bolt will take. I say ideal because this time test was done under ideal conditions making for fast unwinding. **Unwinding one carriage bolt took 3 minutes**, which would mean a potential 8 hours for the entire site.

*Non-ideal obstacles that we did not experience during this test which would slow the process down would be: weighted panels that shift the carriage bolt sideways thus requiring extra people and/or tools; technician fatigue over the course of doing many carriage bolts in a row; inability to bend T-post backward to remove carriage bolt w/o fully unwinding bolt - which saves winding time**; lack of gloves for grip and avoiding injuries; etc.
**unwinding the entire carriage bolt added an additional 30 seconds for a total time of 3.5 minutes

--Test #2: Wind simulation

Structural integrity during intense weather – especially wind – is of great concern, as past wind damage has resulted in thousands of dollars in shelter repairs. We administered a ‘brute force shake test’ on the mock shelter for both the bolt and pin options. We intended for this to simulate a wind storm that put a lot of pressure and vibration at the conduit-bracket junction, i.e. the location where the carriage bolt holds the conduit which just so happens to have been the main point of failure in previous wind storms (carriage bolts did not bind conduit to bracket as bolts/pins will, which allowed conduit to be shaken off the carriage bolt and fall down).

- The **bolt** showed no sign of allowing the conduit to detach from the bracket. The main advantage here was that bolts can be tightened aggressively to the conduit, creating direct contact with no wiggling – eliminating the space for wind to shake the panels. Three points of failure might be: nut loosening throughout the year; over-tightening the bolt to the detriment of conduit integrity; bolt breaking under excessive stress.
- The **pin** held up well but did have one questionable sign. At first, the pin was secured into the closest adjustable hole which gave the effect of a tightened bolt – i.e. direct contact of pin clip and hence no wiggle room. When this was the case, the shake test caused the pin clip to bend slightly (figure 5). However, a second shake test was performed with the pin clip secured through one hole lower than the former test, which allowed some wiggle room. This test (done with a new clip) did not cause clip bending.
    - My guess as to why the pin held up in the second test is because of the reduction in stress that was afforded to the pin thread as a result of the wiggle room. In other words, the space in between 1) allowed the pin thread to **not** be under constant pressure and 2) dissipated some of the force of the shake before the pin clip hit the top of the bracket.
    - An **‘issue’** this could bring up is: Wouldn’t the ability to easily shake the conduit lead to problems down the road for the shingles, panels, and entire structure? Answer: I don’t think this would be a problem, because the current design of carriage bolts allowed a similar amount of wiggle room, and this did not appear to put anything at risk as long as sliding off the conduit was avoided.
        - Still: careful assessment of hardware should be done quickly after storms for the first iteration of this design should it be adopted.

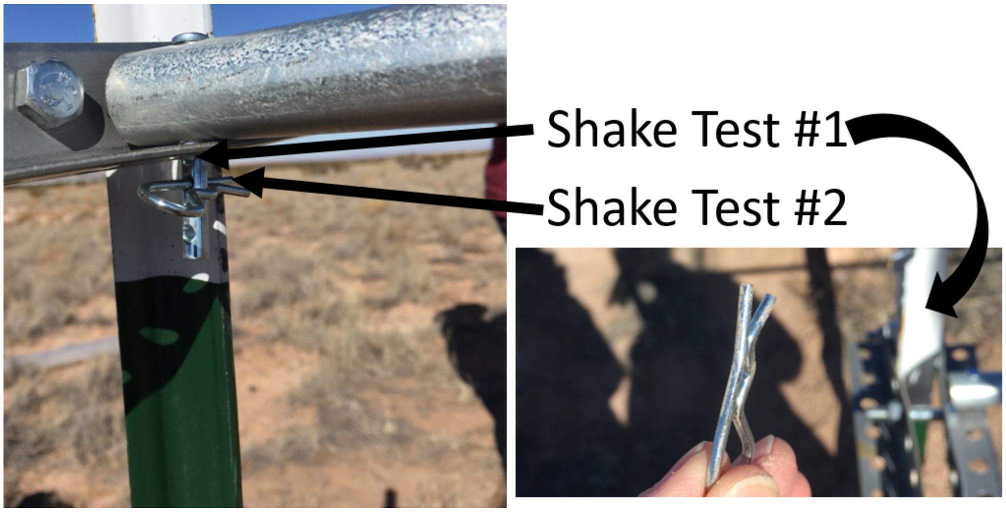


Figure 5: shake test 1 led to overstress of the pin thread and caused it to bend slightly (right); shake test 2 seemed to avoid this problem

--Test #3: Treatment swap simulation

Because panels will be physically removed from one plot and placed onto the corresponding paired plot roughly every year (depending on treatment), we wanted to ensure this could be done without a series of unforeseen obstacles. During our yearly plot treatment swap, panels will ideally be moved from one quadrant to the corresponding quadrant of the paired plot. To simulate this effect on a single plot, we just swapped panels diagonally as seen in figure 6. For example, we expect Panel I to have the same configurations as both Panel III and Panel I on the paired plots, since all T-posts and relative heights of brackets should be installed in a uniform manner. The rotation of all 4 panels in this manner was done successfully.

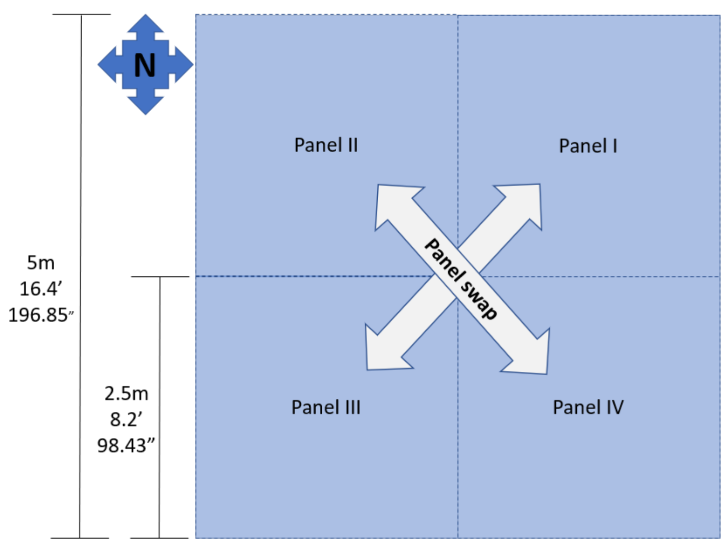


Figure 6: mock treatment swap to ensure panels have the ability to be removed and re-attached as necessary to achieve changes in yearly treatments

Irrigation Design and Specifications

This section covers the current MVE irrigation setup, the specifications of equipment and how they perform in the field. There is an archive of notes on the various iterations, mostly of sub-par designs that led to the current accepted iteration of the design to date. (Like the entire document, this section is subject to change as the irrigation improves over time.)

Overview

Our irrigation system emulates Gherardi et al., 2013 (automated rainfall manipulation system or ARMS); whereby rainout structures over a plot capture precipitation into a temporary storage tank and in turn is immediately pumped to an adjacent plot. ARMS simultaneously induces drought on the capture plot while simulating increased rainfall onto the pumped plot. ARMS has been used to simulate interannual precipitation variability, where pairs of plots rotate between increased and decreased precipitation every year.

