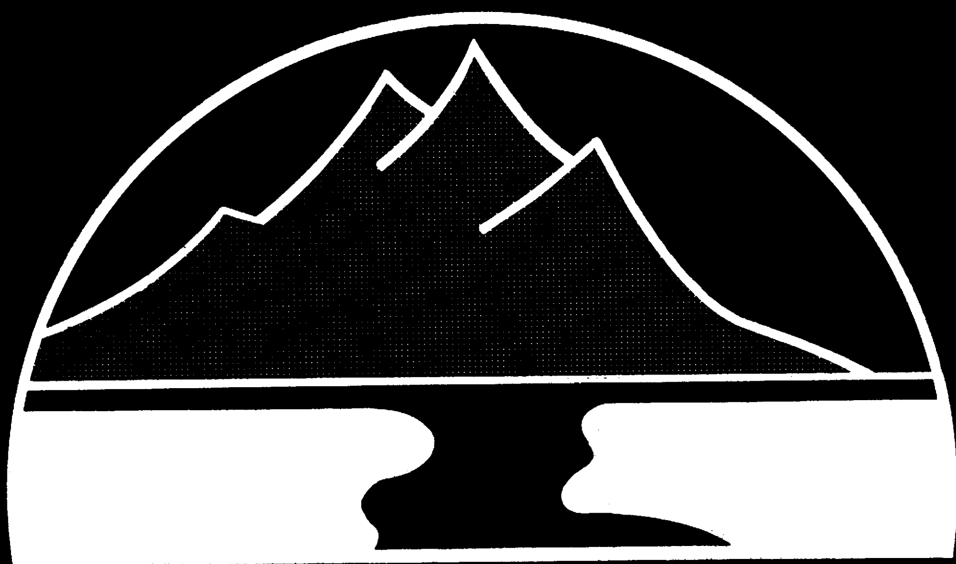
Proceedings

Wyoming Water 1986 And Streamside Zone Conference

Wyoming's Water Doesn't Wait While We Debate



Casper, Wyoming
April 28-30, 1986

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Wyoming Water Research Center
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PREFACE

Water and streamside zones are critical to the future of Wyoming. Both the state's economy and its renowned lifestyle depend upon positive decision-making and constructive public policy toward water and related resources.

The papers included in these proceedings were submitted by speakers at the Wyoming Water '86 and Streamside Zones Conference held in Casper, Wyoming, April 28-30, 1986. In many cases the papers expand upon and include more detail than was possible to cover in the speakers' oral presentations. On the other hand, many speakers used slides to visually illustrate their comments, and regretfully such vivid images cannot be duplicated in these proceedings. Papers submitted by the authors underwent only minor editing. In no case were the statements or intent of the author changed.

This 1986 conference was the first time such a diverse subject has been addressed in Wyoming related to water and riparian zones. But this diversity reflects the wide interest within Wyoming and the breadth of on-going research and concern by rangeland managers and water administrators.

More than 200 participants from Wyoming and the West enjoyed the presentations first hand and took advantage of the opportunity to question the speakers and study more than 20 exhibits of current activities in Wyoming.

These proceedings are published to provide a record of the excellent presentations both for the conference participants and for those who could not attend. Hopefully the conference has contributed to better informed public opinion so necessary to productive public debate concerning the future of Wyoming.

Coordinators:

Donald J. Brosz, Associate Director for Information and Extension
Wyoming Water Research Center
University of Wyoming

J. Daniel Rodgers, Extension Specialist
Range Management Department
University of Wyoming

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CHARACTERIZING RIPARIAN ZONES

Clayton B. Marlow[1]

Prior to 1977, the term "riparian" meant little to the general public. Although water judges and fisheries biologists were familiar with the environmental features described by the word riparian, there were many who secretly believed riparians were cousins of the shy little artesians who flavored a Northwest beer. Public awareness of what is "riparian zone" really was and its role in the human environment began with a series of regional and national conferences in 1977 and 1978. Interest and involvement in riparian protection and rehabilitation has grown steadily with additional conferences in 1980, 1981, and 1984. Concern with riparian issues has grown to the point that in July, 1985, the Bureau of Land Management published a draft Riparian Management policy for public lands under its jurisdiction. The effectiveness of this and any other policy depends upon the knowledge and experience of both those who formulate the policy and those of us who review the drafts. Basic to our understanding of how to manage and protect riparian zones is the knowledge of those characteristics which create this unique landscape feature.

If you were asked to define or describe a riparian zone, what would you say? Lawyers and administrators may describe it as that portion of a stream or river channel which carries water during all or part of the year, an engineer or geohydrologist may define it in terms of flood events and groundwater recharge patterns while a fisheries biologist may discuss the type of streamside vegetation and the shape of banks. Even though it would be more convenient to select one of these definitions for common use, a riparian zone is all of these things and more.

Riparian zones probably support the most complex natural communities in the Intermountain West. Both the number of plant and animal species and the intricate interdependence of living and nonliving components of the community give rise to this complexity. Streamflow duration, wildlife populations and the type of vegetation growing along streambanks are very obvious components of the riparian zone, but the whole ecological community is greater than the sum of these parts. Trout, deer, beaver, songbirds, and livestock depend upon the diverse and abundant vegetation of the riparian zone for all or part of their existence. Although some animal species, such as beaver, may modify the plant community, it is the local hydrologic cycle which shapes the character and structure of the riparian zone. The hydrologic cycle is, in turn, formed by the local and regional climate, geologic structure and soils. Examination of how a riparian zone is formed and develops can illustrate the role of the hydrologic cycle, geology, and soils in creating the character or appearance of a riparian ecosystem.

A drainage will pass through four general phases (Fig. 1) as it progresses to equilibrium or harmony with the physical environment.

Stage I. Flow is intermittent or seasonal and usually destructive, heavily scouring the channel bed and walls. Soil is poorly developed and the vegetation community is dominated by annual or short-lived perennial plants.

Stage II. Channel and bank erosion has been reduced and sediment deposition provides the basic material for soil development. Soil formation is enhanced by increased plant cover. The presence of more vegetation protects banks by slowing streamflow, thereby decreasing its erosive power. Reduced water velocity allows sediment to settle out, further improving soil development.

Stage III. As soil development continues, streamflow gradually becomes perennial rather than seasonal. The vegetative community is developing rapidly with more individual plants and more plant species occupying the banks and immediately adjacent areas. The additional plant cover slows runoff in the channel and overland flow from the uplands which increases sediment deposition and begins the formation of floodplains or terraces. Rather than being straight, the channel has begun to meander, further reducing water velocity and decreasing the destructive potential of runoff events. Because of diverse and abundant vegetation and perennial flow, wildlife numbers increase, and livestock grazing levels are increased.

Stage IV. A meandering stream flowing with deep, well-developed soils provides living space for a diverse plant and animal community. Although extreme runoff events may still occur, damage is minimized because of well-sodded banks and the numerous woody species which reduce streamflow velocity.

The rate at which a riparian zone develops is dependent upon the precipitation pattern generated by the climate and the erodibility of local geologic formations. If precipitation is abundant and occurs regularly and geologic formations weather easily, a riparian zone and its attendant ecosystem will form in a relatively short geologic time span. However, if precipitation is scanty or occurs as irregular, high

[1]Assistant Professor Animal & Range Sciences Department, Montana State University, Bozeman, Montana 59717.

intensity storms or if the local geologic formations weather slowly, development can take a long time. Consequently, the riparian zone is created by the interplay between past and present climatic and geologic processes and the ensuing interaction between colonizing plants and stream channel dynamics. The resulting plant community and streamflow regime are an expression of these conditions and can be used to characterize the riparian zone. As climatic patterns and geology change across the landscape, the character of riparian zones also changes. However, in historic time this general relationship has been altered.

Grazing, mining, logging, farming, highway construction, urban sprawl and recreation can alter streamflow and streambank vegetation whether the use occurs in the riparian zone or adjacent uplands. The alterations tend to disturb the dynamic balance of climate, streamflow, and vegetation and usher in a series of changes which ultimately change the character of the riparian zone. If the disturbance is repeated or continues for a long period of time, the resulting character of the vegetation/stream system may bear little resemblance to the potential ecological community which formed under the existing climatic and geologic conditions.

Riparian zones negatively influenced by human settlement and resource use will go through the following phases of retrogression: (1) accelerated streambank and channel erosion; (2) increased instream sediment loads; (3) loss of resident trout and insects; (4) loss of certain vegetation species or classes; (5) increased incidence of destructive floods; (6) further loss of banks and vegetation; and (7) loss of perennial flow. Those zones formed in areas where geologic weathering is slow or precipitation scanty are more resilient to abuse while those formed in areas with high precipitation or very erodible geologic material will degrade quite rapidly. But, wherever the zone is on the scale from stable to degraded, it will still have characteristics which reflect the local, surface hydrology.

In general, a riparian zone is marked by the presence of a channel, the duration of flow which occurs in that channel, and the plant community which can survive on the amount of water available in the banks. A zone with seasonal flows will have little soil development. Because soil holds the water plants need for survival, only drought tolerant perennials or annuals will occupy the banks. If streamflow is perennial and a deep soil exists along the channel, water is available for a longer period. Drought sensitive plant species can survive on this site and will either protect the riparian zone or enhance its development. Plant species or community types are reliable indicators of streamflow duration and soil development. Because wildlife and humans are dependent upon the availability of water, the presence and abundance of animal life will be greater in well-developed riparian zones. But wildlife, especially terrestrial species, are only indicators of riparian zone health because they rely on the plant community. Eliminate a wildlife species and it can be reintroduced and become established again. Degrade the riparian zone and many species will not survive even if reintroduced because the plants they depend on will be absent. We are no different. Without a stable, well-developed riparian zone there will be few resources (forage, irrigation water, timber) to use, and those that might exist will be too few or stunted to support many people.

BALANCE AND ADJUSTMENT PROCESSES IN STREAM AND RIPARIAN SYSTEMS.

Burchard H. Heede[1]

Abstract

All natural systems are dynamic and are changing regardless of man's or other influences. Natural processes within and between systems will eventually restore dynamic equilibrium after disturbances, but control measures may be desirable to speed the processes after serious disruptions. Control measures must work with rather than against, ongoing natural adjustment processes.

The Problem

Only within recent years has the importance of riparian systems been regarded for wildlife habitats and as stabilizing elements for streams. Indeed, the interaction between streams and riparian systems has since become the focus of research and management. This interaction was the missing link that in the past led to many unfounded conclusions about the present and future condition of either component. Since this research is relatively new, much has yet to be learned about possible relationships within and between these two natural systems. As a result, in many situations, we may qualify causes and expected future processes, but cannot yet quantify them. When we deal with one or both systems, we must be fully aware of this lack of knowledge, and draw a definite line between factual information and surmised perception. This is not easy for managers who are asked to deliver solutions. They, therefore, may have to resort to a value instead of a factual scale.

In the context of this report, riparian zone and stream will be discussed as individual systems, because processes operating in each are different. The report is intended to help the manager distinguish between known physical factors and relationships on one side, and conjecture on the other. Furthermore, I hope this report will help managers qualitatively project future adjustment processes where disturbance has occurred. If the direction of future processes can be evaluated realistically, many pitfalls can be avoided.

Past Work

There is ample literature available on riparian ecosystems and on streams and their channels. The riparian literature deals mainly with plant physiologic, taxonomic and ecologic problems (Irvine and West 1979, Stevens and Waring 1985, Reichenbacher 1984). Only in more recent years have interactions also between streams and their riparian zones been recognized (Platts et al. 1983a, Heede 1985a). Much of the riparian literature concerns influences of grazing on riparian communities (Platts et al. 1983b).

In contrast, the comprehensive hydraulic literature rarely mentions riparian communities and their role in channel processes. Heede (1972) considered the influence of streamside forests on the hydraulic geometry of mountain streams. Other authors, specifically in the Northwest, studied the function of large forest debris in rivers (Keller and Swanson 1979, Mosley 1981). The balance necessary for the existence of healthy natural systems was discussed by Heede (1984). Based on a 5-year experiment (Heede 1985b), and studies of mountain streams in Colorado and Arizona (Heede 1981), I concluded that this balance should exist within and between the interdependent systems. If either is disturbed, adjustment processes will be initiated that will eventually establish a new balance.

The Balance in Nature

When using the term "balance" to describe equilibrium conditions of natural systems such as forests, streams, or riparian communities, we should be aware of the term's limited applicability to nature. We all know nature is changing continuously, as we humans do. We grow older. Change is therefore the rule. Why then do we apply balance or equilibrium to this ever-changing world? We do it to contrast an orderly changing condition with severe disturbance or catastrophy. Severe disturbance prohibits orderly development from one stage to another, or in other words, from one equilibrium to a new equilibrium. In science, we refer to dynamic equilibrium, signifying a condition of balance that is not absolute, but allows for changes into a new balanced condition that, in turn, again will change into another balance with time.

Many factors or elements make up a natural system. If balance has been attained, the individual elements of a stream or riparian ecosystem are adjusted to each other. Hence the life cycle of a riparian community, for instance, can take its course from seedling to seed production into old age. If dynamic equilibrium prevails in the community, disturbances such as loss of some large trees will be healed rather quickly by increased herbaceous ground cover that absorbs the sudden increased radiation input. Other detrimental consquences will not occur, and regeneration of the riparian system is possible.

But we know also of many situations where severe disturbance may prevail for a long perod of time, during which the riparian ecosystem may seriously

[1]Research Hydrologist, Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Lab., Arizona State University Campus, Tempe, AZ 85287.

degrade. In this case, much time is required to regain a new balance within the system, because dynamic equilibrium--the ability to adjust quickly--has been lost.

