MUTUAL IRRIGATION COMPANY MONITORING OF MAIN CANAL NITROGEN LEVELS

by

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Colorado Water Resources Research Institute

Completion Report No. 166

Colorado State University

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A Case Study On The Role Of Mutual Irrigation Companies In Water Quality Management

by

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With Assistance From

The New Cache La Poudre Irrigating Company
and the
The Northern Colorado Water Conservancy District

December 1992

Grant No. 14-08-0001-G2008
Project 09

The research on which this report is based was financed in part by the U.S. Department of the Interior, Geological Survey, through the Colorado Water Resources Research Institute; and the contents of this publication do not necessarily reflect the views and policies of the U.S. Department of the Interior, nor does the mention of trade names or commercial products constitute their endorsement by the United States Government.

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ABSTRACT

This paper presents the results of a focused social survey and weekly water quality sampling conducted during the irrigation seasons of 1991 and 1992 in a mutual irrigation company (ditch company) service area. The company is located in northeastern Colorado. The study was funded by the Colorado Water Resources Research Institute, Colorado State University. The paper discusses the potential future role of such organizations in water quality monitoring and agricultural non-point source pollution management. It also provides data on main canal nitrate loading during one irrigation season.

The research had two principal objectives. The first was to provide baseline data on nitrates in irrigation company canal water in the upper portion of the Cache La Poudre River Basin, a major irrigated area in Colorado. The second goal was to assess the potential of such companies to initiate pro-active water quality management programs that would address practical needs of shareholder-growers, while at the same time addressing overall State water quality mandates impacting the local river basin.

Recycling of nitrate-laden water as a supplement to seasonal sidedressing applications, although theoretically possible, does not appear to be possible in this immediate area since the nitrate concentrations are minimal. Risk to certain crops from canal nitrate concentrations at certain times of the season is also a theoretical possibility, and still needs further investigation. Despite these observations, the irrigation company feels encouraged to pursue this monitoring program as a general "best management practice" in support of shareholder interests.

Several hypotheses are advanced and tested regarding the potential source of nitrates in company canal water, including storm runoff, municipal treatment plant effluent, normal seasonal return flows from neighboring company service areas, and the river supply itself. The paper concludes with recommendations on how the role of such "locality-based" organizations might be enhanced in the future as a means of involving the agricultural sector more directly in water quality management.

ACKNOWLEDGEMENTS

The research effort received substantial in-kind support from the New Cache La Poudre Irrigating Company of Lucerne, Colorado. The company board of directors reviewed and approved the research, as well as the company questionnaire administered to stockholders. The superintendent of the company, Mr. Jeff Harbert, consented to lengthy recorded interviews on company management, and assumed responsibility for taking weekly water samples at twelve data stations. The samples were analyzed by Mark Crookston, Senior Water Resources Engineer at the Northern Colorado Water Conservancy District, and his staff. Special thanks to NCWCD and its technical staff. Initial consulting on the research design was provided by Dr. Ramchand Oad, Department of Agricultural and Chemical Engineering, Colorado State University. Additional valuable assistance in literature review and graphics was provided by Mr. Gary Sands, graduate student, Department of Agricultural and Chemical Engineering, CSU. Special thanks to Dr. Robert Ward for his support and encouragement, and to Shirley Miller for addressing issues and questions regarding grant implementation.

INTRODUCTION

This paper reports on environmental and social research conducted in cooperation with a mutual irrigation company in northeastern Colorado. The irrigation company initially expressed interest in ascertaining the degree to which regular monitoring of nitrates in its main "highline" canal could be adopted as a best management practice, and could be used to report on service area water quality conditions to its shareholders. The sociological implications of the research have to do with the potential future role of such locality-based organizations in sustainable agricultural programs and water quality management, particularly in the seventeen western states where this rather unique organizational form is commonly found.

The concept of "locality-based organizations" has a special meaning in this research. Unlike irrigation districts and conservancy districts which are frequently more public in nature, and often involve both an urban and rural constituency, a mutual irrigation company carries out functions which are more locality specific and self-supportive through shareholder assessments. These functions include: 1) a specific distribution and consumption role, in this case, the delivery of variable shares of water to local company shareholders at cost; 2) a socialization function which assists new water users in the company service area in learning the norms and rules of water distribution within a very specific hydrologic unit; 3) a social control function through sanctions for inappropriate water usage potentially affecting a neighbor's water rights; 4) a social participation function achieved through monthly and annual meetings of shareholders which encourages the input of local "irrigation community" members in water management, and; 5) a mutual support function in terms of conflict resolution at the local level over water issues (after Warren, 1972).

The underlying assumption of the research is that improved water quality management in the future will greatly depend upon the ability of locality-based water organizations to develop the capacity and willingness to monitor water quality and encourage its maintenance through improved information, education and possible water user sanctioning when appropriate.

It is expected that such organizations as water conservancy and irrigation districts, soil conservation districts and local health departments will all be involved in water quality improvement. However, the mutual irrigation company has a unique role in this regard. Over 75% of all irrigated land in the seventeen western states is served by these companies (U.S. Statistical Abstract, G.P.O. 1980). They are frequently responsible for water storage and delivery in traditionally circumscribed service areas. They are frequently involved in informal exchanges and rental agreements with other associations having various degrees of water quality in their respective service areas. A premise of the research is that overall river basin management of water quality can be greatly enhanced by the ability of irrigation companies to routinely monitor their canal water quality, and to provide information to shareholders and other water users about nitrate loading and/or water quality conditions potentially affecting local crops and domestic wells in a way that larger special districts and irrigation districts may not be able to mobilize for.

Furthermore, improving the management capacity of an organizational type serving from thirty to three or four-hundred farmers irrigating anywhere from 2500 to 50,000 acres of farmland is believed to be a potentially more effective social change strategy than one directed exclusively at the farm management style of <u>individual growers</u>. This in no way diminishes the importance of individual producer-oriented extension and/or technical assistance programs directed at improved on-farm soil and water management. However, strategies of social change directed at voluntary individual producer initiatives rely almost exclusively on the rather slow and tedious process of adoption and diffusion of new agricultural practices, and there are many confounding variables affecting this process.

Strategies of social change directed at improving support organization performance, such as locality-based mutual irrigation companies, may result in rapid and widespread improvements in natural resource management by individual growers because they are initiatives voted on and approved by a local organizational constituency. They are collective responses rather than individual responses, and are effected through the peer group pressure and sanctioning power potentially mobilized by such organizations and directed toward their stockholders through organizational bylaws and local norms. It is argued that no individual neighboring producer has the leverage for diffusing desired innovations in natural resource use that a locality-based organization possesses with its five previously mentioned social functions.

BACKGROUND INFORMATION AND RELATED RESEARCH

Recent new environmental legislation, particularly the 1991 Farm Bill, has presented state and local government with the task of implementing water conservation and sustainable agriculture programs on a broad scale. Three alternatives are frequently discussed as ways of facilitating the implementation of these new environmental mandates. Certain national standards of water conservation and sustainable agriculture will require the passing of new state laws regarding the preservation and protection of water resources for public health, wildlife protection, recreation and presently unidentified future use. This may be referred to as the regulatory approach. Regulatory approaches can involve the participation of locality-based organizations, but frequently will rely more heavily on the implementation of statewide programs through existing or new state agencies like health or environmental departments, or state agricultural agencies.

A second alternative involves greater participation of local government and locality-based organizations in addressing water conservation and sustainable agriculture through voluntary compliance and/or enforcement of locally approved standards, such as best management practices (BMP's). We may call this the joint participation approach. Frequently, direct economic incentives are associated with this approach, such as seed money or matching funds being provided by federal agencies or state government to reduce conveyance loss, improve irrigation scheduling, improved local water resource monitoring, etc. An example would be the cost-share programs administered by the Soil Conservation Service, implemented through local soil district boards and SCS technicians, which have been the mainstay of the federal government's soil conservation, salinity control and overall water management programs on fragile lands for many years.

The third alternative involves an expanded role of local water organizations from an era of focus on water development and supply to an era where water conservation and improved delivery to farms are practically integrated into their traditional water management tasks and goals. We may call this the <u>locality-based organizational approach</u>. This third alternative attempts to make use of pre-existing locality-based producer cooperatives, associations and irrigation companies as the vehicle for arriving at acceptable national and/or local standards of water and soil conservation, while at the same time minimizing the negative impact on traditional patterns of water use, land use and property rights.

If the second and third alternatives are to have any impact on achieving national standards of improved water management and sustainable agriculture, then it will be necessary to ascertain the degree to which these organizations, particularly mutual irrigation companies, can realistically assume such responsibilities; a major focus of the current research program. If they cannot, then it may be expected that government will play a much greater role. However, locally unique environmental, social and economic conditions may be deferred to national standards that frequently impact local situations with varying degrees of equity, and make insufficient use of local knowledge.

Mutual irrigation companies were formed to develop and supply water resources for agricultural application (Hutchins, 1929;1936a). Important research and policy questions derive from this observation. First, can such organizations integrate water conservation and improved delivery programs into their regular operating procedures without causing insupportable costs to their shareholders? These organizations are, after all, actual business enterprises. Secondly, can they do so without disrupting their current management goals of water storage and conveyance? Persistent conflicts between new management programs, operating costs and traditional delivery procedures might easily withdraw shareholder support for such programs; not to mention the company management staff responsible for implementing them. Finally, will the attempt by these organizations to address new management tasks actually be sufficient to bring water resources into conformity with new environmental legislation at the state or federal level?

Getches (1986) points to the need for a variety of institutional development initiatives to improve water management. Institutional innovations, as opposed to litigation, are more desirable with regard to water conservation and better planning of water resources. One way to accomplish this is to further promote the involvement of locality-based water organizations as opposed to blanket federal or state legislation. It is mainly through such organizations that federal and state policy is realized in a way that minimizes pressure on an already over-burdened state treasury. If local participation and organizational support are not the environmental policy strategy at the national level, then it is left to state agencies and the state treasury to implement and pay for such programs.

