Mitigating Pesticides and Sediment in Irrigation Run-Off with Polyacrylamide (PAM)

University of California
Agriculture and Natural Resources

Michael Cahn
Irrigation and Water Resources Advisor

Zhixuan Qin and David Chambers
Staff Research Associates

Acknowledgements

California Leafy Green Research Board
Sharon Benzen, Gerry Ochoa, USDA-ARS
Agustin Rodriguez UC Davis
Val King
SNF Holding Company

Overhead sprinklers frequently cause run-off

Pyrethroid pesticides bind strongly to suspended sediments in run-off

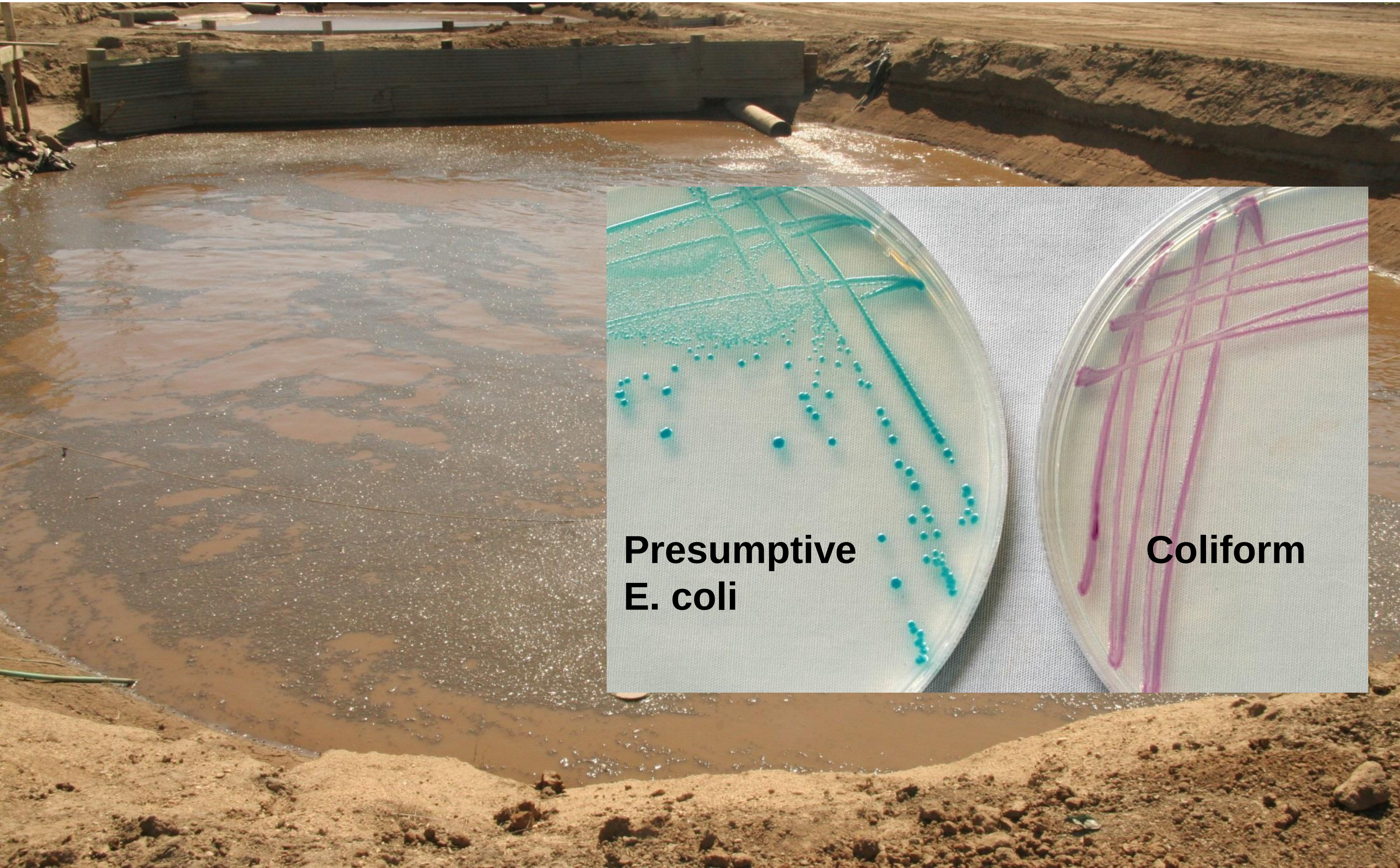
	Koc*
Neonicotinoid:	
Clothianidin	63
Imidacloprid	200
Organophosphate:	
Diazinon	1000
Chlorpyrifos	6070
Pyrethroid:	
Permethrin	100,000
Bifenthrin	240,000
DDT:	2,000,000