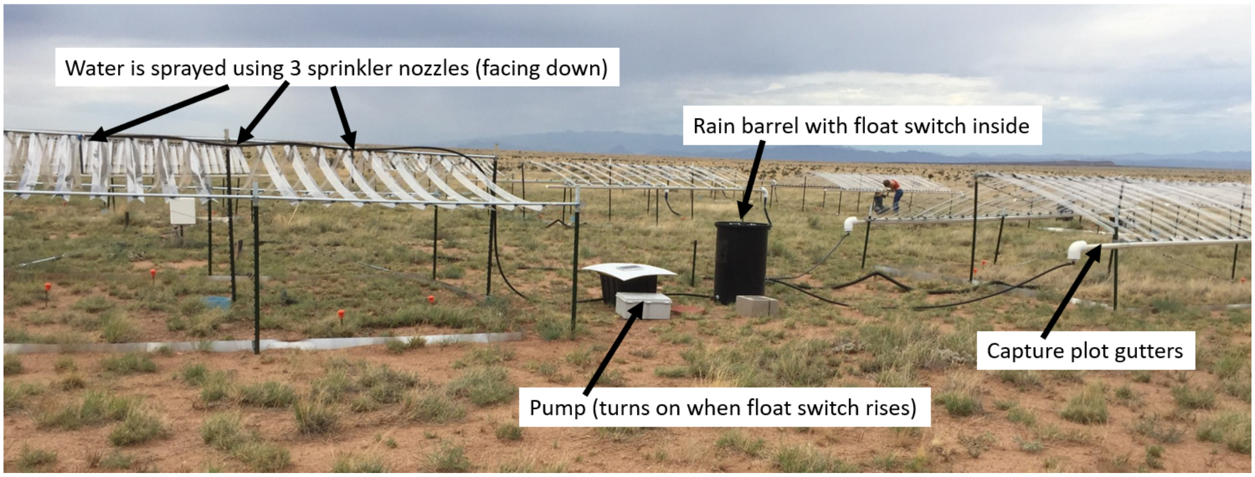
MVE has made several adaptations to the original ARMS design to fit specific experimental and design goals:

1. MVE simulates decreased mean and increased variance effets simultaneously
2. Mock plots containing non-capturing shelters over the pumped plots and control plots ensure environmental forcings from infrastructure are accounted: shade effects, temperature effects, dust interception, precipitation effects such as banding, etc. More on this in the shelter design and contruction section.
3. Irrigation designs unique to MVE are administered for several reasons. These include the fact that to our knowledge, the 25 m^2 MVE plots are the largest plots to date using this design. Additionally, given that MVE will be deployed throughout a variety of ecotypes, some grassland some shrubland, a replicate design that could be employed across all Sev-LTER was considered desirable. The following section details the design pf the MVE irrigation system and
4. ARMS has yet only been eomplyed during the growing season, we attempt to winterize the experiment to include cold-season periciptation treatments as well.

There are twenty plots (out of thirty plots) per site involved in irrigation treatments:

- 10 plots involved in the ambient mean, increased variance paired treatments
  - 5 capture plots (- 50% precipitation)
  - 5 pumped plots (+ 50% precipitation)
    - Mock shelters receiving 100% of intercepted water from -50% plots
- 10 plots involved in the decreased mean, increased variance paired treatments
  - 5 capture plots (- 75% precipitation)
  - 5 pumped plots (+ 25% precipitation)
    - -50% shelters receiving 100% of intercepted water from -75% plots

Overview: Capture plot (right) collects rain into the temporary storage tank (black rain barrel) where the water is immediately pumped to the paired plot (left).
Pictured treatment: **Ambient mean, increased variance** creates random years of +/- 50% precipitation for paired plots (note the downward facing shingles on the pumped plot capture no rain)



General Performance

MVE uses the Seaflo 42-series 12-v diaphragm pump (model SFDP1-030-055-42), which sprays captured precipitation onto pumped plots via three downward-facing rotary nozzles. The models of the nozzles are Rain Bird R-VAN24-360 (1 per plot) and Rain Bird R-VAN14-360 (2 per plot). Some specifications for pump and nozzles are pictured below. The pump performs up to 3 gallons per minute (gpm), while the accompanying nozzles have a combined flow rate of over 6 gpm. The historically largest hourly rain recording at Blue Grama core site met station (Met 50; i.e. MVB) was 27.7 mm. Thus, the amount of water pumped in a hypothetical worst case scenario event (30 mm rain per hour on a 75% shelter) would be 148.6 gallons per hour or 2.5 gallons per minute. The pump can therefore be expected to keep up with most if not all rain event sizes, assuming minimal outflow pressure and adequate power is supplied to the system (more on the electrical specs below).

DIAPHRAGM PUMP 42 SERIES

Features & Benefits

Positive displacemet pump
Can run dry
Up to 3.0 GPM
Quiet operation
Industry standard mount pattern
Demand & By Pass
Easy connect fittings

Typical Applications

General Industrial
Marine/RV
Automotive

PUMP

Type
4 Chamber positive displacement diaphragm pump, self priming, capable of being run dry

Control Type
Pressure switch & By pass

Priming Capability
6 feet (1.8 m) suction lift

Re-start Pressure
Shut-off Pressure 55PSI : 41 PSI ±5 PSI (±0.3 bar)

Max Recommended Temperature
60° C (140° F)

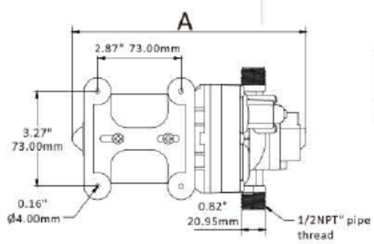
Inlet/Outlet Ports
1/2"-14 MNPT

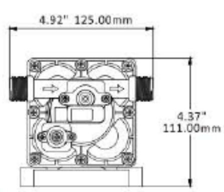
Weight
4.1 lbs (1.90 kg)-
6.6 lbs (3.0kg)

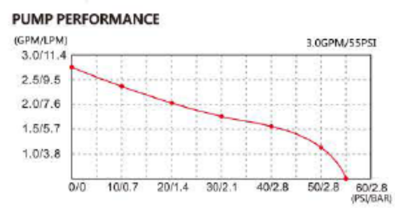
MOTOR

Duty Cycle
Intermittent

Voltage
12V/24V







A	SFDP1 / 2-020-055-42	194.5 mm (7.66")	SFDP1 / 2-040-055-42	230.5 mm (9.39")
	SFDP1 / 2-030-055-42	202.5 mm (7.97")	SFDP1 / 2-050-055-42	

STANDARD PUMP CONFIGURATIONS

Model	Voltage	Control Type	GPM/LPM	PSI/BAR	Max Draw(A)	Valves	Diaphragm	Ports	Wire Connections
SFDP1-020-055-42	12V	Switch & By pass	2.0/7.6	55/3.8	6.5	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead
SFDP2-020-055-42	24V	Switch & By pass	2.0/7.6	55/3.8	3.5	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead
SFDP1-030-055-42	12V	Switch & By pass	3.0/11.3	55/3.8	7.5	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead
SFDP2-030-055-42	24V	Switch & By pass	3.0/11.3	55/3.8	4.0	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead
SFDP1-040-055-42	12V	Switch & By pass	4.0/15.0	55/3.8	10.0	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead
SFDP2-040-055-42	24V	Switch & By pass	4.0/15.0	55/3.8	6.0	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead
SFDP1-050-055-42	12V	Switch & By pass	5.0/18.9	55/3.8	15.0	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead
SFDP2-050-055-42	24V	Switch & By pass	5.0/18.9	55/3.8	7.0	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead

Consult us for other available models, configurations, valve and diaphragm materials.