In a review of current and emerging water problems in the Central Valley of California, Moore and Howitt (1988) discuss the growing importance of non-structural or non-technological solutions to many water conservation and water management problems. It is implied in their analysis that one of the major non-structural approaches will be the increased role of local water organizations in addressing water conservation issues as opposed to relying specifically on federal or state regulation, or expensive technologies. A strong and representative organization with a set of rules for surface or groundwater management, and with adequate sanctioning ability to manage the member "free-rider" who is unwilling to comply with membership-derived bylaws for water quality as well as water consumption, may be a far more effective and less expensive way of addressing water resource problems than blanket regulations from the "political center" that are insensitive to variability in local ecology and needs.

Many important social-organizational questions are at issue in the research reported on here. With regard to internal organization features, Bain et al. (1966) identify potential pressures on local water organizations in reaching consensus on new water management tasks such as water quality. An attempt to arrive at consensus about new water management programs for the organization may impact optimal water resource use for individual growers, thereby creating unmanageable strain within the leadership of the organization and reducing its overall effectiveness.

Goodall, et al. (1978) discuss the degree to which local water organizations based on a one man/one vote principle rather than voting on the basis of property qualification have a bearing on fluctuations in fiscal behavior, the degree of parochial interests and resistance to social change. The impact of these key internal organizational features on the ability of locality-based mutual irrigation companies to adopt water quality and conservation initiatives generally remains unknown and needs investigation.

Weatherford (1982) suggests that such internal organizational features probably have a direct impact on organization decision-making, "and the extent to which water conservation practices may be adopted and implemented" (1982:34).

Smith (1983), in a critique of the public welfare theory perspective that water use efficiency and more balanced distribution of water resources would be higher in publicly financed irrigation districts, finds that mutual irrigation companies tend to proliferate in areas where public subsidization is lower and where water use efficiency is higher. Smith states that irrigation districts have a greater tendency to follow the actions prescribed by "dominant political coalitions" rather than following the voting plurality characteristics of mutual irrigation companies. Hence, some support for the notion that mutual irrigation companies, as opposed to irrigation and conservancy district organizational forms, provide an intriguing institutional window of opportunity to explore in the area of water quality management. Their non-profit, tax exempt status, where the shareholder's "dividend" is a portion of the organization's annual water supply in exchange for contributing to an equivalent portion of the organization's annual operating cost through assessments, make them a unique organizational form in the agricultural economy.

There is another important way in which the goal of improved water management is linked to **social technologies** represented by such organizations as mutual irrigation companies. A social technology is defined here as an organized pattern of responses leading to desired or pre-determined results through management skills, recordkeeping, effective sanctions and community participation. The point of view taken in the current research is that the adoption of sustainable agricultural practices by growers may be very much linked to the performance of the locality-based water organization that serves them.

For instance, a large part of the agricultural technology innovation and adoption literature focuses on the nature of an innovation (technological practice), the method by which the innovation is transferred from one farmer or community to the next, the time frame in which it occurs and the social and cultural context of the community in which the innovation is occurring (Rogers, 1986). When studies are conducted on the reasons for adoption and diffusion of new on-farm agricultural practices, like those commonly defined under the rubric of "sustainable agriculture", the most frequent explanatory variables seen in the literature are those of the grower's age, education, and the size of the farm operation; size meaning many different things, depending upon the researcher (Nowak and Korsching, 1983). In other words, age, education and farm size are somehow the key variables affecting rates of adoption, controlling for the nature of the innovation, its method of transfer, its time frame, and its cultural context. Frequently, less attention is given to the quality of local support organizations that may greatly impact a producer's decision-making regarding innovation/adoption.

In one of the better recent review articles in the field of innovation/adoption, Nowak and Korsching (1983) use many different explanatory variables to evaluate the use/adoption of agricultural best management practices associated with water use and soil management by individual producers. They conclude by pointing out the importance of educational programs, but the cause/effect relations are clearly inconclusive, and they close by pointing out that such individual farm attributes as "gross farm income, experience in farming, and [grower] perceptions of water quality or soil erosion as [an on-farm problem] are not important predictors of conservation management, implementation of an SCS conservation plan, or use of BMP's" (1983:367). In other words, continual problems occur in this field of study using farm characteristics or grower characteristics as the "unit of analysis", without controlling for the local organizational web the individual producer is enmeshed in.

Some observers have suggested that the adoption/diffusion model which has generated over 1000 studies since World War II may not be appropriate at all to public mandated conservation issues, such as those being advanced as "sustainable agriculture". Unlike decision-making situations involving the relationship between the adoption of a particular practice and its income benefit, conservation practices are generally derived from government policy and are justified by government agencies in terms of public good benefits rather than income benefits to growers; although rather invisible long-term income benefits are usually at stake. The economic imperative at work here is that most conservation practices are viewed by growers as "nonproductive expenditures". In short, the adoption/diffusion model appears to be frequently more appropriate to voluntary-type technology transfer situations than to public good issues regarding "the commons" (van Es, 1983).

In many of the aforementioned perspectives, the "organizational web" which the grower is enmeshed in is not adequately measured as a variable in the analysis of adoption processes. Yet, in the research reported in this paper, farmers have expressed great interest in the degree to which a new management task for the water organization that serves them (their organizational web) may facilitate their adoption of more sustainable agricultural practices. The adoption of such practices as improved irrigation timing, improved water application practices and more timely application of other production inputs is viewed by them as very much a function of the overall performance of their mutual irrigation company.

There is a wealth of literature and research on organizational theory, organizational culture, resource mobilization theory of small group action, management science, and public goods theory which can better clarify such relationships in the future. Although mutual irrigation companies are not highly sophisticated organizations, they do appear to exhibit characteristics of rather localized complex "organizational cultures". Following criteria developed by Rogers (1983) to evaluate organizational performance in agricultural innovations, an example would be two companies in a river basin with the same general physical characteristics in terms of service area, but with distinctly different management styles; one delegating much more authority to the company superintendent and the other maintaining strict control of operating procedures through the governing board (organizational centralization).

Another example would be two such companies, one with a rather poorly educated and inexperienced management staff, and the other having a superintendent with a strong background in management and good knowledge of local hydrologic conditions, and who tends to recruit individuals for ditch riders and office management who have a variety of relevant experiences related to their role performance (organizational complexity). Some mutual companies appear to be more assertive in the local irrigation community and to seek out social linkages and special arrangements with neighboring organizations (organizational interconnectedness). Other companies have no inclination to do so. Finally, some companies maintain careful records, while others have little inclination to do so and frequently under-assess operating costs and fail to carry a depreciation account, greatly limiting their resource base to explore new management options (organizational slack).

How do these different management styles affect satisfaction with water deliveries and shareholder participation in management policy, and do they promote or hinder innovation toward sustainable agricultural practices for either the organization or individual producers served by them?

The mutual company cooperating in the current research has indicated a strong willingness to better serve its shareholders through an expanded water management program that includes water quality monitoring. Although preliminary results indicate that the water quality of surface supplies does not appear to be a risk for crops or health, nor are nitrate levels anywhere near enough to be recycled as a supplement to seasonal sidedressing applications, the organization believes in the pro-active approach it is taking to develop a data base on service area water quality.

Growers interviewed during the research continually affirmed that they were in favor of the monitoring program, and were satisfied to take a "wait and see" attitude with regard to the potential benefits of the program. However, all producers interviewed agreed that the performance of the company was central to their willingness and interest in considering new on-farm water management practices that impact river basin water quality.

SUMMARY OF RESEARCH TO DATE

The initial proposal for the research received funding in September of 1991 from the Colorado Water Resources Research

Institute, Colorado State University. Discussions commenced immediately with the board and superintendent of the New Cache La Poudre Irrigating Company of Colorado (henceforth simply "New Cache" company). Agreement was reached on the design of a questionnaire (Appendix A) to obtain information on the following: 1) service area cropping pattern; 2) potential demand for canal nitrates as a supplement to sidedressing applications; 3) the potential risk of certain crops to canal nitrate loading over the course of the irrigation season, and; 4) the water supply hydrograph of the company using 1991 and 1992 river turnout and reservoir release data compiled by the company itself. One-hundred and five questionnaires were returned, about 50% of the questionnaires mailed out. The actual farm acreage represented in the returned questionnaires is about 44% of the total acreage within the company service area.

In addition, data points were identified along the company main canal to obtain water samples (Figure 4), and samples were taken once a week at each point. The Northern Colorado Water Conservancy District, serving the needs of over 100 mutual irrigation companies in northeastern Colorado through the Colorado-Big Thompson Project, generously assisted the research effort by testing water samples for nitrate levels during the 1992 irrigation season.

The following discussion summarizes the results of the company-sponsored questionnaire, the analysis of 1991 and 1992 water supply sources based on current company flow records, a discussion of the hypothesized sources of nitrates based on company experience, and initial results of main canal nitrate testing during the irrigation season of 1992.

1. Irrigated Cropping Pattern

Figure 1 presents data from the questionnaire on the cropping pattern in the company service area. The major crops are onions (9.1%), carrots (7.7%), beans (14.6%), sugar beets (7.2%), alfalfa hay (14.1%), corn (40.2%), barley (.7%) and sorghum (.3%). They are represented in Figure 1 in descending order by the net return per acre as reported in 1990 (CSU-DARE, Information Report, I-R 90-1, July 1990). There is an additional combined 6.1% of other crops in the service area (lettuce, potatoes, wheat, tomatoes, etc).

Onions and carrots are the major cash crops (income per acre), followed by beans and beets. However, corn comprises nearly half of the irrigated acreage in the company service area. Although this might indicate a preference for low risk crops in terms of input costs (gross minus net return) such as corn and hay, growers have indicated a growing trend toward higher value crops such as onions and carrots in recent years. Investment in corn and hay per acre is about $266 and $180 respectively, while that of onions and carrots is about $2702 per acre.

2. Seasonal Water Supply

The company water supply is defined by two primary sources: 1) river decrees along the Cache La Poudre River, all of which are quite old, and; 2) and individual grower water accounts in the Colorado-Big Thompson (C-BT) Project which are integrated into the overall company water management-delivery program.