* Ratio of concentration in soil:water

Overhead sprinklers are needed for irrigating high density leafy vegetables

Retention ponds can capture tail-water for reuse….

But food safety concerns limit growers from using this practice



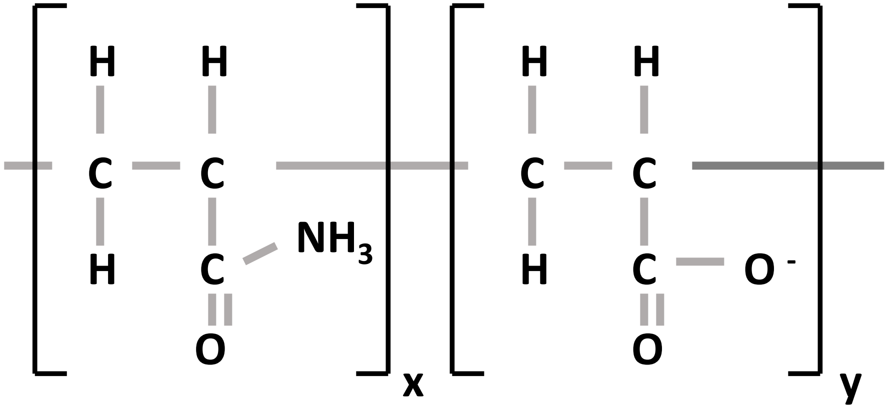
Retention basins can be engineered to infiltrate run-off and settle sediments

Polyacrylamide (PAM) can reduce suspended sediment in run-off

Polyacrylamide (PAM) used in Soil Conservation Technology

Linear PAM

- Water soluble
- Molecular weight: 12-15 Mg mol^{-1};
- Charge: moderately anionic (15-20%)



Polyacrylamide (PAM) use in Soil Conservation

- **Estimated that in the late 1990's about 1 million acres of irrigated lands were being treated with PAM in United States.**
- **PAM acts by stabilizing soil structure, increasing infiltration, and flocculating sediments**
- **PAM used primarily in furrow irrigation**

Using PAM for furrow irrigation

- Can be applied to the soil before irrigating (2 to 3 lbs/acre)
- PAM needs to be in the irrigation water as it advances down the furrows
- Granular PAM can be applied to beginning of the furrow (patch method)
- PAM can be metered into irrigation water

Equipment for metering dry PAM into canal water

Can PAM be used in Sprinklers?

Physical Characteristics of PAM

- **Dry PAM (granular and tablet) is difficult to mix with water**
- **Dry PAM becomes a gooey, slippery material (mess) after it becomes wet**
- **Concern that adding PAM to sprinkler water may plug nozzles**

Liquid Emulsified PAM

- **Liquid PAM is emulsified with mineral oil**
- **Liquid PAM is simpler to handle than dry products and mixes quickly and uniformly in irrigation water**
- **PAM content ranges from 25% to 50% by weight**
- **Liquid PAM is viscous and can clog up pumps**