We know that stream behavior is influenced by riparian systems. Riparian plants may stabilize channel banks, and riparian communities may protect flood plains from severe scour. On the other hand, streams have beneficial influences on riparian ecosystems by providing sufficient moisture for plant survival. Thus, both systems are dependent on each other. For a healthy coexistence between streams and riparian ecosystems, it is basic, therefore, that each system in itself is in a state of balance. If not, balance cannot exist between the systems, and a formerly healthy system may be thrown out of balance. I will discuss some examples later.

Adjustment Processes and Their Effect on Stream, Riparian Community, and Watershed

Thus far, I have discussed balance as a final stage of adjustment between elements or variables that make up a system. Let us consider now how adjustment within a system is achieved, if one or more variables are changed. While doing this, it will be important not only to examine the adjustment mechanism, but also the impact on the dependent system, because the adjustment processes cause changes (damage) to the system until a new balance is established. Examples will illustrate this.

Stream System Undergoes Change

A high dam with reservoir has been installed in a stream. Before dam closure, the stream gradient was sufficiently steep to create flow velocities for transport of the available sediment. After closure, most of the stream's sediment load is trapped. The water flow below the dam, rid of the sediment load it used to carry downstream, suddenly has much free energy that formerly was consumed by the load. The balance is disrupted, because waterflow, sediment, and energy are no longer in equilibrium with each other (Fig. 1). Flow velocities increase since more energy is available. The result is channel erosion, as the stream attempts to attain a flatter gradient. When it is sufficiently flat to carry relatively clear water without erosion, a new balance is attained.

If the adjustment processes are fast, as is possible when impacts are less severe than those from a high dam, balance will be regained quickly, and the impact of disturbance will be minimal.

Unfortunately, most stream processes are slow, especially those directed toward the adjustment of gradients after large sediment volumes are withdrawn. Basically, two mechanisms for lowering the gradient exist. One is lengthening of the stream course by forming meanders, the other is erosion of the streambed. Generally, the stream follows the path of least resistance. Lateral movement by meanders requires less energy expenditure than streambed erosion. But hard bank material may not allow meander formation, and the adjustment must be achieved on the existing bed; bed degradation occurs.

The relatively "hungry" stream picks up sediment load either by bank or bed erosion. During these adjustments, channel gradients and velocities of flow decrease, resulting in decreased sediment carrying capacity of the flow. Bed scour is strongest during the first one or two decades after dam closure, and then decreases considerably (Williams and Wolman 1984). In large rivers, several hundred years of adjustment may be required which may occur over a distance of several hundred miles (Hammad 1972).

During the period of adjustment toward a new balance, bank or bed erosion, and sometimes both, may have a serious impact on riparian ecosystems. Only after a new balance has been obtained in the stream system can the riparian zone begin to find its new equilibrium. We should recognize also that riparian zones of concern may be located at a long distance from the source (cause) of disturbance. In this situation, localized examinations to detect the cause of the disturbance would not be successful.

Riparian System Undergoes Change

Let us consider now a situation in which the riparian zone is disturbed, but the stream is in a healthy condition. Because of serious overgrazing or plant disease, the riparian community is dying and hence losing its ability to withstand the impact of high flows. Not only are shrubs and trees uprooted and carried away, but also lost will be the soils of banks and floodplains. As a result, the sediment load of the flow increases, but not the channel gradient nor, therefore, the sediment carrying capacity. The balance is disrupted. More sediment is available than can be transported through the stream reach. Deposition takes place. The stream has lost its balance between channel and flow. Adjustment toward a new balance begins at this point in time.

Deposition, or channel aggradation, continues until a steeper gradient has been formed which raises the sediment carrying capacity of the flow to a magnitude that makes sediment transport through the stream reach possible. When sediment input into the stream reach equals sediment output from the reach, balance exists.

The discussed considerations are theoretically correct. In reality, however, some other adjustments of hydraulic flow factors and parameters also occur. Streamflow and channel changes meet somewhere in between to allow the new balance. One must also

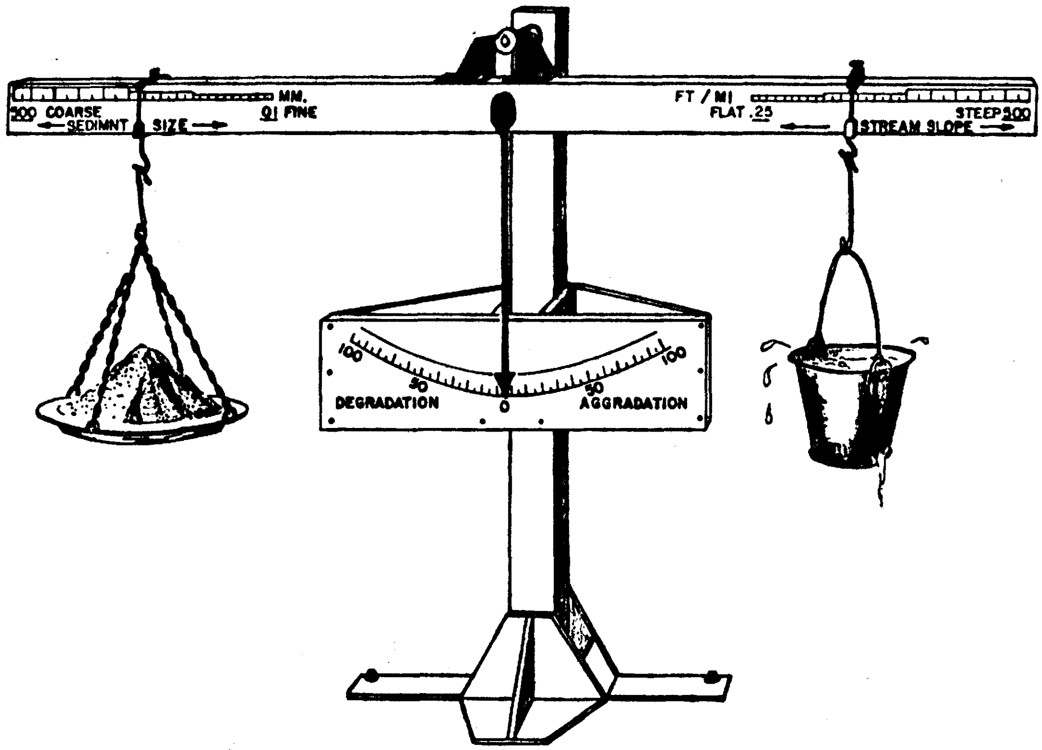

Figure l. Lane's stable channel balance. (sediment loads times sediment size) varies as (stream slope times stream discharge).

consider that developments are not necessarily as straight forward as discussed, because sediment supply from the disturbed riparian zone may decrease, or bedrock be exposed. Hence, it is possible that the steeper channel gradient, formed during the period of aggradation, suddenly is too steep for future flows with pre-adjustment sediment levels. Then degradation ensues, and the stream is again out of balance.

Disruption of riparian and stream systems, as well as their balanced coexistence, may cover very long time periods, if the pendulum between aggradation and degradation is repeated due to geologic or other circumstances, such as grazing of an unbalanced riparian system.

In summary, while channel flooding increases during the period of aggradation, impacting the riparian zone additionally, degradation disrupts stabilizing developments at banks and floodplains.

Watershed Undergoes Change

As stated earlier, change is the role in nature. Were it not for erosion of mountainous lands, our fertile agricultural lands would not exist. Yet, developments of this geologic time scale were not one-directional. For instance, climatic changes could enhance the vegetation cover at times and at others impair it. With this, the erodibility of watershed surfaces changes also, leading to periods of strong and minor erosion. Such developments occur also within shorter time frames. A wild fire may consume the vegetation in a watershed, and it may take years before a new, effective ground cover can regrow. When regrown, the eqisode of high erosion rates (severe changes) is replaced by an episode of low erosion rates (moderate changes).

During episodes of high erosion rates on the watershed, stream channels may be filled by sediment (aggradation), because sediment delivery from the watershed may have increased more than runoff. The raising of the channel bottom leads also to widening of channel and floodplains, which favors the establishment of riparian communities. With regrowth of an effective vegetation cover on the watershed, sediment delivery to the stream decreases and the flows carry less sediment on a gradient too steep for the maintenance of balance between flow and channel. Free energies increase and transport the formerly deposited sediments downstream resulting in erosion of banks and flood plains. The new riparian zones may be destroyed. In this example, the balance, once at-tained by aggradation of the streambed, could have been disrupted by natural developments or by human interference. Regardless of the course, a third natural system, the vegetation on the watershed, was thrown out of balance and affected the stream and riparian system.

The Lesson

What are the lessons to be learned, based on our better understanding of the relationship and interdependency of riparian and stream systems? For one, we know that change of one or more elements in a system can lead to loss of balance for long time periods. If changes are not drastic, adjustments within the system may create a new balance relatively fast, say within a few years. Besides unusual external events such as earthquakes, extremely severe storms, or serious human interference, this represents the normal situation in nature. Because change is the rule in natural systems, the dynamic equilibrium condition--the ability to adjust quickly--is a desirable stage in systems development. In this situation, we don't have to interfere. Indeed, we will gain, if we simply let nature take its course. Where serious impacts exist, however, and adjustment processes require long time periods for the attainment of a new balance, we can help to speed up developments. Our help should be directed toward enhancement of the ongoing processes of adjustment. Our measures must therefore work with, and not against, the processes. This is less costly and certainly more successful. An example will illustrate how a control measure can work with the existing processes.

Let us refer to the example of high dam installation discussed earlier. The streamflow below the dam was free of its main sediment load, and the freed flow energies scoured the bed to create a more gentle bed gradient. Gradient control structures (check dams), installed at calculated spacing, can achieve the same effects as the long-lasting adjustment processes, but much more quickly. The average stream surface slope is dampened by the creation of pools behind the dam, and the flow energies are decreased by the water overfalls at the structures. The dams also reduce bed erosion because they transfer a turbulent flow into a more tranquil one. Overall, the flow is tamed as compared with the original condition after dam closure. An analysis would be required to determine whether the benefits derived from a balanced stream and a healthy riparian zone would exceed the cost of the control structures.

Before effective measures can be planned, it is imperative to establish the cause of the disruption. This requires examination of the system as a whole, because the origin of the disruption may be located far away from the site in question. Indeed, if we inspect a stream as a possible cause of riparian zone impairment, it may be necessary to examine also the master stream of which the stream is tributary. For instance, the master stream may have lowered its bed by erosion and thus forced the tributary to lower its bed by erosion. Only where hard bedrock exists, would the tributary join the main stream with a waterfall. Streambed lowering with resulting bank instability would be determined as cause for the riparian zone impairment, originating in the master stream. Stabilization within the riparian zone would therefore require that further down cutting of the main stream channel be controlled. This example illustrates the complexity of natural systems response that make easy answers a rarity.

Summary

There is always a cause for the disruption of balance within and between natural systems. Any disruption activates adjustment processes that will lead to a new balance. This balance will be achieved by mutual adjustment of the system's elements, which may include ground surfaces, channel configurations, flow velocities, and plant composition. In streams, adjustment processes are mainly recognized by erosion; in riparian zones, by rock surfaces and weak or absent plant regeneration.

If balance is lost for long periods of time, corrective measures may be desirable. If we work with the ongoing adjustment processes, the results will be better, faster, and cheaper. Where dynamic equilibrium--the ability to adjust quickly--has not been lost, we should allow nature to take its couse and not interfere, with the exception of restricting use for protection. This will enable nature to perform adjustments without interruptions that could be caused by activities such as grazing or recreation.

The complex response of natural systems. forces us to examine them very thoroughly before deciding on management actions. Due to the interactions within and between systems, we cannot focus only on impaired locations, but must include the system as an entity.

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RIPARIAN ZONES THEN AND NOW

Quentin Skinner[1]

Introduction

Riparian zones exist because: (1) water is available to plants during their entire growing season, (2) this water promotes dominance of plant species that need a water table near their root zone during their entire growing season, and (3) if the water table near the root zone of water-loving plants is removed they are replaced by plant species capable of occupying more xeric land areas which have no permanent water table during an entire growing season. Because water supply in the semiarid western United States is often limited in quantity and distribution, condition and aerial extent of riparian zones can be the focus of emotional discussion between a multitude of users and managers of wildland drainage basins. This paper will, therefore, provide a general perspective of water storage potential in non-man manipulated western drainage basins before settlement. This effort will set the stage for reflecting on how man has influenced streamside zones and manipulated water thus creating or reducing land mass capable of supporting riparian plant species to present time. This paper, however, only represents this author's first attempt to review historical literature and provide himself with a logical basis to help evaluate current research needs and direction. At best, the content should offer food for thought after also reading, "Hydrologic Impacts in Riparian Zones" of this same proceedings.

Six historical periods are identified for the convenience of presenting this paper. These are: (1) before western immigration, 1804-1840, (2) during western immigration, 1840-1870, (3) during settlement, 1870-1930, (4) after creation of reservoir storage, 1930-1960, (5) while emphasizing multiple use management, 1960-1975, and (6) while emphasizing the need to distinguish riparian zones from other vegetation types for changing land and water management policies, 1975-1986.

Change in riparian zones will be attributed to: (1) natural and introduced large grazing animals, (2) alteration of flow caused by diversion of water for irrigation and reservoir storage, (3) multiple use of watersheds, and (4) present exploration for oil and gas.

Natural Storage of Water

Stream channels adjust to changes in flow regime. Flow regimes are controlled by condition of the entire drainage basin watershed under the influence of climate. A representative annual flow regime in the central semiarid Rocky Mountains region where streams begin in mountains is as follows: (1) base flow occurs during late fall and winter, (2) high flow occurs in spring when snow pack melts, (3) spring runoff declines into summer and drops to base flow conditions during late fall and winter. High intensity short duration summer thunderstorms may produce localized increase in runoff. Excluding user impacts on drainage basins, stream channels and associated riparian zones historically would have had to adjust to this type of flow regime. Each year, with the exception of summer storms, most runoff occured in approximately forty days during spring. The power of this heavy runoff (flushing flow) shaped channels to meet the average annual discharge over a period of years by flushing deposited channel bed material downstream and removing bank deposits not stabilized by vegetation. Low flow conditions existed during the remaining eleven months. Historic pictures and literature show that large low gradient basin streams were often wide, braided with islands, and riparian vegetation as we know it today was isolated to islands, margins along channel banks, on the inside curve of meanders, and at the point where two streams join each other. Late summer stream flow was shallow and often confined within small channels in wide stream beds.

