APPLYING POLYACRYLAMIDE (PAM) TO REDUCE EROSION AND INCREASE INFILTRATION UNDER FURROW IRRIGATION

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Polyacrylamide (PAM) has received widespread attention in the last 3-4 years as a potential new tool for virtually halting irrigation-induced erosion in furrow irrigated agriculture when added in small amounts to the advance phase of water application. When used properly, 3-7 lbs of PAM per acre per year can reduce erosion from typical furrow irrigated fields in Idaho an average of 94%. Because PAM in irrigation water retards surface sealing, it also generally increases net infiltration and lateral movement of infiltrated water. Season-long infiltration totals for PAM-treated fields in Idaho have averaged 15% higher than non-treated fields.

Research by the USDA Agricultural Research Service in Kimberly, Idaho has documented the effectiveness of PAM and provided general guidelines for safe use (5, 6, 7, 13, 14, 15, 16, 17, 18, 19). The October 1994 issue of *Soil Science* deals comprehensively with PAM-use efficacy and environmental safety (1, 2, 3, 4, 5, 7, 8, 10, 12, 15). Another recent review (11) covered the topic independent of the symposium reported in *Soil Science*. Basic familiarity with PAM-use in irrigation water, can be obtained from two publications (7 & 14) available from the authors. Recent work (Stieber) with farmers using PAM has shown the need for certain cautions regarding field scale applications of PAM. These are discussed later in this paper.

Commercial formulations of PAM are now available as soil amendments under approved labels in Idaho and several other Western states. An interim conservation standard was approved in January 1995 for PAM-use in furrow irrigation for the Western US by the NRCS (formerly SCS). It is expected that this will pave the way for cost sharing in some areas. Local NRCS and Consolidated Farm Service Agency (formerly ASCS) offices should be contacted for specific information.

GENERAL CONSIDERATIONS

Overall Before considering PAM-use a farmer should read the PAM label, the interim west-wide conservation standard and supporting literature (e.g. 7 & 14) mentioned above. PAM requirements for sprinkler application have not been thoroughly researched to date. It is generally assumed, however, that application rates for results similar to those seen with furrow irrigation may require several times the per acre application rate. PAM will perform better in high quality irrigation water than in waters impaired by high sediment content and/or high sodium adsorption ratio (SAR). PAM works best on silt to clay textured soils, and may have little effect on sandy soils. Proper mixing and uniform application of PAM are essential to proper performance.

Although thorough cost benefit analysis for PAM use has not been performed, the practice is regarded as economical and possibly profitable. The cost of PAM to farmers at this writing is expected to be $4-6 per pound (@ 3-7 lbs/acre/year anticipated application requirements for complete erosion control). Yield increases may result from water infiltration benefits and through enhanced retention of plant nutrients. A thorough economic analysis must include the reduced need for furrow reshaping and the decreased need for settling-pond or return-flow ditch cleaning.

Water Quality - Chemistry Salinity per se (i.e. electrical conductivity, or EC) is seldom a problem if the alkalinity (SAR) remains low, within the range of EC acceptable for irrigation water. In fact, a slight electrolyte content (small measurable EC) of divalent cations (e.g. Calcium or Magnesium ions) will improve PAM efficacy compared to distilled water. The PAMs currently labeled for use in furrow irrigation are moderately anionic. Divalent cations have small hydrated radii compared to the hydrated sodium ion. Thus divalent cations "bridge" the anionic PAM and soil adsorption sites whereas sodium's lower charge and greater volume impairs bridging.

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Thus high SAR or very low EC could require addition of more PAM for desired effectiveness, or addition of a divalent electrolyte to irrigation water to aid PAM efficacy (e.g. addition of gypsum—$CaSO_4$).

Water Quality - Suspended Sediment PAM is a potent industrial flocculent—a powerful settling agent for suspended solids. If water supplied at the head ditch contains appreciable amounts of suspended sediment, the addition of PAM to the water will cause the suspended sediments to settle rapidly to the bottom of the ditch. If sediment loads are particularly high (>5 g/l), the settled sediment can fill-in large reaches of the head ditch in only a few hours. Even for moderately turbid water (1-5 g/l) addition of PAM to the water may increase the intervals of required ditch maintenance.