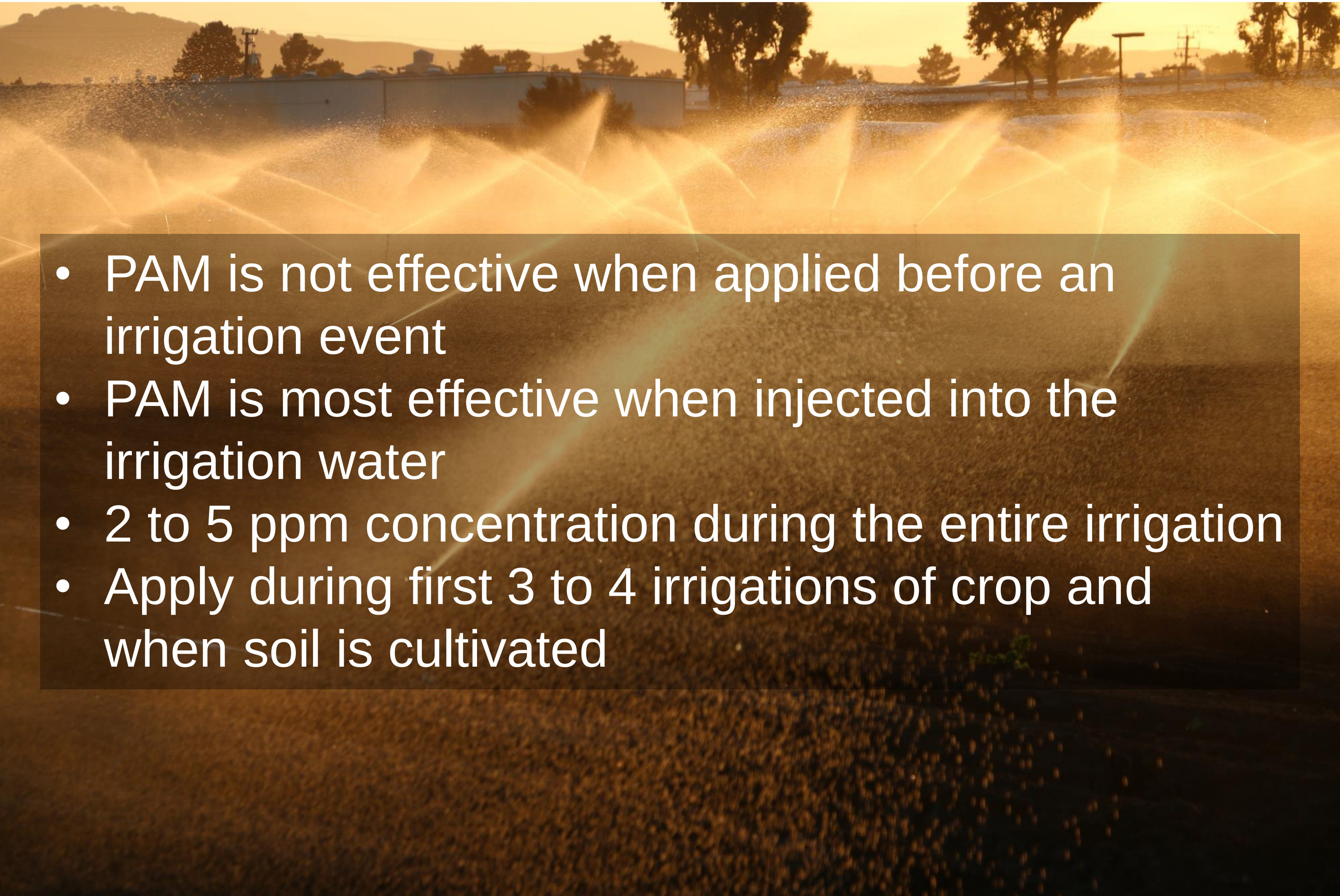
PAM can be premixed in a tank (0.1 to 0.15% concentration) and injected into the main line using a gas powered pump

- **Need a large tank**
- **Need time for mixing**
- **Will not mix uniformly at high concentrations**

Auger metering pump can inject emulsified liquid PAM into pressurized irrigation systems

- No need to premix or use large mixing tanks
- Easy to operate and calibrate pump
- Pump does not clog and injection rate is not affected by mainline pressure
- Pump costs > $3000

