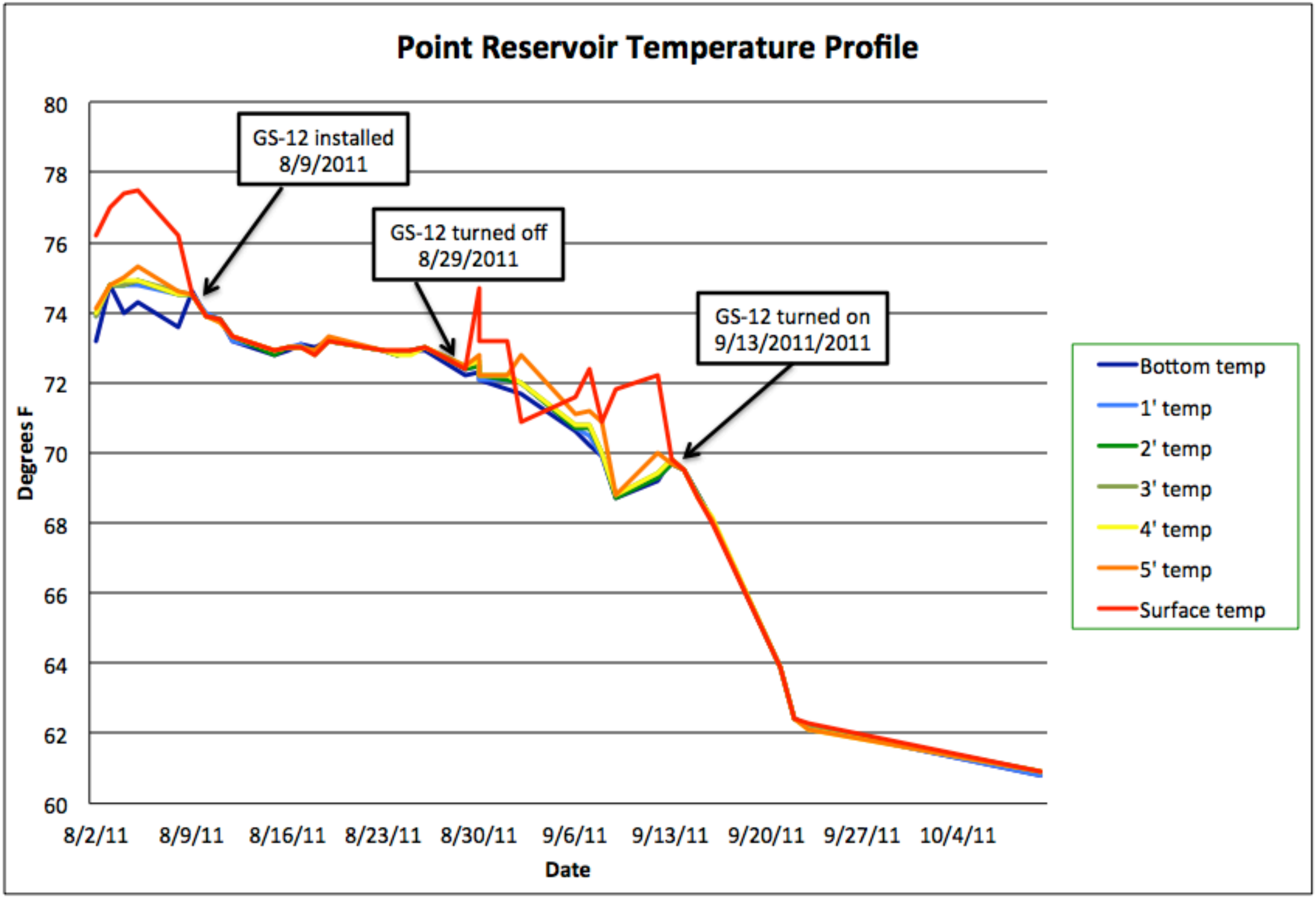


PROJECT: Water Temp Testing June through Setpember 2011
TITLE: Temperature Sensor Configuration
SCALE: NTS | DRAWN BY: Corey S | PART NO: NA | REV: 0
DATE: 9/9/2011 | FILE NAME: GS12_TempSensorConf_20110909


Rectangle Tank String 1 Temperature Profile
20
19
18
17
16
15
14
13
12
11
10
Deg Celcius
GS-12 Turned OFF
GS-12 Turned ON
GS-12 Turned ON
6/22/11 0:00
6/29/11 0:00
7/6/11 0:00
7/13/11 0:00
7/20/11 0:00
7/27/11 0:00
8/3/11 0:00
8/10/11 0:00
8/17/11 0:00
8/24/11 0:00
Surface
5 FT Below Surface
10 FT Below Surface
Bottom

SolarBee®


2.5MG GST String 6 Temperature Profile
GS-12 Turned ON
Deg Celcius
22
21
20
19
18
17
16
15
14
13
12
11
10
6/22/11 0:00
6/29/11 0:00
7/6/11 0:00
7/13/11 0:00
7/20/11 0:00
7/27/11 0:00
8/3/11 0:00
8/10/11 0:00
8/17/11 0:00
8/24/11 0:00
Surface
5 FT Below Surface
10 FT Below Surface
Bottom
SolarBee



Point Reservoir Temperature Profile
GS-12 installed 8/9/2011
GS-12 turned off 8/29/2011
GS-12 turned on 9/13/2011/2011
Degrees F
80
78
76
74
72
70
68
66
64
62
60
8/2/11
8/9/11
8/16/11
8/23/11
8/30/11
9/6/11
9/13/11
9/20/11
9/27/11
10/4/11
Date
Bottom temp
1' temp
2' temp
3' temp
4' temp
5' temp
Surface temp

