

LINEAR ANIONIC PAM AS A CANAL WATER SEEPAGE REDUCING TECHNOLOGY

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ABSTRACT

Reclamation has been collaborating with the Desert Research Institute and Colorado State University to better understand the use of linear anionic polyacrylamide (PAM) to reduce canal seepage. The project has been divided into four main areas – laboratory experiments, quasi-field scale experiments, full-scale canal applications, and environment/human risk characterization. An independent peer review panel of experts has convened several times to provide guidance on the research that is being done for the field and laboratory studies as well as the risk characterization report. A final Risk Characterization Report will be completed in 2007 and will provide water managers with guidance on the use of dry PAM formulations and to what extent PAM is an environmentally acceptable technology. Most of the field experiments will be completed by the end of Water year 2007. If it is determined that PAM applications to canals is environmentally acceptable, guidance will be developed on how best to responsibly apply PAM and what field conditions are most favorable.

During Water Year 2005 a series of 30 very controlled experiments were run in a 160-foot long test trough along with some quasi-field scale experiments, to gain an understanding on how and to what extent various application rates of PAM reduced canal seepage. Data from these experiments were used in Water Year 2006 to design and carry-out full scale canal applications on six canals. The main focus of this paper will be on seepage results from applications on three canals in southeast Colorado.

INTRODUCTION AND BACKGROUND

There is increasing interest among water user organizations, State and Federal agencies, and the public in using irrigation water more efficiently. On a majority of irrigated lands in the western U.S., more efficient water use could be achieved. The continuing increase of water requirements for municipalities and industry, fish, wildlife and habitat, and recreation is closing the gap between available water supply and demand. In addition to reducing water available to others, inefficient conveyance and excessive application of water for irrigation often causes local drainage problems and may result in excess return flow which add to downstream salinity on some Western rivers.

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Past comprehensive studies of water conservation opportunities carried out by the Bureau of Reclamation (Reclamation) and the Bureau of Indian Affairs (1) concluded that overall average irrigation system efficiency, resulting in reduced diversions, could be improved by appropriate implementation of off-farm and on-farm water conservation measures. Improvement of conveyance systems appears to have potential for improving efficient use of water. From the table below, the studies concluded about **two-thirds** of the improvement would result from better management and improvement in the water conveyance (off-farm) system.

Seepage reduction by lining and/or piping canals and laterals (off-farm facilities) accounts for over one-third of the reduced diversions. Seepage losses, caused principally by pervious soils in which canals and laterals are constructed, offer the greatest opportunity for increased water delivery efficiency.

Table 1. Project Management and Facilities to Point of Farm Delivery

<u>Type of Conservation Measure</u>	<u>Reduced Diversion</u>
Improved water management	10 percent
Automation and improved control measures	7 percent
Seepage reduction (canal lining and pipe)	37 percent
Recycling of return flow	11 percent
Other	<u>1 percent</u>
Total conveyance system	66 percent

(Table reproduced from "Report on the Water Conservation Opportunities Study", Department of the Interior, Bureau of Reclamation and Bureau of Indian Affairs, September 1978).

References

- (1) Report on the Water Conservation Opportunities Study, Department of the Interior, Bureau of Reclamation and Bureau of Indian Affairs, September 1978.
- (2) Irrigation Water Use and Management, Interagency Task Force Report, Department of the Interior, Department of Agriculture, Environmental Protection Agency, June 1979.

POLYACRYLAMIDE (PAM)

PAM has been used for more than 10 years in furrow-irrigation to control soil erosion. Experiments of using PAM to reduce canal seepage started in 1999 by the Reclamation and the Uncompaghre Valley Water Users Association. They set up a wooden trough and began running experiments with porous soils and various application rates of PAM. Experiments of using PAM as a canal seepage control technology expanded from 2000 to 2004 into several small canals in western Colorado and it became important for Reclamation to have a better understanding of the risks and benefits of this new technology.