The company divides its service irrigation season into a **river season** of approximately seven weeks and a **reservoir season** of approximately twelve weeks (Figure 5A and 5B). During the **river season**, the river decrees are used to: 1) run the main canal; 2) engage in informal but traditional river exchanges with neighboring companies along the river; 3) replenish its one company-owned reservoir if needed, and; 4) replenish its water storage options in two other reservoirs owned by neighboring companies. All reservoirs are located high enough to serve the company's entire main canal throughout the **reservoir season** as the river declines in flow rate.

Traditional informal river exchanges and swaps in storage options between neighboring companies help smooth out their individual water supply hydrographs by moving abundant supplies of water during the peak flow of the **river season** to later in the irrigation season when the hydrograph of the river drops drastically, cutting out various water decrees companies have in the river.

Figure 5A and 5B present data on company water supply. This information was collected from company records. Near the end of New Cache's **river season**, it begins to draw from its three reservoir sources. The most important one early in the **reservoir season** is Windsor Reservoir (Figure 4) which is owned by the neighboring company above. This neighbor diverts river decree water of the New Cache through its own main canal for use early in the irrigation season, in exchange for reservoir water out of Windsor Reservoir needed by New Cache for its **reservoir season.**

Similar kinds of exchanges occur with reservoir storage options involving other neighboring companies. The informal rule of the river basin, jointly practiced by all companies, is to store high first and release low first. The river basin companies cooperate with each other, and with the State Engineer's Office, on a daily basis to ensure this practice.

As can be seen in Figure 5A and 5B, the hydrographs for 1991 and 1992 are different. The year 1991 represented a somewhat dryer irrigation season, with earlier and greater reliance on reservoir storage. The year 1992 was an unusually wet season, and reservoir releases were not needed until the ninth week. Major storm events usually result in the closing of the main canal. The company reported that water supplies were good in 1991, and that reliance on their own reservoir (Timnath Reservoir, actually located within a neighboring company service area) was minimal during the **reservoir season.** Water from Fossil Creek Reservoir, in which New Cache has storage options, made up a substantial portion of the **reservoir season** water supply. The year 1992 is turning out to be an unusually wet year, with reservoir releases coming on very late.

3. Potential Sources of Nitrates

Figure 8 shows a variety of potential sources of nitrates, based upon discussion with company board members, management staff and a sample of growers in the area. These various sources actually represent hypotheses being tested through the water sampling data. They are not viewed as alternate hypotheses, but rather separate hypothesis, since all sources are believed to contribute to company main canal nitrate loading to some degree. The numerical scale on the Y-axis is purely arbitrary, and designed to show only relative relationships at this time.

Hypothesis #1. The first hypothesis having to do with predicted changes in the level of nitrates in company canal water has to do with irrigation system runoff in general (Figure 8; RF-I and RF-M). This is because most fertilizer application throughout the area has occurred just prior to the beginning of the irrigation season. In addition, application of fertilizer sidedressing occurs primarily during the **river season** (Figure 2). As the irrigation season progresses, these applications are taken up by plants or gradually washed through the soil profile, minimizing surface runoff of nitrates back into the company canal late in the season.

An important point should be made here. All of the irrigated area served by New Cache is below its main canal. Irrigated acreage above the main canal is in a neighboring company service area (Figure 4). This means that nitrate loading in the New Cache canal is very much a function of irrigation and fertilizer application scheduling in this neighboring company service area. However, a preliminary survey indicated that the cropping pattern and application scheduling of this neighboring company is very similar to New Cache.

Hypothesis #2. The second hypothesis having to do with changes in the level of nitrates in company canal water predicts that an increase in nitrates will generally occur when a storm event occurs in the **river season**, whereas such an event will produce minimal nitrate loading in the **reservoir season** (Figure 8, shaded boxes). However, the real issue the degree to which a storm event occurs during the period of sidedressing application.

<u>Hypothesis #3, #4 and #5</u>. These hypotheses propose that nitrate loading in the main canal is primarily a function of water quality conditions in the three reservoirs. Windsor Reservoir (Figure 4) is predicted to have the lowest level of nitrates of the three because a large portion of its storage is direct river flow via the Larimer and Weld Company Canal, although some nitrates are probably being picked up from yet another company service area above this canal.

Fossil Creek Reservoir is predicted to have the next highest level of nitrate loading, primarily through storm drain return flows from the City of Fort Collins, and one of the city treatment plants that disposes effluent into the reservoir.

Finally, the company-owned Timnath Reservoir is predicted to have the highest level of nitrates, primarily because it receives a substantial portion of non-decreed effluent from one of the other City of Fort Collins water treatment plants. If the company has had to draw upon this reservoir substantially during the **reservoir season**, it will be filled during the winter reservoir storage season directly from the river, which regularly receives treated city effluent just above the reservoir inlet.

<u>Hypothesis #6</u>. The final hypothesis concerns potential nitrate contributions from the river itself. It is expected to be minimal, if at all, and occurring primarily during the **river**

season when it is used as a principal supply source. There are no other apparent sources of nitrates or heavy metals. The headwaters of the Cache La Poudre River were not heavily mined as were other Colorado rivers around the turn of the Century.

4. Summer Weather Patterns

Some mention should be made of summer weather patterns in general, and their potential impact on nitrate levels. Company management staff and growers regularly refer to a local weather phenomenon termed the "July Monsoons" (Figure 8 and 9). These rains, which frequently occur in the early to middle part of July generally determine whether the irrigation season will be a wet or dry one for growers; winter snowfall and high country reservoir storage aside.

The analysis of thirty years of precipitation for the City of Fort Collins shows a clear increase in precipitation during the month of July, following a gradual decline in June from the highest annual precipitation which occurs in the month of May. In fact, there are only two significant weather months in the local eco-system; 1) the Spring season precipitation occurring from the middle of April to the end of May, and; 2) the July "monsoon" from the middle of July to the middle of August. The probability of receiving more than .01" of precipitation on any day outside of these two periods is only twenty percent (Kleist, et al; 1991).

5. Potential Demand and Risk of Nitrates

Figure 2 presents actual data collected through the company-sponsored questionnaire administered in the Fall of 1991. It indicates that a maximum of seventeen percent of the service area acreage actually receives sidedressing applications (week 3 through 7). Figure 2 indirectly shows the currently known potential grower demand for recyclable nitrates in canal water, as well as the potential risk of high nitrate concentrations to certain crops. Potential grower demand for available canal water nitrates is simply equivalent to when sidedressing applications are generally made. Potential risk from high nitrates was derived from the questionnaire which asked at what point in the season certain crops would be at high risk from water-bearing nitrates (see questionnaire in Appendix A; Question 2).

In order to more properly match canal nitrate loading with nitrate demand and risk, the company is investigating ways in which canal nitrate loading might be adjusted to better fit the nitrate demand and risk curves. Using management options on how various water supplies (river and reservoirs) can be drawn and blended during the irrigation season, the nitrate loading curve (discussed next) would be physically manipulated to achieve a peak during the period of sidedressing application while being minimized during high risk periods for such crops as sugar beets, brew barley, etc.

By way of a reliable data base developed over several years, the management staff of the company would then be able to adjust reservoir releases in a way that allowed shareholders to maximize the use of available nitrates in the canal water while minimizing the impact of nitrates on sensitive crops; in other words, pushing any existing nitrate loading curve under the sidedressing application curve to make a better fit.

6. Results of Nitrate Sampling

The results of nitrate sampling during the irrigation season of 1992 are shown in Figure 3A and 3B. The twelve stations or data points shown in Figure 4 have been collapsed and averaged to better display seasonal trends. Figure 3A and 3B, then, represent an initial, and tentative, nitrate loading curve. Figure 3A represents the loading curve at the head of the main canal, while Figure 3B represents this curve at the tail. These curves would be refined in measurement through subsequent water testing under normal company operating conditions before manipulations were made in water supply to potentially adjust them.

Although the data is preliminary, and as yet insufficient to really test any of the six hypotheses previously stated, the following interpretations are being considered.

<u>Hypothesis #1.</u> The higher nitrate levels at the beginning of the irrigation season (Figure 3A and 3B) are attributed by the company superintendent to the flushing out of the main canal, when water is first diverted from the river and winter debris is pushed out.

Another interpretation, one currently preferred by the researcher, is that the early high readings are a function of the first flushing of the irrigation season of the pre-emergent fertilizer that the majority of growers apply. The return flows following initial irrigations are entering the main canal and increasing the nitrate readings. The nitrate readings then subside as this flushing is completed, but begin to increase again during week 5 through 8 as sidedressing applications are performed while irrigation continues.

There are two pieces of data which suggest that the week 5 through 8 increase in nitrate loading is directly related to **river season** sidedressing applications. The first is the close conformity of the sidedressing application rates reported by the growers in the questionnaire and the nitrate readings themselves. Week #4 of the irrigation season roughly corresponds to the beginning of June when the nitrate readings begin to climb. However, it is important to note that much of the nitrate coming into the canal is most likely coming from the neighboring company service area above. This neighboring company is generally believed to have the same cropping pattern, and hence the same sidedressing application scheduling pattern, as the New Cache company service area.

Other source supplies of nitrates seem to be precluded because week 5 through 8 water supplies are coming primarily from a rather fresh supply of river water, and not from the nitrate-bearing sources of company reservoirs. Finally, the nitrate levels begin to decline in week 9 and 10 as sidedressing applications tail off.

Hypothesis #2. This hypothesis predicts some relationship between canal nitrate loading and storm events. The major storm event of the 1992 irrigation season that temporarily closed down the main canal (Figure 5A) appeared to correspond to a high nitrate reading at the head of the canal. Due to the storm, there were no water samples taken at any of the canal data points during week 8.

Hypothesis #3, #4 and #5. These hypotheses predict some relationship between reservoir storage releases and nitrate loading. Figure 3A shows an increase in nitrate levels roughly corresponding with the release of water from Timnath Reservoir, which is heavily laden with nitrates from city effluent. Although at the time of publication the irrigation season was not over, it is quite possible that this trend will continue if the nitrate-bearing sources of Timnath and Fossil Creek reservoirs continue to be used.