Presence of suspended solids need not preclude the use of PAM, but it will require certain precautions. If possible, rather than adding PAM directly to the ditch, PAM can be added in a small holding pond along side of the ditch at the upper reaches of the field. This can allow the treated flow to drop-out its sediment load in the confined area without risk of damming up the head ditch. When PAM is not being added, the flow need not run through the pond, and captured sediment can be spread on the field.

Where possible, PAM can be added near the point of water entry into gated pipe. Water flowing through pipe will usually retain a higher velocity than in an open ditch and flocculated sediments will be carried further in the flow. A large fraction of these flocculated sediments will be flushed through the open gates and deposited within a few feet of the furrow inlets across the upper end of the field. A farmer should inspect his gated pipe when using PAM to determine the possible need for flushing the pipe at the end of an irrigation. PAM should not be added to high sediment bearing water being delivered great distances via gated pipe at low head, as the risk of loading the pipe with sediments will be greatly increased. Research is underway using modified drip lines to deliver PAM stock solutions to individual furrows, avoiding the large scale sedimentation of bulk flows in head ditches.

Soil Properties Soil salinity, structure, texture, organic matter content and mineralogy are all factors that may effect PAM effectiveness. These factors have not been thoroughly researched. It is generally thought that high exchangeable sodium percentage (ESP), high amounts of shrinking-swelling clays (smectites, e.g. montmorillonite or "bentonite"), or high amounts of organic matter in soils increase the amount of PAM needed in irrigation water to achieve erosion control. Structure and texture effects are somewhat better documented.

Structure Polyacrylamide acts to stabilize soil structure that is present at the time of treatment. For optimal effect PAM should be applied to well structured soils, ie. after tillage or cultivation operations done at appropriate soil water contents. Treatment of freshly cultivated furrows is important because the application will help preserve the high infiltration and surface roughness characteristics that reduce furrow runoff and soil losses.

Texture PAM is thought to control erosion and increase infiltration best on medium textured soils (sandy loams, silt loams, loams, silty clay loams). Sandy soils with little or no silt or clay (loamy sands, sands) may show considerably less PAM efficacy and PAM will have little or no impact on infiltration. Clayey soils will see a greater relative impact of PAM on infiltration and may see a smaller relative impact on erosion.

Slope Steeper slopes, breaking slopes, and longer slope runs, have the greatest potential to see benefit from PAM-use. Extensive research has shown that 10 ppm of PAM in the advance phase water will control erosion on slopes up to 3.5%. Greater slopes may need higher rates.

Subsoil layers If shallow subsoil layers have poor infiltration properties, PAM will still help prevent erosion, but may have little net effect on infiltration once the soil above the restrictive layer is wet. PAM cannot increase infiltration into an already restrictive layer. The PAM infiltration benefits are the result of structure stabilization in the surface few millimeters of soil.

Application Timing To achieve the maximum benefit of both erosion control and increased infiltration, 10 ppm PAM should be in the advancing water of the first irrigation. If PAM is not applied until after water has begun to flow down the furrow, or if added at lower rates, some of the surface soil structure will be damaged by the non-treated water, reducing the PAM's effectiveness. PAM should be reapplied in the same manner after soil disturbance (e.g., traffic or cultivation). Best results are usually obtained on well formed, moderate depth wheel track furrows. PAM application cannot overcome the effects of excessive wheel track compaction.

Lower rates of PAM (1-5 ppm) in the advance water may prove beneficial during irrigation on undisturbed previously irrigated furrows. Each irrigation of undisturbed previously irrigated furrows without any PAM in the advance water will result in a 50% loss of treatment effect. In the absence of soil disturbance, the need for PAM treatment will decline as the season progresses. This is because furrow sediment transport generally declines later in the season as furrows become more stable, and/or vegetative material enters the furrow.

Infiltration PAM treatment maintains water infiltration rate into the soil. Net increases in infiltration with PAM-use reported in scientific studies are on a comparative basis. Compared to irrigating without PAM, the season-long infiltration totals obtained by irrigating with PAM are greater. Both non-treated water and PAM-treated water cause gradual sealing of the soil surface, causing the actual infiltration rate to decline with time. PAM treatment of water simply slows that decline in infiltration rate, compared to non-treated water. The difference is referred to as an "increase" in infiltration rate with use of PAM.