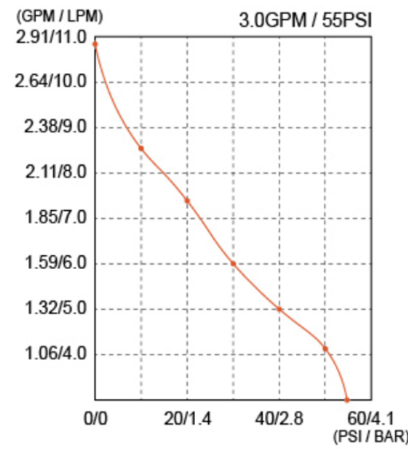
STANDARD PUMP CONFIGURATIONS

Model	Voltage	Control Type	GPM/LPM	PSI/BAR	Max Draw(A)	Valves	Diaphragm	Ports	Wire Connections
SFDP1-020-055-42	12V	Switch & By pass	2.0/7.6	55/3.8	6.5	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead
SFDP2-020-055-42	24V	Switch & By pass	2.0/7.6	55/3.8	3.5	EPDM	Santoprene	1/2"-14 MNPT	14 AWG, 9.4" Lead
SFDP1-030-055-42	12V	Switch & By pass	3.0/11.3	55/3.8	7.5	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead
SFDP2-030-055-42	24V	Switch & By pass	3.0/11.3	55/3.8	4.0	EPDM	Santoprene	1/2"-14 MNPT	16 AWG, 9.4" Lead

3.0GPM / 55PSI

12V

PRESSURE		FLOW		CURRENT
PSI	BAR	GPM	LPM	AMPS
0	0	2.85	10.8	3.9
10	0.69	2.27	8.6	4.5
20	1.38	1.96	7.4	5.1
30	2.07	1.59	6.0	5.8
40	2.72	1.32	5.0	6.3
50	3.45	1.11	4.2	6.7
55	3.8	0	0	7.0



Full Circle Nozzles (360°)

R-VAN14-360 8' - 14' (2.4 to 4.6m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	▲
360°	30	13	1.10	0.63	0.72
	35	13	1.12	0.64	0.74
	40	14	1.22	0.60	0.69
	45	**14**	**1.27**	**0.62**	**0.72**
	50	15	1.41	0.60	0.70
	55	15	1.45	0.62	0.72

R-VAN18-360 13' - 18' (4.0 to 5.5m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	▲
360°	30	16	1.65	0.62	0.72
	35	16	1.67	0.63	0.73
	40	17	1.80	0.60	0.69
	45	**17**	**1.85**	**0.62**	**0.71**
	50	18	2.05	0.61	0.70
	55	18	2.11	0.63	0.72

R-VAN24-360 17' - 24' (5.2 to 7.3m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	▲
360°	30	19	2.35	0.63	0.72
	35	20	2.52	0.61	0.70
	40	22	3.13	0.62	0.72
	45	**23**	**3.48**	**0.63**	**0.73**
	50	24	3.61	0.60	0.70
	55	24	3.74	0.62	0.72

Hunter®

FRICTION LOSS CHARACTERISTICS
POLYETHYLENE (PE)
SDR-PRESSURE RATED TUBE

(2306, 3206, 3306) SDR 7, 9, 11.5, 15 C = 140
PSI loss per 100 feet of tube (PSI/100 FT)
Sizes 1/2" thru 6"
Flow GPM 1 thru 600

https://www.hunterindustries.com/sites/default/files/tech_friction_loss_charts.pdf

SIZE	1/2"		3/4"		1"		1 1/4"		1 1/2"		2"		2 1/2"		3"		4"		6"		SIZE
ID	0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068		4.026		6.065		ID
FLOW G.P.M.	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	VELOCITY F.P.S.	P.S.I. LOSS	FLOW G.P.M.
1	1.05	0.49	0.60	0.12	0.37	0.04	0.21	0.01	0.15	0.00	0.09	0.00									1
2	2.10	1.76	1.20	0.45	0.74	0.14	0.42	0.04	0.31	0.02	0.19	0.01									2
3	3.16	3.73	1.80	0.95	1.11	0.29	0.64	0.08	0.47	0.04	0.28	0.01	0.20	0.00							3

Elevation changes can add or subtract water pressure from your water system. That seriously changes how well the system works. Each foot of elevation change is equal to 0.433 PSI of water pressure. Think of a vertical column of water. At the bottom of

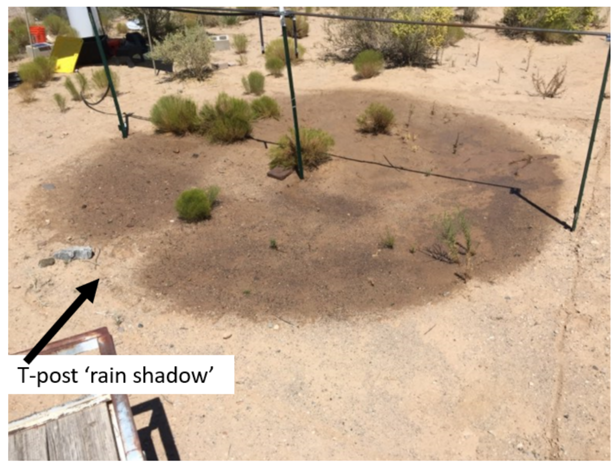
https://www.irrigationtutorials.com/elevation-pressure-loss-in-irrigation-systems/

25' of PE tubing = PSI loss of 0.95 * 0.25 = 0.24 PSI
6' of elevation gain = 6 * 0.433 = 2.6 PSI
Liberal round-up: 4 PSI of system pumping pressure

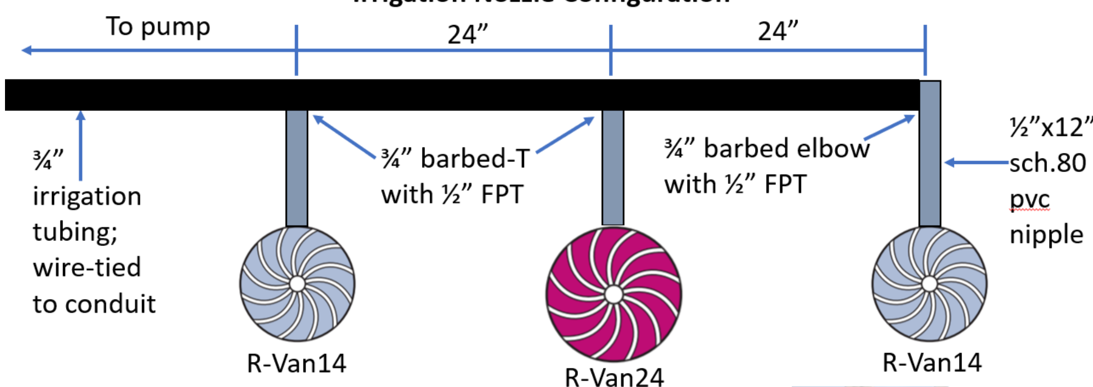
The pumped plots are irrigated with a uniform downward-spraying nozzle design that was determined over an iterative trial-and-error process. Many trials have been conducted over time including two days at the UNM Field Station where the current configuration (see pics below) was determined. There exist some flaws in the design, but the current iteration discused below has proven the most pragmatically successful. The design was chosen for its replicability over multiple vegetation types; e.g. hanging nozzles from above can be replicated for shrub-sites. However, it is inevitable that some dry patches will exist. **Justifications for the existing design** and additional info on this and other differences from the original ARMS design is discussed in the ARMS vs. MVE section.