When added to canal water, linear, anionic PAM, a long-chain synthetic polymer flocculates and drops suspended sediments out of suspension. This creates a lower hydraulic conductivity layer along the canal perimeter that can reduce seepage losses. PAM is potentially an attractive alternative for seepage control since it is relatively easy to apply and is inexpensive compared to conventional channel lining materials. Its flexibility of application also provides the potential to create seepage reduction schedules and to selectively control seepage quantities in response to

changing economic and hydrologic conditions. PAM application to canals in the Arkansas River Valley was field tested on reaches of the Catlin Canal, Lamar Canal, and Rocky Ford Highline Canal in the summer and fall 2006. Seepage estimates were made using a mass balance procedure that employed flow measurements with acoustic Doppler current profilers (ADCP) and/or acoustic Doppler velocimeters (ADV) along with other measurements. Water samples were collected during the field test and analyzed for PAM and for the acrylamide monomer, which is the compound from which PAM is created. Objectives included an evaluation of the effectiveness of PAM in seepage reduction as well as an assessment of possible environmental and health risks from the application.

Preliminary Findings on Seepage Reduction

In the summer of 2006, four PAM applications were completed in Arkansas River Valley irrigation canals. Study reaches were chosen on three different canals to capture variability in water and channel properties. By studying canals that differ from one another, the conditions that maximize the effectiveness of PAM should be easier to identify. The conditions within the studied canal reaches are summarized in Table 2. Further analysis, including assessment of measurement error, will be conducted in the future to refine these results. The polyacrylamide product used in all canal applications contained a 92% active ingredient. The active ingredient of PAM varies among manufacturers, so the application rates shown in Table 1 reflect active quantities.

Table 2. Summary of Preliminary Findings on Use of PAM for Seepage Reduction, Summer 2006

Canal	Test Length (mile)	Average Pre-PAM Seepage		PAM Application Rate		Average Canal Flow Rate within First Month of Application	Average Seepage Reduction within First Month of Application
		(cfs/acre)	(cfs/mile)	(lbs/acre)	(lbs/mile)		
Catlin	2.7	0.90	2.5	17.9	50.6	111 cfs	87%
Lamar	5.8	0.90	2.0	11.6	28.1	48 cfs	38%
RF Highline #1	19.9	0.20	0.7	12.3	46.8	144 cfs	0%
RF Highline #2	2.5	0.70	3.4	13.0	63.3	124 cfs	59%

The first application was conducted in early June on the Catlin Canal south of Rocky Ford (Figure 1). The study reach extended 2.7 miles from the upstream site 201 to the downstream site 202. Granular PAM was applied dry to the water from a motorized boat using two handheld spreaders. Each handheld spreader was filled with a pre-weighed amount of PAM, which was then applied by two people within the boat while traveling in the upstream direction over 0.10-mile increments so that the rate of application could be measured and maintained. As seen in Table 1, this first experiment resulted in the greatest impact among tests in 2006, as seepage was reduced by about 87% within the first month after PAM application. This large reduction may have resulted from water chemistry that favored PAM-suspended sediment flocculation, an application rate that was greater than that used on the other canals, and from the possible presence of finer-grained sediments within the canal water. Follow-up seepage loss measurements were continued through November (5 months after PAM application) so that the effect of PAM over time could be observed. The longevity of the PAM influence will be discussed later in the report.