SolarBee

Sunset Reservoir South Basin

Mixer Study

Report Published August 2004

Sunset South In-Ground Concrete Reservoir

(1) SB10000 SolarBee

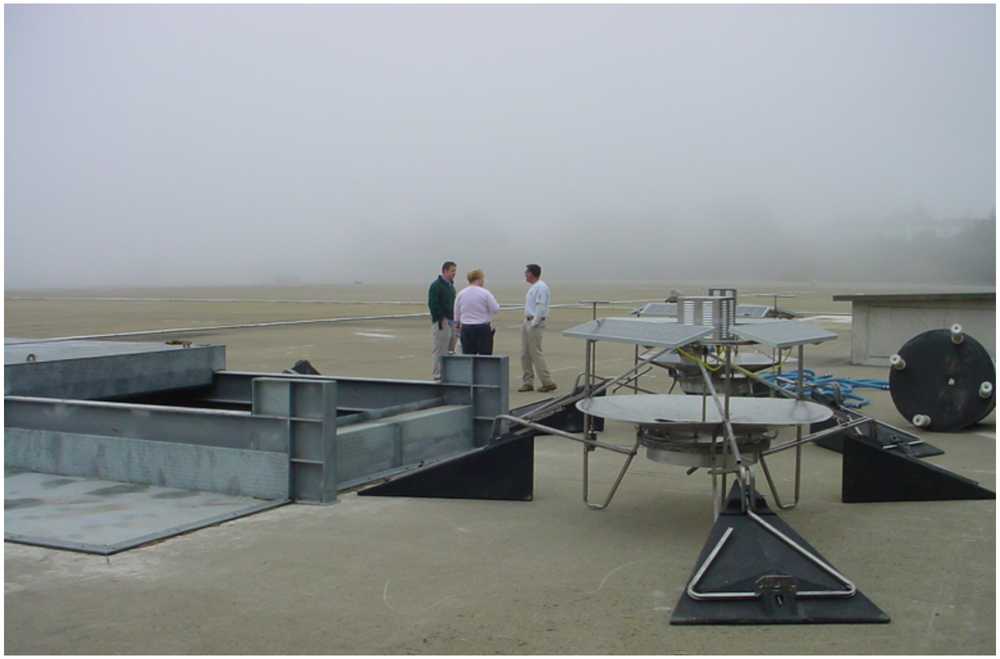
90 million gallon reservoir

11 surface acres

1000 ft by 500 ft

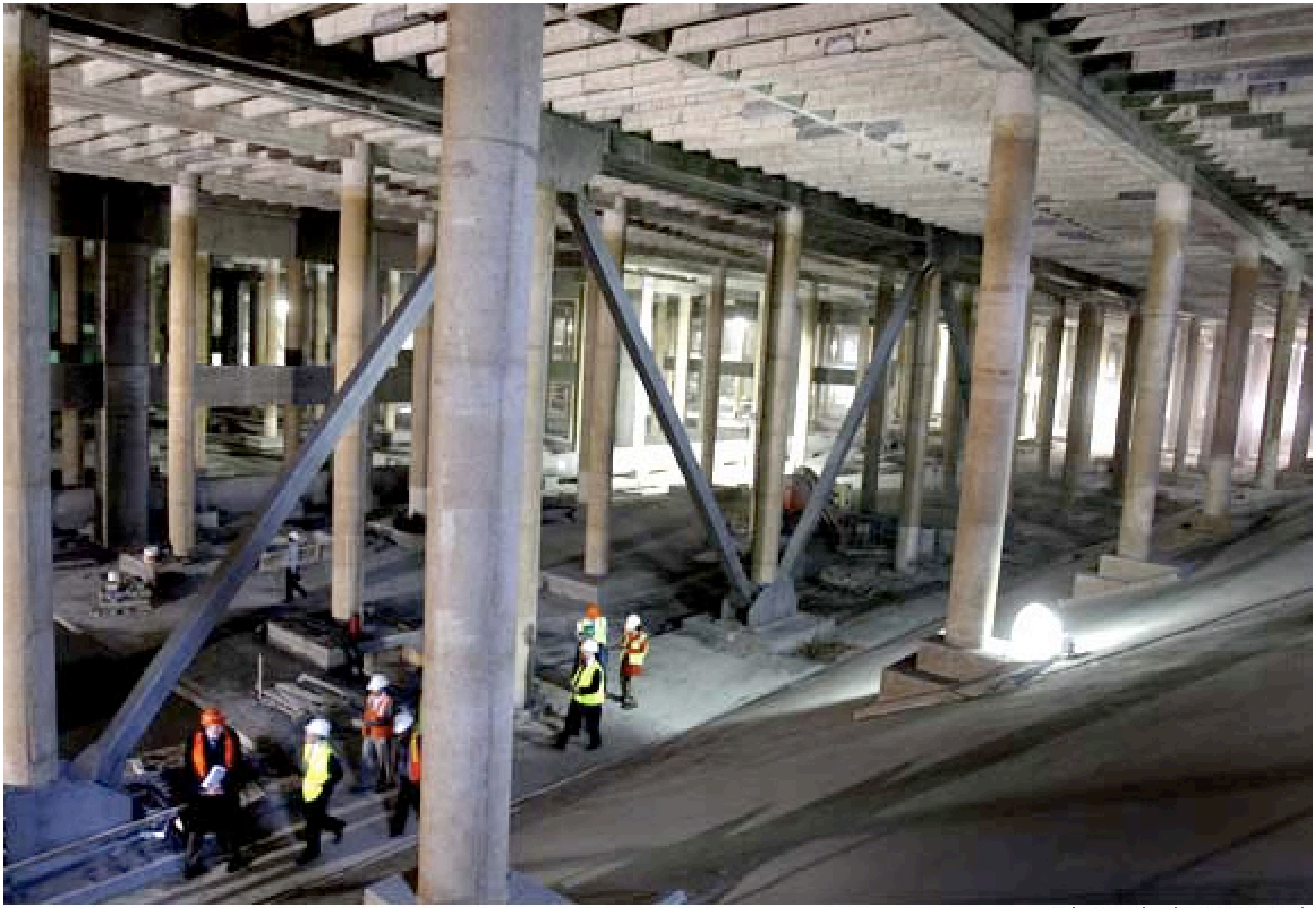
30 ft deep, 4C stratification

720 roof support columns



SolarBee

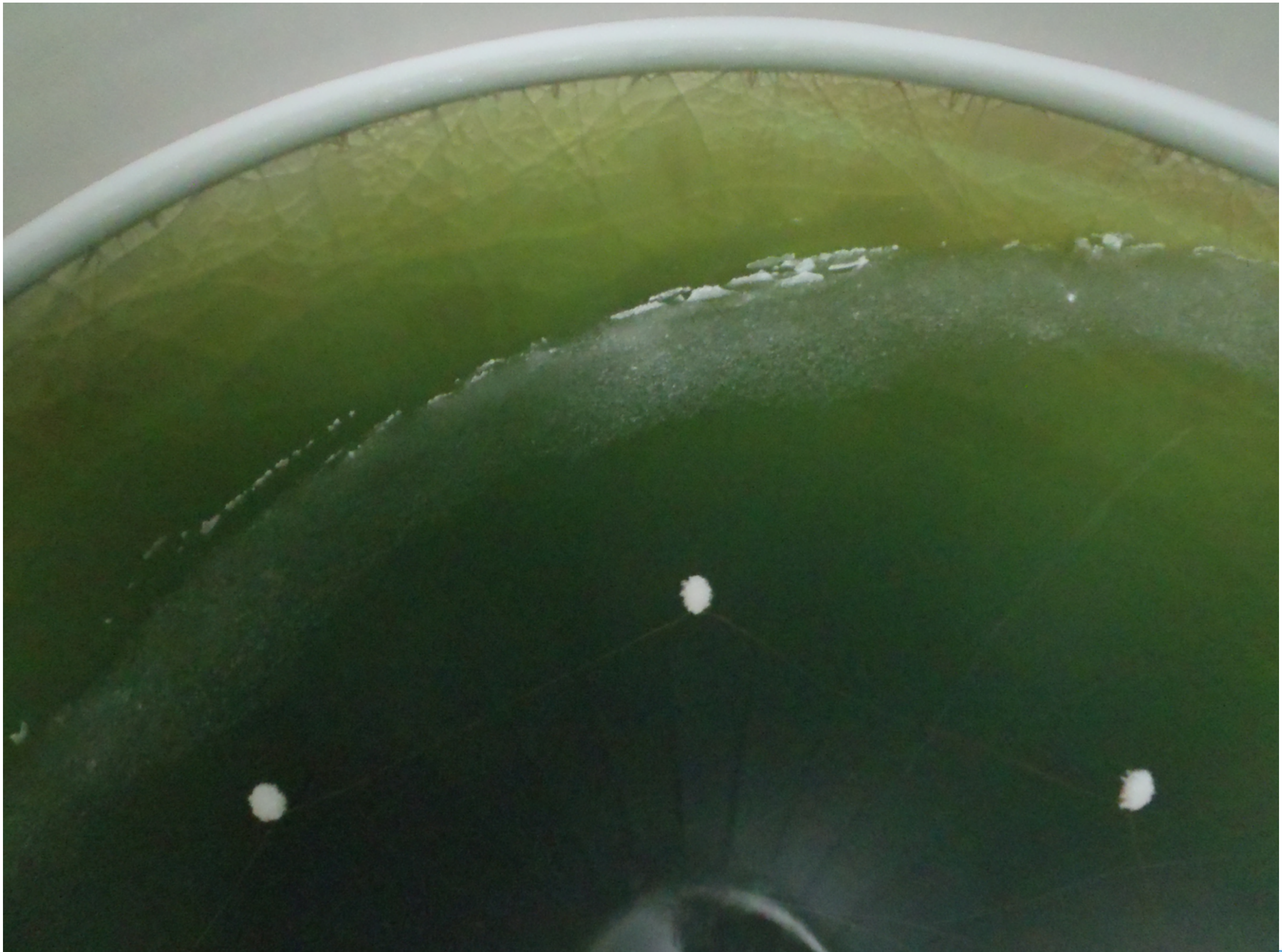
Seismic Retrofit of SFPUC's Reservoirs

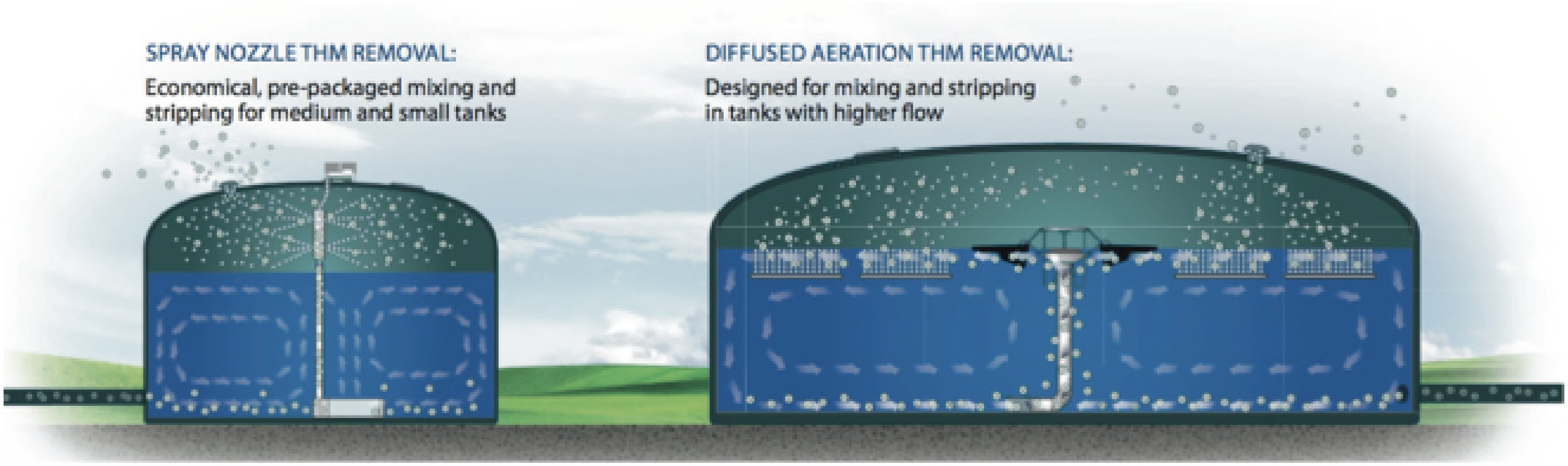


Chronicle / Brant Ward

Tank with Ice - No Mixer

Mixer installed - Tank with minimal ice





THM Removal Systems

EPA Disinfectants and Disinfection Byproducts Rule (DBPR)

Stage 1 DBPR, 2002:

- Four locations designated and sampled for TTHM and HAA5 for each groundwater source or treatment plant. One must represent the maximum residence time in the distribution system.
- TTHM and HAA5 samples collected and analyzed quarterly for the running annual average.
- **System-wide running annual average** must be below 80 µg/L for TTHM and 60 µg/L for HAA5.
- All regulated utilities were required to comply by January 2004.

Stage 2 DBPR, 2006:

- Number of sampling locations based on population, likely an increase for most utilities.
- Locations based on highest TTHM and/or HAA5 values in the distribution system.
- Each **location's running annual average** will be reported (no longer system-wide average)
  - For example, a water utility serving 1,000,000 to 4,999,999 people is required to have 16 monitoring locations for a water treatment plant source. If any of these 16 monitoring locations exceed 80 µg/L for TTHM or 60 µg/L for HAA5, the utility will be out of compliance with the Stage 2 DBPR.
- Phased compliance implementation (by population size) as early as April 15, 2012.