Irrigation spray trials (Field Station 8/30 – 8/31/2019)

Left: main nozzle in center (R-VAN24-360) saturates large band of the plot, covering most research-sensitive areas (quads; seed additions, sensors, etc.). **Right**: additional nozzles (R-VAN14-360) sit 2’ on both sides of main nozzle to saturate plot’s center, including soil moisture sensors.



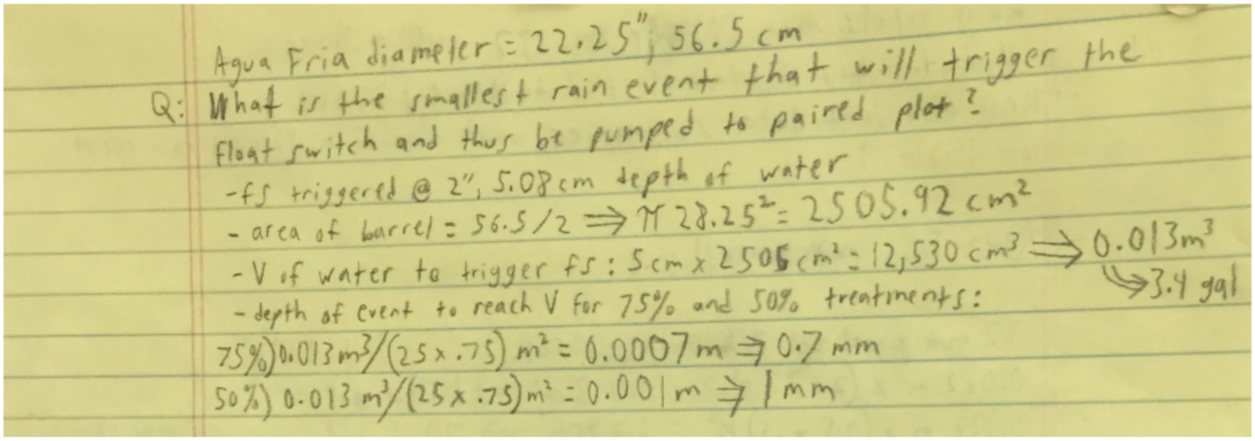
Irrigation Nozzle Configuration



R-VAN14-360	8’ - 14’ (2.4 to 4.6m)				
Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	▲
360°	30	13	1.10	0.63	0.72
	35	13	1.12	0.64	0.74
	40	14	1.22	0.60	0.69
	45	**14**	**1.27**	**0.62**	**0.72**
	50	15	1.41	0.60	0.70
	55	15	1.45	0.62	0.72

R-VAN24-360	17’ - 24’ (5.2 to 7.3m)				
Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	▲
360°	30	19	2.35	0.63	0.72
	35	20	2.52	0.61	0.70
	40	22	3.13	0.62	0.72
	45	**23**	**3.48**	**0.63**	**0.73**
	50	24	3.61	0.60	0.70
	55	24	3.74	0.62	0.72

Fun fact (pic below): The smallest rain event that can trigger the pumps is a 1 mm rain for the 50% capture plots and 0.7mm of rain for the 75% capture plots. Treatments are therefore very reactive and should achieve good simulation even for very small rain events.



Agua Fria diameter = 22.25", 56.5 cm

Q: What is the smallest rain event that will trigger the float switch and thus be pumped to paired plot?

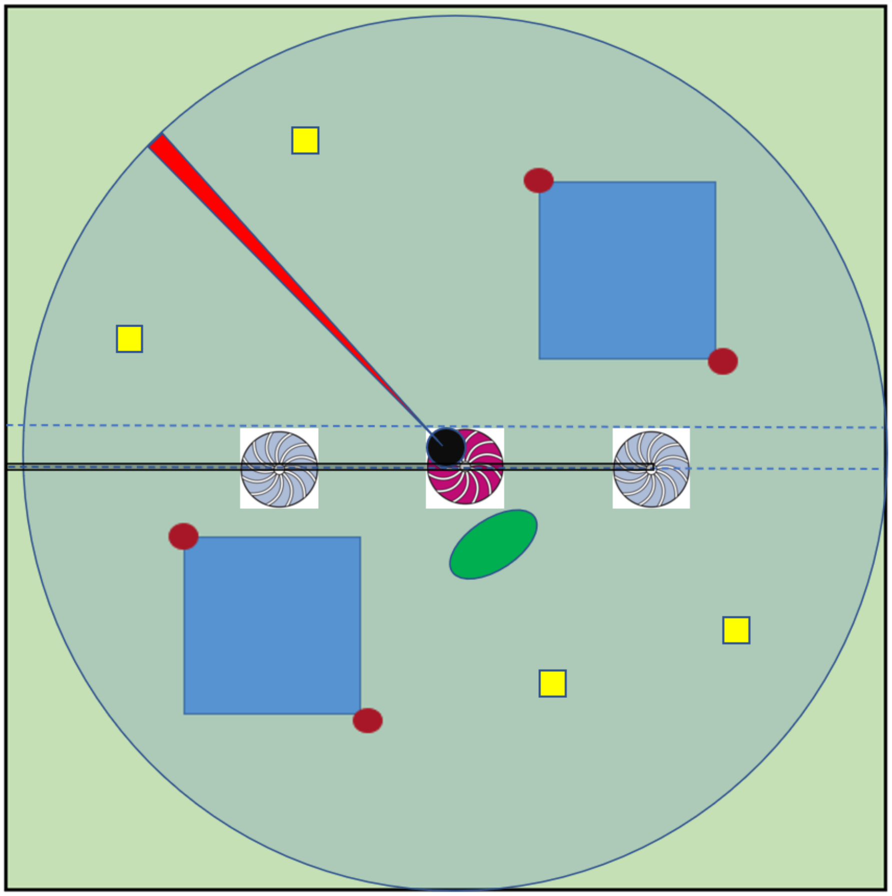
- fs triggered @ 2", 5.08 cm depth of water
- area of barrel = 56.5/2 ⇒ $\pi\ 28.25^2 = 2505.92\ cm^2$
- V of water to trigger fs : $5 cm \times 2505\ cm^2 = 12{,}530\ cm^3$ ⇒ $0.013\ m^3$ ↳ 3.4 gal
- depth of event to reach V for 75% and 50% treatments:

75%) $0.013\ m^3/(25 \times .75)\ m^2 = 0.0007\ m$ ⇒ 0.7 mm

50%) $0.013\ m^3/(25 \times .75)\ m^2 = 0.001\ m$ ⇒ 1 mm

Irrigation footprint (pic below):

Downward-facing, 360° spraying nozzles are manually adjusted to optimally saturate (large blue circle) the points of interest within the plots including soil moisture sensors (green oval). Nozzles hang slightly off-center because irrigation line (dark strip) is bound to only 1 of the 2 conduit (dashed lines) that straddle the true center (black dot; middle T-post). The nozzles are purposefully placed on the side of the T-post where a small, dry 'T-post shadow' (red band) does not affect the 1x1 m sample quads (blue squares). Experimental seedling additions were placed in quad-opposite corners in four 10x10 cm grids, after field trials of saturation footprint (yellow squares).