In Idaho, PAM has increased infiltration an average of 15% on medium to fine textured soils, and should be similarly effective on a range of soil textures, including sandy loams, loams, silt loams, and silty clay loams. The PAM treatment will have little or no effect on more coarse-texture soils (loamy sands and sands). When dissolved in water, PAM thickens the solution and makes it more viscous. At higher PAM concentrations, flow of treated water through soils can be greatly inhibited by the attendant increased viscosity. Label recommended rates will provide soil surface stabilization without impeding water entry. PAM treatment at the 10 ppm rate in advance water has proven effective on slopes up to 3.5%.

For furrows of approximately 4 inches in depth, PAM has increased lateral wetting an average of 25%. This is because prevention of furrow downcutting and sealing of the furrow wetted perimeter provides a stronger gradient for lateral movement of water. This allows for a shorter irrigation set time early in the season, when water movement to the seed zone is all that is required. Similar increases in lateral wetting have not been seen in deeper furrows (e.g. with potato hills). In these instances the shape and depth of furrow and bed prevent measurable differences in lateral movement of water.

Erosion In Idaho, using recommended application strategies, field sediment losses have been reduced an average of 94% (range 80-99%). Because erosion is greatly reduced, furrow configuration is much more stable, reducing the need to reshape furrows as often through the season. Pam enhances other management practices designed to reduce erosion. For example settling ponds will require emptying far less frequently since most soil will remain on the field. PAM benefits will be enhanced if stream size cut-back is practiced (i.e. treat the advance with 10 ppm at a high rate of flow, then, when runoff begins, cease applying PAM and cut the water stream back to a lower flow rate). PAM-use is an effective means of helping farmers meeting water quality goals, by decreasing return flow sediment, lowering biological or chemical oxygen demand (BOD or COD), and preventing loss of phosphate into streams, rivers, reservoirs and riparian areas. Data from California (9) also show reduced loss of soil-adsorbed pesticides. These effects will ultimately help improve Snake River water quality.

Irrigation Water Management Since PAM-use increases infiltration, water management may need to be adjusted to avoid excessive water application. In fields with steeply sloping furrows (> 2%), infiltration tends to be lower and water normally advances rapidly down the field. Improved infiltration and longer furrow advance times resulting from PAM treatment are not likely to be a problem here. Although, on very steep fields, PAM may increase net infiltration enough to warrant reducing irrigation set times. In fields with gently sloping furrows (0-0.5%), infiltration can be relatively high and advance times excessively long -- leading to nonuniform, down-furrow water application. PAM technology can overcome this nonuniformity problem because PAM allows irrigators to increase inflows without increasing furrow erosion losses. Enlarging initial stream size greatly reduces advance time and equalizes infiltration-opportunity-times for the top and bottom of the field. On the other hand, if PAM is applied to flat fields *without* changing water management, it will further reduce water application uniformity and may cause excessive water application and leaching at the field head. Also, PAM will usually accentuate the difference between wheel track and non-wheel track furrow advance times and infiltration rates.

Fields with variable slopes generally have improved infiltration uniformity in the entire field - sometimes providing economic return from previously marginal field areas where steep slopes prevented adequate infiltration and/or were deeply eroded by season's end.

PAM APPLICATIONS

Commercial PAM Products Most states (Idaho is one) require that agricultural chemicals (including soil amendments such as PAM) meet safety and state labelling requirements. The PAMs currently labelled are water-soluble, anionic (15-20%), high (10-15 million) molecular weight compounds meeting EPA and FDA monomer limits below 0.05%. Consult the label for current approved use recommendations.

When should PAM be applied? As a minimum PAM should be used on the first irrigation and when soil is disturbed by traffic and/or cultivation. Additional applications at or below label amounts may be considered to provide complete erosion control for the entire season. If PAM is applied in the first irrigation and subsequent irrigations have no PAM in the water, then erosion control and infiltration effects can be expected to decline approximately 50% with each non-treated irrigation. Thus, by the third irrigation little effect remains. For those crops in which erosion naturally subsides during mid season (e.g., potatoes when vines elongate) PAM need not be applied after the natural erosion reducing properties ensue.