SolarBee®

Regulated THMs

Henry's Law Constant

- The ability to remove a **liquid chemica**l from **water** by air stripping is based on the chemical's volatility and its solubility in water, a property referred to as "Henry's law constant" for that chemical.

Four regulated THMs:*

- Chloroform (trichloromethane) - easiest to strip out
- Bromodichloromethane - harder to strip out
- Dibromochloromethane - harder to strip out
- Bromoform (tribromomethane) - hardest to strip out

Chlorine – why is it not affected / stripped out?*

- Chlorine gas is easy to strip out. But chlorine gas in water quickly forms hypochlorous acid; and is very hard to strip out.

** Note: Henry's Law Constant relationships are taken from the National Institute of Standards and Technology (NIST, 2011).*

Several opportunities for reducing THMs

- **At the treatment plant**
  - **Change treatment process / Switch disinfectants.**
  - **Install a mixer in the CT basin.** Intense mixing of the CT basin can improve T10 time to possibly allow for significant reduction of chlorine, which will result in less THMs.
  - **Do air stripping of THMs at the clearwell.**
- **In the distribution storage tanks**
  - **Install a mixer in some or all tanks**. Mixing alone will often reduce THM by a measurable amount. And mixing may allow for less system boosting to be needed, leading to less THMs.
  - **Do air stripping of THMs at one or more tanks.**

Reducing THMs at the plant >
Improve "T" in the CT basin with mixing

- **Mixing a CT basin with a mixer**
    - It improves the plug flow, making it "vertical plug flow" by taking advantage of the layering of water into horizontal layers. We believe **0.7 or higher** baffle factor can be achieved, vs . **0.3** for a baffle.