Efficacy of PAM with Sprinklers



- PAM is not effective when applied before an irrigation event
- PAM is most effective when injected into the irrigation water
- 2 to 5 ppm concentration during the entire irrigation
- Apply during first 3 to 4 irrigations of crop and when soil is cultivated

Field Demonstrations in 2004

Field trials demonstrated 90% to 95% reduction in suspended sediments in sprinkler run-off

PAM reduced suspended sediments in run-off by 90 to 95%

Treatment	Total N	NO3-N	P (Total)	P (Soluble)	Total Suspended Solids	Turbidity
	------------------------ ppm				--------------------------	NTU
	-----------------Watsonville (clay loam) ----------------					
PAM (5 ppm)	0.8	58.6	1.2	1.2	47	33
Control	2.9	48.4	2.0	0.9	652	1289
	-------------------Salinas (sandy loam) -----------------					
PAM (5ppm)	1.4	1.7	0.7	0.7	72	63
Control	4.2	1.7	1.9	0.7	985	2291
	----------------Salinas (sandy loam) --------------------					
PAM (10 ppm)	2.7	1.3	0.4	0.2	179	108
Control	5.5	1.8	2.4	0.5	1332	3536
	------------------Chualar (loamy sand) -------------------					
Pam (5 ppm)	2.3	2.7	1.9	0.8	646	218
Control	11.8	6.5	8.2	2.1	3870	503
	----------------- Santa Maria ----------------------------					
Pam (5 ppm)	1.6	14.78	0.6	0.51	60	13
Control	7.0	17.02	10.1	0.95	5930	4417
	---------------------- Gilroy (silt loam) ---------------------					
Pam (4 ppm)	1.2	8.1	1.0	0.9	74	42
Control	4.0	6.5	3.5	1.2	2057	2408

PAM was more effective than other practices in reducing sediment and nutrients in run-off

Treatment Description	Total N	NO3-N	Total P	Soluble P	Total Suspended Solids	Turbidity
	--------------------------------		ppm		------------------------	NTU
Untreated control	7.45	2.17	3.33	1.09	1540	4130
Sediment trap	6.15	2.42	3.03	1.18	1165	3447
Vegetated ditch	3.55	2.32	1.80	1.00	740	1689
PAM (7.5 ppm)	1.40	1.94	0.88	0.81	50	54
$LSD_{0.05}$	2.37	0.32	0.95	0.18	584	1418

Emulsified oil based formulations of PAM were shown to have aquatic toxicity

Toxicity of Anionic Polyacrylamide Formulations when Used for Erosion Control in Agriculture

Donald P. Weston* University of California
Rodrick D. Lentz USDA
Michael D. Cahn University of California
R. Scott Ogle Pacific EcoRisk
Amanda K. Rothert and Michael J. Lydy Fisheries and Illinois Aquaculture Center and Southern Illinois University

Addition of anionic polyacrylamide (PAM) to agricultural irrigation water can dramatically reduce erosion of soils. However, the toxicity of PAM to aquatic life, while often claimed to be low, has not been thoroughly evaluated. Five PAM formulations, including two oil-based products, one water-based product, one granular product and one tablet product, were evaluated for acute and/or chronic toxicity to five species commonly used for freshwater toxicity testing [*Hyalella azteca* (Saussure), *Chironomus dilutus* (Shobanov et al.), *Ceriodaphnia dubia* (Richard), *Pimephales promelas* (Rafinesque), and *Selenastrum capricornutum* (Printz)]. When applied as an oil-based product, acute toxicity was seen to four of the five species at concentrations less than the 10 mg/L that is often used for erosion control. Toxicity was diminished, but still remained, after passage of the irrigation water across an agricultural field, indicating a potential impact to nearby surface waters. Results from the non-oil-based products indicated minimal toxicity associated with PAM even at concentrations 10 times those used in agriculture when applied in the granular form, as a tablet, or in a water-based liquid. These data suggest that other agents in the oil-based products, such as surfactants or emulsifiers, rather