Some interpretation should be given to why "source" readings are usually lagging behind "ditch" readings, since this seems counter-intuitive in some instances. The "sources" tracked in Figure 3B are three draws bringing return flows into the company canal from a neighboring company service area above. It is believed that the "ditch" nitrate readings are a function of these draws, plus additional field runoff and reservoir flows entering the main canal above these data points.

The lag of "source" readings beginning from the crossover in Figure 3A are believed to be a function of the storm event runoff in week 8 and 9, which dramatically increased canal nitrate loading. The higher source readings subsequent to week #10 are clearly related to the beginning of releases from Timnath Reservoir. These "source" values appear to be quickly diluted as reservoir releases enter the main stem canal.

Hypothesis #6. At the current stage of this baseline data collection effort, it is simply not possible to comment on the relationship between river water usage and canal nitrate loading, although again it is believed to be minimal. This is because the headworks of the New Cache canal are high up in the river basin, before return flows from irrigated lands throughout the river basin begin to make an impact on the quality of water in the river itself.

In closing, it must be admitted that the potential use of canal nitrates to supplement seasonal sidedressing in this company service area appears to be minimal. The canal nitrate readings are so low as to preclude any beneficial use to company shareholders. If one converts a nitrate reading of five parts per million into pounds of nitrogen per acre inch of water, the yield would be about 3/4 of a pound of nitrogen for an average irrigation application of three acre feet of water for the season.

7. Summary and Future Research Needs

The 1991 and 1992 research seasons revealed many interesting facets of this case study company operation, particularly the potential degree of flexibility in managing water supplies to better fit the actual nitrate loading in the main canal with potential demand and risk curves linked to cropping patterns. Most of the information on management operation was gathered through a series of in-depth interviews with growers and the company superintendent. These recorded interviews provide a wealth of information on the kinds of management options that might be considered in the future once more complete baseline data on nitrate levels have been gathered.

The network of gauging stations shown in Figure 4 represents what the principal investigator regards as just sufficient to evaluate the affects of nitrate loading from the major irrigation water sources, on the spatial and temporal distribution of nitrate levels in the main canal. One potential limitation in this method is that the three reservoirs do not comprise 100% of the supplemental water inflow to the canal. Subsurface return flow may contribute to the total nitrate loading in the canal. With the proposed scheme of data collection, the latter cannot be explicitly measured. A much more sophisticated sampling strategy would be required to isolate and quantify all potential sources of nitrate loading, which is beyond the scope of the research at this time. However, the research team did have specific "source hypotheses" to test (Figure 8).

Although the research employs a case study approach to analysis, it is argued that information gathered from the research can be replicated throughout the river basin, and quite possibly into neighboring basins, such as the South Platte River. There are virtually hundreds of mutual irrigation companies in neighboring tributary basins. It is anticipated that once the practicality and management techniques of this program are known and adopted by the case study area, many other irrigation companies will began to evaluate the applicability of this management tool to their normal water management program. One neighboring company above New Cache has expressed interest in possibly participating in the future.

CONCLUSION

The mutual irrigation company organizational form has probably been one of the more successful water management traditions, particularly if one includes its sister-form, the Spanish "acequia" (Hutchins, 1928; Maass and Anderson, 1979). Many less developed nations are looking to mutual companies and the Spanish tradition as prototype models to improve what is frequently a poorly performing public irrigation sector (personal observation from irrigation management training conducted recently in Spain, Sri Lanka, Pakistan and Nepal). This organizational type appears to out-perform many public-funded irrigation districts and water user associations in the United States as well. Public-funded irrigation districts traditionally have had poor internal rates of return on their investment (Leshy, 1982).

As noted by an early observer of mutual irrigation companies at a time when the Nation, as well as the farming community, were looking for successful models of locality-based farmer organizations to shore up a sagging agricultural sector, the mutual irrigation company represents a very complex organizational and property right tradition (Hutchins, 1936b). It is an organizational form not without its problems, and has been particularly resilient to investigation by social scientists since the 1930's. In fact, the complaint has been made that these organizations tend to function like "secret societies".

However, the most successful companies have been those which have sought new missions above the traditional ones of water development, such as improved water management, including local rental markets within their service areas or between neighboring companies (Maass and Anderson, 1979). It is believed that these organizations constitute one of the foundations of agrarian democracy, as well as being an appropriate vehicle for community participation in natural resource management. They appear to be under threat by investigators and commentators who frequently fail to understand the importance of this water culture to American agriculture. Arguments that mutual irrigation companies dry up rivers and convert marginal land into poorly sustainable agricultural production appear to be somewhat over-simplified. Such arguments may be more appropriate to the public irrigation sector of frequently over-designed and unnecessarily expensive irrigation district "construction projects" that farmers can never hope to pay for, than they are of the mutual irrigation company tradition involving locally-generated capital through shareholder assessments.

Extensive research is needed on how to improve the performance of this organizational culture, but it will be difficult to conduct at best. Instead of attempting to understand and learn from the strength and weaknesses of these organizations in American agriculture, in a true sociological sense, some have criticized their legal foundation in the western prior appropriation doctrine, frequently claiming that such a doctrine is unsuitable to environmentally sound water resource management. It is nearly impossible to conduct social and organizational research on this "water culture" at present because the layman irrigation community feels threatened by a well-educated community seemingly bent on destroying what has taken over one-hundred and fifty years to build. Agriculturalists in the West claim that those advocating a strict riparian doctrine, more regulatory control of irrigation water use, and rationalization of water distribution through robust, free-wheeling water markets have yet to show how such approaches could sustain irrigated agriculture in the future.

Research is greatly needed on the operation and management of mutual irrigation companies, to understand ways in which their role in water management can be expanded. This research will involve cultivating a degree of trust and considerable sensitivity to the social values and patterns of interaction represented by this tradition.

In the search for solutions to environmental problems, much greater promise might be expected from social change strategies which focus on locality-based collective organizational responses. The focus of the research reported in this paper represents an attempt to understand how previous organizationally successful responses can be re-directed into natural resource management areas involving new environmental imperatives.

Water quality management is not a public issue easily addressed without the active cooperation and participation of local community members in a constructive, as opposed to an accusatory, manner. Mutual irrigation companies appear to be ready to approach the task of water quality monitoring in a way that could save the state central treasury an enormous amount of money typically invested in centralized agency program administration. The issue of local control over natural resource management has been continually expressed from the community-at-large. These locality-based companies appear to be well-suited to fulfilling an expanded role in water resource management, commensurate with their traditional role in water management.

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Figure 1
Percent Of Area In Each Crop
(Company Service Area)