High gradient streams of mountains and foothills in contrast to basin streams are: (1) closer to perennial snowfields, (2) located in areas of higher precipitation distributed more evenly over 12 months, (3) flow through shallow soils over bedrock, (4) located near the top of drainage basins where they drain less area and consequently channel size is smaller, and (5) influenced by bedrock and often biological dams. Potential for storage of groundwater to support riparian plants may cover a broad area at higher elevations when compared to canyons and large basin streams because: (1) water can be replenished often during frequent storm events, (2) bedrock forces groundwater downgradient to depressions or streambanks, (3) shallow soils over bedrock allow roots of plants opportunity to reach shallow water tables season long, (4) bedrock dams, resistant to erosion and which cause lakes of all sizes and shape, trap sediment and are eventually filled with water-reworked fine soil material high in organic matter (alluvium),

[1]Professor, Range Management Department, P.O. Box 3354, University Station, Laramie, Wyoming 82071

(5) bogs and water related meadow types take on the shape of sediment filled lakes, and (6) groundwater is maintained at a level approximately to the height of the bedrock dam. Additional groundwater at higher elevations is also stored behind biological dams. Because streams are smaller and structual material like willow and trees is often present, beaver are able to construct dams within channels or on top of sediment filled lakes behind bedrock dams. Biological dams are eventually filled with sediment and create a soil/vegetation rise above the original gradient of stream channels or sediment filled lake surfaces behind bedrock dams. Build-up of sediment/vegetation above this original gradient is also enhanced by vegetation debris dams retarding overland and channel flow during flood producing events.

Groundwater storage of snowpack melt, springs, and summer precipitation events at higher elevations prolong flow downstream in canyons and larger basin streams. This slow release of groundwater will continue until water table levels drop to the height of bedrock dams. When this occurs, streams may quit flowing even at high elevations. Additional loss of ponded groundwater occurs because of evapotranspiration. Plants using depression stored water may further reduce reservoir levels behind bedrock and biological dams. Recharge of the system must occur before sustained flow resumes in the stream channel.

Recharge of the high elevation groundwater system, besides being related to shallow soils over bedrock, depends on contributing area between stream channels. Contributing area is the land area between adjoining stream channels. Many small channels tributary to each other exist near the top of headwaters of drainage basins. This high density channel network collects and conveys runoff and groundwater into fewer but larger channels downslope. Acreage between small channels is less near the headwaters and greater between larger streams as they exit mountain or headwater drainage basins. Contributing area promotes stream flow during any one precipitation event or snowmelt in the following manner. Water first enters the channel as runoff from banks. If additional runoff is to become streamflow it must flow across the land surface of the contributing area of the stream. The larger and flatter the contributing area the longer it takes overland flow to reach the channel. Like surface flow, groundwater first enters the channel from bank storage. Travel time is extended as distance is increased into contributing area away from the channel. Channel size, then, adjusts to flow regime caused by: (1) amount and type of precipitation, (2) drainage network, (3) water storage capacity behind geologic and biological dams, and (4) condition of streamside zones as well as biological and physical structure of contributing area.

Stream flow passing from small into larger streams existing in the mountains passes through canyons. In these canyons storage capacity for groundwater is largely confined to narrow streamside zones caused by large particle soil material eroded or falling from canyon walls, which unlike alluvium is lower in organic matter (colluvium,). Colluvium often forms a steep slope between stream channel edge and base of the canyon wall. The stream botton represents bedrock. Peak flow passing though these canyons cause water tables to rise quickly within colluvial fill and drop as fast when flow recedes because colluvium is often porous and low in organic material compared to alluvium.

Riparian zones are confined to colluvium near water tables supported by base stream flow conditions. These are most often narrow because of the steep slope of colluvial deposits, which act as the only potential storage area for water during low flow conditions. Only overland flow of water coming from extensive contributing area between canyons and slow release of spring water from geologic groundwater storage is available to supplement annual flow during summer, fall, and winter downstream. Frankly, canyons act as pass-through conduits for water from mountains to basins. Bedrock, like in mountains, keeps the channel from downcutting but channels may become wider and aggrade temporarily during summer when the flow regime decreases or user impacts occur. Impact to the hydrologic function of the riparian zone, because of user pressure, does little to inhibit water storage capabilities of the colluvial storage system. Many high gradient streams in canyons can be subjected to biological damming of flow. Often this is temporary because of wash out during spring flushing flows. However, any accumulation of alluvial deposits behind dams adds water storage area and regulates velocity of flow downstream. Alluvium is less porous than colluvium, stores more water, and will therefore, release flow longer during periods of less than peak flow.

Rock, tree debris, and beaver dams help curb peak flow velocity caused by higher bedrock gradients in canyons and the funneling of water into larger but more constricted streams than those in the higher mountians. Reduced velocity in canyons curbs power of peak discharge of flow into basin stream channels which are low gradient and often meander across valley from upland to upland slopes. Meanders of developed stream channels and adjoining riparian zones can act as a dam during peak discharge from canyons and cause overbank floods along the valley bottoms.

Because basin streams are often located over deep alluvium deposited on bedrock, storage potential for water is enhanced but confined to valley bottoms. Large arid contributing areas separate basin streams and may provide some water input to main streams as overland flow. The first pulse of this overland flow will occur because of basin snowmelt, perhaps causing an early peak flow event in valley streams before mountain runoff of snow melt occurs. There may or may not be enough melt to cause overbank flooding. Secondary pulses may occur because of summer convective storms which again may or may not cause overbank flooding. Groundwater return to stream flow largely will be in response to stored water from overbank flow events on floodplains. Recharge of groundwater to alluvium surrounding the channel from adjoining contributing area is slow and often to deep aquifers, thus is not visually observed as augmenting surface flow.

Riparian zones are confined to the floodplains of basin streams and are therefore isolated by extensive contributing area covered with vegetation adapted to arid conditions. It is often said that basin riparian zones make up less than 1 percent of a drainage basin area but may be the most important because of the presence of available water for plants and animals. This water supply for support of riparian zones is stored because of overbank flooding mostly during spring snowmelt runoff. The streams in their present condition are often too large and runoff too powerful for beavers to construct and maintain dams. Biological damming often becomes insignificant as cause for overbank flooding.

A real cause for overbank flooding in basin streams is change in channel morphology. Basin streams are low gradient compared to those in canyons and head-waters within mountains. They also have increased meanderings. Low gradient and increased meandering are conditions which promote encroachment of sediment and vegetation during low flow within channels. Encroachment decreases channel width and meandering increases length of stream for length of valley. High flows during spring runoff traveling through basin streams must either scour sediment and vegetation out of the channel to meet peak stream discharge or flood adjoining land. Thus basin riparian zones and channel conditions act like dams for water being discharged from canyons. Their spillway is channel size and their reservoirs are the adjoining floodplains. If you release or decrease water through canyons or from contributing areas then you stand the chance of changing: (1) width, (2) depth, (3) meandering, or (4) area flooded along basin streams.

In summary, water is best stored in alluvium behind geological dams. These deposits are shallow in mountains and deep in basins (Figure 1). Within canyons and in stream reaches where topography confines stream flow to straighter channels, instead of allowing meanders to develop, alluvial deposits are reduced and flow is confined by bedrock. Biological dams occur in small streams where high runoff events don't remove them year to year. These are most often present within headwaters of basin streams and in mountains. Riparian plants have a broad distribution at high elevations because of shallow soils over bedrock and more frequent precipitation events during the growing season. Aerial extent of riparian zones increase where streams meander and decrease where flow is confined in straighter channels. Where water is diverted, stream channel length is increased and thus riparian plant distribution can also increase (Figure 2).

Historical change of riparian zones can now logically be related to change in water storage along stream channels. Meriwether Lewis and William Clark (Lewis and Clark 1804-1806) formally opened up the central Rocky Mountains by following the Missouri River to the headwaters of the Columbia. Their journals serve as an excellent source for describing water storage and depicting riparian zones before immigration through the Rocky Mountains to the West Coast.

Before Western Immigration - 1804-1840

Lewis writes July 12, 1804 where the Nemahaw empties itself into the Missouri from the south and is eighty yeards wide at the confluence, "From the top of the highest ground a delightful prospect presented itself...the level and extensive meadows watered by the Nemahaw, and enlivened by the few trees and shrubs skirting the borders of the river and its tributary streams...the lowland of the Missouri is covered with undulating grass, nearly five feet high, gradually rising into a second plain, where rich weeds and flowers are interspersed with copses of the Osage plum...The sand where we are encamped is covered with the two species of willow, broad and narrow leaf" (1).

On July 19, 1804 "The sandbars which we passed today are more numerous and the rolling sands more frequent and dangerous than any we have seen, these obstacles increasing as we approch the river Platte" (1).

July 21, 1804 at the mouth of the Platte River "Captain Lewis and Clark ascended the river in a perogue for about one mile and found the current very rapid, rolling over sands and divided into a number of channels, none of which are deeper than five to six feet. One of our Frenchmen who spent two winters on it says that it spreads much more at some distance from the mouth, that its depth is generally not more than five or six feet, that there are many small islands scattered through it, and that from its rapidity and the quantity of its sand it cannot be navigated by boats or perogues though the Indians pass it in small flat

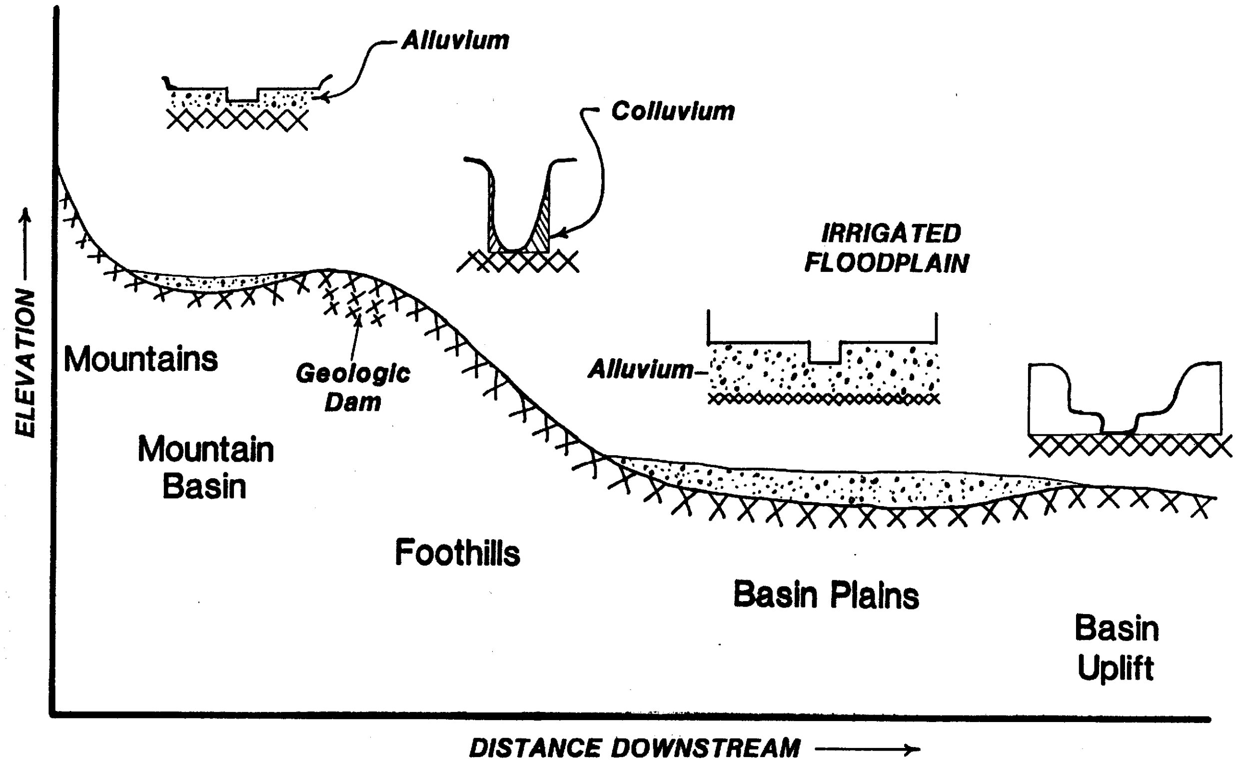

Figure 1. General natural water storage from mountains to basins in the Central Rocky Mountains.