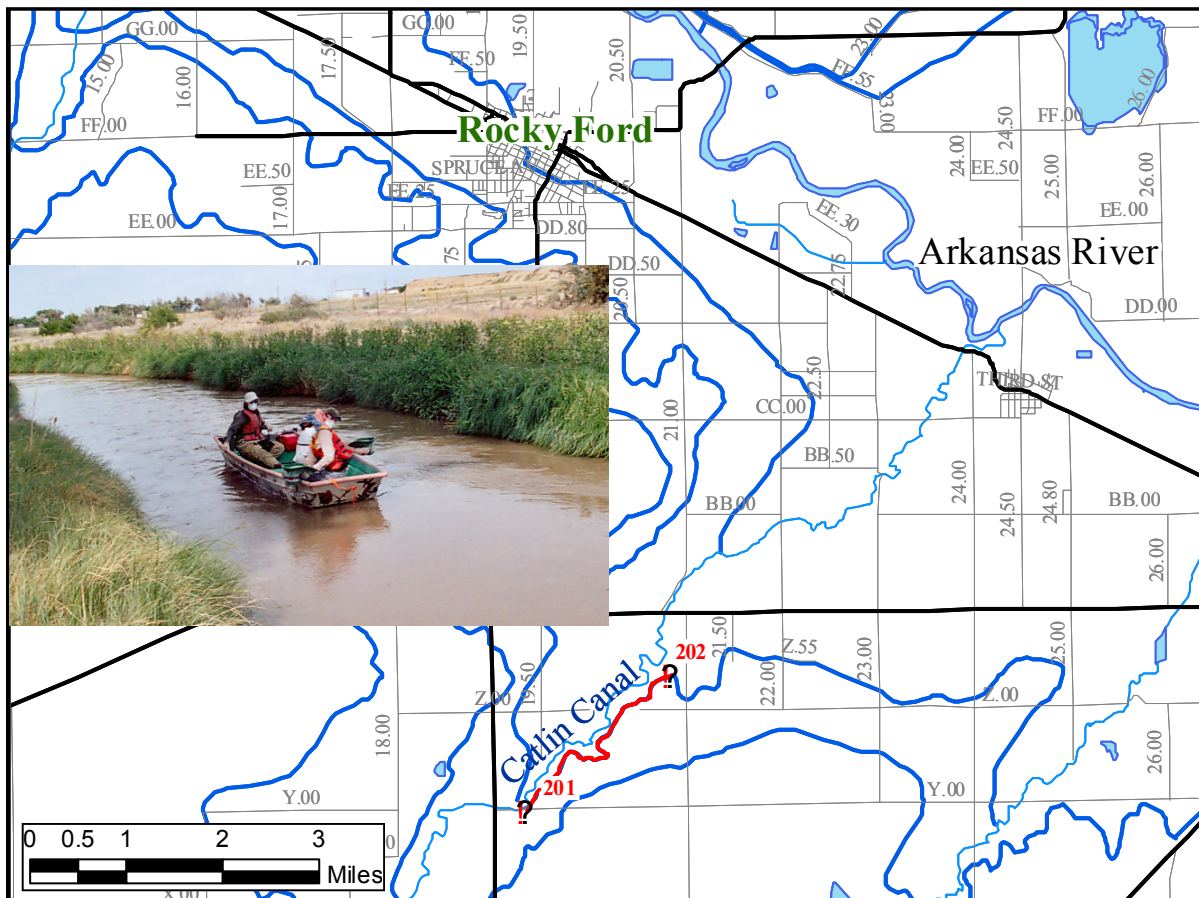


Figure 1. PAM Application Study Reach on the Catlin Canal in Summer 2006.

The second PAM application in 2006 was conducted on a reach of the Lamar Canal. The 7.4-mile study reach was located between Lamar and Granada just south of Colorado Highway 50, extending from site 400 to site 405 (Figure 2). PAM was applied to the entire study reach; however, due to irrigation diversions from the canal, all post-application measurements were taken over a 5.8-mile canal segment between sites 401 and 405. Therefore, all results reported herein apply to the reach between the upstream site 401 and the downstream site 405. The application technique was similar to that of the Catlin Canal application, as a motorized boat and two handheld spreaders were used. A picture of this application technique appears in Figure 2. As seen in Table 2, the PAM application on the Lamar Canal is estimated to have reduced seepage losses by an average of about 38% within the first month after application. It is thought that if sediment levels within the Lamar Canal had been higher during the application process, seepage reduction would have likely been greater.