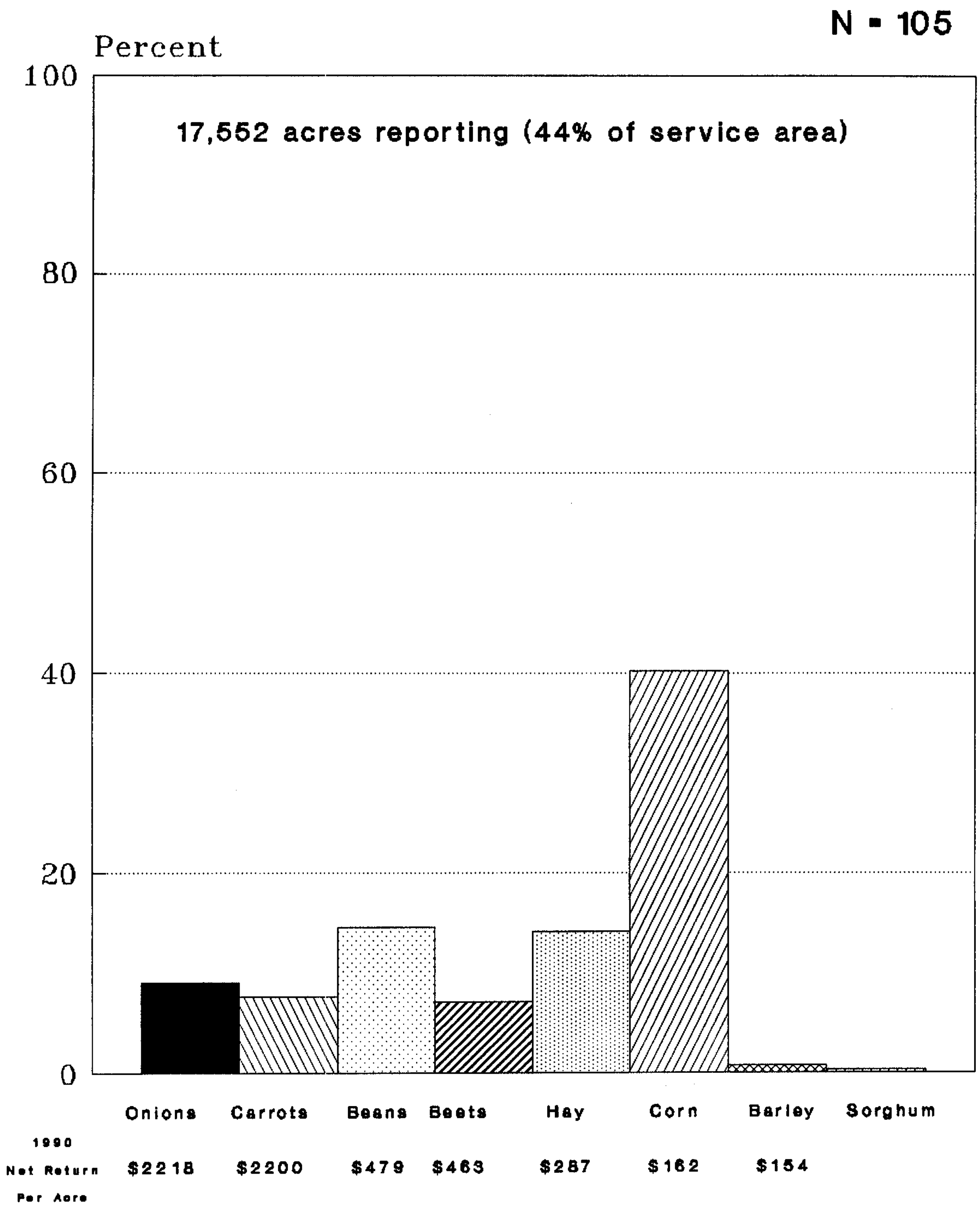
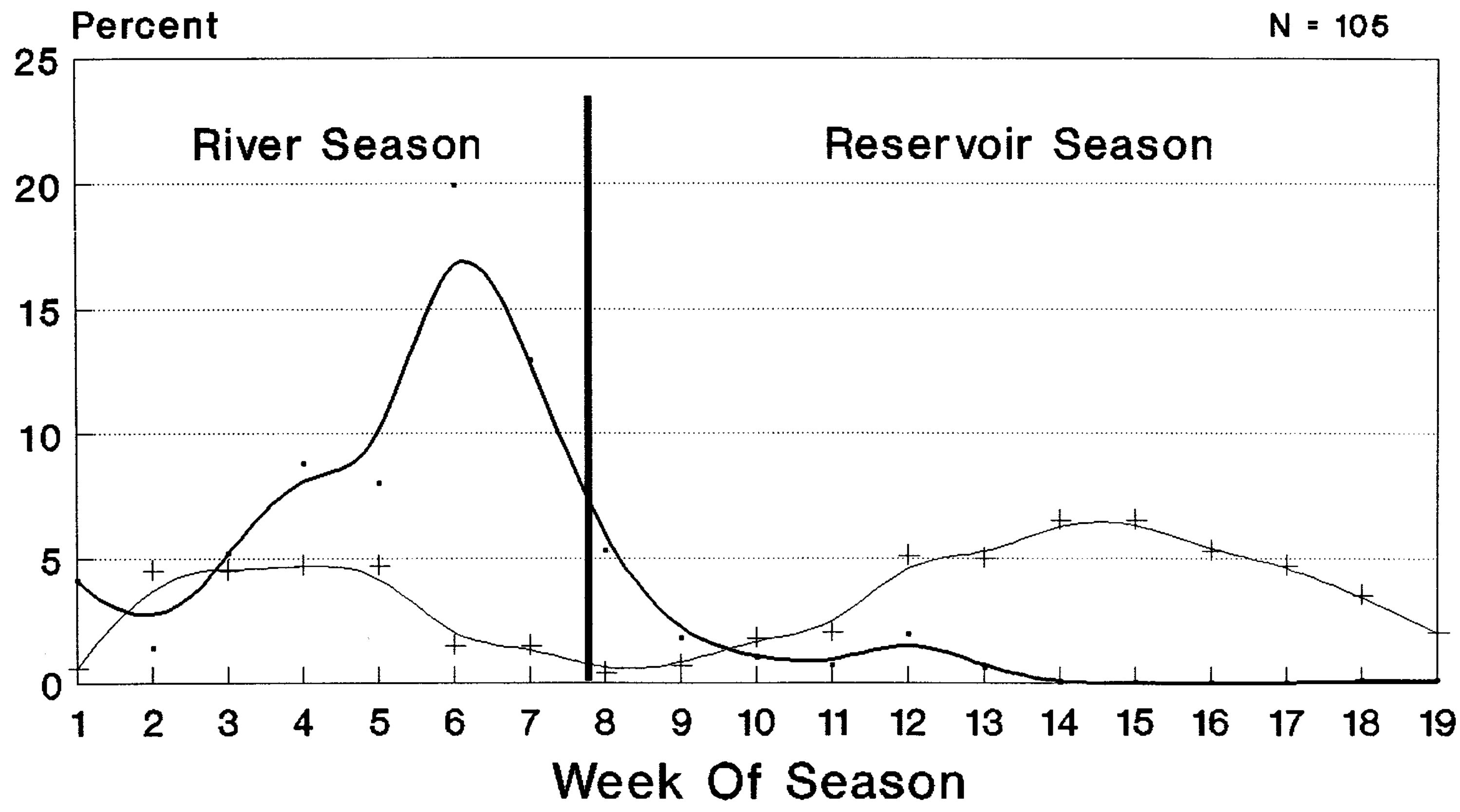


Figure 2

Potential Demand And Risk Of N
(Percent Of Total Reported Acreage)



17,552 Acres Reporting (approximately 44% of service area)