Applying PAM to Irrigation Water Regardless of what form of PAM is supplied to the farmers (dry material, concentrated material, or pre-mixed stock solution) it is important to provide aggressive mixing (agitation) at the point of application of PAM to the water sources. The agitation requirement increases as the concentration of stock solution increases and is greatest for use of direct dry PAM application. Agitation should be provided by use of a stream drop and multiple flow obstructions near the point of injection. With vigorous turbulent flow 25-50 ft of ditch canal should be allowed for stock solution mixing before the first siphon tube withdrawal or gate. Dry PAM may need longer ditch runs for adequate mixing. If using gated pipe, the first length of gated pipe after the point of PAM injection should have one or two baffles to enhance mixing. PAM should not be added above weed screens or filters of any kind. Heating of water or stock solution greatly enhances PAM dissolution and mixing.

Choosing Which Form of Pam to Apply - Liquid or Dry

Advantages of Liquid Application

*easy to calculate and meter exact rates
*easy to keep track of amounts applied, since volume applied can easily be recorded
*requires minimal "in the ditch" mixing to work well
*slower to clog weed screens, filters or narrow siphons
*low risk of exposure if operator doesn't handle dry concentrate
*applications can be accomplished without specialized mixing or metering equipment

Disadvantages of Liquid Application

*may be more expensive than granular method due to increased handling cost
*requires bulkier equipment that isn't manually portable
*large stock solution volumes needed for large fields, or where advance rate is slow
*mixing field solution from concentrate takes considerable time and requires 'dedicated' equipment

Advantages of Dry Application

*portable equipment that can be moved manually
*a season's supply of dry PAM can be purchased and stored
*may be a less expensive form of PAM
*less need to rely on suppliers to refill tanks on farm for irrigators sets

Disadvantages of Dry Application

*application equipment tends to plug
*requires more vigorous mixing than liquid for dissolution and uniform application
*will rapidly plug weed screens and filters
*there is some danger of choking from inhalation of PAM dust while filling machine
*need to purchase or build application equipment
*greater PAM losses from the field since there is less control of dissolution
*poorer uniformity of distribution than with liquid application

Preparing Liquid PAM Solutions Proper mixing equipment is required to prepare liquid PAM solutions from dry granules. The mixer should be capable of producing a distinct vortex in the water volume contained in a full mixing tank. It is imperative that dry PAM granules be added slowly to the vigorously agitated water volume, ensuring that granules are dispersed individually in the solvent. Best results are obtained when the solution is agitated for 60 min after all PAM has been introduced. If possible, the solution should be allowed to stand over night, to ensure that the PAM is fully hydrated and dispersed.

Liquid solutions can be prepared from concentrated pre-dissolved PAM liquid using a recirculating nurse tank. Liquid concentrates are generally 2.25% PAM and are the consistency of cold honey. Furrow treatment strength is obtained by first diluting to field solution strength in a nurse tank and the final dilution takes place in the ditch or pipe on the way to the individual furrows (Table 1). Usually a 9:1 dilution ratio is used and resulting field concentration kept below 2500 ppm to ensure easy handling in the field.

STOCK SOLUTION —>	FIELD SOLUTION —>	FURROW TREATMENT
(22,500 ppm)	(2250 ppm)	(10 ppm)
(2.250%)	(0.225%)	(0.0001%)

Table 1. Diluting liquid PAM stock concentrate to field solutions.

Stock Concentration ppm	Dilution Ratio Water to PAM	Resulting Solution ppm	Pounds PAM per 100 gals
22,500	10:1	2045	1.28
22,500	9:1	2250	1.41
22,400	8:1	2500	1.56
22,500	7:1	2812	1.76

Diluting Stock Solutions in a Nurse Tank

1. Start with a clean nurse tank 1000 gallons or larger that is set up to recirculate. Plumb a delivery hose and float box or valve to the tank if it will be used for applying PAM to fields.
2. Add 200-300 gallons of water and start recirculation.
3. Begin to add 2.25% stock solution slowly while recirculating. Add 100 gallons total.
4. Fill tank to 1000 gallons with water while recirculating.
5. Resulting 2250 ppm PAM solution will not require continuous recirculation.

Calculating Liquid PAM Application Rate The rate of PAM to apply depends on 1) irrigation flow rate, 2) concentration desired in water, and 3) concentration of PAM field solution. Use Table 2 or Worksheet #3, which is similar to the one below, to calculate the flow rate of liquid PAM to inject. Advantages of a worksheet are that it can also serve as a record keeping tool that allows adjustment of PAM delivery based on field observation.