Irrigation Footprint

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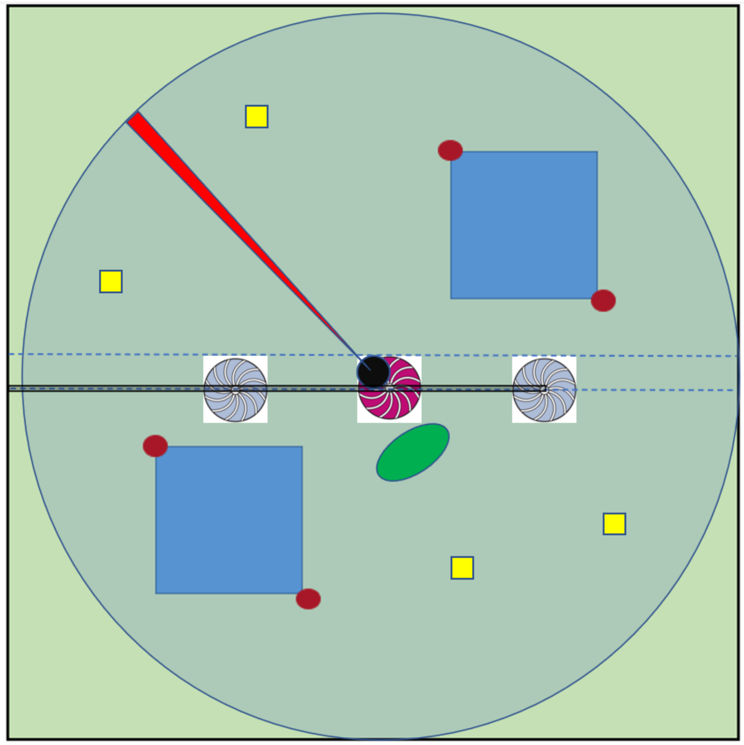
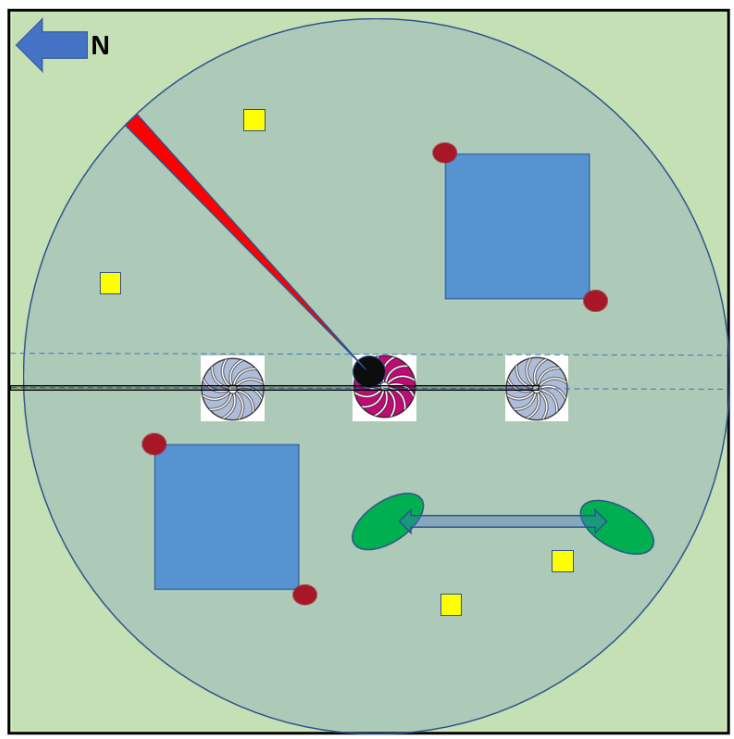


Irrigation Footprint (moving sensors @ MVC 2020)

MVC sensors were installed Oct 2020. Notice the new position of the placement (green oval). This was done 1) to avoid the center of the plot where T-posts are installed which obviously can conflict w/ sensors and 2) as an attempt to place the sensors in a more actively treated area, since the spray of water is more reliable in a circular band of the plot that contains the veg-quads. Here we expect MVC soil moisture data to be more representative of the amount of water received in the quads. The sensors are placed opposite the veg-quads (either NE or SW quadrants) and wherever bare ground is ample (arrow represents placement moving laterally, i.e. to avoid plants)

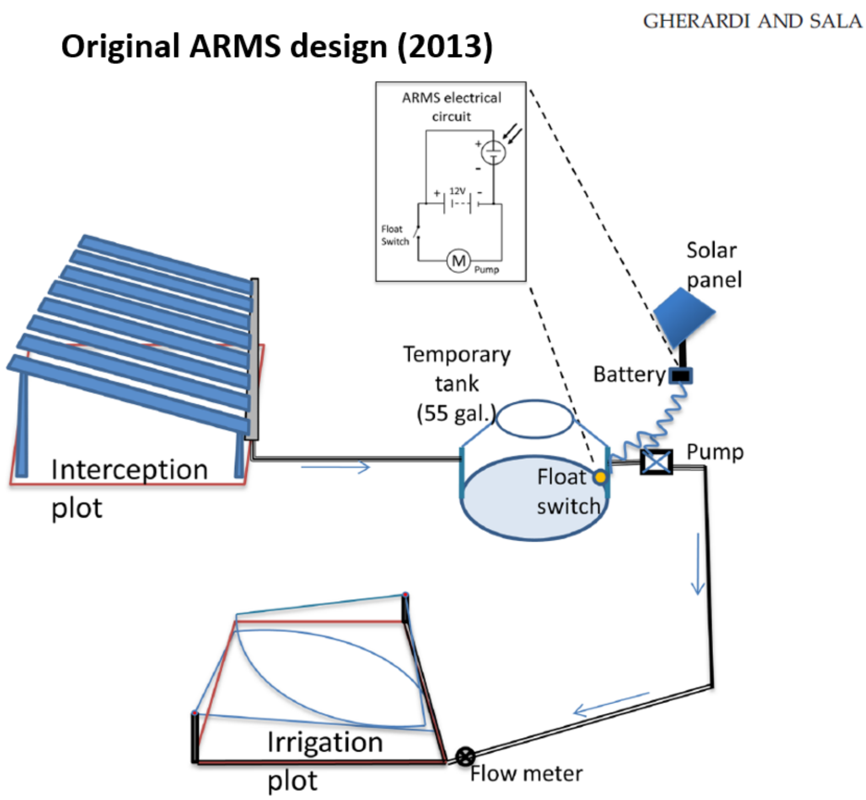


Field adjustments (7/7/20)

Some irrigation overshooting (foreground and righthand side) occurring while adjusting nozzles for optimal saturation. Some dry corners are inevitable in the current iteration of the irrigation design.
Still, the current design allows replication across shrub sites, <u>and insert another justification here?</u>

Electrical

The pumping and electrical specifications have gone through several phases as system needs have expanded. The following material details the current design. The electrical specs includes the **heat tape** which is employed specifically during winter months to freeze-proof the pump – more details about that in the Winterization section. MVE uses distinct components and has a unique power budget, but mimics the original ARMS schematic (pic below).



Below is a list of all components in the 12-volt electrical circuit and their power demand (rounded up to allow safe buffer of estimated power draw). The resulting power budget analysis follows to justify existing design under expected field conditions.

- Pump (Seaflo SFDP1-030-42-1; 3 GPM): **4 amps; 7.5 amp max**
- Float switch (Attwood 4202-7 Automatic Float Switch)
- Solar panel (Solarland SLP100-12U): **100 W**
- Battery (Moreco 24-DC1): **95 AH**
- Heat tape (OEM Heaters Freezestop Low Voltage): **4 W; or 0.33 amps**
- SunSaver (SS-10L-12V)

Borrowing power budgeting spreadsheet tools and expertise from the Litvak Lab (UNM; Mikael Schlumpf), the following analysis was posed, based off of actual field deployments of the above electrical components combined with hypothetical, over-estimated scenarios.