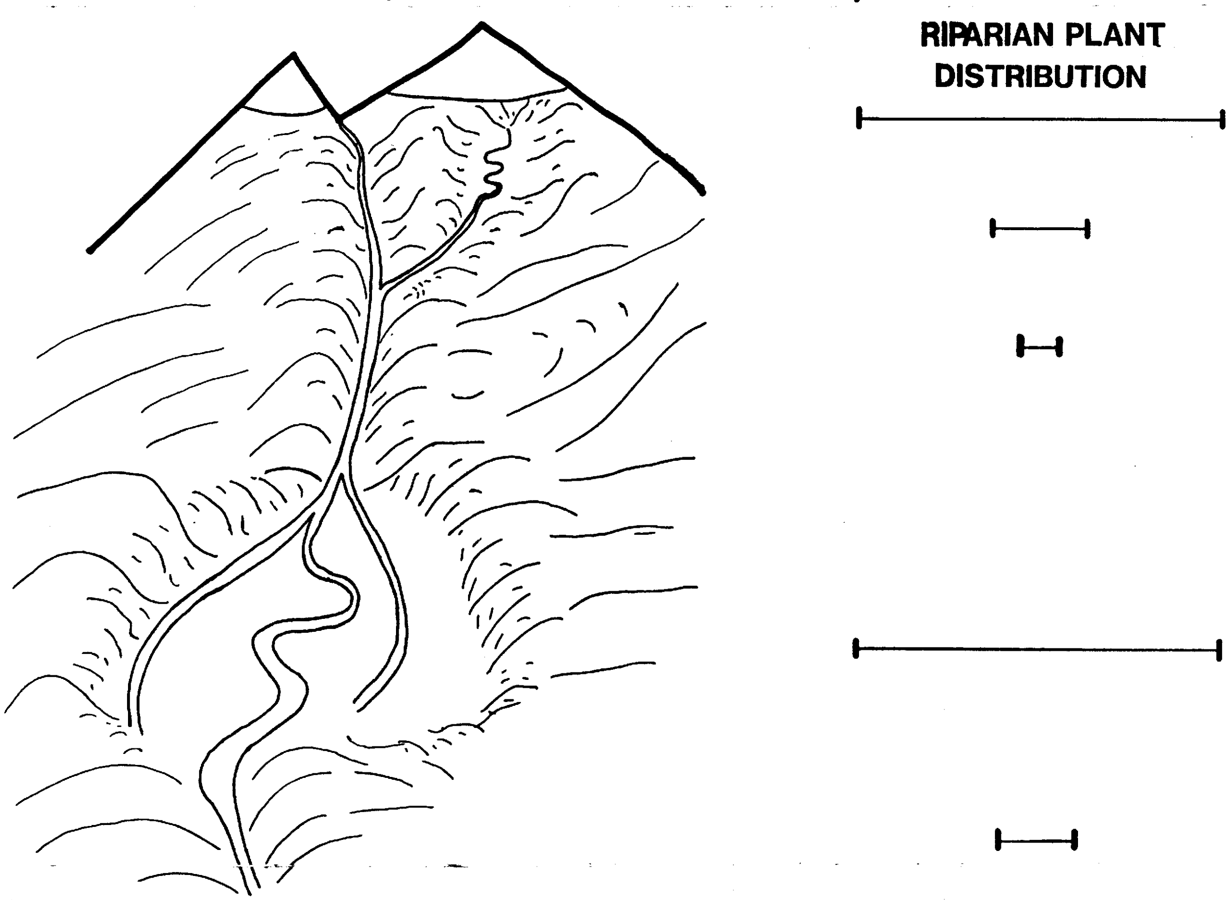

Figure 2. General riparian plant distribution from mountains to basins in the Central Rocky Mountains.

canoes made of hides...At its junction the Platte is about six hundred yards wide...With much difficulty we worked round the sandbars near the mouth" (1). They then traveled up the Missouri.

On June 27, 1843 Captain John C. Fremont talked with John Lee who tried to float the Platte during high flow from Fort Laramie. "A brief account of their fortunes will give some idea of navigation in the Nebraska. Sixty days since they had left the mouth of Laramie's fork some three hundred miles above in barges laden with furs of the American Fur Company. They started with the annual flood, and, drawing but nine inches of water, hoped to make a speedy and prosperous voyage to St. Louis, but after a lapse of forty days found themselves only one hundred and thirty miles from their point of departure. They came down rapidly as far as Scotts Bluff where difficulties began. Sometimes they came upon places where the water was spread over a great extent and here they toiled from morning until night, endeavoring to drag their boat through the sands, making only two or three miles in as many days. Sometimes they would enter an arm of the river where there appeared a fine channel, and after descending, prosperously for eight or ten miles would come suddenly upon dry sands and be compelled to return, dragging their boat for days against the rapid current and at others they came upon places where the water lay in holes, and getting out to float their boats would fall into water up to their necks, and the next moment tumble over against a sandbar. Discouraged at length, and finding the Platte growing more shallow, they discharged the principal part of their cargoes one hundred and thirty miles below Fort Laramie...after fifteen or twenty days more struggling in the sands, during which they made but one hundred forty miles, they sank their barges...Commenced the day before we encountered them, their journey on foot to St. Louis" (6).

The Platte River, with its headwaters in Wyoming and Colorado, is the first major river encountered by Lewis and Clark on their journey up the Missouri that is characteristic of having a flushing flow from melting central Rocky Mountain snowpack during spring. It is evident that the Platte was wide and aggraded with many islands and numerous channels. During high flow the water spread out over a wide sandbed and during low flow was isolated in small braided channels. Fremont generally describes timber of the Platte (most cottonwood) from Grand Island to the south fork of the Platte and then up the south fork of the Platte to the Rocky Mountains. Large islands are often well timbered. The banks were often void of timber or what was there was a fringe or consisted of clumps on meander bars.

Lewis and Clark's description of smaller streams exiting the Rocky Mountains and reaching the Missouri are not so different from the Platte. Above the Platte the Missouri riparian zone changed to more prairie plus cottonwood groves, the channel more crooked and less rapid, On August 23, 1804 Lewis wrote "The wind blew so hard from the west that we proceeded very slowly, the fine sand from the bar being driven in such clouds that we could scarcely see" (1). This is evidence the Missouri was near low flow and point bars were not wooded enough to keep sand in place. "There is, however, no timber except on the Missouri, all the wood of the Whitestone River not being sufficient to cover thickly one hundred acres" (1) Evidently the smaller rivers in this area were not well wooded. On September 14, 1804 Lewis described the mouth of the Rapid River, its headwaters in the Black Hills. The Rapid River...is one hundred and fifty-two yards wide, and four feet deep at the confluence...Captain Clark acended three miles to a beautiful plain...he found that the river widened above its mouth, and much divided by sands and islands which joined to the great rapidity of the current, makes the navigation very difficult even for small boats. Like the Platte...it throws out into the Missouri great quantities of sand...which form sandbars and shoals near its mouth" (1).

On September 15, Lewis and Clark reached the White River (Niobrara). "This river has a bed of about three hundred yards though the water is confined to one hundred and fifty. The current is regular and swift, with sandbars projecting from the points. It differs very much from the Platte...in throwing out comparatively little sand...This resemblance was confirmed by the sargent who ascended about twelve miles (7) at which distance it was about the same width as near the mouth...interrupted by islands and sandbars...at the confluence of the White River with the Missouri is an excellent position for a town...the neighborhood furnishing more timber than is usual in this country" (1).

Lewis, on October 1, 1804, described the Cheyenne River as being "...400 yards wide, the current gentle and discharging not much water and very little sand...although the river did not seem to throw out much sand, yet near and above its mouth we find a great many sandbars difficult to pass. On both sides of the Missouri, near the Cheyenne, are rich thinly timbered lowlands. As we proceeded we found that the sandbars made the river so shallow and the wind so high that we could scarcely find the channel, and at one place were forced to drag the boat over a sandbar...the ascent soon became so obstructed by sandbars and shoal water, that after attempting in vain several channels, we determined to rest for the night and...send out to examine the best channel...we found that there was no outlet practicable for...this channel...we therefore returned three miles and attempted another channel in which we were more fortunate" (1).

The Moreau, Grand, Cannonball, and Little Missouri represent other major rivers draining western range to the Missouri smaller than the Platte. Their headwaters are also in the Black Hills. Lewis describes them. "October 7, 1804 we came to the mouth of a river...Sawawkawna River (Moreau)...its current is gentle and that it does not seem to throw out much sand...and though it has now only water of twenty yards width, yet when full it occupies ninety...in the low timbered ground near the mouth of the Sawawkawna, we saw the tracks of large white bear...October 8, 1804 Wetawhoo (Grand)...its bed, which flows at the mouth over a low soft slate stone, is one hundred and twenty yards, but water is now confined within twenty yards...two miles above the Wetawhoo and on the same side, is a small river...it is twenty yards in width, but so dammed up by mud that the stream creeps through a channel of not more than an inch in diameter...October 18, 1804... Cannonball River...its channel is about one hundred and forty yards wide, though the water is now confined within forty. April 12, 1805...The Little Missouri enters the Missouri with a bold current, and is one hundred and thirty four yards wide, but its greatest depth is two feet and a half, and this joined to its rapidity and its sandbars make the navigation difficult except for canoes which may ascend it for a considerable distance...April 24, 1805...between the Little Missouri and Yellowstone River...The party are very much affected with sore eyes which we presume are occasioned by the vast quantities of sand which are driven from the sandbars in such clouds as often to hide from us the opposite bank" (1).

Evidence thus submitted again suggest streams reaching the Missouri from the Black Hills region of the Rocky Mountains were wide and during low flow, water was shallow and isolated from banks in small braided channels. Lewis and Clark did not mention evidence of or actual overbank flooding on the Missouri or tributaries during the spring of 1804, 1805, or 1806 except at the junction of the Yellowstone with the Missouri and near the Missouri headwaters where beaver could maintain dams year to year. This implies water, during high flow, (1) spread out over wide channels, (2) became deeper, and (3) seldom over flooded their banks. Consequently recharge of water to the banks of the larger rivers would only occur during spring and through only the banks themselves, but would then drain during summer. Thus riparian vegetation had to be limited to: (1) the very edge of channels in straighter reaches, (2) on meander point bars where groundwater interflow could occur from the upstream reach of the meander to the downstream reach, (3) stream junctions where surface and ground water moved from one stream to the next, and (4) islands where channel water would be available during low streamflow conditions.

Lewis states on April 26, 1805 at the junction of the Yellowstone and Missouri "The ground on the lower side of the Yellowstone near its mouth is flat and for about a mile, seems to be subject to inundation, while that at the point of junction, as well as on the opposite side of the Missouri, is at *usual height* of ten or eighteen feet above the water and therefore not overflown. There is more timber in the neighborhood of this place and on the Missouri, as far below as the Whiteearth River than on any part of the Missouri on this side of the Cheyenne. The timber consists principally of cottonwood, with some small elm, ash, and box alder. On the sandbars and along the margin of the river grows the small-leafed willow, in the low grounds adjoining are scattered rosebushes three or four feet high, the redberry, serviceberry, and redwood. The higher plains are either immediately on the river in which case they are generally timbered, and have an undergrowth like that of the low grounds, with the addition of the broad-leafed willow, gooseberry, chokecherry, purple currant, and honeysuckle, or they are between the low grounds and the hills, and for the most part, without wood or anything except large quantities of wild hysop...it is always understood that the upland is perfectly naked and that we consider the low ground well-timbered if even one fifth be covered with woods" (1).

Lewis and Clark's descriptions of streams entering the Missouri and Yellowstone Rivers which originate on basin uplands and mountain foothills show some channel response to early spring snowmelt but more so, most likely, to high intensity short duration summer thunderstorms. Examples include: May 3, 1805, Porcupine River (Poplar River) (2) from the north draining northeastern Montana and Saskatchewan. "This is a bold and beautiful stream one hundred and twelve yards wide, though the water is only forty yards at its entrance...Captain Clark ascended it several miles and passed it above where it enters the highlands, found it continued nearly of the same width and about knee deep, and as far as he could distinguish for twenty miles from the hills...there was much timber on the low grounds...the water of this river is transparent, and is the only one that is so of all those that fall into the Missouri before entering a large sandbar through which it discharges itself, its low grounds are formed of a stiff blue and black clay, and its banks, which are from eight to ten feet high and, seldom, if ever, overflow are composed of the same material (1)...May 6, 1805...We passed three streams on the south...the first...was about twenty-five yards wide, but although it contained some water in standing pools it discharges none...Little Dry Creek (Prairie Creek) (7), Big Dry Creek (Sand Creek) (7), fifty yards wide, without any water, the third...has the bed of a large river two hundred yards wide, yet without a drop of water...Big Dry River (Elk Prairie Creek) (7) like the other two, this stream ...continues its width undiminished as far as we can discern. The banks are low, the channel formed of a fine brown sand, intermixed with a small proportion of little pebbles of various colors and the country around flat and without trees...They had recently discharged their waters and from their appearance and the nature of the country through which they pass, we concluded that they rose in the Black Mountains, or in the level low plains which are probably between this place and the mountains; that this country being nearly of the same kind and of the same latitude, the rains of spring melting the snows about the same time, conspire with them to throw at once vast quantities of water down these channels, which are then left dry during the summer, autumn, and winter, when there is very little rain...May 9, 1805...We reached the bed of a most extraordinary river which presents itself on the south. Though as wide as the Missouri itself, that is about half a mile, it does not discharge a drop of water and contains nothing but a few standing pools...it passes through a wide valley without timber...the banks are abrupt...but though they do not rise more than six or eight feet above the bed, they exhibit no appearance of being overflowed...like the dry rivers we passed before, this seemed to have discharged its waters recently, but the water mark indicated that its greatest depth had not been more than two feet" (1).

Riparian zones along these basin streams which had all but gone dry by early May did not support extensive riparian zones marked by the presence of cottonwood trees. However, the Poplar River must have supported perennial flow to be wooded as described by Lewis.

On May 20, 1805, Lewis and Clark reached the Musselshell River joining the Missouri on the south shore. "This stream...is one hundred and ten yards wide and contains more water than streams of that size do in this country; its current is by no means rapid...its bed is chiefly formed of coarse sand and gravel, with an occasional mixture of black mud, the banks abrupt and nearly twelve feet high, so that they are secure from being overflowed. The water is of greenish-yellow cast and much more transparent than that of the Missouri, which itself, though clearer than below, still retains its whitish hue and a portion of its sediment. Opposite to the point of junction the current of the Missouri is gentle and two hundred and twenty two yards in width, the bed principally mud (the little sand remaining being wholly confined to the points) and still too deep to use the setting pole ...our Indian information is, that it rises in the first chain of the Rocky Mountains not far from the sources of the Yellowstone. The party who explored it for eight miles represented low grounds on the river as well supplied with cottonwood of a tolerable size" (1). Also on May 29, Lewis describes the Judith River along the same bank. "It rises in the Rocky Mountains in about the same place with the Musselshell and near the Yellowstone River. Its entrance is one hundred yards wide...the water occupying about seventy-five yards, and in greater quantity than the Musselshell River...no stones or rocks in the bed, which is composed entirely of gravel and mud with some sand, the water is clearer than any which we have yet seen and the low grounds as far as we could discern, wider and more woody than those of the Missouri. Along its banks we observed some box alder intermixed with the cottonwood and the willow, the undergrowth consisting of rosebushes, honeysuckle, and a little red willow" (1).