The equation to calculate liquid PAM injection rate is relatively simple:

PAM Injection Rate (gpm) = [Irrigation Flow (gpm) x Desired Inflow ppm)] / [PAM Stock (ppm)]

Example Worksheet for Calculating Liquid PAM Application Rate

Date/Field	Irrigation Flow (gpm)	Desired PAM Conc. (ppm)	Field Solution (ppm)	Injection Rate (gpm)
e.g. 6/21/94	450 gpm	x 10 ppm	÷2250 ppm	= 2.0 gpm

Table 2. Injection rate (gpm) of 2250 ppm PAM solution to achieve a range of concentrations.

Irr. Ditch Flow (gpm)	Desired PAM Concentration of Inflow Water ppm										
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	12.0
	PAM Injection Rate (gpm)										
150	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8
250	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.3
350	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.9
450	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.4
550	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.4	2.9
650	0.3	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.9	3.5
750	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	4.0
850	0.4	0.8	1.1	1.5	1.9	2.3	2.6	3.0	3.4	3.8	4.5
950	0.4	0.8	1.3	1.7	2.1	2.5	3.0	3.4	3.8	4.2	5.1

Volume of Liquid PAM Required to Treat a Field Using the rate of application of 2250 ppm field strength PAM from Table 2 and predicted irrigation advance rate, volume of liquid PAM can quickly be determined using Table 3. For early irrigations when the desired PAM inflow rate is 10 ppm or greater, the volume of liquid PAM can be quite high. For fields larger than 20 acres, more than 1000 gallons of PAM stock solution may be needed (Table 3). Volume of PAM solution can be reduced by increasing field solution concentration to its maximum based on handling limitations; around 3000 ppm PAM.

Many furrow irrigators use 24-hour sets. Some use 12-hr sets. Advance rates typically range from 6 to 18 hours for a first irrigation and 4 to 8 hours subsequent irrigations. Surface irrigation is most efficient when advance time is one 1/4 to 1/3 of the total set time. Larger inflows can be used with PAM-treated water, thereby decreasing advance time, yet without risk of erosion. Irrigations may be reduced to twelve hour sets on some fields when PAM is applied. These management changes could also reduce leaching of N.

Table 3. Volume of 2250 ppm PAM delivered for various set times and PAM injection rates.

PAM Flow Rate (gpm)	HOURS OF PAM APPLICATION TO FIELD											
	1	2	3	4	5	6	7	8	9	10	12	24
	gallons of application											
0.5	30	60	90	120	150	180	210	240	270	300	360	720
1.0	60	120	180	240	300	360	420	480	540	600	720	1440
1.5	90	180	270	360	450	540	630	720	810	900	1081	2160
2.0	120	240	360	480	600	720	840	960	1080	1200	1440	2880
2.5	150	300	450	600	750	900	1050	1200	1350	1500	1800	3600
3.0	180	360	540	720	900	1080	1260	1440	1620	1800	2160	4320
3.5	210	420	630	840	1050	1260	1470	1680	1890	2100	2520	5040
4.0	240	480	720	960	1200	1440	1680	1920	2160	2400	2880	5760
4.5	270	540	810	1080	1350	1620	1890	2160	2430	2700	3240	6480
5.0	300	600	900	1200	1500	1800	2100	2400	2700	3000	3600	7200

Liquid PAM Metering Devices

1. Poly tanks should be a minimum of 1000 gal. size but a 1500 gal. tank would fit most situations and doesn't cost appreciably more. Trailer or pickup-mounted poly tanks can prove a useful convenience, however, actual tanker trucks that sit at a specific field during irrigation may be over-kill. Remember that tanks may need refilling between irrigation sets on some fields.

2. Flow of PAM solution from the poly tank to the irrigation supply ditch will usually be from 1 to 4 gpm. Accuracy of delivery should be 0.1 gpm, especially in the 0 to 2.5 gpm application range. Rapid adjustability is important if the system will be moved between fields.

3. Although "float boxes" (constant delivery rate gravity flow boxes) are desirable to keep outflow constant, they are not essential equipment. A timer shutoff may pay for itself. A complete application system would include a shutoff timer, flow gauge, and totalizing flow meter.