Assume a day when the heat tape is operating continuously at max capacity (0.33 A) for the entire day, while a 30 mm rain event occurs, and causes the pump to operate at max amperage (7.5 A) for 2 hours.

The power budget spread sheet is not designed to be used in this type of estimating, but the good news is it is fairly easy to figure out because you already know the power use constants.

The heat tape is consuming 5.25 watts (.44 amps X 24 hours = 10.5 amps/day), this is more by itself than the 5 watt solar panel is supplying when it is at its peak performance.

If you have a cloudy day where the solar panel is not charging the battery, then the 12 amp hour battery would be depleted in less than 24 hours by the heat tape alone.

The pump rating at 7.5 amps must be over rated. If the pump was drawing that much current, the 12 amp hour battery would be depleted in about 1.5 hours.

Some other notes:

Figure about 80% of the amp hour rating of the battery when you are doing your calculations to prevent damage to the battery
12 amp hour battery would work out to be 9.6 amp hours for the calculations.
These sealed lead acid type batteries will not hold a good charge if they have been depleted to less than 10.5 ish volts.
Battery must be replaced if this has happened.
It is best to not let them get much below 12 volts to keep them healthy.

Pump - 7.5 amps X 3 hours = 22.5 amps consumed
Heat tape - 5.25 watt = .44 amps X 24 hours = 10.5 amps consumed in 24 hours.
22.5 + 10.5 = 33 amps assuming pump is on 3 hours each 24 hours, heat tape on 24 hours.
36 amp hour battery or larger would be best.

33 amps = 396 watts at 12 volts.
So, you would need to supply 400 watts back into the battery over a 24 hour period.
If you have good sun for 4 hours a day, that would require a 100 watt solar panel.
100 watt or larger solar panel would be best.

Pump box setup

Weather-proof and UV-stabilized box (Bud Industries, NBB-15245) w/ metallic backplate (NBX-10986) to help weigh down box, drain any leaks, and elevate components above drainage holes at the head of box (unpictured)

7/8" holes drilled on the sidewalls to allow fittings out

Solar charge controller modulates all electrical activity involving irrigation Model: SunSaver SS-10L-12V (Morningstar Corporation)

Hole drilled out the back of box for electrical connections to solar panel, battery, etc. (all 14 AWG solid coated wire)

Note for future pump box setups: In Oct 2020, two plots at MVB got a larger battery box so that solar controllers no longer sit within the pump box. This should be much better in the long run in terms of keeping moisture (from inevitable dripping of pump fittings) from damaging electrical components. MVC installs in 2021 should probably incorporate this idea!

Winterization (freeze-proofing)

As of 2020 all pump boxes @ MVB, MVG received insulation (square cuts of R-38 fiberglass). Heat tape was put in boxes but not yet installed or plugged in). Some pic and notes below. Pics and protocols can be improved but below is a rough timeline:

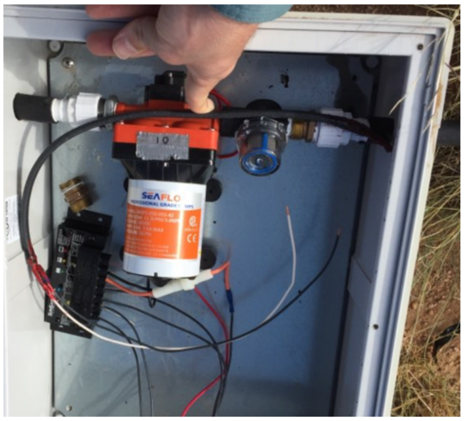
1) Sometime in October before freezing weather arrives, cut out squares of insulation and insert in pump box
2) Tie pipe insulation around vulnerable fittings (pvc risers sticking out from boxes) – don't worry about black poly-lines as they should not breal
3) Plug heat tape in
    a. Tapes should already be tied to pump diaphragm and fittings inside the box
    b. Plug them into the + and – 'load out' terminals of the charge controller; polarity should not matter

Earliest Freeze dates (data compiled by Kris Hall Oct 2020)
Met 49, for MVG, MVC (left) and Met 50 for MVB (right)

earliest_freeze_dates	earliest_freeze_dates
2013-10-05	[redacted]
2007-10-08	2006-10-19
2019-10-11	2013-10-19
2008-10-13	2019-10-21
1999-10-17	2007-10-22
2006-10-19	2008-10-23
2003-10-26	2003-10-26
2012-10-26	2009-10-28
2002-10-28	2002-10-30
2009-10-28	2004-10-30
2010-10-28	2011-11-03
2004-10-30	2014-11-05
2005-11-01	2015-11-06
2000-11-01	2018-11-09
2011-11-02	2010-11-10
2014-11-05	2005-11-15
2015-11-06	2017-11-18
2018-11-09	2016-11-18
2017-11-18	
2016-11-18	
2001-11-20	

Winterization 2020 (heat tape)

Left: Tape is tied across top. Pros: better contact with fittings and top portion of pump; can use just about ~1 ft. of tape. **Right**: tape wraps underneath bottom. Pros: closer to portion of pump that is furthest from insulation and “heat rises”
I’m leaning left since 12” → 15” of heat tape = 25% more power



Irrigation Maintenance

The irrigation system should receive regular attention througought the year, especially during rainy seasons and before and after rain events. Even small breaks can cause the entire treatment to fail, so it is important to keep an eye on certain details. The following are some things to look out for on a regular basis.

- Check irrigation infrastructure (shingles, gutters, polyehtelyene lines, sprinklers) for evidence of damage, leaks, etc.
- Barrels should be checked frequently during rainy seasons and after large storms to ensure that pumps have been operating.
- Other stuff

Troubleshooting un-pumped water in the barrel

(<u>float switch</u> issues and more!)

Arriving at a plot that has failed to pump can be a common problem, and there are many potential causes. Float switches can be finnicky and will sometimes fail to trip and turn on the pumps, even as water levels in the barrel are well above the float switch. Follow the below steps to solve this and other potential causes of unpumped water:

1. **Trip the float switch**: The particular brand of float switch we use (Attwood 4202-7) can often be raised up mechanically without being tripped electrically. It usually just requires a prod to get it going.
    1) Locate the body of the float switch by taking off vent cap;
        a. Remove barrel lid completely if it is hard to find
    2) Using a clean (i.e. NOT covered in mud) pipe or rod, press down on the float switch to its resting or ‘non-triggered’ state
    3) Let go, allowing switch to pop back up
    4) Upon popping back up, the float switch should make a charactersitic clicking noise and the pump should begin to operate
    5) Do step 4 several times if it does not work the first time; prodding the switch up and down continuously (use hands if you are not afraid of water)

2. **Reposition the float switch**: Wind storms and dust devils can violently shake the rain barrels as well as the contents inside (usually when barrel is dry and hence lighter). This can upend the float switch, trapping the unit on its side or in another position prohibiting it from working properly.
    1. Locate the float switch within the tank
    2. Re-secure the switch so it is sitting right-side up and bound to its anchor as it was before purturbation; pump should begin operating

3. **Test the power and electrical circuit**: Power to the pump can be cut in numerous ways. Perform a variety of tests to find a potential short in the system:
    1. Use the SunSaver charge controller manual to interpret LED indicator lights
    2. Test the voltage on the battery and all of the charge controller ports using a meter
        - Solar should be well above 12v (but <20v) in sunlight; battery should be ≥12v; If this is not the case, try to find issues in the wiring such as chewed cables.
        - Load output should be similar to the battery, if this is not the case follow these steps:
            - Check to make sure that the pump strainer is not clogged with debris, if so clean it up
            - Unscrew the power terminals from the charge controller, wait 10 seconds, and plug them back in
            - If applicable, install a new fuse (MVE Blue has a 10A in-line fuse from the + load terminal that can be damaged if the pump is clogged or draws too much power or overheats)