Figure 3A
1992 Nitrate Concentrations
New Cache La Poudre Irrigating Company

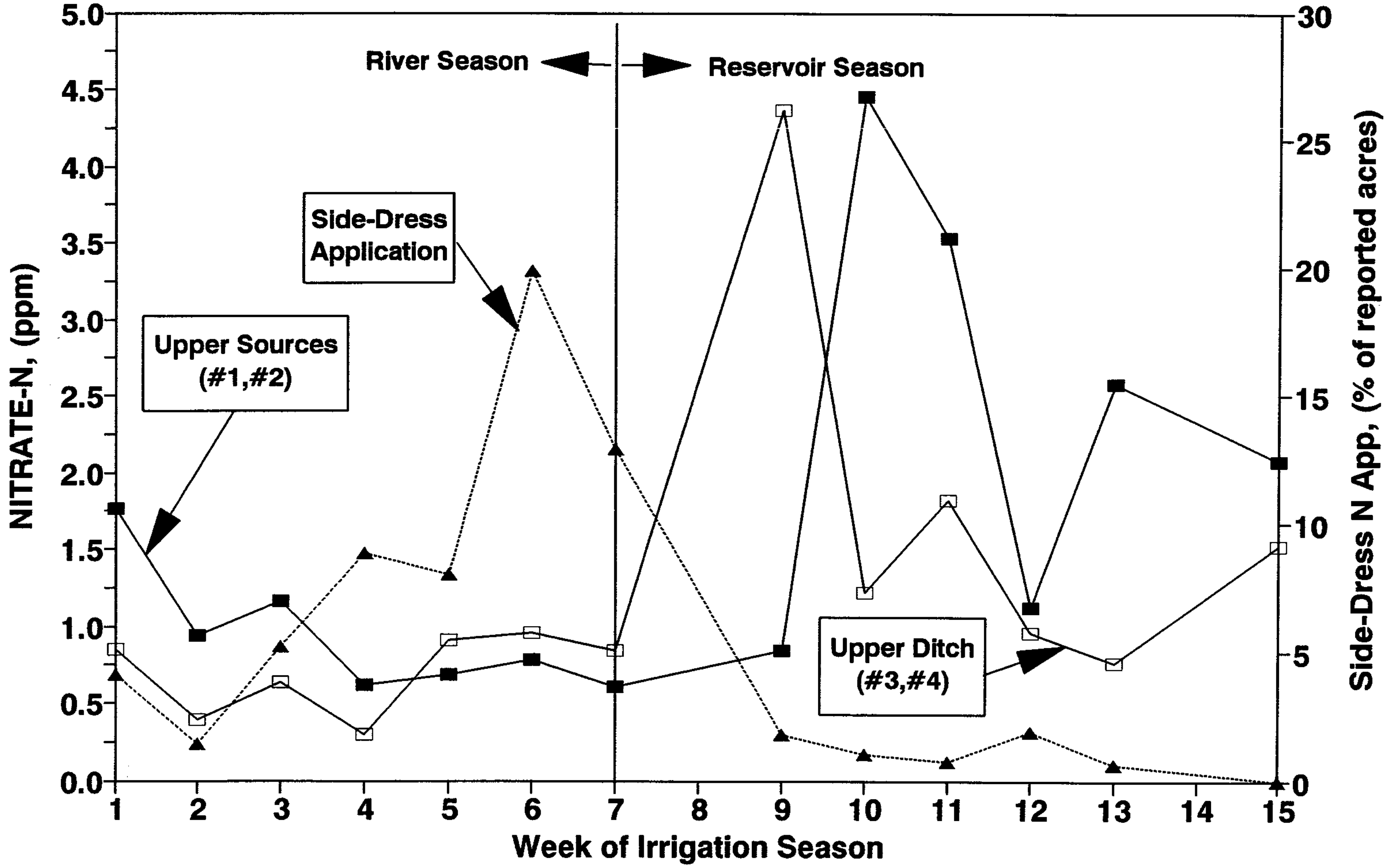


Figure 3B
1992 Nitrate Concentrations
New Cache La Poudre Irrigating Company

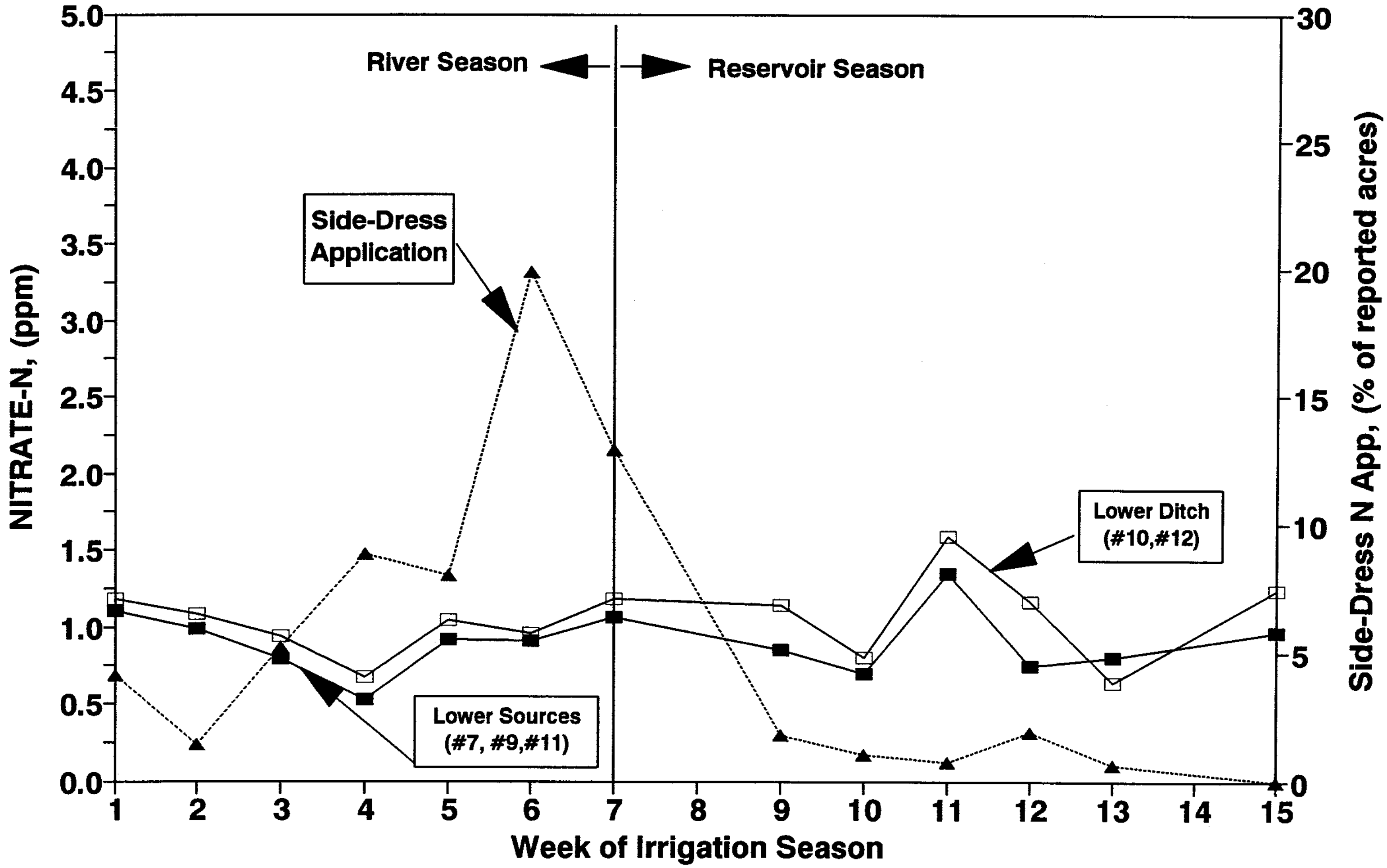


Figure 4: Local Canal and Reservoir System

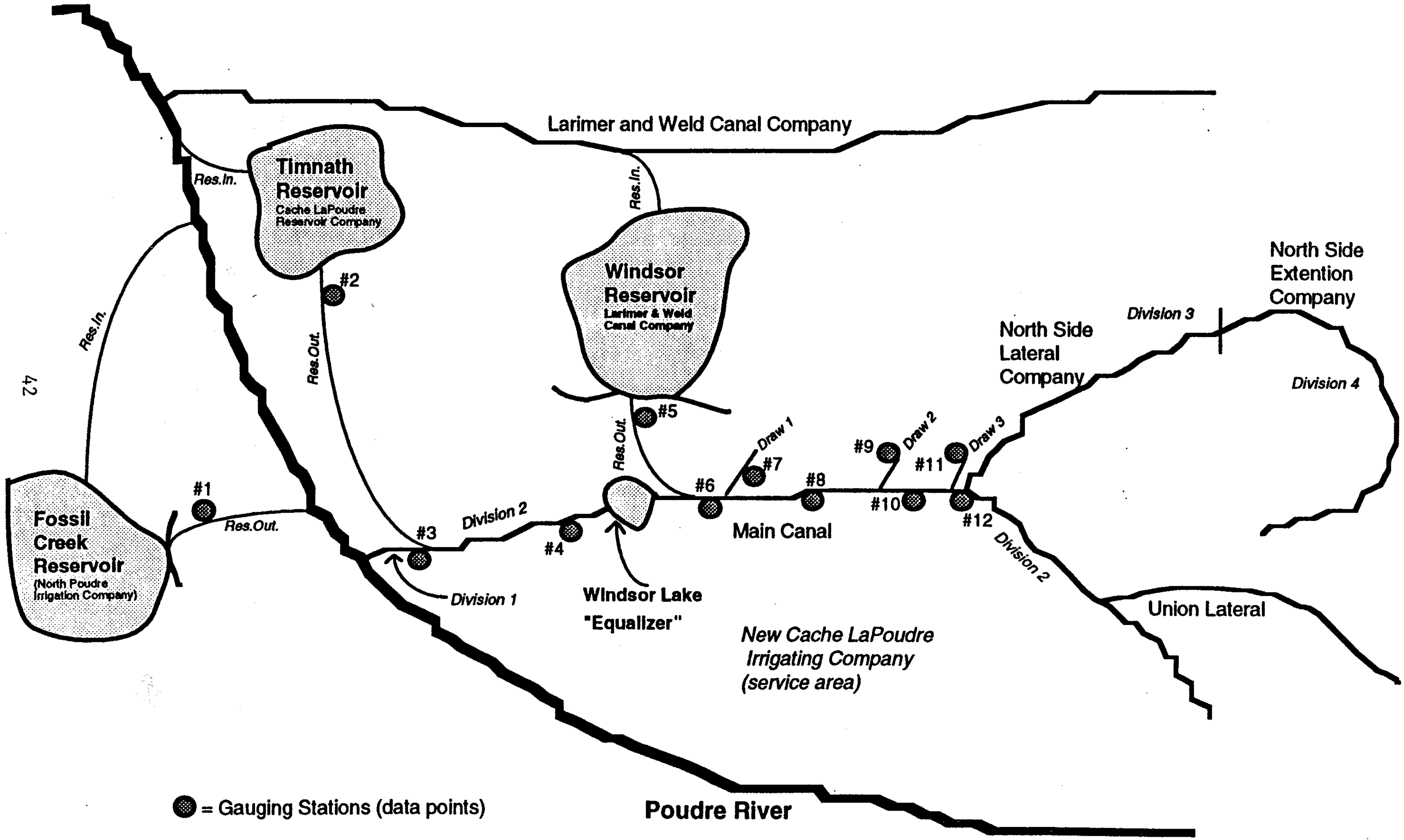


Figure 5A
1992 Seasonal Water Volumes
New Cache La Poudre Irrigating Company

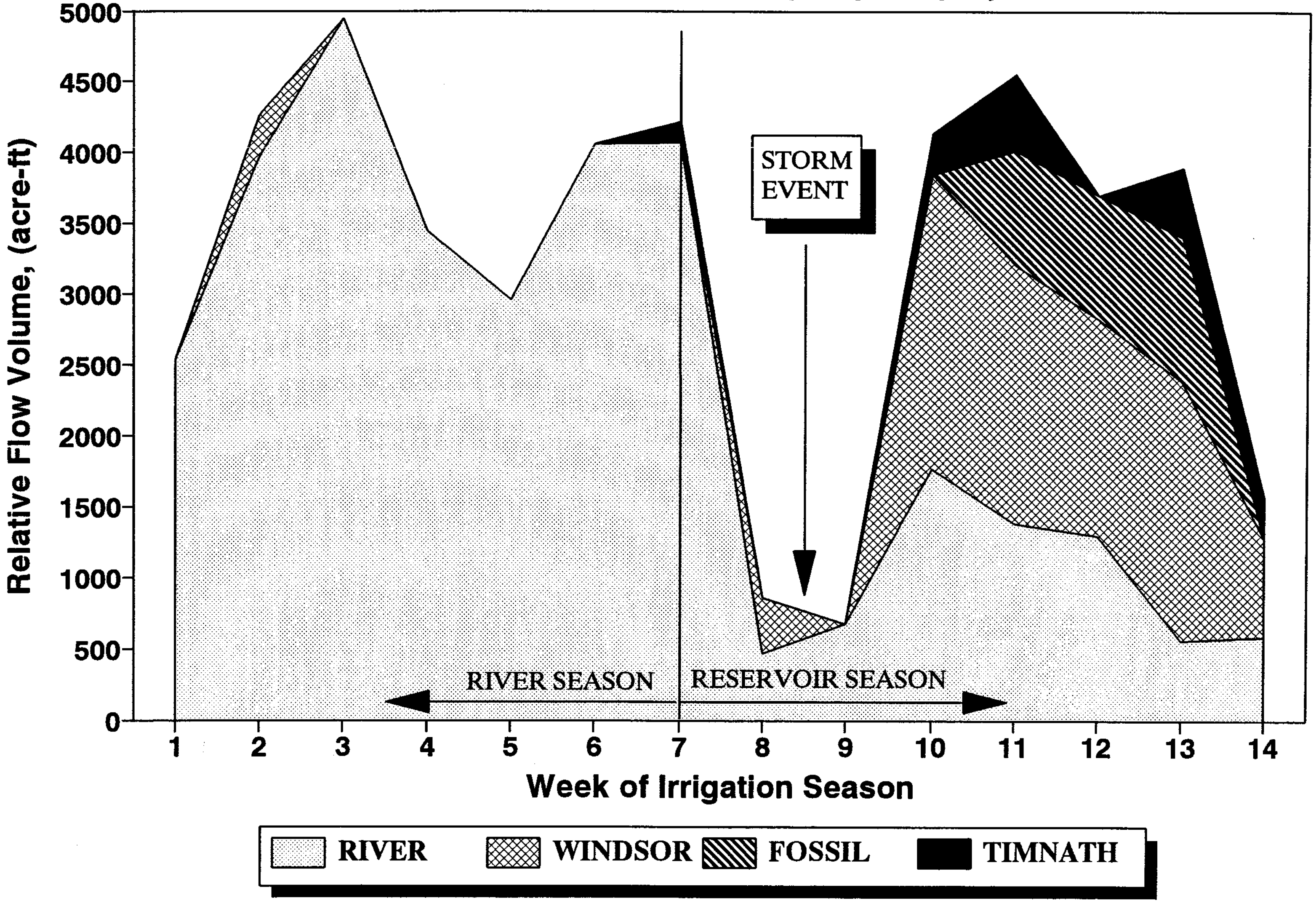