- **A simple tracer study will verify increased "T"**

- **With more detention time "T", less chlorine can be used, resulting in less THM**

Bend, Oregon: Clear Well Contact Time

Case Study on Outback Reservoir #2

Function: Clear Well

Capacity: 2.23 MG tank above ground steel tank

Flow Rate: **7,000 gallons** per minute at peak

Inlet Outlet Structure: Separate 180 Degrees Apart

Before SolarBee: 30 minutes "T" detention time, baffle factor 0.1

With SB10000: 80 minutes "T" detention time, baffle factor 0.25

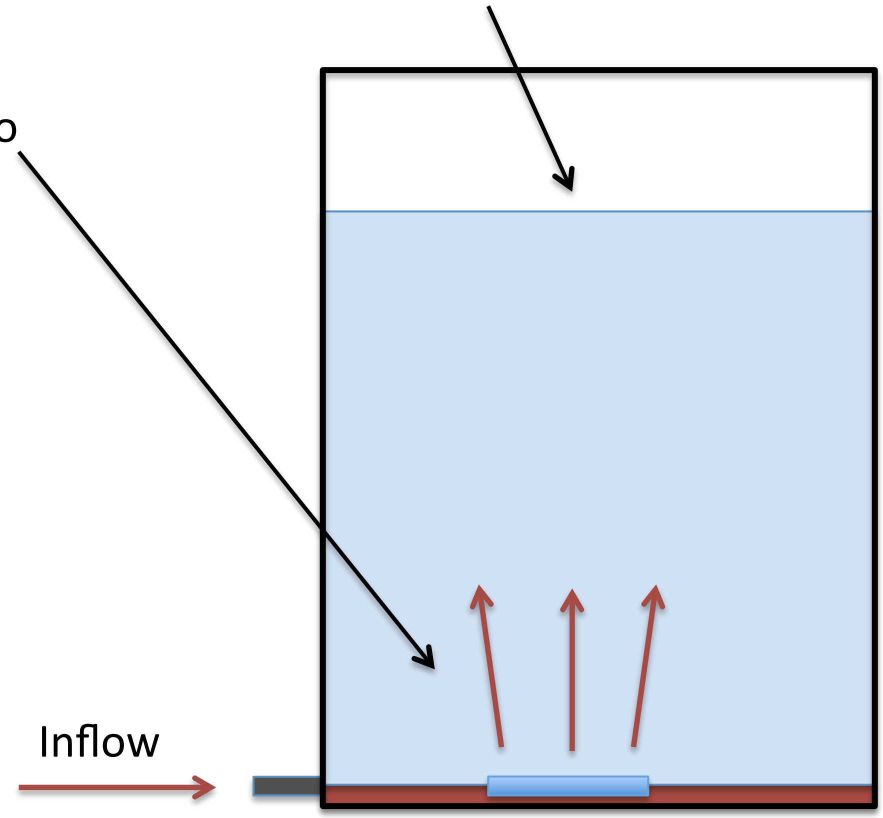
This was achieved with (1) SB10000v12, with 3,000 gpm direct flow. Customer had expected to need 2 or 3 units to achieve goal.

Reducing THMs in the distribution storage tanks > using <u>tank mixing</u> alone, 3 mechanisms at work

1. "<u>Solution by dilution</u>". If a mixer is picking up the untreated inflow water (a) as fast as it is coming in, and (b) all the way to the bottom of the tank, like the GS-12 does, then high THM water is mixed into low THM water before it can go back into system.

2. <u>Volatization at the surface</u>. Constant surface renewal exposes THM to the air in the headspace

3. <u>**Less stagnation** in the tank will cause better residual</u>, both in the tank and downstream. So <u>**less downstream boosting**</u> will be needed, resulting in less system THM problems.

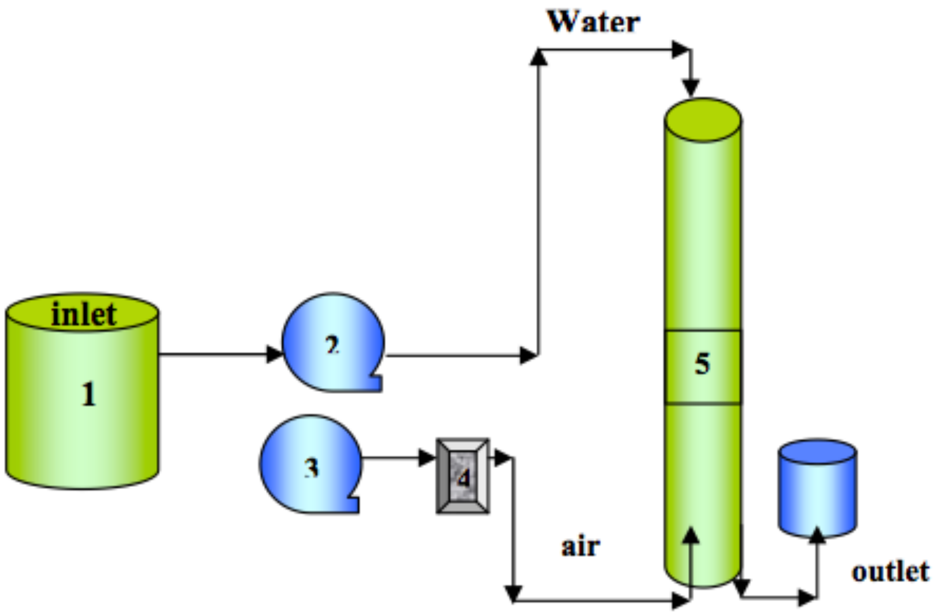


***BUT**, not all distribution water goes into a tank before it gets to the customer, so the effectiveness will vary based on exact flow path.*

Reducing THMs at the Plant > Air stripping THMs at the clearwell

- **The benefit:**
  - The intense mixing that accompanies stripping can more-fully react chlorine and NOM, and form more THM at clearwell, for higher THM levels here and more stripping there
  - The forced formation of THMs here, and stripping them as soon as formed, benefits THM levels in whole city
- **The disadvantage:**
  - Incoming THM level may be low (But intense mixing can offset this and form more so that stripping is feasible)
  - Sometimes much more chlorine is added later on in system anyway, defeating some of the benefits

Traditional Air-Stripping Technology



1. Feed tank
2. Feed pump
3. Air compressor
4. Flow meter
5. Air stripping column

- Air strippers remove volatile contaminants from water by contacting air and water to optimize transfer kinetics.
- Common types of air strippers include packed towers, multi-staged bubble systems, venturi eductors, and spray nozzles.
- Removal effectiveness is related to the air:water ratio.

THM Removal Systems

1. Spray Nozzle Systems with forced ventilation –system used for many years for various types of VOC's. Most cost effective system for most types of tank / reservoirs and clear-wells.

2. Shallow Set Diffuser System with high flow efficient mixer(s) and forced ventilation – very effective and reduces HP of bottom diffuser systems by approx. 80%.

3. Bottom Diffuser System – large network of air diffusers plumbed in grid across the tank bottom, with PVC pipe. High HP, expensive, complex, and maintenance-intensive.

4. Deep Bubble system – traditional air stripping system, could be installed as a side-stream to potable tank. Has mostly focused on contaminants other than THMs – radon, carbon dioxide, methane, hydrogen sulfide.

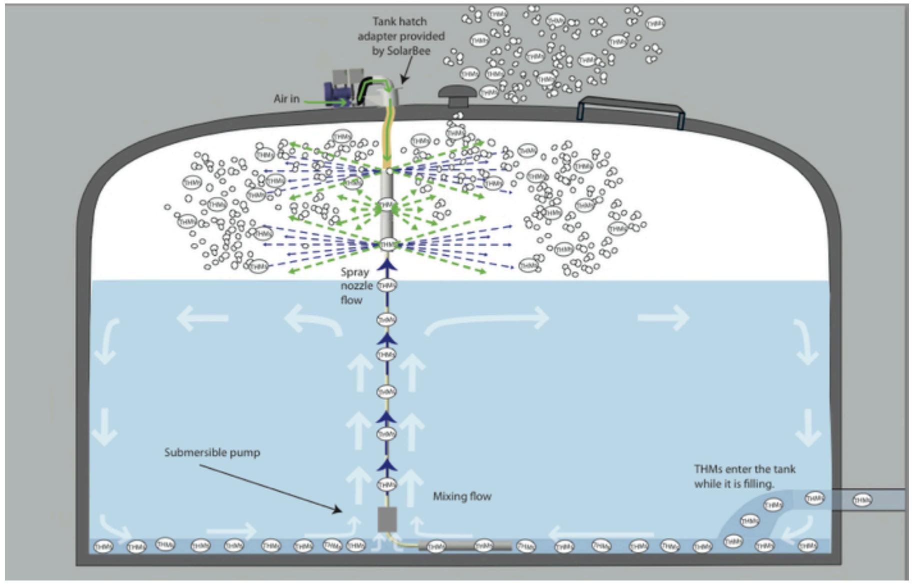
5. Surface Aerator – a wastewater aeration system with guide rails converted for use in potable tanks, with forced ventilation. Hatch size and other Installation issues due to size / design, effectiveness issues due to not pulling new water from floor of tank.