These rivers from the Rocky Mountains have cleaner water and transport little mud. They don't overflow their banks but support riparian zones because of perennial flow. Examples of their low flow channel conditions as they exit the mountains below and above the three forks of the Missouri in July 1805 are: July 22..."We set out at an early hour. The river being divided into so many channels by both large and small islands, that it was impossible to lay it down accurately by following in a canoe any single channel, Captain Lewis walked on shore, took the general courses of the river and from the rising grounds laid down the situation of the islands and channels, which he was enabled to do with perfect accuracy, the view not being obstructed by much timber...July 23...during the whole day the river is divided by a number of islands which spread it out sometimes to the distance of three miles, the current is very rapid and has many ripples and the bed formed of gravel and smooth stones. The low grounds are wide and have very little timber but a thick underbrush of willow and rose and current bushes...our journey today was twenty two and a quarter miles, the greater part of which was made by means of our poles and cords...July 24...the current of the river was strong and obstructed as indeed it has been for some days by small rapids or ripples which descend from one to three feet in the course of one hundred and fifty yards, but they are rarely incommoded by any fixed rocks, and therefore, though the water is rapid, the passage is not attended with danger...beaver seem to contribute very much to the number of islands and the widening of the river. They begin by damming up the small channels of about twenty yards between the islands, this obliges the river to seek another outlet and as soon as this is effected, the channel stopped by the beaver becomes filled with mud and sand. The industrious animal is then driven to another channel which soon shares the same fate, till the river spreads on all sides and cuts the projecting points of land into islands" (1).

The three rivers making up the three forks of the Missouri were described by Lewis as "all being about ninety yards wide and run with great velocity and throw out large bodies of water. The Gallatin River is, however, the most rapid of the three. The Madison River though much less rapid than the Gallatin, is somewhat more rapid than the Jefferson, the beds of all of them are formed of smooth pebble and gravel, and the waters are perfectly transparent. The low grounds, although not more than eight or nine feet above the water seem never to be overflowed except where bayous were formed by beaver, where rushes as high as a man's chest grew" (1).

Above the three forks on the Jefferson..."As we proceeded, the low grounds were covered with cottonwood and a thick underbrush, and on both sides of the river, except where hills prevented it the ground was divided by bayous, which are dammed up by the beaver...Captain Lewis proceeded after dinner through the extensive low ground of timber and meadow land intermixed; but the bayous were so obstructed by beaver dams, that in order to avoid them he directed his course towards the high plain...when he desired to rejoin the canoes he found the underbrush so thick and the river so crooked that this joined to the difficulty of passing over the beaver dams, induced him to intercept the river at some point where it might be more collected into one channel...July 31, 1805...the Jefferson continues as yesterday, shoaly and rapid, but as the islands though numerous are small, it is, however, more collected into one current than it was below and is from ninety to one hundred and twenty yards in width. The low ground...contains a considerable quantity of timber with the bullrush and cattail flag very abundant in the moist spots, while the drier situations are covered with fine grass, tansy, thistle, onions, and flax. The uplands are barren and without timber...and the only produce is the pricklypear, the sedge, and the bearded grass, which is as dry and inflammable as tinder." Higher up the Jefferson August 3rd..."In the level parts of the plains and the river bottoms there is no timber except small cottonwoods near the margin, and an undergrowth of narrow-leafed willow, some honeysuckle, rosebushes, currants, serviceberry and gooseberry, and a little birch" (1).

August 8th on the middle fork of the Jefferson 30-35 yards wide..."The bottom is rich, with some small timber on the islands and along the river, which consists rather of underbrush, and a few cottonwoods, birch, and willow trees...through the valleys are scattered bogs. On all of the three branches of the Jefferson River are immense quantities of beaver, otter, and muskrat. At our camp there was an abundance of rosebushes and briars but so little timber that we were obliged to use willow bush for fuel...the river increases in rapidity as we advance (August 9th) and is so crooked that the eleven miles, which cost us so much labor, only bring us four miles in a direct line...August 10th the river, which before it enters the mountains was rapid, rocky, very crooked, much divided by islands and shallow, now becomes more direct in its course as it is hemmed in by the hills, and has not so many bends nor islands, but becomes more rapid and rocky and continuous as shallow" (1).

The last valley before the continental divide, August 10, 1805, "...a beautiful and extensive plain about 10 miles long and five or six in width. At this place they halted for the night...and having lighted a fire of dry willow bush, the only fuel which the country affords, supped on deer...the river not so rapid as yesterday, though more narrow and still very crooked, and so shallow that we were obliged to drag the canoes over many ripples in the course of the day (12 yards wide)...these low grounds are very much intersected by bayous and bogs covered with tall grass...we saw a number of geese, ducks, beaver, otter, deer, and antelope, all of which one beaver was killed with a pole from the boat, three others with a tomahawk and the hunters brought in three deer and an antelope" (1).

All River Lewis and Clark. Your dedicated description of rivers exiting the central Rocky Mountains confirm: (1) channels in low gradient river reaches were wide with high banks, (2) aggraded with gravel and cobble, (3) during low flow conditions were braided with islands thus the rivers were split into more than one channel, and (4) during high flow did not often overflow their banks except where beaver were able to dam up smaller channels along the sides of larger main flow routes. Near the head waters of these mountain streams, in low gradient reaches, beaver dams caused spreading of water as over bank flooding thus creating bog-wet meadows laced with willow and few trees.

Indians and Buffalo, 1804-1840

The presence of riparian vegetation, particularly marked by cottonwood trees, was not extensive along entire river corridors. Indians and buffalo were confined to these zones because of the need for water and shelter. Osborne Russell (1834-1843) writes about buffalo, "In summer they go to water and drink once in 24 hours, but in the winter they seldom get water at all" (3).

Examples of numbers of buffalo using limited riparian zones are further described.

Captain Lewis' July 11, 1806,..."The hunters were sent down the Medicine River (Montana) to hunt elk...they had seen elk; but in this neighborhood the buffalo are in such numbers that on a moderate computation there could not have been fewer than ten thousand within a circuit of two miles" (1). July 18, 1806 between the Maria and Tansy rivers in Montana Captain Lewis records..."reached a creek...about twenty yards wide, though with no water except in occasional pools in the bed. Down this creek we proceeded for twelve miles through thick groves of timber on its banks, pasing such immense quantities of buffalo, that the whole seemed to be a single herd." Captain Clark describes buffalo crossing the Yellowstone August 1, 1806..."A herd happened to be on their way across the river. Such was the multitude of these animals that although the river, including an island over which they passed was a mile in length, the herd stretched as thick as they could swim, completely from one side to the other, and the party was obliged to stop for an hour...two other herds of buffalo as numerous as the first soon after crossed the river" (1).

Washington Irving's "Astoria" of Wilson P. Hunt's crossing of the plains east of the Rocky Mountains in 1811 on the Missouri writes, "Boundless wastes kept extending to the eye, more and more animated by herds of buffalo. Sometimes these unwieldy animals were seen moving in long procession across the silent landscape, at other times they were scattered about singly or in groups on the broad, enameled prairies and green acclivities, some cropping the rich pasturage, others reclining amidst the flowery herbage, the whole scene realizing in a manner the old scriptural descriptions of the vast pastorial countries of the Orient, with "cattle upon a thousand hills." At one place the shores seemed absolutely lined with buffaloes, many were making their way across the stream...at another place a number were described on the beach of a small island, under the shade of trees, or standing in the water, like cattle, to avoid the flies and the heat of the day" (4).

Washington Irving writes about Captain B.L.E. Bonneville's view of buffalo in his trip of 1832 between the South and North Forks of the Platte Rivers. "They had reached also a great buffalo range, Captain Bonneville ascended a high bluff, commanding an extensive view of the surrounding plains. As far as his eye could reach, the country seemed absolutely blackened by innumerable herds. No language, he says, could convey an adequate idea of the vast living mass thus presented to his eyes" (5).

Captain Fremont on the South Fork of the Platte River July 4, 1842..."Column after column of buffalo came galloping down directly to the river. By the time the leading herds had reached the water, the prairie was darkened with the masses. Immediately before us, when the bands first came down the valley, stretched an unbroken line, the head of which was lost among the river hills on the opposite side. And still they pound down the ridge on our right. From hill to hill, the prairie bottom was certainly not less than two miles wide and allowing the animals to be ten feet apart and only ten in a line, there were already eleven thousand in view. In a short time they surrounded us on every side, extending for several miles in the rear and forward as far as the eye could reach" (6).

Osborne Russell, 1834-1843, on Christmas, writes "The bottoms along the rivers are heavily timbered with sweet cottonwood and our horses and mules are very fond of the bark which we strip from the limbs and give them every night as the buffalo have entirely destroyed the grass throughout this part of the country." Near where the Clark's fork joins the Yellowstone on the Yellowstone..."The bottoms along the Powder River were crowded with buffalo insomuch that it was difficult keeping them from among the horses who were fed upon sweet cottonwood bark as the buffalo had consumed everything in the shape of grass along the river" (3) 7 February.

Indians also influenced buffalo use of riparian zones by enticing them to feed near their camps in spring. Lewis writes March 6, 1805, "The day was cloudy and smoky in consequence of the burning of the plains by the Minnetarees, they have set all the neighboring country on fire in order to obtain an early crop of grass which may answer for the consumption of their horses, and also as an inducement for buffalo and other game to visit it...March 29...every spring as the river is breaking up, the surrounding plains are set on fire, and the buffalo tempted to cross the river in search of fresh grass which immediately succeeds to the burning; on their way they are often insulated on a large cake or mass of ice which floats down the river; the Indians now select the most favorable points for attack; and as the buffalo approaches, dart with astonishing agility across the tembling ice, sometimes pressing lightly a cake of not more than two feet square; the animal is of course unsteady, and his footsteps insecure on this new element, so that he can make but little resistance, and the hunter who has given him his death wound, paddles his icy boat to the shore and secures his prey" (1).

Indians had to use trees in riparian zones for lodging, food for horses, and firewood. Captain Fremont on the North Platte River near Casper, Wyoming, July 23, 1842 reports, "We found no grass today at noon; and, in the course of our search on the Platte, came to a grove of cottonwoods where some Indian village had recently encamped. Boughs of the cottonwoods, yet green, covered the ground, which the Indians had cut down to feed their horses upon. It is only in the winter that recourse is had to this means of sustaining them; and their resort to it at this time was a striking evidence of the state of the country" (6). Forts, for trading purposes, used these streamside zones for the same purposes. Steamboats traveling the Missouri and Yellowstone used trees to fuel steam engines until coal could be developed. Although there was also trapping of beaver on the larger streams entering the Missouri during the middle seventeen hundreds, real competition for their valuable furs in the Rocky Mountains started with Wilson Hunt's expedition in 1811.

Osborne Russell wrote in November 1843, "The trappers often remarked to each other as they rode over these lonely plains that it was time for the white man to leave the mountains as beaver and game had nearly disappeared" (3). The beaver market collapsed in the late 1840s.

Beaver Harvesting to the Later 1840s

There is controversy of thought as to what effect beaver harvesting played in modifying stream channels and riparian zones during the middle 1800s after being trapped out. We know that beaver were able to dam headwater streams tributary to larger basin streams. We have read that where dams were prevalent, trees were scarce. This is a realistic picture because beaver are not conservative harvesters of structural supplies. Willows were prevalent, however, behind and below these biological dams. Perhaps once dams were in place and trees gone, willows would suffice for dam maintenance purposes in bog areas like those described by Lewis and Clark. Once beaver were eliminated, dams without maintenance were sure to fail. Collective failure of beaver dams in headwater streams would insure an increase in flushing flow to larger basin streams during spring runoff of snowmelt.

For sure, beaver dam failure would cause downcutting of stream channels supported by alluvial fill to a point controlled by bedrock or bedrock dams maintaining depression storage of alluvium. Tributaries to main stem streams would adjust to the new main stream gradient. In mountains where bedrock is near the surface, downcutting would be slight but increased flushing flow would widen the channel. In basins where bedrock control is deep, downcutting of headwaters streams could be substantial but only to a point where gradient concavity would meet large main stem channel bed profiles or resistive geologic strata. Logically, increased flushing flow would carry large sediment loads to low gradient wide stream sections or basin streams and increase channel bed aggradation as well as perhaps channel widening. This would promote backfilling of tributary streams thus lowering their channel gradient and would promote channel filling near mainstem tributary junctions of smaller streams. To further increase the rate of aggradation of basin low gradient stream reaches, summer and fall stream flow would have been reduced because of water storage loss in mountains.

Willow and wet meadow riparian vegetation would have been reduced along mountain streams. However, reduced beaver numbers and channel disturbance would have increased tree establishment. Along headwater streams in basins, if beaver had created alluvial deposits and riparian vegetation was established, these water storage zones would have been drained and willows and water loving herbaceous vegetation reduced, as trees were scarce.