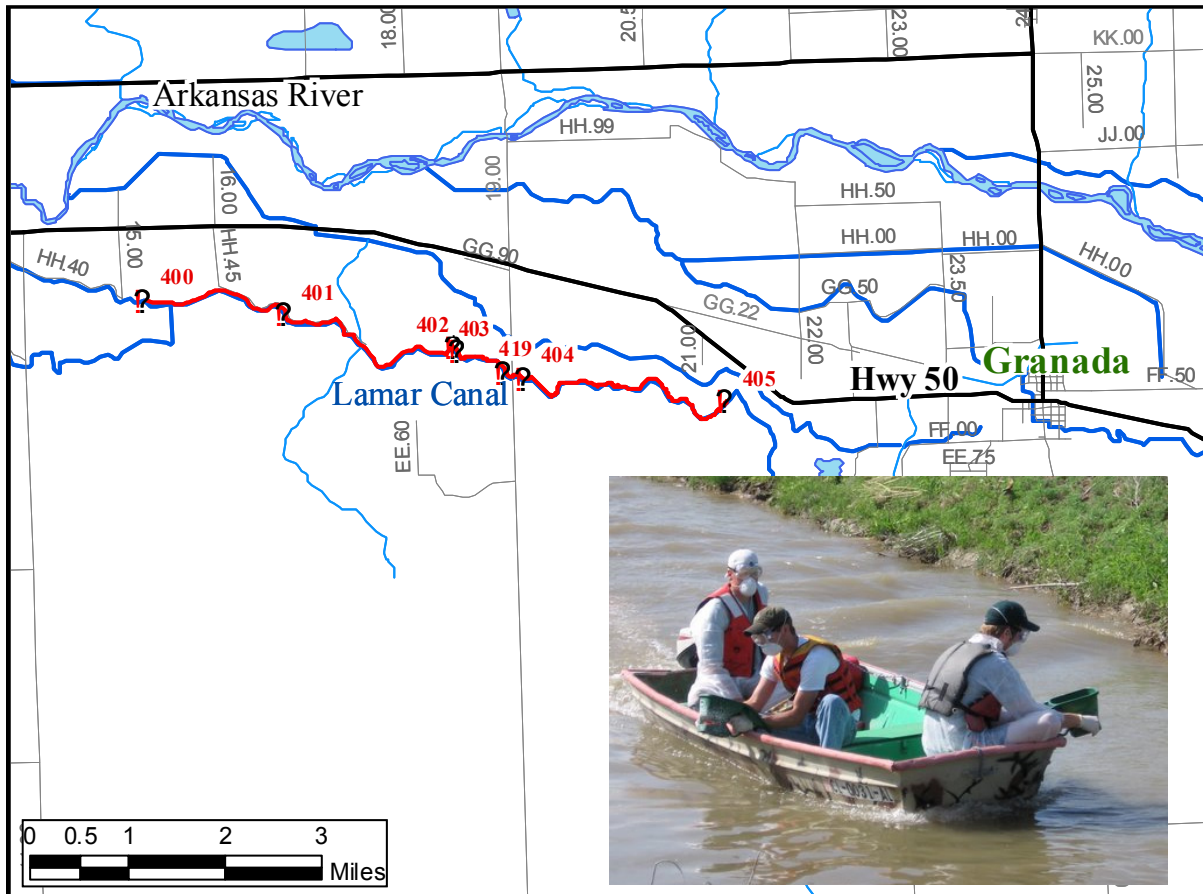


Figure 2. PAM Application Study Reach on the Lamar Canal in Summer 2006.

Two PAM applications were completed on the Rocky Ford Highline Canal. The first application stretched 19.9 miles from the upstream site 201 to the downstream site HH-4.27 (Figure 3). The canal segment between sites 200 and 201 was used as a control reach so that the canal's conditions could be observed without the presence of PAM. This is the longest length of canal to which PAM was applied in 2006; accordingly, the application process took two days to complete. For this test, PAM was applied using an automatic battery-powered spreader that was mounted on a small boat. The spreader's hopper was filled with a pre-measured amount of PAM then emptied while moving in the upstream direction over an incremental length of canal so that the application rate could be maintained. A photograph of this technique and the automatic spreader appears in Figure 3. The first PAM application to the Rocky Ford Highline Canal was not as successful in reducing seepage. Multiple factors could be used to explain the ineffectiveness of this application, including the application method, water chemistry, and a variety of canal conditions. From pre-PAM and post-PAM seepage measurements, the stretch of canal between sites 201 and 202/301 displayed the greatest amount of seepage. Since post-PAM measurements revealed no seepage reduction in this section of canal, it was the chosen study reach for a second PAM application, which took place following a storm event that created high sediment levels in the canal. For the second application, granular PAM was applied to the 2.5-mile canal segment between sites 201 and 202/301. PAM application also included a segment extending a distance of 1.5 miles upstream of site 201 to ensure adequate hydration of PAM and

sediment flocculation prior to reaching site 201. As seen in Table 1, the second PAM application resulted in average seepage reduction within the first month of about 59%. It seems that the higher sediment concentration present in the canal water during the second application resulted in more sediment and PAM settling to the canal bottom, which more effectively lined the channel bed and reduced seepage to a greater extent.