4. **Put in a new float switch**: If the float switch is prodded up and down several times and there is no "clicking" sound, and there are no apparent power issues try putting in a new switch
    1) Unscrew the float switch wires from the load terminals of the charge controller
    2) Remove the old float switch by cutting the wires at the existing splice, and undoing the ties from the submersed brick that anchors the float switch
    3) Install a new float switch
    4) Once new cables are spliced, re-insert the wires into the charge controller load output and the pump should begin operating

Cleaning irrigation debris

Attempts were made to put screens on the gutter ends, but this clogged up rain flow into the barrels. As such, debris build up in the barrell is regular and some of this gets sucked up by the pump (see below). The bottoms of the barrels thus should be cleaned once a year, preferably during treatment swaps. This was done for the first time at MVE Blue in October 2020 (see pic below) by removing the float switch components, pouring out the dirty water, and wiping down the inside of the barrel with a rag. Buckets of clean water were brought to the site to clean off the rag throughout the process.

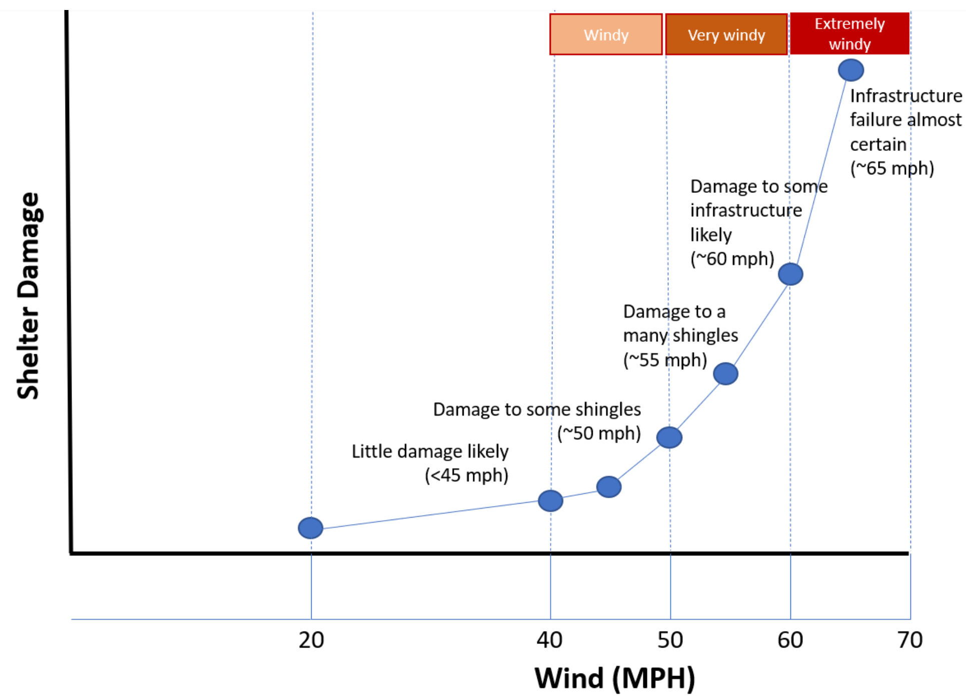
Insert photo here when this cleaning occurs

On the intake (vacuum) end of the pump there is a strainer that allows water to flow through, but prevents debris from getting into the pump diaphragm chambers. Debris includes dust, dirt, dead bugs and plants, and other random waste. With bad buildup (see pic below), the pump will clog. Clean the strainer as regular as possible to prevent clogging by de-gunking the strainer with a cloth or even bare hands; after getting thick gunk off, swish the strainer around in a cup or bucket of clean water to remove smaller, more tightly bound debris.

Kugfkgf

Wind Damage

From the perspective of keeping infrastructure and treatments operational, the biggest challenge by far has been wind. Two catastrophic storms have occurred that resulted in lost data, thousands of dollars in material replacement, and hundreds of hours of people-labor. First, there will be a brief description of the two major wind storms at MVE Blue, and some solutions that have been applied to combat repeat scenarios. Then there will be some generic descriptions of wind effects on the shelters, and what we have learned about the issue thus far. This section will be an additional resource to what was already discussed in the shelter maintenance section regarding wind abatement. To get things started, below is a hypothetical chart of wind effects on shelters based off of observations we have made from wind speed measurements and site damage.



Case studies

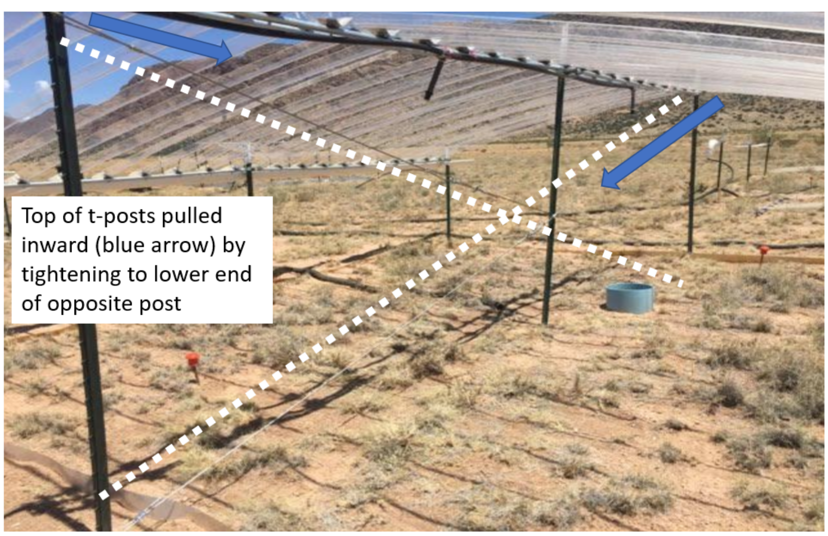
Storm #1 occurred in June 2019, shortly after the site had been completed and shortly before the monsoon rainy season which led (among other problems) to poor treatment applications until the Fall season. 65 mph wind led to major damage to individual shingles and to entire rainout panels and other infrastructure. The jist is that the rainout panels were caught by heavy winds, shaken free from the carriage bolts that held them up, and proceeded to fly off of the T-post structure, breaking plastic, hardware, and other materials in the process. **The main problem**: is that the rainout panels are made of conduit that is suspended in the air by 6" carriage at all four corners. If one or more corners of the panel slips off of the carriage bolt, havoc can ensue – at best contorting the panel and stress-cracking shingles and at worst being pummelled around by the wind breaking all of the shingles and the hardware of the structure (carriage bolts, brackets, etc.). Because it was apparent that the panels could separate from the carriage bolt/bracket/T-post connection points, and that this was most likely to happen at the higher end of the shelter it led to **solution #1** (pic below). Most plots needed re-installation, as the majority of shingles had cracked and brackets had to be replaced.