Gully Erosion to the Middle 1840s

The loss of beaver because of trapping up the 1840s has been suggested as cause for accelerated erosion of upland rangeland. We see this could have happened in headwater streams in basins and foothills of mountains. However, there is evidence that accelerated erosion of uplands was caused, in part, by extensive wildlife (buffalo) impact of vegetation. These animals were obligate grazers of lands near water during summer and used stream channel areas in winter for protection from storms. Just sheer numbers of these animals alone, moving in herds of large size, were enough to cause trails, decrease vegetation cover, and compact soils; all of which are known to increase overland flow of water. Arguments that buffalo did not use riparian zones and grazed uplands more than cattle in fenced pastures do not hold up as a cause of accelerated erosion of uplands. Distance from water had to be a barrier against wildlife distribution. Pasture size and orientation would have been dictated by river and stream corridors. Accelerated erosion of uplands caused by wildlife would have partitioned contributing area thus increasing flushing flow. Perhaps gully erosion in the central Rocky Mountain region was at a peak before settlement by white man. This would mean that riparian zones were reduced to a minimum, excluding where beaver could dam streams.

Gully erosion is illustrated by Fremont's description of a tributary of the South Platte near the Rocky Mountains. July 7, 1842 "The sun was getting low and some narrow lines of timber four or five miles distant promised a pleasant camp where, with plenty of wood for fire, and comfortable shelter, and rich grass for our animals, we should find clear cool springs, instead of the warm water of the Platte. On our arrival, we found the bed of a stream fifty to one hundred feet wide, sunk some thirty feet below the level of the prairie, with perpendicular banks, bordered by a fringe of green cottonwood, but not a drop of water. There were several small forks to the stream, all in the same condition...turning off towards the river, we reached the bank in about a mile and were delighted to find an old tree, with thick foliage and spreading branches where we encamped...July 28 on the North Platte near Casper, Wyoming..."the principal obstructions are near the river where the transient waters of heavy rains have made deep ravines with steep banks, which render frequent circuits necessary" (6). Robert D. Dorn, 1985, concludes in *The Wyoming Landscape 1805-1878* "Today grass is more abundant than it was prior to white man's influence in the area...dry streambeds, in many cases, were natural prior to settlement...deep gullying and barren, washed lands were natural phenomena and not products of more modern time" (2).

During Western Immigration 1840-1870

The principal route through the Rocky Moutains to the west coast used by immigrants was the Platte and Sweetwater rivers. "An estimated 350,000 people crossed Wyoming between 1841 and 1866 primarily heading for the California gold fields or to settle in Oregon or California" (2). Other major routes to Colorado and Montana used river corridors for roadways. "One should keep in mind that the primary needs of all these travelers were grass for the animals, water for the people and animals, and fuel for the campfires" (2). Movement of people scared wildlife to distant drainage basins but grazing of roadway routes was replaced by domestic animals. Certainly trees and willows were further used for firewood.

Where beaver could reestablish on headwater streams new storage of water would have occurred to create riparian zones like those before the era of the trapper. Buffalo were reduced for food by the Indians and trappers when it could be procurred so wildlife grazing of riparian zones would have been reduced. However, along mainstream rivers, permanent white man establishments and consolidation of Indians would have used these areas more readily. Little change in stream channel conditions would have occurred because flushing flows from mountain snowpack would have not changed substantially.

During Settlement 1870-1930

Pass of traffic through the Rocky Mountains was replaced by ranches, farms, towns, and industry. The Pony Express was established to connect east with west followed by stagelines and then a railroad (1869). These links of travel again used river corridors and thus riparian zones. The railroad was the first major attempt to channelize stream flow and change the natural flow regime of basin mainstem streams. Railroad beds were placed along streams where continental elevation was low and canyons allowed access through mountain ranges. Ephemeral streams (these which only respond to individual precipitation events) may have been dammed by the rail bed and these would have decreased flushing flow to mainstem streams. Where rail beds crowded stream channels (channelized) and bedrock bottoms were not present, stream velocity during high flows and confined within narrower streams longer during summer could have deepened the main stem streams. This would have caused further downcutting of tributaries and increased contributing area gullying. Consequently, flushing flow would increase in this case. Where rail beds straightened channels to pass water beneath the bridges or culverts, increased velocity of flow would occur and channel adjustments of downcutting, filling, and widening would further result. Highways to meet the advent of the automobile had similar effects on stream channels. Riparian zones would decrease where channelization occurred and increase where roadway dams across ephemeral streams existed. Where rail and road beds were placed in flood plains growing riparian vegetation, riparian area would be eliminated.

Ranching and farms would have first placed their base operations along streams for obvious reasons. Ranches replaced grazing of rangeland by buffalo with cattle and sheep. True, livestock is blamed for causing gullying of contributing area to mainstem streams. However, we have seen in the central Rocky Mountains, that rangeland was grazed heavily by wildlife. We only replaced grazing by wildlife with livestock; first with large numbers and then by the middle 1930s reduced them. We did expand the ability of livestock to graze away from stream corridors by developing off stream water. This would have placed them where vegetation cover was less and or perhaps steeper slopes. Reduced vegetation cover, soil compaction, and trails because of livestock grazing would have increased flushing flow of lands not previously grazed because of the lack of water. Accelerated erosion from these areas would have increased aggradation of low gradient stream reaches of mainstem basin streams thus causing back filling of tributaries along the mainstem and increased gullies near the headwaters. New gullies would not support riparian zones in the headwaters and increased aggradation could have increased stream side vegetation near the backfilled tributaries along the mainstem streams. Grazing by livestock of riparian zones along the mainstem stream corridors would not have been so different than by wildlife before settlement. Results of farming of sod covered uplands during this period were evident from the dust bowl days of the late 1930s. The impact of livestock grazing on riparian zones has to be minimum compared to these farming practices. Certainly increased flushing flows occurred when native vegetation was altered to produce crops. Again gullying would occur on headwater areas and aggradation on mainstem low gradient stream reaches.

Diversions of water to sustain base ranching operations and provide water for municipalities were developed as mainstem basin streams and low gradient mountain streams were settled. Diversion of water during high flow conditions reduced the power of stream flow. Flood irrigation had the potential to store groundwater and thus return it slowly to mainstem streams later in the summer when low flow conditions exist. Reduced power of high flow conditions allowed stream bank encroachment forcing braided streams to consolidate into fewer channels. Increased sediment loads in tributaries, if present, would increase rate of channel bank building. Irrigated pastures would have provided vegetation cover and root mass to hold banks in place. Sediment deposits on building banks and controlled grazing of livestock would have induced cottonwood and willow establishment. Rate of encroachment of channel banks would have been regulated by: (1) amount and timing of flow left in channels after diversion, (2) aerial extent of watershed contributing area between diversions, and (3) the condition of contributing area itself. As more diversions were put into place, less power was available to sustain riparian vegetation as it returned to maintain late season stream flow. The overall result of this process was mainstem stream channels narrowed, became deeper, and overbank flooding occurred depending on climatic conditions and variable mountain snowpack year to year. Overbank flooding would further help increase riparian vegetation. In mountains, beaver were left to mother nature thus providing water storage for maintaining late summer flow. Increased grazing by livestock, if it occurred compared to wildlife could have increased flushing flow by trailing action and reducing vegetation cover. However, this could have been offset by any reduction in fire of mountain woodlands by providing a net increase in groundcover. Downcutting would have been minimum because of biological damming and bedrock control near the soil surface. Impact to mountain streams would be wider channels and aggradation of bottoms in low gradient reaches.

After Reservoir Storage 1930-1960

We have witnessed how important water development was to the settlement of the central Rocky Mountains region and how diversion of water could cause increases in riparian zones because of channel bank encroachment of braided streams and return flow of groundwater. Dam building and reservoir storage of water to regulate stream flow minimized overbank floods, increased available water during time of need, and increased delivery systems for irrigation of crops. Riparian zones increased because more area below dams had water longer during growing seasons by direct application and return flow of groundwater. For sure riparian zones above the dam were flooded and lost. However, this is temporary, because as dams fill with sediment, riparian vegetation can increase. Hungry water (water without sediment) released from dams can erode riparian zones until sediment supply is replaced by runoff of water from tributaries of below dam contributing areas. Perhaps, however, regulated release because of dams, to control downstream flooding of municipalities, have most generally allowed stream banks to stabilize at a given width and depth even if hungry water is released.

Small reservoir storage has, no doubt, increased riparian zones even if designed for livestock water, distribution of animals, and erosion control. Because of water development for agriculture, riparian zones exist now where none existed before.

Increased riparian zones along streams, not recent livestock grazing practices, could be a reason we see recent downcutting of headwater contributing areas of basin and foothills drainage basins without bedrock controls. Wide streams, with aggraded channel bottoms adjusted to natural flow events, became narrow when riparian zones encroached. This narrower stream would move bed material downstream causing a drop in the bed level of the mainstem channel. Tributary streams would backcut to adjust to the new channel bed level because a nick point in the tributary is present (Figure 3). On small headwater tributaries without bedrock control, downcutting would be emphasized compared to the mainstem because of: (1) steeper gradients, (2) less contributing area between tributaries, and (3) little chance of aggradation of moving sediment because of increased stream power (Figure 4).

Mountain riparian zones most likely changed very little during this period. Flushing flow would be altered because of road development for timber, fire control, and reduced grazing by livestock. Beaver numbers either increased or were managed to sustain appropriate streamside vegetation. Little dam building and diversion occurred at high elevations and if so, mountain and canyon stream gradients were maintained by the presence of bedrock. Scouring of canyon colluvium by reservoir release would alter little riparian zone habitat.

Multiple Use Management 1960-1975

Several new issues to riparian zone management surfaced during the 60s and early 70s. Public interest in the fishing industry increased. Persons interested in fishing insisted on action to mitigate the impact of stopping fish migration up and downstreams because of storage dams. Having made substantial progress on this problem, fishery biologists and enthusiastic fishermen begin to evaluate fish habitat needs. Poor fish habitat was tied to deteriorated riparian zones. This effort was complimented because the general public had increased leisure time and used it for recreation. Certainly, the recreation experience is normally perceived as being enjoyed more by the presence of water. This is especially true for one recreation activity, fishing.

Access to more remote areas of drainage basins was improved for recreationists using the four-wheel drive automobile. After World War II these vehicles were available from surplus sources. Public land agencies, ranchers, and some of the general public found them useful as replacements for horses, wagons, and 2-wheeled drive vehicles to help accomplish their livelihood. It was not long before the automobile industry capitalized on this market. New unimproved roads and off-road vehicle abuse was on the rise. This is especially true for public lands where access could not be curtailed. Increased road construction also rose because of oil and gas development in basin areas.

Increased facilities on stream reaches were developed to mitigate the public's cry for more recreation opportunities. These facilities localized larger numbers of people to small areas. Mountain home developments increased and ski areas and associated industries occupied substantial mountain valley areas. Hunting and fishing, using horses in mountains, also increased as did backpacking. Livestock grazing pressure decreased.

This increase in access and human activity in remote areas of drainage basins has increased flushing flows because of channelization of headwater areas by roads and trails. Activities in these areas remove vegetation, decrease infiltration of water into soils, and increase overland flow to streams. Riparian zones created by geological, biological, and man-made dams have decrease locally where these impacts occur. On headwaters, increased sediment and stream flow velocity of water would have been transferred downstream to low gradient reaches and basin mainstem streams.

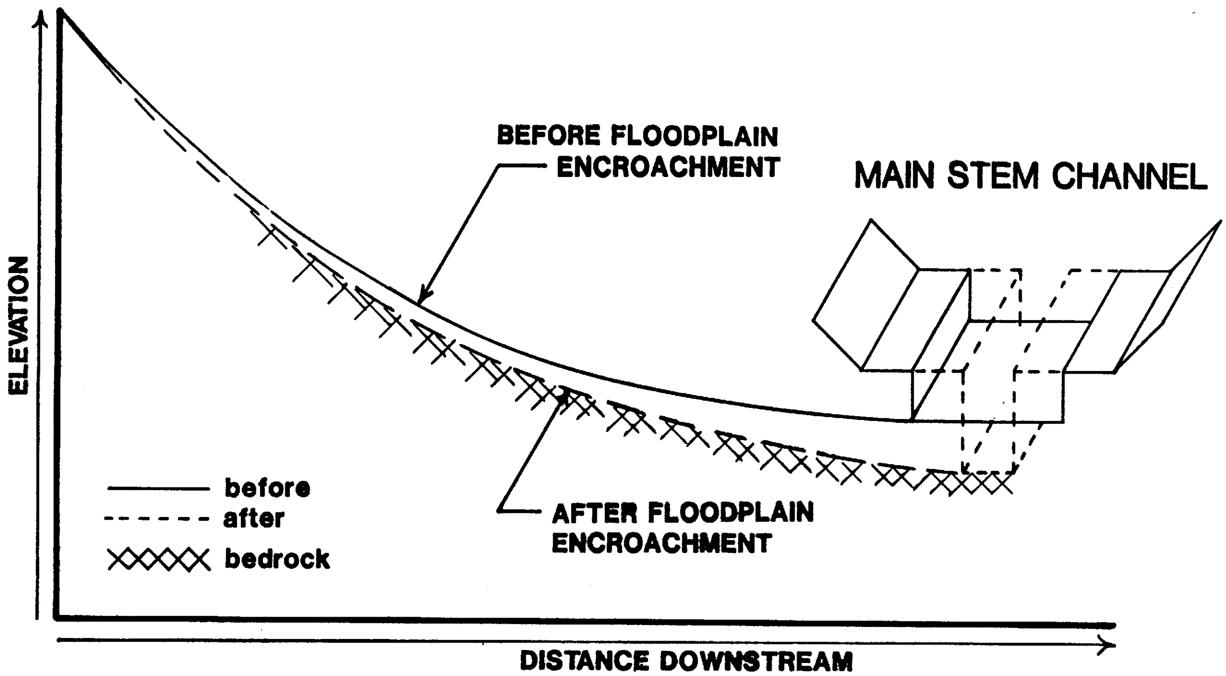

Figure 3. Stream channel encroachment and tributary backcutting caused by change in channel bed elevation.