Figure 5B
1991 Seasonal Water Volumes
New Cache La Poudre Irrigating Company

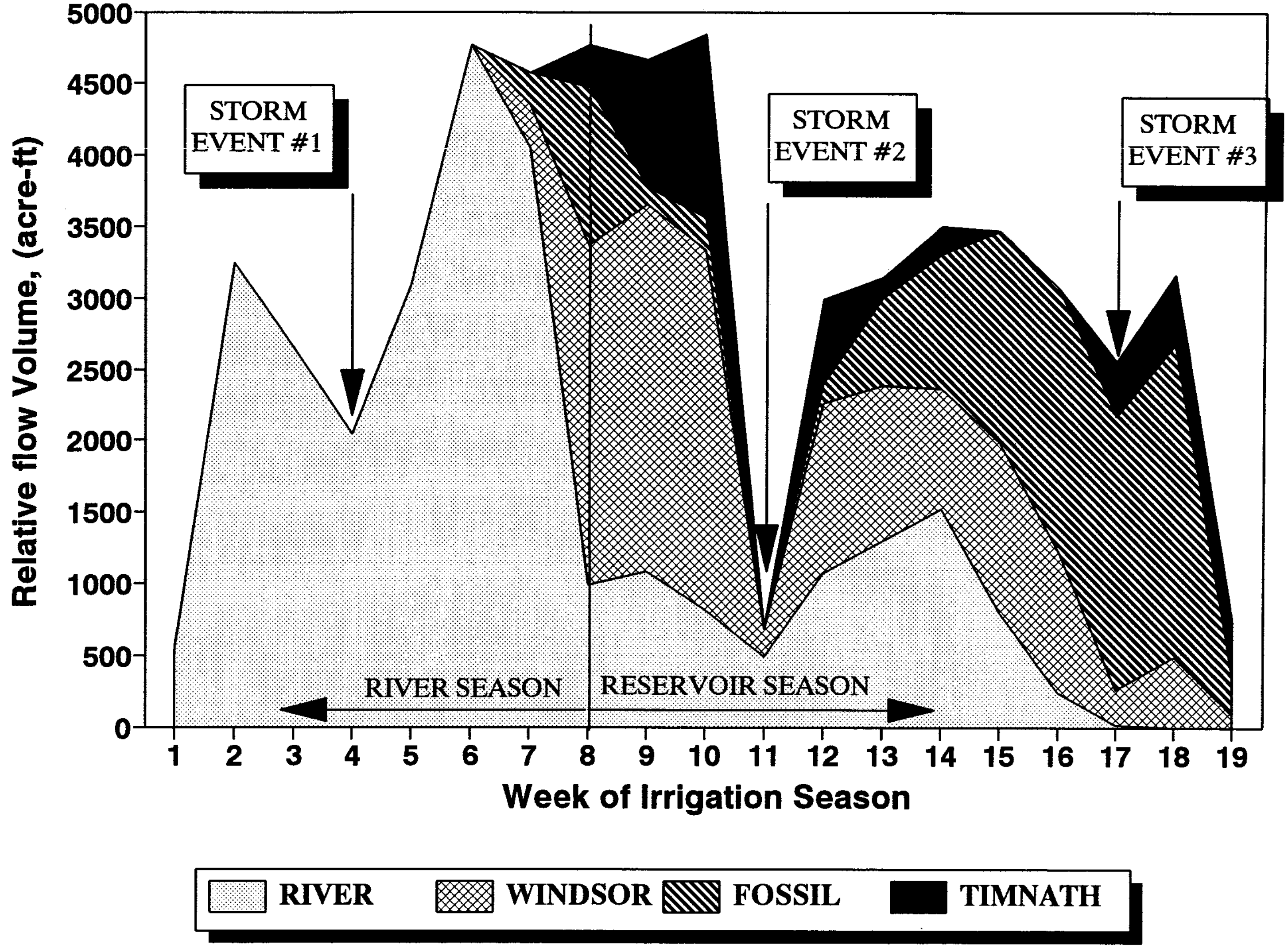


Figure 6
1992 NITRATE CONCENTRATIONS FOR SOURCES

New Cache La Poudre irrigating Company

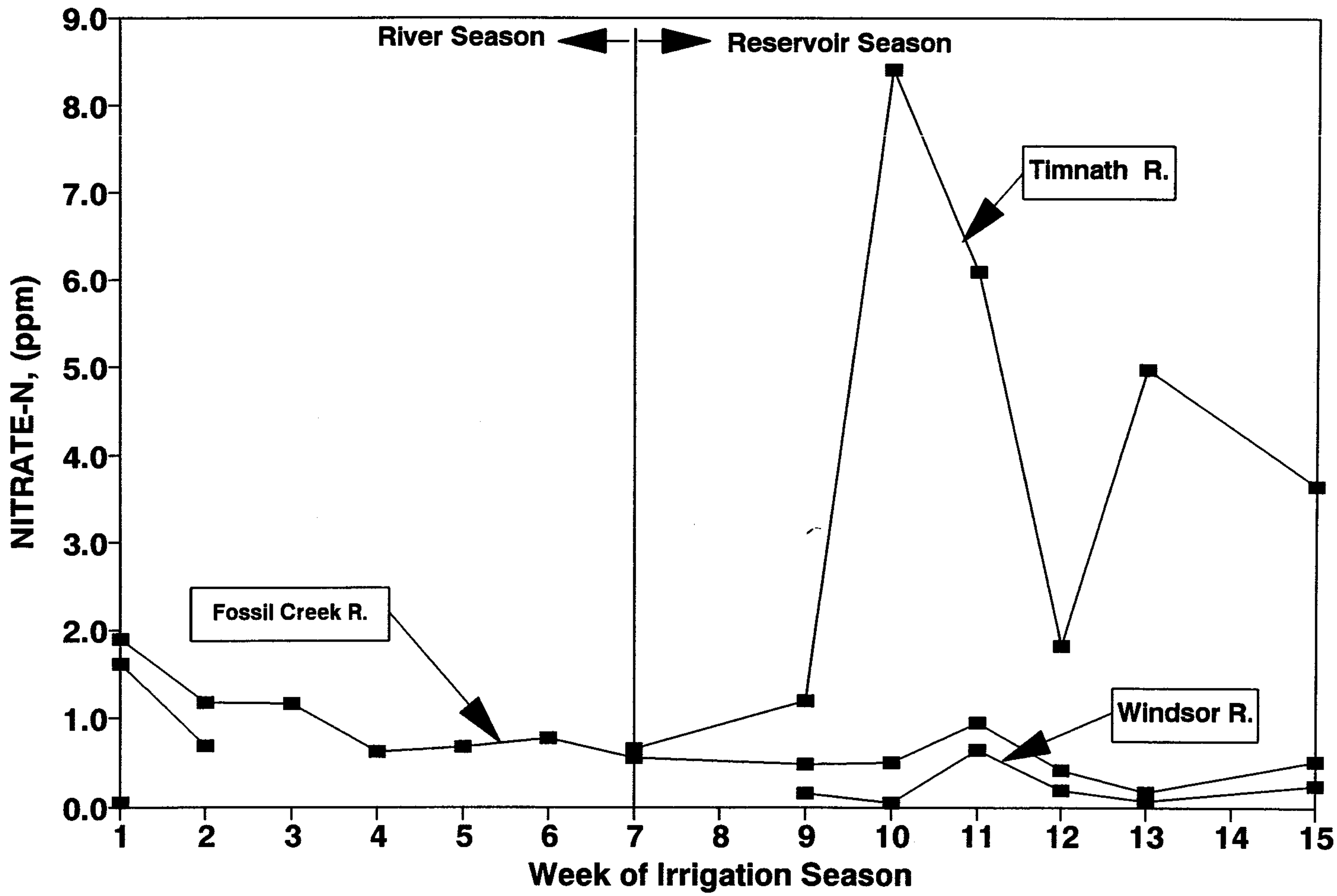


Figure 7
1992 Nitrate Concentrations for Canal
New Cache La Poudre Irrigating Company

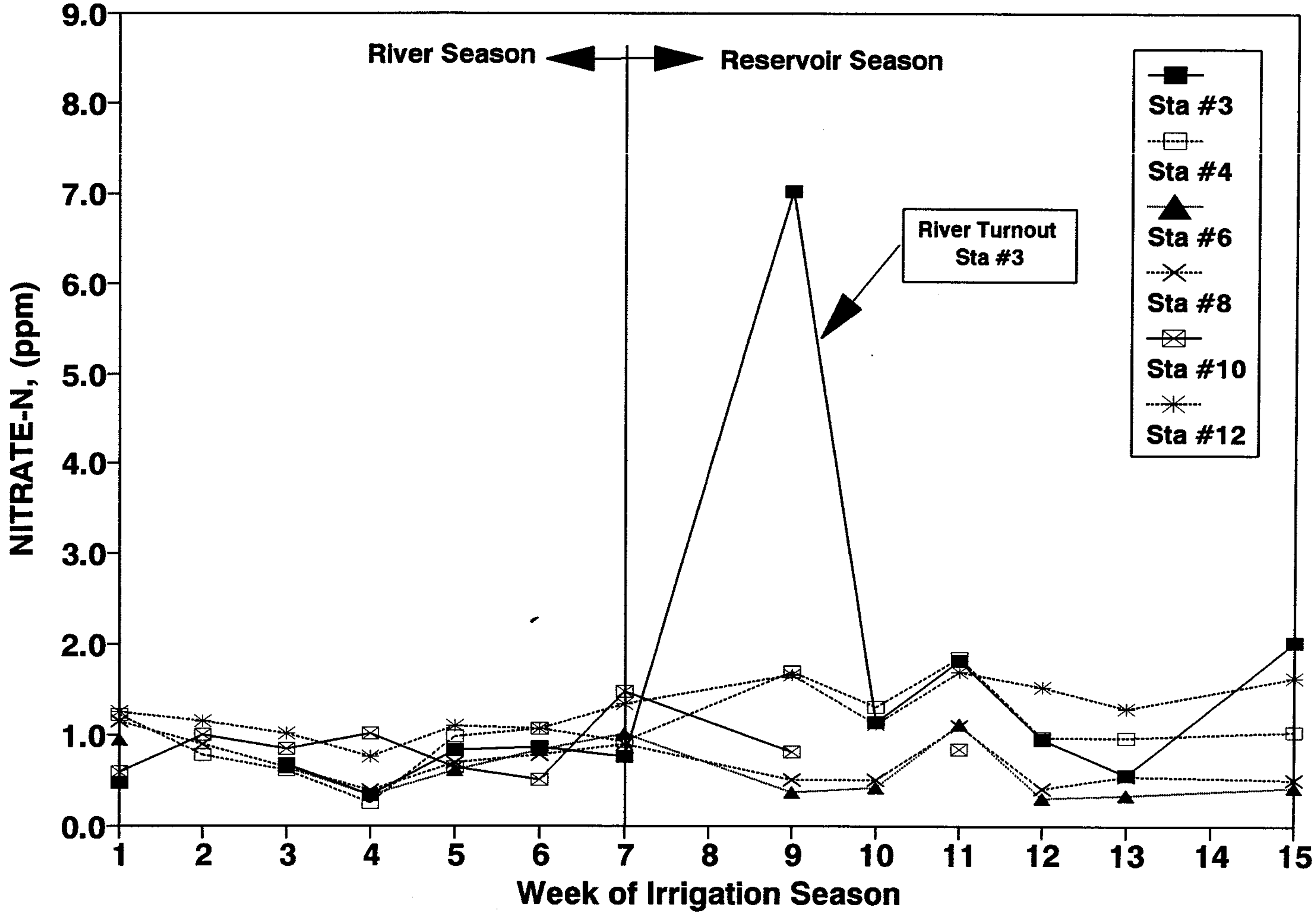


Figure 8
Potential Sources Of Nitrates
(Company Service Area)