Anionic polyacrylamide polymers, when added to irrigation water, have been shown to be extremely effective at reducing soil erosion (see Sojka et al. [2007] for review). The PAM used in agriculture consists of high molecular weight polymers (12–15 megagrams per mole) containing >150,000 acrylamide monomer units. These long, linear, negatively-charged molecules stabilize the soil surface, inhibit resuspension of sediment, and flocculate those few particles that are resuspended. The PAM can be applied as a liquid metered into the irrigation water (typically at 1–10 mg/L), or as a solid tablet or granule placed in the bottom of the furrow. The solid forms dissolve in the water as the furrow stream passes over them. In most cases, the use of PAM results in a 75 to 95% reduction in the loss of soil via the runoff (Aase et al., 1998; Lentz and Sojka, 1994, 2000; Goodson et al., 2006).

Cationic and neutral PAM polymers, as well as the acrylamide monomer (a micro-contaminant found in PAM products), are all recognized to have significant toxicity issues associated with them, but the anionic forms used in agriculture are typically portrayed

Potential benefits of a dry PAM applicator for pressurized irrigation systems

- ✓ Granular and tablet formulations of PAM are less costly than liquid formulations

- ✓ Avoid potential toxicity from mineral oil (used in emulsified PAM liquid products)

- ✓ Eliminates the need for expensive metering pumps

Developing a dry PAM applicator for pressurized irrigation systems

Objectives:

1. Develop and test prototype PAM tablet and dry product applicators for pressurized water systems.

2. Evaluate the effectiveness of the dry PAM applicator to reduce sediment concentration in run-off from vegetable fields.