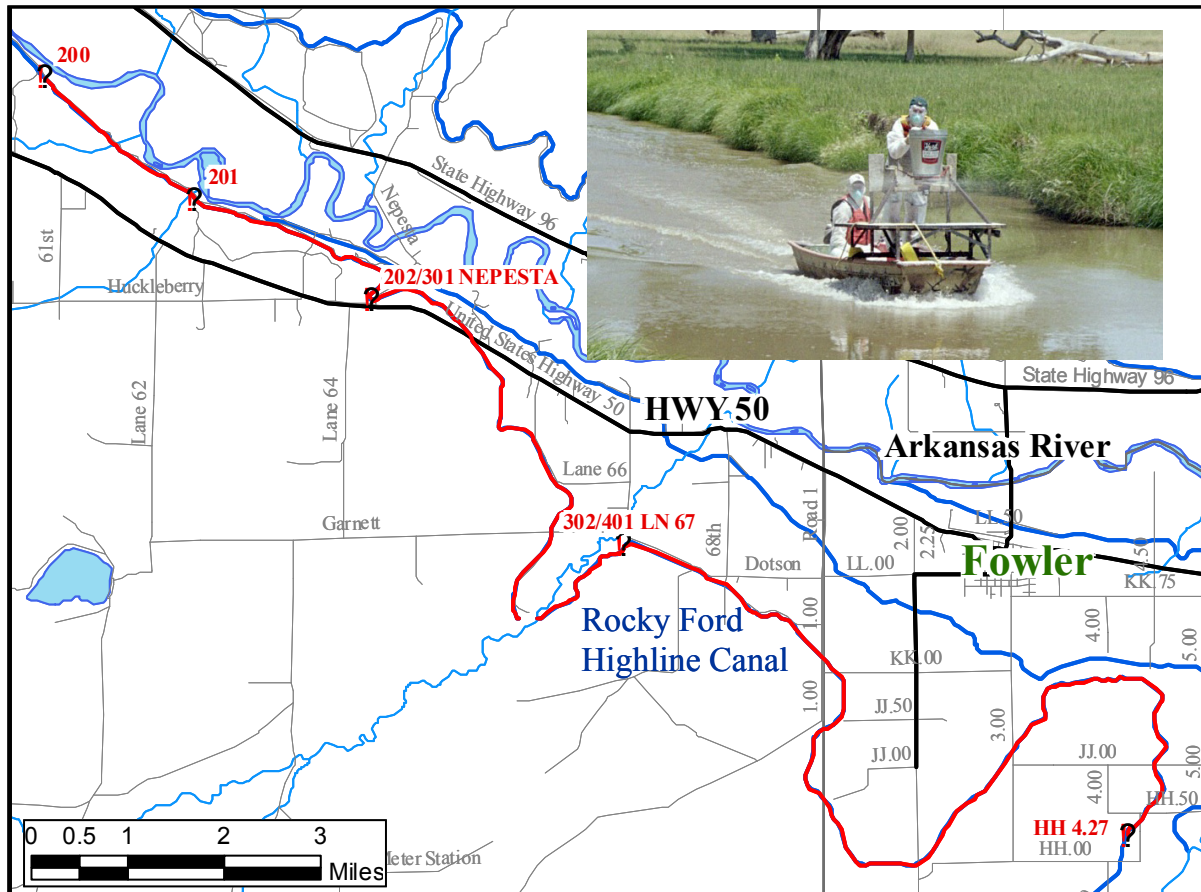


Figure 3. PAM Application Study Reach on the Rocky Ford Highline Canal in Summer 2006.

Follow-up seepage measurements were conducted throughout the 2006 water season to assess the effectiveness of PAM in sustaining canal seepage reduction over time. Based upon data collected in 2006 on the Catlin, Lamar, and Rocky Ford Highline canals, it appears that PAM continued to be relatively effective within three to four months after application. Data suggest a slight drop in seepage reduction by about 10 percentage points.

Seven post-PAM application seepage measurements were conducted over a span of 152 days on the Catlin Canal. The results show a minor drop in seepage reduction towards the end of the water year; however, the effectiveness of the PAM application was still substantial (Figure 4).