Dry PAM Metering Devices The AQUA II[1] is a patented granular applicator made specifically for applying granular PAM. It is very difficult to meter unconditioned granular materials. Products such as fertilizer and granular insecticides were manufactured to be easy to meter in granular form. When exposed to humidity, polyacrylamide granules tend to stick to each other and to drop tubes which can then plug. The flow rate for granular PAM ranges from 2 to 33 grams per minute depending on irrigation flow and desired concentration in the irrigation water. A small error in the rate of metered PAM will lead to large differences in concentration in irrigation inflow water. Despite having some problems, several producers have successfully adopted the use of granular PAM application equipment and operate several machines on the same farm.

[1]Mention of trademarks, proprietary products, or vendors does not constitute a guarantee or warranty of the product by the University of Idaho or USDA-Agricultural Research Service and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

TROUBLE SHOOTING GUIDE

The following is a list of possible reasons why a given PAM application does not achieve desired results. Most of the common problem areas are addressed here, but other complicating factors may also be involved.

1. *Inadequate Mixing of PAM Concentrate* - Liquid PAM solutions require considerable mixing during dilution. Field solutions should be clear and free from small jelly globules called "fisheyes" which would indicate undissolved concentrate.

2. *Not Enough PAM Was Applied* - Rate of PAM addition must be based on total irrigation inflow rate, erosion potential for a field, and desired injection concentration. Also consider #3 and #4.

3. *Losses of PAM During Application, Mud Ditches* - Several factors can decrease the concentration of PAM delivered to the furrow. PAM will adhere to the sides of a mud ditch and to siphon tubes since PAM is attracted to metals. Preliminary data indicate that ditch losses are highest during the first "PAM" application and can be 20 to 30% during the first hour of an irrigation event. Measurements taken during the third PAM application indicated negligible losses to the ditch.

4. *Losses of PAM During Application - Sediment in Irrigation Water* - As discussed earlier, PAM injection will settle suspended sediment in irrigation water. This will reduce the amount of PAM applied to the field since some PAM is 'deactivated'. Further research is needed to relate the amount of PAM deactivated by suspended sediment in irrigation water. Groundwater high in metallic salts may also deactivate some PAM and slightly reduce field effectiveness.

5. *Poor Mixing of Applied PAM with Irrigation Water* - Inadequate mixing of PAM may result in highly concentrated PAM being applied in the first few furrows and insufficient PAM in the furrows furthest from the point of injection. For open ditch systems, multiple tins or dams can be used to mix PAM prior to application to the furrow; one or two dams have proven adequate for liquid applications. Three to four dams and at least 100 feet of ditch are recommended to adequately mix granular applied PAM. PAM must be mixed well prior to entering a gated pipe system since water does not mix as well in a pipe. If PAM cannot be mixed prior to entering a gated pipe system then multiple in-line control boxes should be installed. Plastic in-line control boxes are available (K Box, Fruitland, Idaho) that will provide turbulent mixing and a place to inject polymer and fertilizer. Field testing indicates that a weed screen should not be used to mix PAM treated water since it can easily plug the screen.

6. *Poor Prediction of Advance Time* - The use of automated timers or liquid shutoff valves can be problematic for controlling PAM injection because it is difficult to accurately predict furrow advance time. If advance time is slower than expected, the bottom portion of the fields will not be treated with PAM. If furrow advance is faster than expected more PAM than necessary will be applied and PAM losses in runoff water could occur.

7. *Cold Irrigation Water* - Irrigation water from a well will be colder than surface water. It is more difficult to dissolve PAM in cold water than in warm water. Greater time and agitation will be required to dissolve PAM in cold water.

THE COST OF PAM TECHNOLOGY

Cost of PAM-use will vary between sites and operators depending on the amount and type of PAM applied and management costs.

Amount and Type of PAM
*desired level of erosion control
*field and soil characteristics
*cost for PAM
*carriers or additives added to pure PAM

Management Costs
*pick-up and delivery costs
*mixing costs for liquid PAM
*regulation of PAM injection

To achieve 8 to 10 ppm in the irrigation advance water generally requires 1 to 2 pounds PAM per acre. Since the rates per acre are low, it is easy to over apply PAM. Therefore calibration and monitoring of your injection equipment is important. The cost for PAM may justify changes in irrigation practices to facilitate a rapid irrigation advance, thus lowering the amount of PAM required.