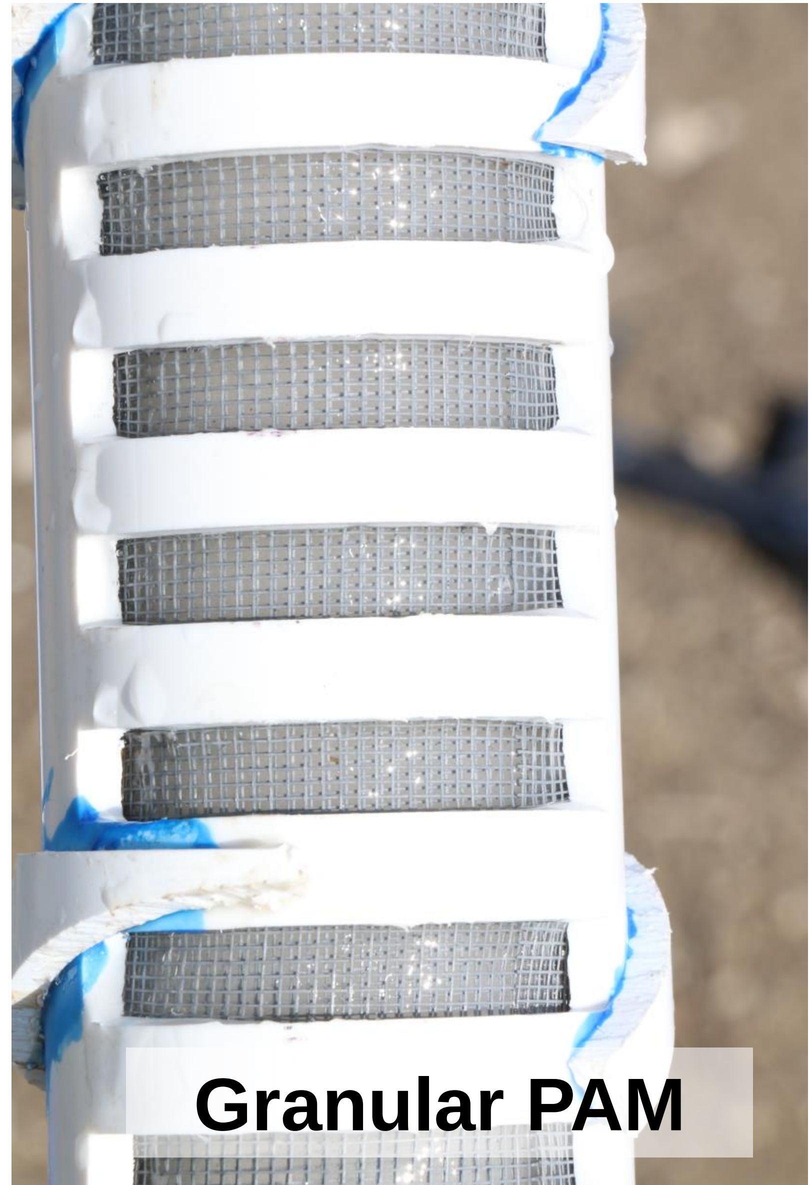
Prototype PAM applicator

Chamber

PAM Cartridge

Cartridge can hold tablet or granular PAM

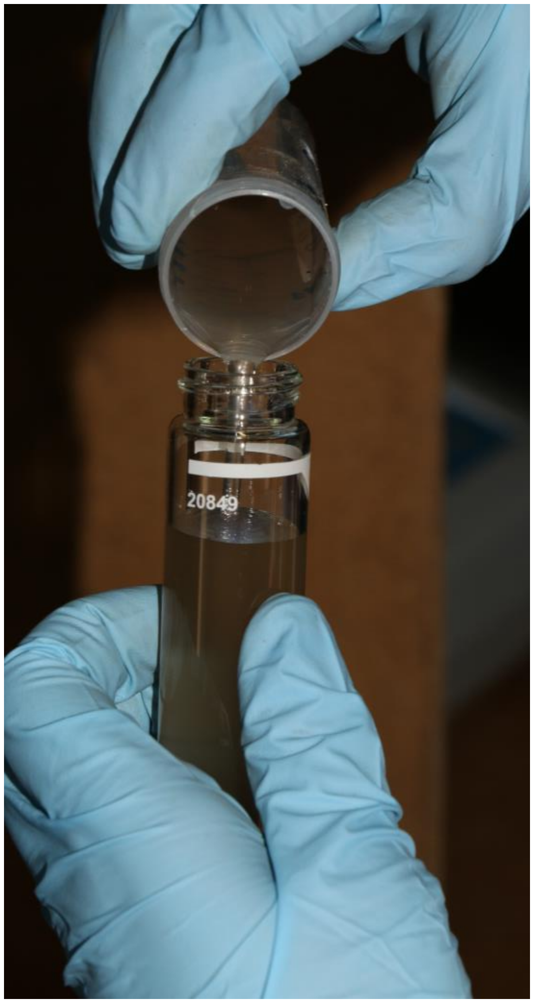
Tablet PAM



Granular PAM

Test stand to evaluate flow rate, dilution rate, and exposure time effects on dissolution of PAM