Surface aerator system

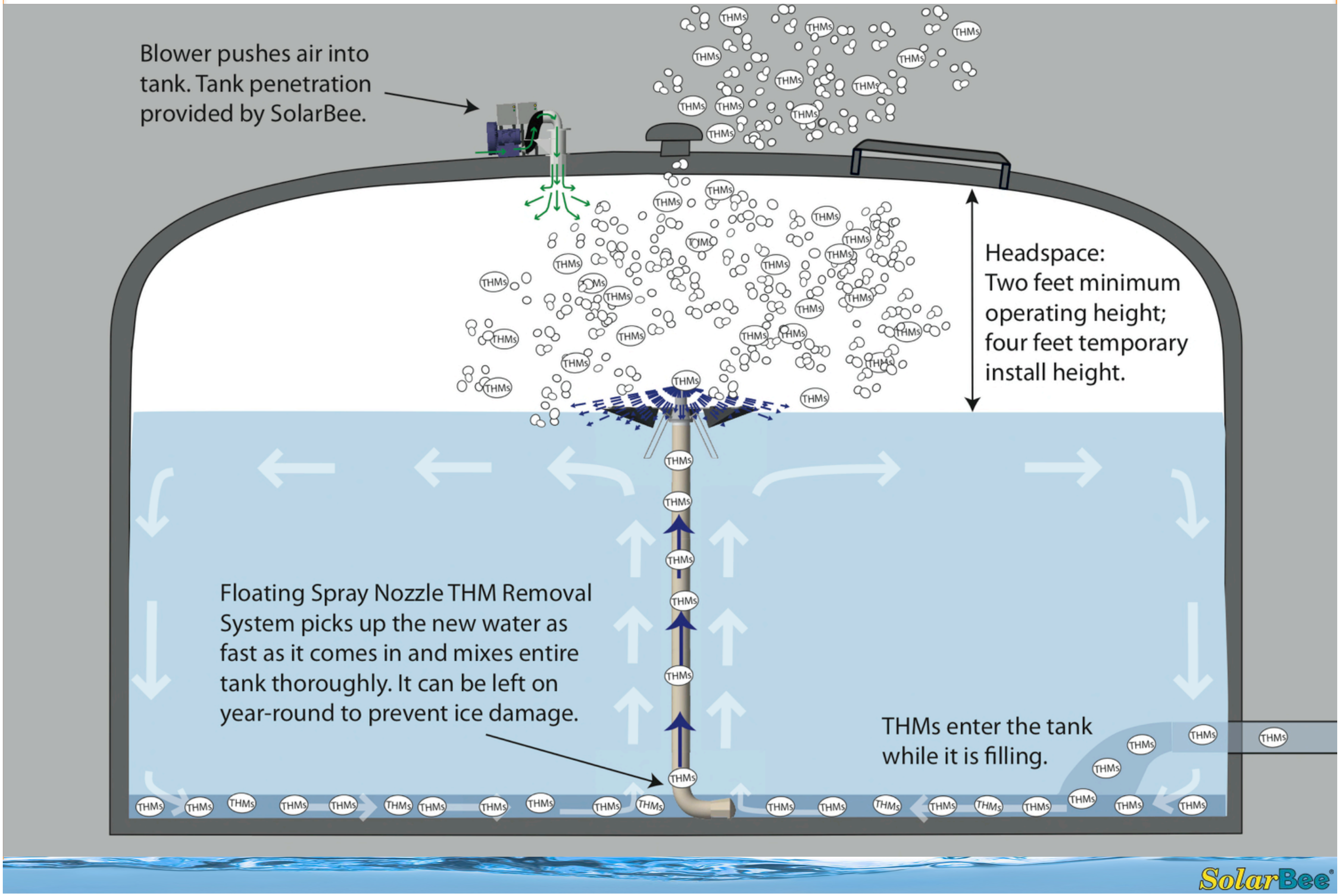
Deep Bubble System

SolarBee®

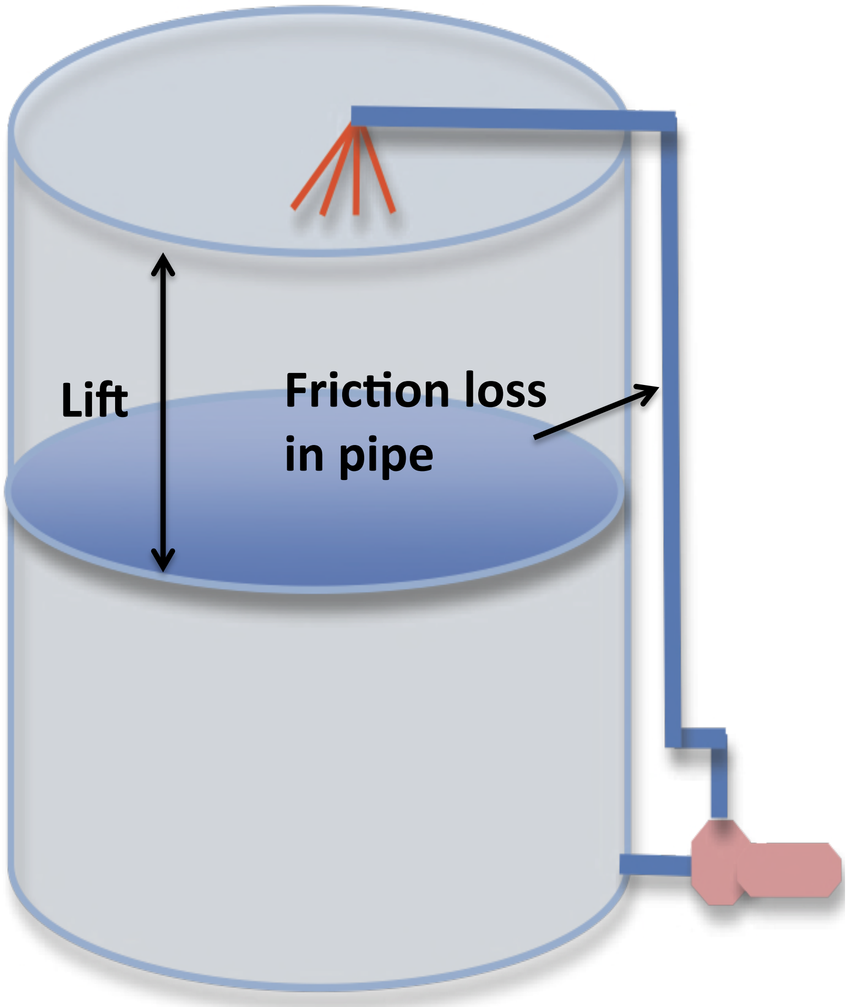
Fixed Spray Nozzles, fan for ventilating headspace