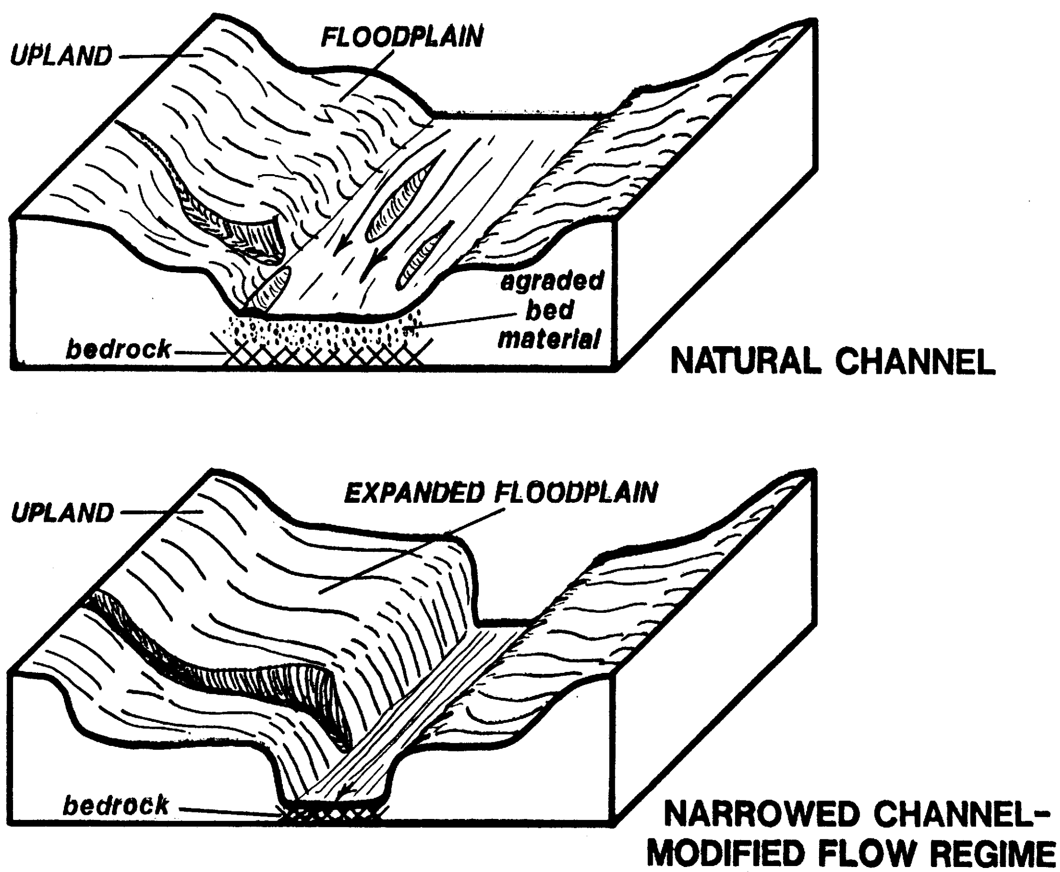

Figure 4. Downcutting of tributaries caused by lowering of mainstem channel bed elevations.

Emphasis of Riparian Zone Management 1975-1986

No less than seven national conferences have been held in the United States since 1975 to specifically address riparian zone issues. Increased knowledge of fish habitat needs, demand for recreation opportunity, emphasis placed on bird and other wildlife habitat, and decreased emphasis on water development have contributed to making streamside zones an emotional issue.

Agriculture and livestock grazing industries have taken their share of criticism for causing a decrease in riparian zones. However, this paper should help confirm Bob Dorn's conclusion about Wyoming. "Riparian vegetation may be as extensive now, if not more so, than prior to settlement" (8). G.P. William's 1978 research clearly shows the North Platte River in Nebraska has had a substantial increase in riparian zone. "The decreases in channel width are related to decreases in water discharge. Such flow reductions have resulted primarily from the regulating effects of major upstream dams and the greater use of river water by man. Much of the former river channel is now overgrown with vegetation...The changes are most pronounced in the upstream 365 km of the study reach (Minature to Overon). Within this reach, the channel in 1969 (and 1977) was only about 10-20 percent as wide as the 1865 channel. A significant part of this reduction in width has occurred since 1940" (9).

One doesn't have to give agriculture, livestock grazing, and water development a break; just give them a fair shake. There is little doubt riparian zones on private and public lands have changed from 1804 to present. Before all impact to existing riparian zones are blamed on the obvious, livestock, look behind the scenes to see what we have now compared to what we had. Without water development, basin riparian zones were marginal. Basin riparian zones are an extension of mountain watersheds. Other impacts now taking place on headwaters may change flow regimes far more than herbivory and hoof action by livestock. For instance, oil and gas development, is now occurring on headwater streams where they were not before because of technology of deep drilling. Imagine how road construction and facilities needed to provide these energy products to the United States will increase flushing flow, channelization of contributing area, and sediment downstream. This drilling activity is in addition to still increasing utilization of high elevation mountain valleys for recreation and business opportunities. We must acknowledge that riparian zones created by water development and agriculture is contributing towards holding low gradient mountain and basin river systems together as we presently know them. Irrigated vegetation has created constrictive dams, as riparian zones, which cause overbank flooding and thus decrease velocity of flow in existing channels. Other benefits include storage of water in soils and return flood and irrigation water which sustains increased aquatic habitat late in the low water seasons. If this system of using water in the western United States is disrupted, we stand the chance of losing an existing water storage capability. Can we afford to have this happen?

Dam construction is all but at a standstill because of public outcry against large reservoir storage and government permitting procedures. Reservoir storage capacity should be decreasing because of sediment deposition behind dams. As water storage decreases, more efficient use of water becomes necessary. Sando's et al. (1985) research concludes from a study on efficient irrigation of a river valley..."the primary effects of increased irrigation efficiencies are higher flows in spring months, higher peak annual discharges, and lower flow due to decrease in groundwater recharge. Large increases in spring flows can cause bank erosion (8)." Perhaps this practice of efficient irrigation is a way to return to 1804 riparian zones management. The effort of returning to 1804 type riparian zones can be partially supplemented by: (1) converting use of water for irrigation practices to be later used by industry and municipalities, (2) reducing use of livestock on public land and taking away any economic opportunity of providing ranchers a livelihood and thus, no reason for agriculture to sustain riparian zones on private lands, (3) drain water from behind geologic, biological, and constrictive riparian zones, and (4) ignore developing any additional water on the continental headwaters of the western United States where sediment is minimum and speed of runoff is maximum.

Today in Wyoming, Dorn concludes "Riparian vegetation may be as extensive now, if not more so, than prior to settlement." What do you think and what do you want? Dorn also concludes that "Today grass is more abundant than it was prior to white man's influence in the area, the prevalence today of cactus, sagebrush and other shrubs was not caused by livestock overgrazing" (2).

Please remember that, without water, riparian zones cannot exist. Distribution and extent of riparian zones change as water use changes. Perhaps we tend to focus attention on local areas meaningful to individuals' purposes instead of evaluating resources of entire drainage basins for the good of all users. Change in distribution of water for agriculture has created extensive riparian zones along basin streams. Efficient irrigation of yards, street margins, and parks; within towns and cities provide riparian zone habitat where none existed before settlement. We cannot throw rocks at water storage unless riparian zones are low priority resource needs. Entire drainage basin planning based on historial information and use is needed to move forward to meet future demands for this now desired resource. With basin planning, water utilized to meet the needs of one user can be utilized again and again to meet demands of others.

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WYOMING'S CHALLENGE IN RIPARIAN HABITAT MANAGEMENT

Fee Busby[1]

This conference, like many others dealing with riparian habitat management, will emphasize livestock use of the riparian zone. It is easy to focus on the negative aspects of livestock use, but it is the challenge of this conference and Wyoming to look objectively at the multiple use management of the riparian zone. The presentation included (1) trends of livestock grazing and other uses of Wyoming's rangelands in which riparian and stream ecosystems occur, (2) implications of these use trends to past and present ecological condition of riparian and stream habitats, (3) range, livestock, and multiple use management approaches that might help improve and maintain desirable riparian and stream ecosystem conditions, and (4) economic development opportunities that riparian and stream ecosystems can provide the rangeland owner and the State of Wyoming. The appeal is for multiple use rather than single use finger pointing, and for true multiple use management of our riparian and stream ecosystems.

[1]For more details contact Fee Busby, President, Society for Range Management and Director, Wyoming Cooperative Extension Service, College of Agriculture, P.O. Box 3354, University Station, University of Wyoming, Laramie, Wyoming 82071

FEDERAL/STATE WATER LAWS

Lawrence J. Wolfe[1]

Federal and State laws governing the use of water have substantial impact upon riparian areas. The interstate compacts and court decrees to which Wyoming is a party determine how much water Wyoming can consumptively use from rivers and streams. In addition, the doctrine of reserved water rights has given to the federal government the ability to claim large quantities of water for consumptive and nonconsumptive uses. These claims will take on increasing significance as litigation over the reserved rights is concluded. This paper will briefly outline some of the most important federal and state laws that affect Wyoming's use of water.

Interstate Streams

There are basically two methods by which states can resolve disputes over the use of interstate streams. The first method is through the negotiation of an interstate compact. The compact is negotiated by representatives from the states. Once the compact is agreed to, it is submitted to the state legislatures of the signatory states, enacted into law by each of the states, and then consented to by Congress. The consent of Congress transforms the interstate compact into a federal law. *Intake Water Company v. Yellowstone River Compact Commission.*

The second method is through an equitable apportionment lawsuit filed with the United States Supreme court. The U.S. Supreme Court has original jurisdiction over actions between two states. A state that believes it is being injured by the neighboring state's use of water in an interstate stream may file a petition with the Supreme Court, requesting that the Court apportion the river between the two states. The Supreme Court generally appoints a special master to receive the evidence and make a recommended decision. The Court then reviews the facts and the decision and issues a decree. The decree defines the right of each state to use water flow to the interstate stream.

Wyoming is a party to seven interstate compacts and is subject to equitable apportionment decrees on three rivers. Attached is a brief discussion of these compacts and court decrees that is taken from a publication of the Wyoming State Engineer's Office. All of the compacts are also found in the Wyoming statutes in Title 41, Chapter 12. Laws relating to the interstate stream commission and the appointment of commissioners to negotiate compacts is in W.S. § 41-11-101 through 206.

Wyoming participates in the compact commissions that administer the interstate compacts. The most active are the Yellowstone River Compact Commission, the Bear River commission, and the Upper Colorado River Commission.

Federal Reserved Rights

The reserve rights doctrine was established by the U.S. Supreme Court in 1908 in the case of *Winter v. United States.* The court held that when the federal government reserves land (such as Indian reservations, national forests, or national parks), it impliedly reserves water necessary to accomplish the purpose of the reservation. The result of this decision is to allow the federal government, on its own behalf and as trustee for Indian tribes, to claim enormous quantities of water for use on federal reservations.

There are several effects of the reserved rights doctrine:

1. The reserved right is vested as of the date of the creation of the reservation. Thus, since the Wind River Indian Reservation was created in 1868, that is also the priority date for the reserved water rights.

2. The reserved right is superior to the water rights of all future appropriators.

3. The reserved right is not subject to state law requirements such as notice of application of water to beneficial use of forfeiture for nonuse.

The existence of reserved rights on the Wind River Indian Reservation caused the State of Wyoming to file suit in 1977 for a general stream adjudication of the Big Horn River. This litigation is presently pending before the Wyoming Supreme Court. The result of this adjudication to date has been to award to the Indian Reservation several hundred thousand acre-feet of water for present and future uses.

The Big Horn River General Adjudication also involves claims by the federal government for reserved water rights on the national forest and the BLM lands in the Big Horn Basin. Through the concerted efforts of state and federal officials, these reserve rights claims were resolved by a negotiated settlement in November, 1982. This settlement, which is entitled Partial Interlocutory Decree and Supporting Documents Regarding the United States' Non-Indian Claims, was submitted to the court on November 22, 1982 and a decree was entered on February 9, 1983.

[1]Attorney, Holland & Hart, 2020 Carey Avenue, Suite 500, Cheyenne, Wyoming 82001.

The settlement accomplished a number of things including:

1. Establishing the water rights for those parts of Yellowstone National Park that are included with the Big Horn River drainage.

2. Quantifying water rights for other federal reserves such as: (a) public water reserves; (b) stock driveways; (c) water producing oil and gas wells; (d) BLM wells; (e) BLM reservoirs; and (f) quantified instream flows.

Perhaps the most significant achievement of the settlement was the establishment of quantified water flows (instream flows) on all streams that originate in the Big Horn and Shoshone National Forests. These water rights were based on Forest Service claims to the right to pass certain quantities of water to satisfy the purposes of the Forest Service Organic act of 1897 and the Multiple Use and Sustained Yield Act. The quantified water flows are set forth in acre-feet for each stream arising on the national forest. The quantified instream flows, an example of which is attached, are subject to limitations contained in the decree:

1. The flows are administered as junior to any existing water right under state law (existing as of November 22, 1982), if the exercise, operation or use of the quantified instream flow conflicts with a right established under state law.

2. The decree reserves water for future development on certain streams. The decree lists the streams that are reserved for future development, and makes any development senior to the instream flow right.

3. The decree protects water for future development on specific streams in the Big Horn and Shoshone National Forests. This water is listed by specific amounts (see example attached) For these streams, the instream flow right would be junior to all development up to the specified amount.

The negotiated decree enabled the parties to resolve these claims without the necessity of protracted and expensive litigation. The decree was an innovative solution to the complex problems that are created by the reserved rights doctrine.