Turbidity assay to evaluate effectiveness of PAM applicator



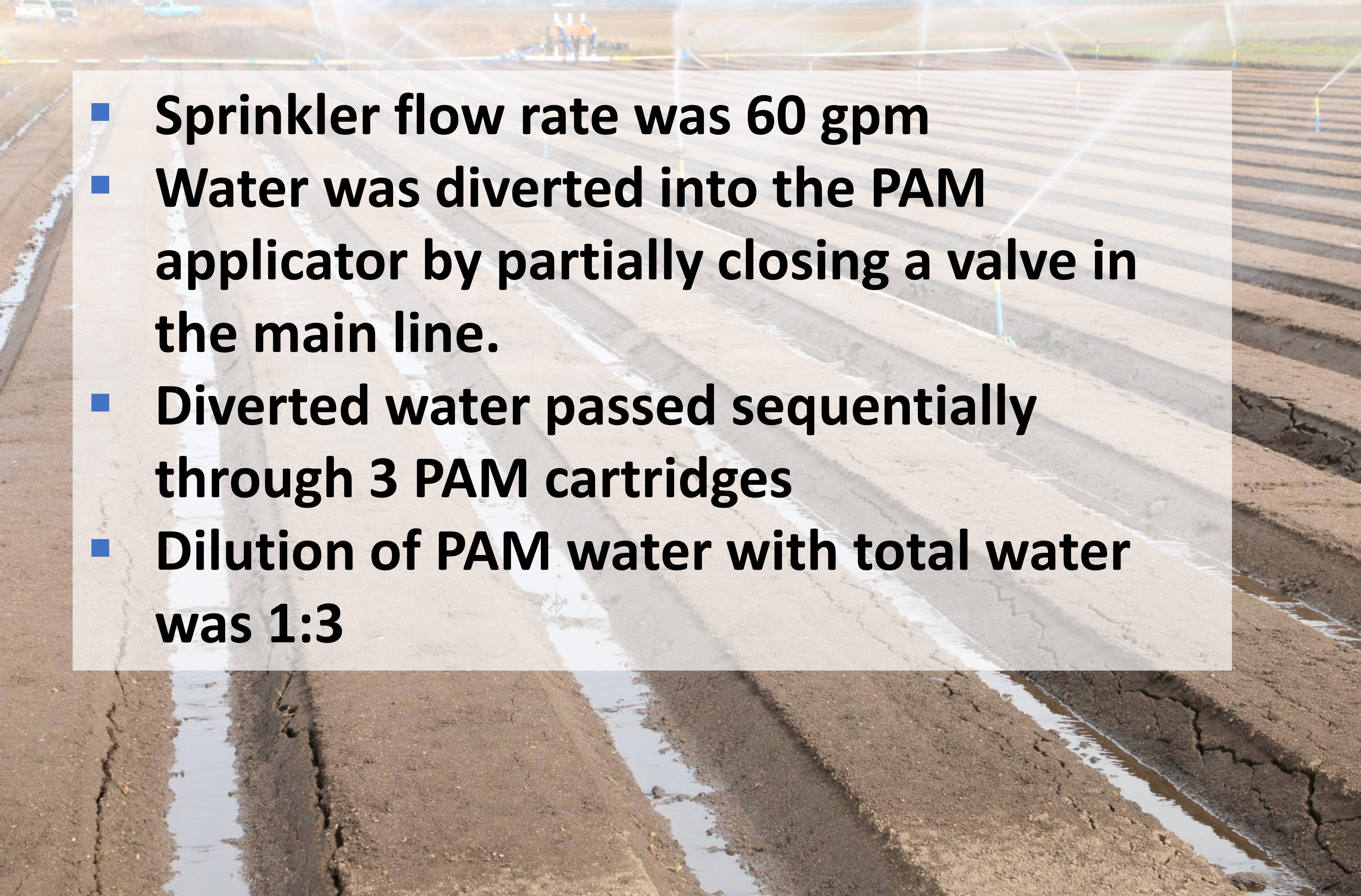
Evaluation of prototype PAM tablet applicator

	Dillution of PAM treated water		
cycles	no dillution	1:5	1:10
	% reduction in turbidity		
1	79	48	38
4	82	78	65
5	88	77	57
6	90	78	65