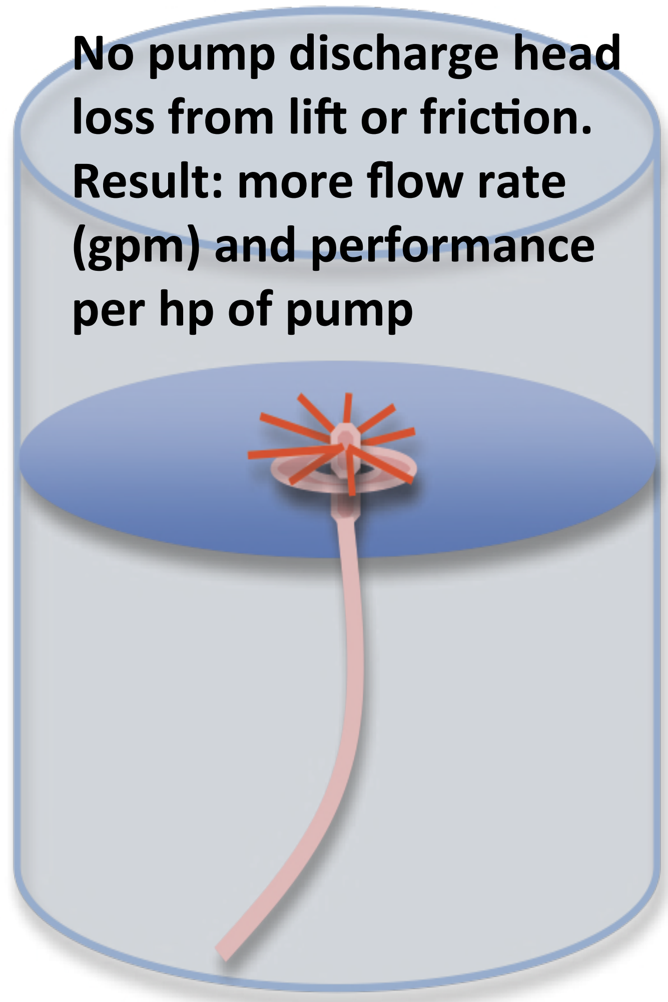
Floating Spray Nozzle Design



Energy benefit of Floating Nozzle vs. Fixed Nozzle

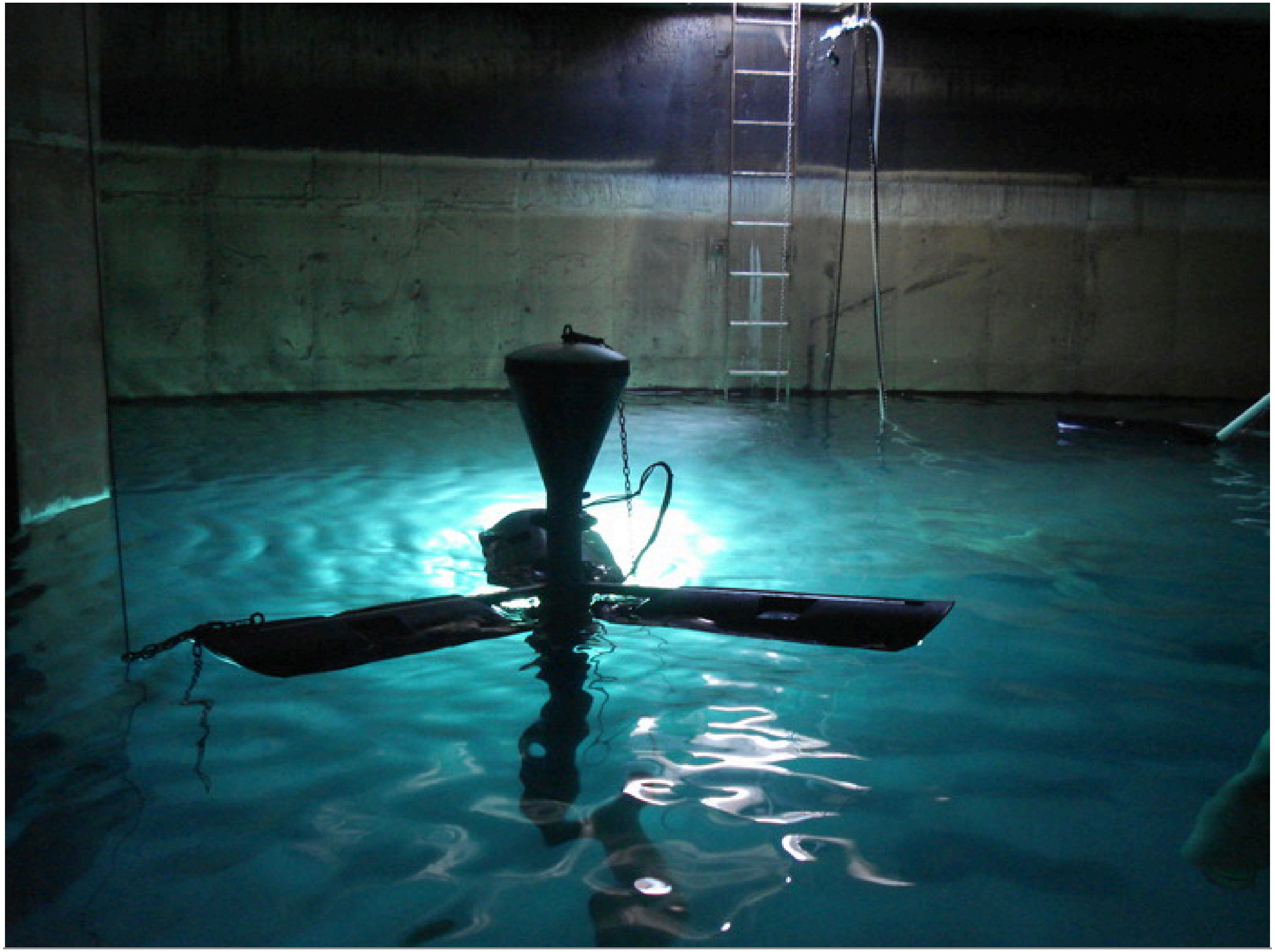


Fixed Spray Nozzle System



Floating Spray Nozzle System

THM Removal – Floating Spray Nozzle Design



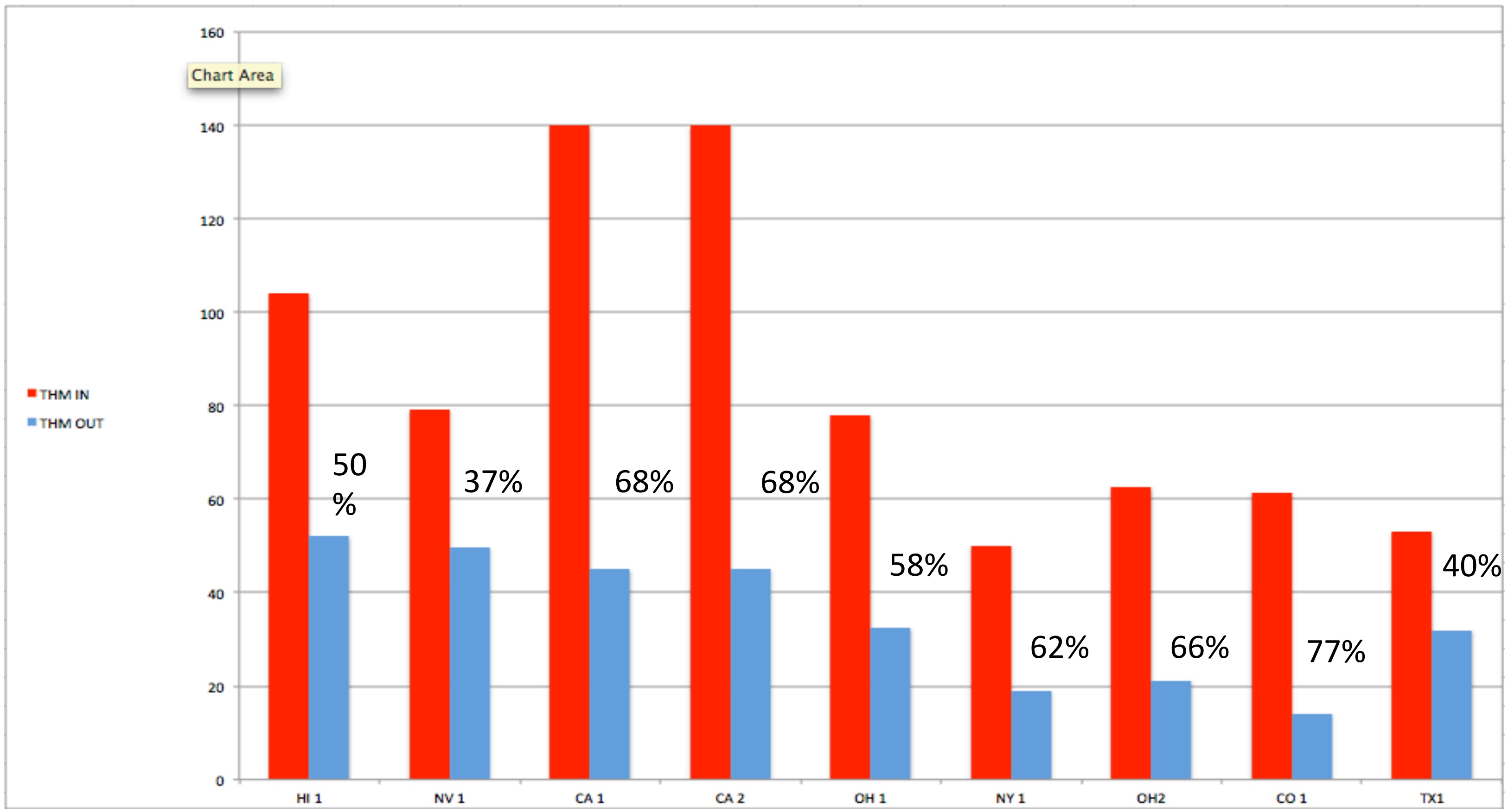
FSN-15 floating spray nozzle in operation

2hp turbine blower on skid, on top of tank