If all irrigations following soil disturbance are treated, row crops will require from 3 to 5 PAM applications for the season. This results in a seasonal cost of $15 to $50 per acre if PAM costs to the producer is $5.00 per pound (Table 4).

Table 4. Seasonal costs for PAM at $5.00 per pound

Injections per season (number)	Amount of PAM applied (lbs per acre per application)	Seasonal cost per acre ($/ac)
1	1	$5
1	2	$10
3	1	$15
3	2	$30
5	1	$25
5	2	$50

Cost estimates in Table 4 are conservative since they do not include management costs or inefficiency factors associated with PAM-use. Adhesion to mud ditches, failure to shut off tanks in a timely manner, and disposal of "left-over mix" will increase the amount of PAM used. For pesticide applications it is common to mix from 5 to 15% greater volume than is needed based on exact calculations. Equipment costs to apply PAM were not included in Table 4. A good quality 1500 gallon tank with plumbing can be obtained for about $950 and an AQUA II granular applicator for $1500.

Note: These are COSTS only, but do not reflect possible reductions in other field management costs (e.g. soil replacement or reduced nitrate losses); nor do they reflect possible improved gross returns (e.g. yield increases on steep slopes due to improved infiltration).

POLYACRYLAMIDE WORKSHEET #1
Calculating Granular Rates Based on Pounds Per Acre

STEPS:

1. Determine the area irrigated by one irrigation set. Use feet for distances [furrow length x bed width x number of furrows] / 43560 = acres for set

2. Acres served multiplied by 454 grams/lb = total grams needed at 1# /acre. Greater or less than 1 pound per acre (454 g) may be required.

3. Estimate the furrow advance time. Divide the total grams needed by hours of advance to obtain the advance phase rate in grams/hr.

Date & Field	Acres Per Irrigation Set (acres) x 454=	Total Needed For Set (grams) ÷	Advance Time (hours)=	Rate To Apply PAM (grams/hour)	Notes:
Example	5 acres	2270 grams ÷	6 hours =	378 g/hour	erosion controlled ☺

POLYACRYLAMIDE WORKSHEET #2

Calculating Granular Rates Based on Concentration

STEPS:

1. To achieve a known concentration of PAM you need to determine total flow rate of irrigation water to the field in gallons per minute.

2. Select a multiplier based on desired PAM concentration. Irrigations after cultivation should be treated with 10 ppm PAM and subsequent irrigations with 1 to 3 ppm.

DESIRED RATE	MULTIPLIER TO USE	
10 ppm	2.27 x gpm =	
9 ppm	2.04 x gpm =	
8 ppm	1.81 x gpm =	
7 ppm	1.59 x gpm =	
6 ppm	1.36 x gpm =	RATE TO APPLY GRANULAR PAM
5 ppm	1.13 x gpm =	
4 ppm	0.91 x gpm =	grams per hour
3 ppm	0.68 x gpm =	
2 ppm	0.45 x gpm =	
1 ppm	0.23 x gpm =	

3. Multiply gpm irrigation flow x selected multiplier to obtain grams/hr.

Date/Field	Irrigation Flow (gpm)	(above) x multiplier	Granular PAM rate = grams per hour
EXAMPLE	450 gpm	x 2.27	= 1021 grams/hr

POLYACRYLAMIDE WORKSHEET #3

Calculating Liquid Application Rates Based on Concentration

1. Determine water flow to the field in gallons per minute.
2. Record the desired PAM concentration in the treated water.
3. Determine or record the field solution (tank) concentration. This may vary from 2000 ppm to 3000 ppm PAM.
4. Multiple irrigation flow (gpm) by desired PAM concentration (ppm), then divide by the field solution strength (ppm). This will equal the flow rate (gpm) of PAM field solution from the tank to the ditch (Injection Rate).
5. Adjust PAM flow using a catch can and stop watch.
6. Total volume (gallons) of field solution needed can be obtained by multiplying Injection Rate (gpm) by total minutes projected to be run as dictated by furrow advance rate.

Date & Field	Irrigation Flow Rate (gpm) x	Desired PAM Conc. (ppm) ÷	Field Solution (ppm) =	INJECTION RATE (gpm) x	Projected Advance (min) =	TOTAL VOLUME (gallons)
EXAMPLE	450 gpm x	10 ppm ÷	÷2250 ppm	=2.0 gpm	360 min =	720 gals

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