PAM applicator: Field testing prototype

PAM applicator field trial

PAM applicator field trial



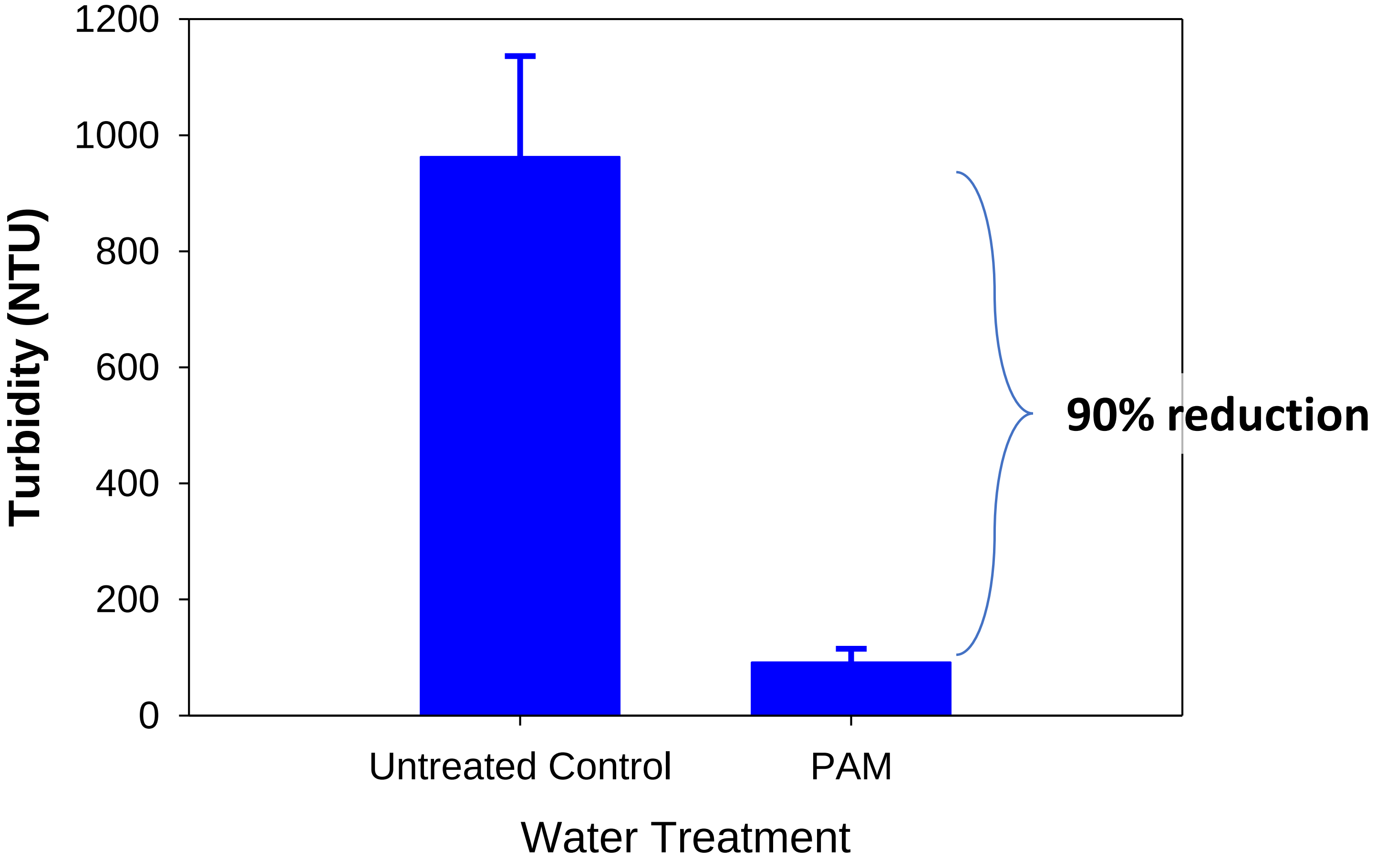
- Sprinkler flow rate was 60 gpm
- Water was diverted into the PAM applicator by partially closing a valve in the main line.
- Diverted water passed sequentially through 3 PAM cartridges
- Dilution of PAM water with total water was 1:3

Grab samples of run-off collected every 30 minutes

Run-off from PAM treatment was clear

Grab samples of run-off from field trial

Dry PAM applicator field trial: turbidity of sprinkler run-off



Lessons learned

- **Dry PAM applicator shows potential for reducing suspended sediments (and pesticides) in run-off**
- **Applicator likely results in less than a 1 to 2 ppm PAM concentration in irrigation water.**
- **PAM cartridges may only need to be refilled once or twice per season**
- **Requires minimal labor to operate and PAM may cost less than $5 per acre**
- **Potentially could locate PAM applicator at the pump and filter station**

Lessons learned

- Minimal pressure loss through the applicator
- Need to add low pressure release valves to the bottom of chambers and replace lay flat with stronger hose
- Stainless steel prototype planned for upcoming season
- Plan to evaluate effectiveness of PAM applicator to reduce pyrethroid concentration in run-off

Questions?