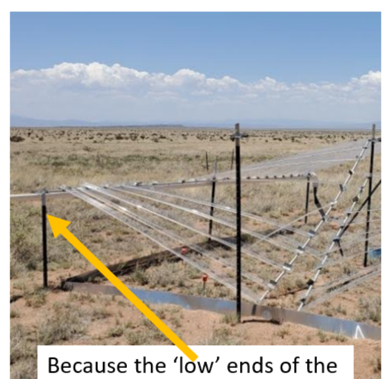
Storm #1 (June 2019)

The upper ends of the shelters, suspended 5' up the T-posts via carriage bolts, were more susceptible to wind. Failure to stay on the bolts led to whole panels (4 panels per shelter) flying off, damaging plastic shingles and bending hardware

Solution #1

3/16" metal rope (guy wires), 2 per plot in an 'x' formation across the center, tightened via turnbuckles to hold the tops of T-posts inward and prevent them from shaking, effectively disallowing conduit to slide off of the carriage bolts (conduit was now seated more firmly on the brackets themselves)





Because the 'low' ends of the shelters appeared unaffected, they were deemed less susceptible to wind, and guy wires were only put on 'high' ends to save costs

Storm #2 occurred on Feb 11, 2020 during a winter storm that brought cold weather (some precip?) and 66 mph Southbound winds (coming from the north). The storm damaged about 300 shingles, and damaged infrastructure such as bent brackets and conduit. **The main problem**: was similarly a failure of the carriage bolts, but this time occurred on the low sides (gutter ends) of the shelters; seemingly a transfer of the problem from the highly wobbly and wind-susceptible upper ends, to the less-so but still vulnerable low ends. **Solution #2** (pic below) was to again employ guy wires to pull T-posts inward, thus preventing the conduit from wiggling free of their carriage bolt suspenders. In an effort to save material, a single guy wire was stretched from top to top across the lower ends (2 per shelter) in a 'rubber band' configuration. This rubber band method still allows the side-to-side movement of shelters, but effectively prevents the major problem of conduit separating from the carriage bolt/bracket/t-post junction.

One final note on storm 2 was that it was truly quite strong, as evidenced by the damage at EDGE Blue, the experiment just to the north of MVE Blue. Not only did much structural damage occur – from plastic to bent poles to ripped antennae – but five 1,000 gallon rain barrels rolled away from the site, disappearing for days. While these barrells were empty, they still broke away from the anchors that had bound them for years and made it many miles into the interior of the Sevilleta!

Storm #2 (Feb 2020) + solution #2

The same carriage bolt problem repeated itself, this time on the lower ends, which did not receive guy wires after storm 1

Guy wires were tightened across the lower ends from top to top, as if 'rubber bands' were pulling them inward, to prevent conduit flying off carriage bolts and brackets

Background wind (stabilizer lines): Background wind can be described as the normal wind occurring throughout the year, most notably in the Spring as frequent moderate to high winds. After the various structural improvements mentioned above, this common high 'background wind' may not damage more rigid infrastructure on the shelters but can lead to damage of many individual acryllic shingles, which remain the most vulnerable components. As wind speeds increase, shingles can be loosened over time and eventually shake to their breaking point, especially as winds approach ~50 mph. One such incident occurred on April 29, 2020 when high southbound winds (53 mph) blew continuously through MVE Blue throughout the morning. Structures remained fine as a whole (this could have been a testament to the above solutions), but many shingles were thrown around in the wind and reach their cracking point. 20 shingles were broken and replaced, and while some of them may have been weak already, this type of high wind is sure to contribute to the next batch of broken shingles. One **solution** to background wind being tested as of summer 2020 (pic below), was reccomended by contractors JB Henderson. It consists of a rigid (PVC) or semi-rigid (Polyethelyne) perpendicular **'stabilizer lines'** across the center of a rainout panel secured via wire tie to individual shingles. This a) adds rigidity to individual shingles by binding them together as a unit, preventing individuals from excessive wind capture. It also adds a 'connection point' to the shingles, effectively cutting in half their susceptibility to wind capture. In other words, instead of being an 8' shingle bound only at the conduit with ~ 7 additional feet of unsupported plastic to flail around, the 'support lines' cut them down to 4' shingles – much less opportunity for unsupported acryllic to flail around.

Some evidence confirms that stabilizer lines work thus far: after two days of wind that damaged 11 shingles (45 mph on 7/30/20 and 51 mph on 7/31/20), no shingles connected to stabilizer lines were damaged. Still, the viability is still being assessed: Lines do wiggle free in wind (see below), and so better tying or stoppers on the ends may be needed. One potential pitfall is the stress this may put on the structure as a whole. By binding all of the shingles together in the middle to prevent them from shaking on as individuals, this might cause entire panels to act as one large unit. If that happens, much more stress might be put on the rest of the infrastructure (T-posts, hardware, etc.), and lead to structural failure. We do not have an easy way of knowing these thresholds and so the viaility of this solution is still being assessed. As of July 2020, the support lines are on 11 plots at MVE Blue (plots: 2,4,5,6,7,8,11,15,17,18,28).

Solution to 'background wind' – as of summer 2020

To combat shaking and breaking of shingles in the wind, a perpendicular stabilizer line is wire tied to individual shingles across the panel.

This provides extra support and rigidity, so there is not 7+ feet of unsupported acrylic w/o a point of contact that is available to fly around in the wind

Semi-rigid black poly-line was chosen over rigid PVC for its cheapness; future assessments will be made to put in more or find different solutions

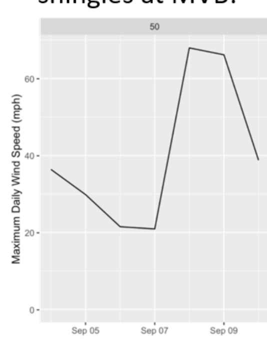
Stabilizer lines. Good news: after a high wind event, no shingles attached to stabilizer lines were broken (left) while others were (right). **Bad news**: winds can wiggle the line free; better ties/stoppers will be needed

Storm #3 led to more damage but promising results for the stabilizer lines, and occurred on September 8-9, 2020. The storm was another cold weather, SW-bound (coming from the north) storm which brought two days where maximum speeds reached 66 and 67 mph at MVB. Damage included many downed gutters, and 185 broken shingles, mostly occurring on the N-side of the plots (where the wind hit the shelters head on). Damage at MVG was just 3 shingles, though wind speed was undetermined due to sensor temporarily out of commission.

While the damage from the storm was nothing new, counting numbers of broken shingles plot by plot showed promising results regarding the stabilizer lines installed several months prior. **Good news #1**: was that with stabilizer lines the shingle break rate for a shelter was 10% compared to 17% without stabilizer lines and 23% without stabilizer lines on capture plots only (ommiting mock plots). **Good news #2**: is that the above benefits to stabilizer lines are likely very conservative given the fact that most of the stabilizer lines wiggled free of their initial installation becoming ineffective for the portions of the panels where they were no longer connected to shingles. Indeed, one plot during the storm (P15) had fully installed stabilizer lines across all four panels and the shingle break rate was zero! In other words, if the stab. lines are more effectively bound to the panels, the break rate would probably be a lot lower. Thus, one solution in response to storm 3 is that, after shingle installation/repairs, new stabilizer lines were installed but this time with holes drilled on one end of the polyethylene tubing so that it could be looped around a shingle (pic below) in order to prevent lateral wiggling and movement. As always, time will tell on these solutions. Finally, thicker wire and or double wrapping of the gutters will be necessary.

Storm #3 + solution (Sept 2020)

Heavy wind damaged many shingles at MVB:



Promising: where stabilizer lines were securely attached, shingle breakage was extremely low. Unfortunately, previous observations about insecure lines proved to be a problem (see above pics)

Solution: cut two holes on one end of line to loop around a shingle to prevent lateral wiggling