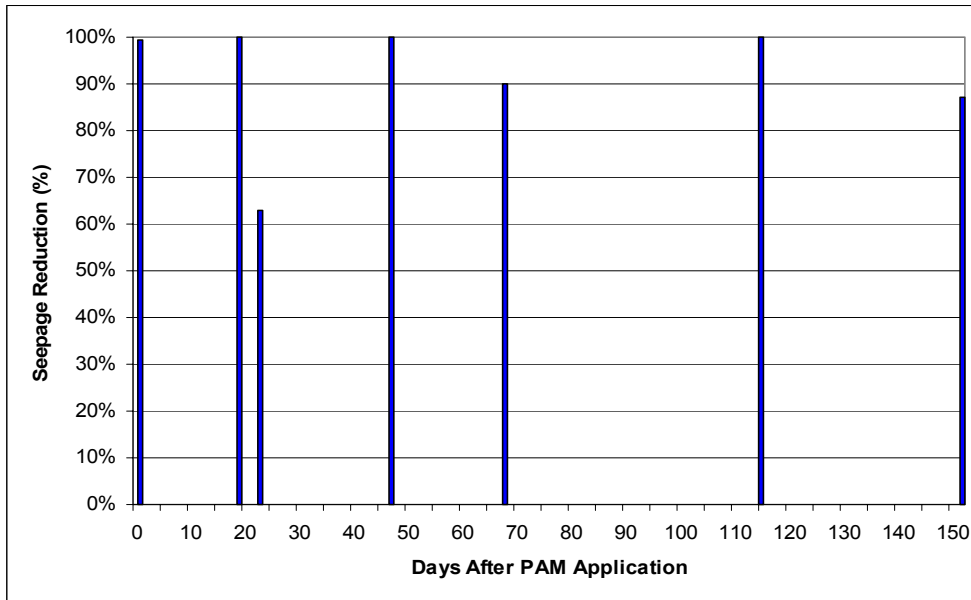


Figure 4. Plot of Estimated Seepage Reduction in the Catlin Canal after PAM Application.

Four seepage measurements were conducted on the Lamar Canal over a 113-day period following the PAM application. PAM effectiveness appeared to have respectable longevity. The Lamar Canal showed results similar to the Catlin Canal, as seepage reduction declined slightly in the months following PAM application (Figure 5).

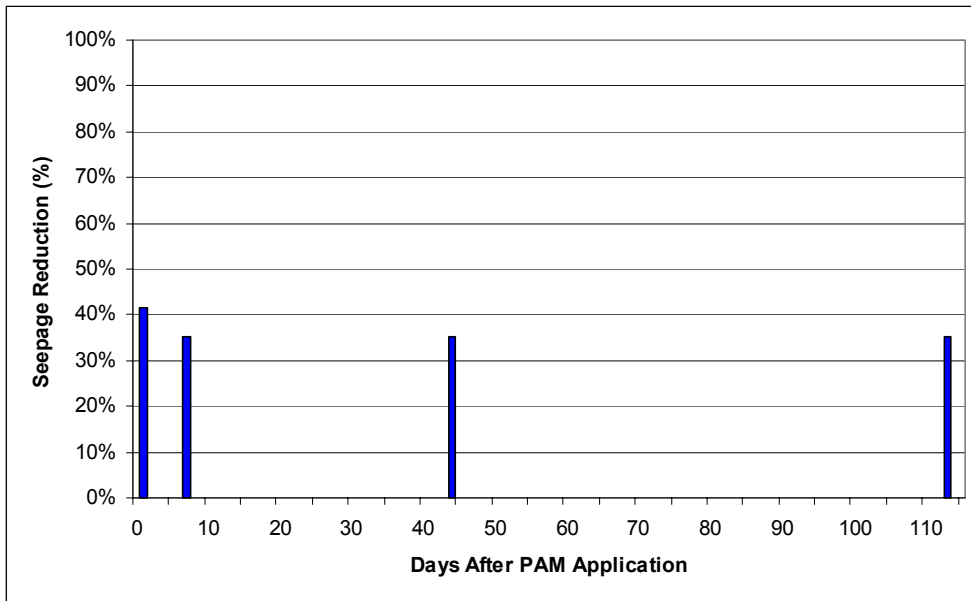


Figure 5. Plot of Estimated Seepage Reduction in the Lamar Canal after PAM Application.

In the 105 days after the second PAM application to the Rocky Ford Highline Canal, five seepage measurements were completed (Figure 6). With respect to longevity, the second PAM application on the Rocky Ford Highline Canal revealed results similar to those for the Catlin and

Lamar canals. Canal seepage reduction was the greatest in the first few days following the application then it began to reduce by approximately 10 percentage points over the following months.

Overall, preliminary results suggest that longevity is considerable, since reduction in estimated water loss from canals remained fairly stable in the weeks and months following an application. Continued research will be conducted to test the frequency of PAM application required to sustain significant seepage reduction in irrigation canals under a variety of representative conditions. It is quite possible that the necessary number of applications will vary from irrigation season to irrigation season, depending upon water, channel, and ground water characteristics.