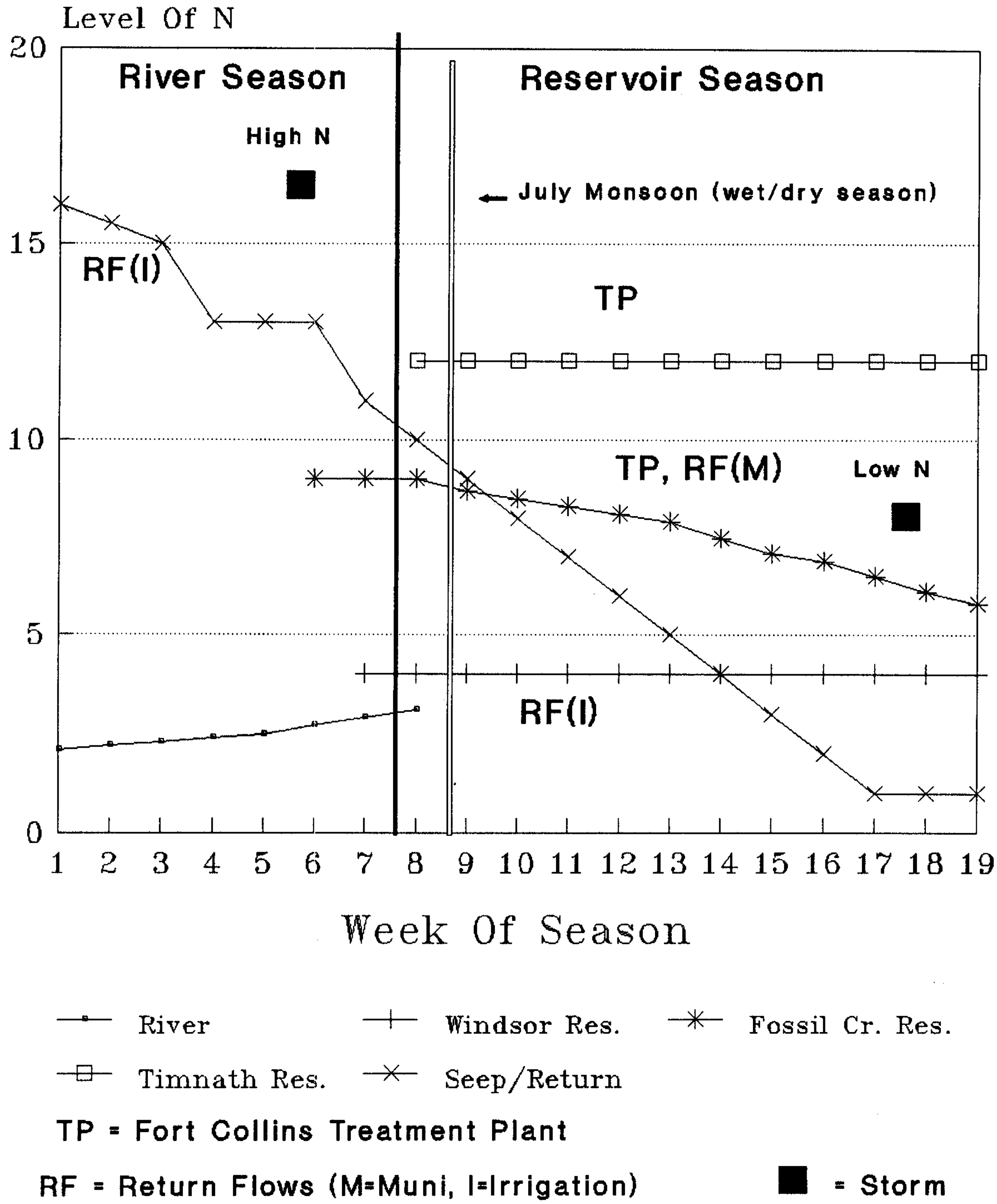
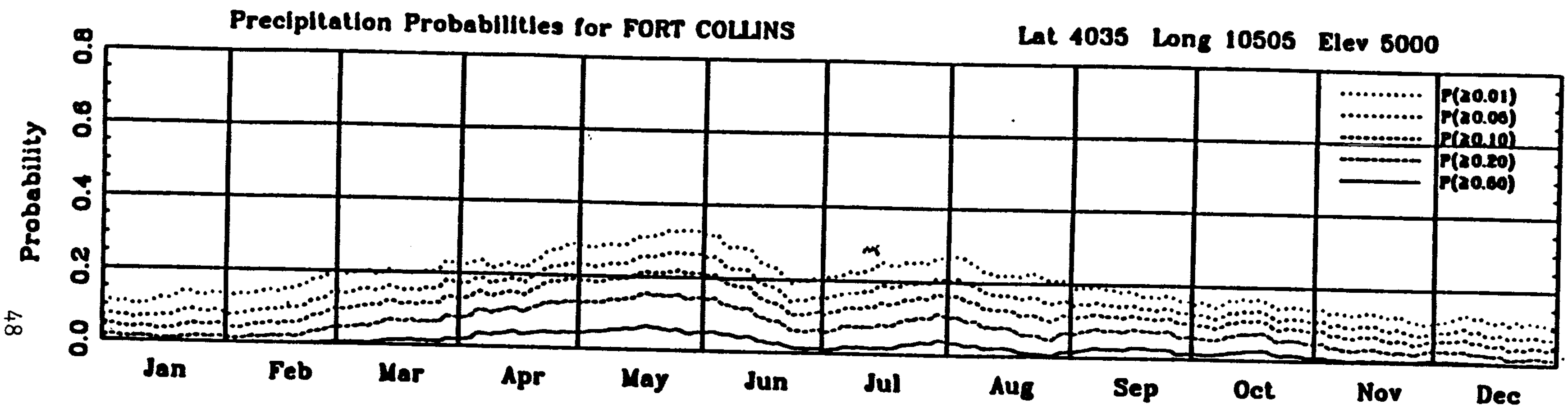


Figure 9



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APPENDIX A

QUESTIONNAIRE

Canal Nutrient Loading Study - Company Questionnaire

Division I

The following Greeley #2 delivery schedule for 1991 has been provided to help you recollect the irrigation season in answering the four questions below. Note that each box represents a delivery week, beginning on a Tues day and ending on a Monday. The reservoir season is noted by shaded boxes.

According to our company records, you ordered water at some time during each week stamped with an "X" below.*

	May 14 To May 20	May 21 To May 27	May 28 To Jun 3	Jun 4 To Jun 10	Jun 11 To Jun 17	Jun 18 To Jun 24	Jun 25 To Jul 1	Jul 2 To Jul 8	Jul 9 To Jul 15	Jul 16 To Jul 22	Jul 23 To Jul 29	Jul 30 To Aug 5	Aug 6 To Aug 12	Aug 13 To Aug 19	Aug 20 To Aug 26	Aug 27 To Sep 2	Sep 3 To Sep 9	Sep 10 To Sep 16	Sep 17 To Sep 23	
		X	X					X	X	X		X	X	X	X	X	X			
Field Crops:																				
Barley, brew																				
Beans, dry edible																				
Corn, grain							25													45
Corn, silage								75												55
Hay, alfalfa																				21
Hay, other																				30
Oats																				
Potatoes, summer																				
Sorghum, grain																				
Sorghum, silage																				
Sugar beets																				
Wheat, spring													R	R	R	R	R			10
Wheat, winter																				
Other crop______																				
Other crop______																				
Vegetables:																				
Carrots																				
Corn, sweet																				
Cucumbers																				
Lettuce																				
Onions																				
Tomatoes																				
Cabbage																				
Other crop______																				

Question #1
The following question seeks information, by company division, on sidedressing application patterns in the company service area during the past season. Please identify the crops you grew from the list above. If a crop you grew is not listed, print it in the space provided next to "other crop". For each crop you grew, move carefully to the right through the weeks of the season and mark an "S" ("S" = sidedressing) whenever you applied a sidedressing to it. You may have made more than one application for a particular crop. If you remember the actual amount of a particular application (lbs. per acre), please enter the amount instead of an "S".

Question #4
Do you have well water to mix with surface water supplies if a "high nitrate level" was reported by the company during the course of the season, based on reliable information developed by the company in the future? Yes___ No X

Question #2
The following question seeks information, by company division, on farm operations potentially at risk from unusually high nitrate levels in Greeley #2 during the course of an irrigation season. Again, refer to the same list of crops above. For each crop you grew, move to the right through the weeks of the season and mark an "R" ("R" = risk) where an ***unusually high*** *nitrate level in Greeley #2 could conceivably have affected your targeted yield* ***negatively****, regardless of whether or not you were in a position to dilute such unusually high levels with well water.*

** Information on river season orders is not available for growers located on the Northside Lateral and Northside Extension.*

I

Question #3
In the column above, please enter your total acreage in each crop.