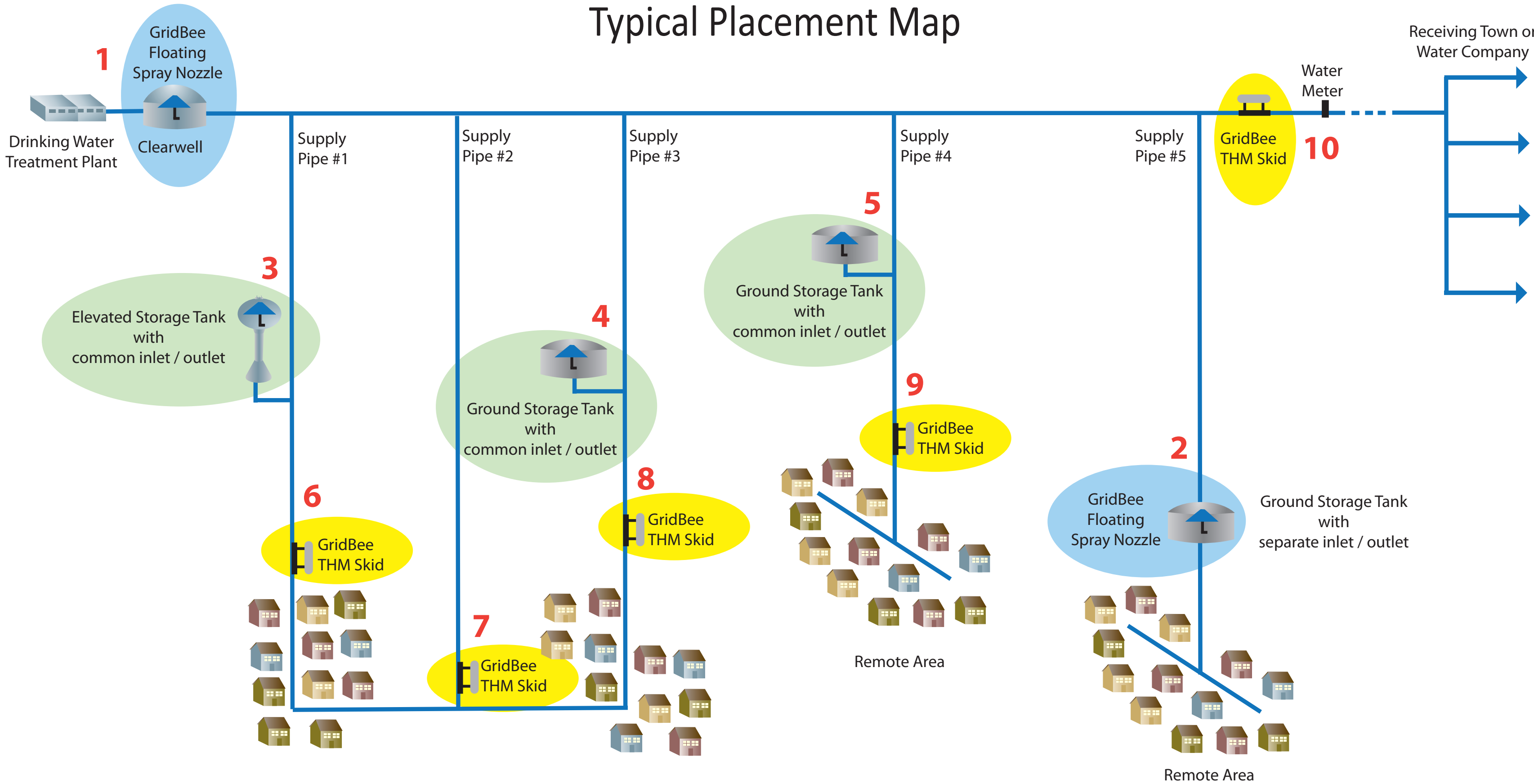
Blower on skid at base of tank

THM Removal Proven Results

Systems can be designed for virtually all reservoirs, and any desired reduction in TTHM. Actual results shown are for systems designed for 40-50% TTHM removal. The removal rate shown is based on actual TTHM entering and leaving the reservoir. Additional reduction also occurred in downstream TTHM formation potential.