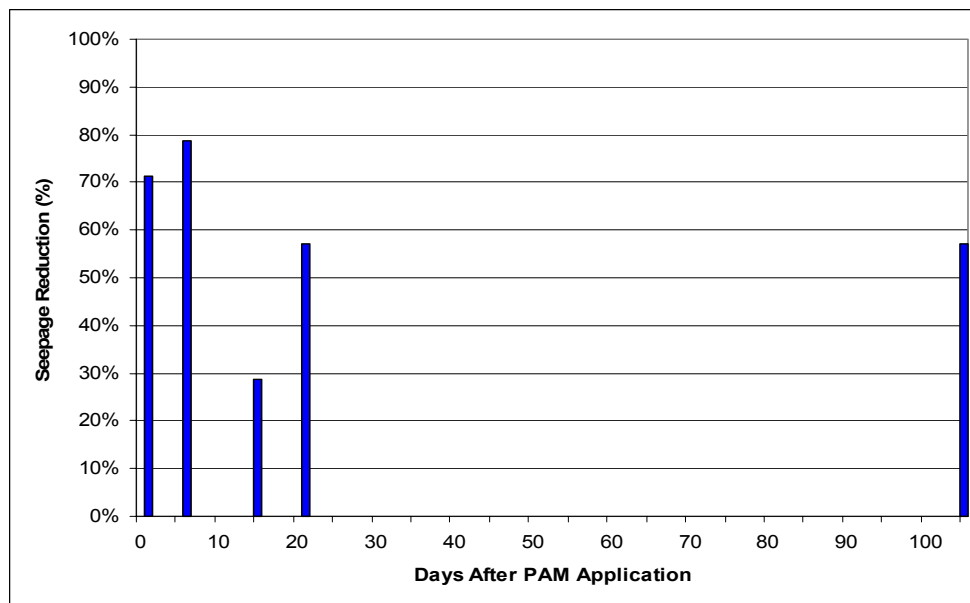


Figure 6. Plot of Estimated Seepage Reduction in the Rocky Ford Highline Canal after PAM Application.

Preliminary Assessment of Environmental and Health Risks

The concentration of PAM found in the water column after application peaked at 2 to 4 times that of the EPA Drinking Water Standard of 1 part per million (ppm). However, these elevated concentrations were short-term, lasting during PAM application and up to 5 hours after completing the application of PAM. Concentrations then remained below the drinking water standard. A soon-to-be-released report on environmental and health risks from PAM application and the release of the acrylamide monomer showed that the concentrations measured in the canal water would pose little to no risk to humans, especially given that the concentrations were elevated for a very short period of time.

Expected Impact of On-Going Research

Investigations will continue over the next couple of years to better understand the impact of method, rate and frequency of PAM application; suspended sediment concentration; water salinity and temperature; soil texture in the canal perimeter; adjacent groundwater elevation; and other factors on the effectiveness and economy of PAM for controlling seepage.

PAM can potentially have significant economic impacts due to inexpensive application costs and a number of benefits that can be derived from reduced canal seepage. It is currently estimated that PAM application will cost \$122 to \$327 (2006 dollars) per mile along a canal per year, which is less than about 3% the cost of conventional lining methods. The application cost does not include the price of equipment; however, preliminary estimates suggest a boat, motor, and spreader can be purchased for an approximate total of \$2,000 - \$3,500 and protective gear costs \$20 per application per person. It is believed that a portion (perhaps 10 to 20%) of the saved seepage water may be able to be salvaged and converted to beneficial crop consumptive use. This salvaged water would be derived from the likely reduction in upflux to non-beneficial evapotranspiration from high water tables which are partially caused by seepage. According to the Arkansas River Compact, all remaining seepage must be allowed to return to the river. Reduction in canal seepage likely will lead to a lowering of the saline shallow water table in the Valley, contributing not only to reduced non-beneficial water use but also to a decrease in waterlogging and salinity with a consequent increase in crop production. Furthermore, reduced canal seepage would enhance river water quality by lessening subsurface flows and the associated dissolution and mobilization of salt and selenium loads that move to the river.

Experiments are planned to continue into the 2007 irrigation water year in the Catlin, Lamar, Rocky Ford Highline, and other Arkansas River Valley canals. It is hoped that the most beneficial ways for canal companies to use PAM in reducing canal seepage can be discovered and implemented.