GridBee® THM Removal
In-tank Floating Spray Nozzle and Skid-mount Systems
Typical Placement Map



Items 1 and 2: In-tank Floating Spray Nozzle THM Removal Systems are available to provide treatment of the entire plant output at the clear-well, or in storage tanks. They are particularly effective in storage tanks with a separate inlet and outlet, where all of the flow goes through the tank.

Items 3, 4, and 5: An In-tank Floating Spray Nozzle System will work well, but it only treats the water that comes into the tank.

Items 6, 7, 8, 9, and 10: In-line Skid-mounted THM Removal Systems will allow a city to remove THMs in a specific neighborhood or remote end-of-line region. The city's engineer can design the pad, piping retrofit and building to house the skid system. An in-line skid system may be the best solution when the distribution flow can bypass the tank in the system and go directly on to the user.

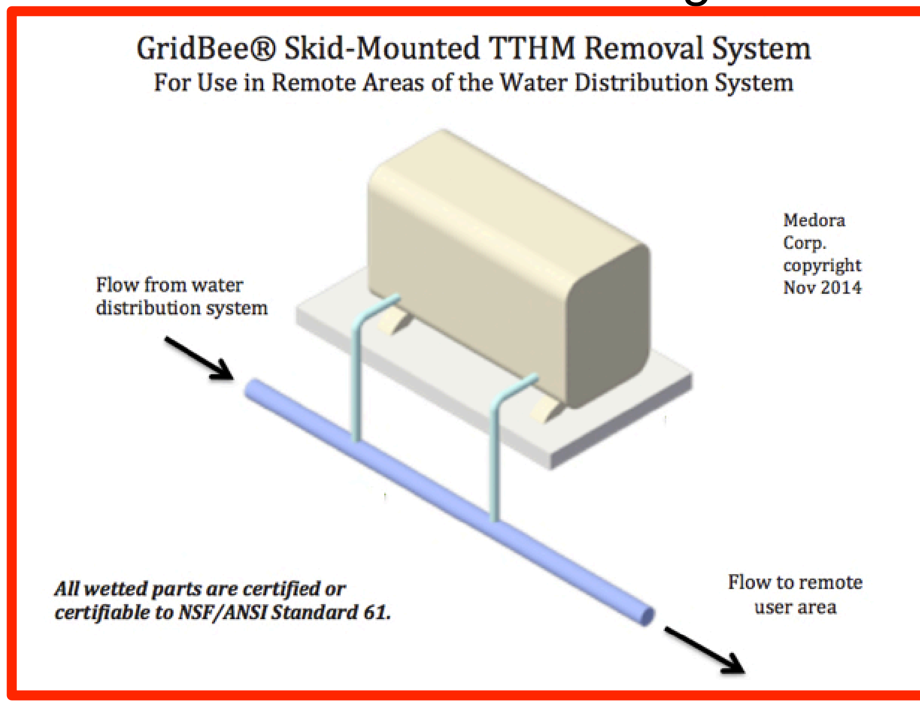
Both systems utilize Medora Corporation's patented long-life spray nozzle technology to treat all the water, minimizing THM formation downstream.

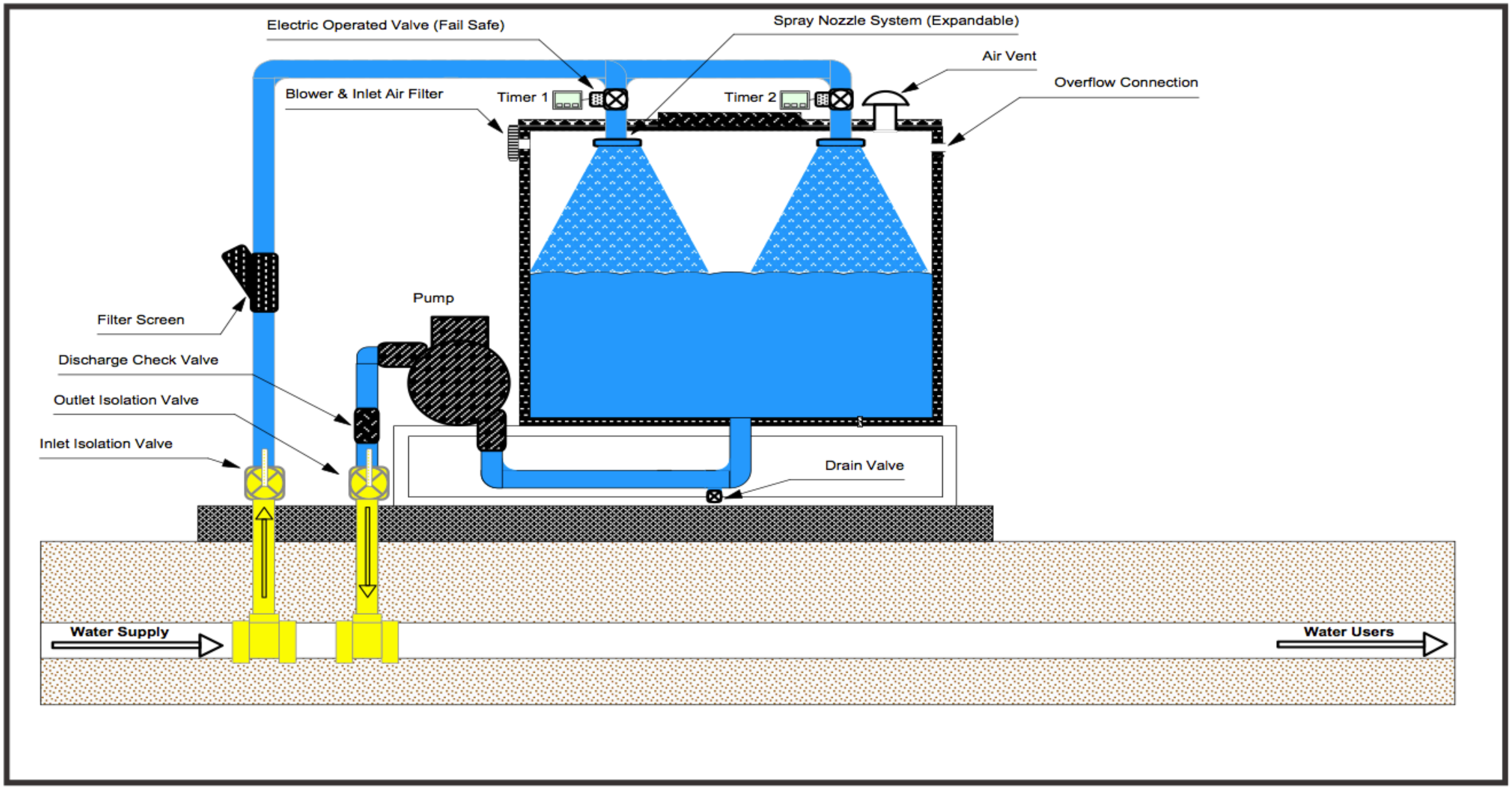
GridBee® SolarBee®
Medora Corporation

SolarBee®

In-Tank / In-Clearwell Design

Skid-Mounted Design





In-line Skid THM Removal System

Thank You ! – *Questions ?*

Harvey Hibl, US West Manager
303-469-4001 - harvey@solarbee.com

Visit: www.medoraco.com   800-437-8076

Literature, videos, case studies and more information

at our Website or at our Conference Booth