Wyoming Instream Flow Legislation

The 1986 legislature passed an instream flow bill, after many years of very bitter legislative battles over this issue. The instream flow bill, although not perfect, will allow water rights to be established for the purpose of protecting game fisheries. The law sets up a complicated process by which the Game and Fish Department can make a report to the Water Development Commission and request that certain streams be evaluated for the establishment of an instream flow right. The Game and Fish request sets into motion an elaborate evaluation process that may culminate in either the legislature appropriating funds to construct a water storage project or action by the State Engineer to grant an instream flow right.

DOCUMENTS ON THE USE AND CONTROL OF WYOMING'S INTERSTATE STREAMS

Compacts, Treaties, and Court Decrees

Compiled under the direction of George L. Christopulos, State Engineer

STATE OF WYOMING 1982

SUMMARY

COMPACTS

Interstate compacts basically provide for the distribution and use of the waters of streams or rivers that flow across state lines. An integral part of any division or apportionment is the method of measurement or accounting. In general, two methods of providing for the measurement of the agreed division are found in the compacts affecting Wyoming rivers.

The first method involves the division of the consumptive use of the waters, which implies the ability to measure such use by irrigation, municipal, or other beneficial purposes. The second method is to divide the divertible flow, that is the water that flows, or would flow, past some defined point, among the States.

The primary purpose of interstate river compacts is the division of stream flow among the participating States. Also of considerable importance and interest are the many supplemental clauses contained in the compacts. For instance, in most Wyoming compacts, downstream States are given the right to acquire sites for storage or control structures in upstream States. In connection with this, an important feature contained in many compacts is the provision that downstream States must make "in lieu" tax payment for any revenue lost to the other State due to these structures.

*1. **Amended Bear River Compact (1978).***
This compact provides that in the administration of the Bear River among the States of Idaho, Utah, and Wyoming, the river shall be divided into three divisions. When a water emergency exists, as provided by the terms of the compact, water administration becomes effective to diversions by section in the Upper Division; by percentage between the States of Wyoming and Idaho in the Central Division; and by priority of right in the Lower Division.

Upper Division: This division is comprised of that portion of Bear River from its source in the Uinta Mountains to and including Pixley Dam, a diversion dam in the Southwest Quarter of Section 25, Township 23 North, Range 120 West, Sixth Principal Meridian, Wyoming. A water emergency shall be deemed to exist within this division when the total divertible flow is less than 1,250 cubic feet per second and such divertible flow is allocated for diversions in the river sections of the diversion as follows:

Upper Utah Section Diversions	0.6%
Upper Wyoming Section Diversions	49.3%
Lower Utah Section Diversions	40.5%
Lower Wyoming Section Diversions	9.6%

Central Division: This division is comprised of the portion of the Bear River from Pixley Dam to and including Stewart Dam, a diversion dam in Section 34, Township 13 South, Range 44 East, Boise Base and Meridian, Idaho. A water emergency shall be deemed to exist within this division when the total divertible flow is less than 870 cubic feet per second or the flow of Bear River at Border Gaging Station is less than 350 cubic feet per second, whichever shall first occur. When such a condition exists, all divertible flow in this division shall be allocated such that the portion of the river between Pixley Dam and the point where the river crosses the Wyoming-Idaho line near Border shall be limited for the benefit of the State of Idaho, not to exceed forty-three (43) percent of the divertible flow. The remaining fifty-seven (57) percent of the divertible flow shall be available for use in Idaho in the Central Division, but if any portion of such allocation is not used therein, it shall be available for use in Idaho in the Lower Division.

Lower Division: This division is comprised of the portion of the Bear River between Stewart Dam and Great Salt Lake, including Bear Lake and its tributary drainage. When the flow of water across the Idaho-Utah boundary line is insufficient to satisfy water rights in Utah covering water applied to beneficial use prior to January 1, 1976, any water user in Utah may file a petition with the Commission alleging that by reason of diversions in Idaho, he is being deprived of water to which he is justly entitled, and that by reason thereof, a water emergency exists, and requesting the distribution of water under the direction of the Commission. If the Commission finds a water emergency exists, it shall put into effect water delivery schedules based on priority of rights and prepared by the Commission without regard to the boundary line for all or any part of the Division and during such emergency, water shall be delivered in accordance with such schedules by the State official charged with the administration of public waters.

Rights to water first applied to beneficial use on or after January 1, 1976, shall be satisfsfied from the following respective allocations made to Idaho and Utah which apportion the remaining water in the Lower Division including ground water tributary to the Bear River.

1. Idaho shall have the first right to the use of such remaining water resulting in an annual depletion of not more than 125,000 acre-feet.

2. Utah shall have the second right to the use of such remaining water resulting in an annual depletion of not more than 275,000 acre-feet.

3. Idaho and Utah shall each have an additional right to deplete annually on an equal basis, 75,000 acre-feet of the remaining water after the rights provided above have been satisfied.

4. Any remaining water in the Lower Division after the allocations above have been satisfied shall be divided; thirty (30) percent to Idaho and seventy (70) percent to Utah.

The original compact grants to Wyoming and Utah the right for each store, above Stewart Dam, an additional 17,750 acre-feet of Bear River water in any water year and to Idaho the right to store 1,000 acre-feet of water in Idaho or Wyoming on Thomas Fork for use in Idaho. In addition, the Amended Compact (1978) allows further storage entitlements to Utah and Wyoming for 70,000 acre-feet of Bear River water in any water year above Stewart Dam to be divided equally and to Idaho an additional 4,500 acre-feet of Bear River water in any water year to be stored in Idaho or Wyoming for use in Idaho. Water rights granted or water appropriated under this last entitlement, including groundwater tributary to the Bear River, which is applied to beneficial use on or after January 1, 1976, shall not result in an annual increase in depletion of the flow of the Bear River and its tributaries above Stewart Dam of more than 28,000 acre-feet in excess of the depletion as of January 1, 1976. Thirteen thousand (13,000) acre-feet of the additional depletion above Stewart Dam is allocated to each of Utah and Wyoming, and two thousand (2,000) acre-feet is allocated to Idaho. Idaho, Utah, and Wyoming are also granted the right to store and use water above Stewart Dam that otherwise would be bypassed or released from Bear Lake at times when all other direct flow and storage rights are satisfied. Water availability and depletions are to be calculated and administered by a Commission-approved procedure.

2. Belle Fourche River Compact (1943).
The Compact for the division of the waters of the Belle Fourche River between Wyoming and South Dakota was negotiated and ratified by the two states and the Federal government in 1943. This Compact recognizes all existing rights in Wyoming, as of the date of the Compact. It permits Wyoming unlimited use for stock water reservoirs not exceeding 20 acre-feet in capacity, and it allows Wyoming to deplete the flow under the conditions existing as of the date of the Compact by an additional 10 percent.

3. Colorado River Compacts (1922 and 1948). A compact between the Upper Colorado River Basin States (Wyoming, Colorado, New Mexico and Utah) and the Lower Colorado River Basin States (Arizona, Nevada and California) was negotiated in 1922. This Compact allocated 7 1/2 million acre-feet of consumptive use annually to the Upper Basin. It also provided that a minimum flow of 75,000,000 acre-feet in any consecutive ten-year period should be maintained at Lee Ferry, which is the point on the river dividing the Upper Basin from the Lower Basin. Also, provision was made for future treaties with Mexico. As a result of this clause, the 1944 Coloardo, Tijuana, and Rio Grande Treaty indirectly has its influence on the regulation of the Colorado River. In 1948 a compact among the Upper Basin States was negotiated. It was ratified by all the states and the Federal government in 1949. Arizona has a small area in the Upper Basin, and therefore was included in the Upper Basin negotiations. This Upper Colorado River Basin Compact apportions the use allocated to the Upper Basin by the 1922 Compact as follows: 50,000 acre-feet per annum to Arizona and of the remaining quantity 51-3/4% to Colorado; 11-1/4% to New Mexico; 23% to Utah; and 14% to Wyoming. The 1948 Compact also divided the waters of Henry's Fork between Wyoming and Utah on a straight priority basis, and the waters of the Little Snake River below its confluence with Savery Creek between Wyoming and Colorado for existing development on a straight priority basis and the unused water, 50% to each of the two States.

4. Upper Niobrara River Compact (1962).
The compact dividing the waters of the Niobrara River between the States of Nebraska and Wyoming was negotiated by the two States in 1962 and approved by Congress in 1969. It provided that stock water reservoirs (not larger than 20 acre-feet capacity) in Wyoming should not be restricted except by Wyoming law. No restrictions were placed on diversion or storage of water in Wyoming except on the main stem east of Range 62 West and on Van Tassel Creek south of Section 27, Township 32 North, Range 60 West. In this area direct diversions are regulated on an interstate priority basis with lands in Nebraska west of Range 55 West, and storage reservoirs with priority dates prior to August 1, 1957 may store water only during the period of October 1 to June 1, while storage reservoirs with priority dates after August 1, 1957 may store a maximum of 500 acre-feet in any water year with dates of storage limited to the period of October 1 to May 1. Groundwater development was recognized to be a significant factor and the compact provides for investigation of this resource and possible apportionment at a later date.

5. Snake River Compact (1949).
The Compact dividing the waters of the Snake River and Salt River between the States of Idaho and Wyoming was negotiated by the two states in 1949 and ratified by them and the Federal government in 1950. The Compact recognizes, without restrictions, all existing rights in Wyoming as of the date of the Compact. It permits Wyoming unlimited use for domestic and stock uses provided that stock water reservoirs shall not exceed 20 acre-feet in capacity. It permits Wyoming to divert (not deplete) for new developments, either for supplemental or original supply, 4% of the Wyoming-Idaho State line flow of the Snake River.

6. Yellowstone River Compact (1950).
The Yellowstone River Compact dividing the waters of the tributaries (Clarks Fork, Big Horn, Tongue and Powder) of the Yellowstone among the States of Wyoming, Montana and North Dakota was negotiated in 1950, and ratified by the three states and the Federal government in 1951. This Compact included the following provisions for all four of the tributaries:

A. Existing rights as of January 1, 1950, maintain their status quo.

B. Existing and future domestic and stock water uses including stock water reservoirs up to a capacity of 20 acre-feet are exempted from provisions of the Compact.

C. Devices and facilities for the control and regulation of surface water are exempted from the provisions of the Compact.

The unappropriated or unused total divertible flow of each tributary after needs for supplemental supply for existing rights are met, is allocated to Wyoming and Montana as follows:

Clarks Fork of the Yellowstone River:

Wyoming. 60%
Montana. 40%

Big Horn River (exclusive of Little Big Horn River):

Wyoming. 80%
Montana. 20%

Tongue River:

Wyoming. 40%
Montana. 60%

Powder River (including the Little Powder River):

Wyoming. 42%
Montana. 58%

Lands in Montana and North Dakota below Intake, Montana are entitled to beneficial use of the flow of the Yellowstone River on a proportionate basis of acreage irrigated.

The points of measurement and the gaging stations used to define the divertible flows are:

Stream	Point	Designated Compact Gaging Station
Clarks Fork	above Rock Creek	Clarks Fork at Edgar, Montana
Big Horn	at Mouth (Exclusive of Little Big Horn River)	Big Horn River near Custer, Montana Little Big Horn River near Hardin, Montana
Tongue	at Mouth	Tongue River at Miles City, Montana
Powder	at Mouth (Exclusive of Little Powder River)	Powder River near Locate, Montana

INTERNATIONAL TREATY

The International Treaty between the United States and Mexico dated 1944 dividing the waters of the Coloarado River, which flows from the United States into Mexico, also affects Wyoming. This treaty guaranteed to Mexico the delivery of 1,500,000 acre-feet of water per annum. By the 1922 Colorado River Compact the burden of supplying this water to Mexico during periods of short water supplies, is equally borne by the Upper Basin, of which Wyoming is a part, and the Lower Basin.

The Colorado River Basin Project Act (PL 90-537, Sec. 202) provides that the satisfaction of the requirements of the Mexican Water Treaty from the Colorado River constitutes a national obligation which shall be met by any augmentation project developed under the provisions of the Act.

COURT DECREES

*1. **North Platte River.*** During the middle 1930's Nebraska started action against Colorado and Wyoming in the Supreme Court in regard to the waters of the North Platte River. In 1945, the Supreme Court handed down its decree, which included the following provisions:

(a) Exclusive of the Kendrick Project and Seminoe Reservoir, the State of Wyoming is enjoined from diverting water from the North Platte River above the Guernsey Reservoir and from the North Platte River and its tributaries above Pathfinder Dam, for the irrigation of more than a total of 168,000 acres of land during any one irrigation season.

(b) Exclusive of the Kendrick Project and Seminoe Reservoir, the State of Wyoming is enjoined from storing more than 18,000 acre-feet of water from the North Platte River and its tributaries above the Pathfinder Reservoir for irrigation purposes during any one year.

(c) The storage rights of the Pathfinder, Guernsey, Seminoe, and Alcova reservoirs are junior to 1165 second-feet of rights for the irrigation of land in Western Nebraska, and the State of Wyoming is enjoined from storing or permitting the storage of water in these reservoirs otherwise than in accordance with the rule of priority.

(d) The natural flow of the North Platte River in the section of the river between the Guernsey Dam and Tri-State Dam, or approximately the Wyoming-Nebraska state line, between May 1 and September 30 of each year, is apportioned 25% to Wyoming and 75% to Nebraska.
It also limits Colorado to the irrigation of 135,000 acres, the storage of 17,000 acre-feet of water in any one year, and the diversion of an average 6,000 acre-feet out of the North Platte River Basin annually.

By stipulation agreed upon by the three States and approved by the Supreme Court of the United States the decree was amended as follows:

Colorado was permitted to increase its irrigated acreage to 145,000 acres and the States of Wyoming and Nebraska were permitted to store 40,000 acre-feet during any water year in Glendo Reservoir, with such storage, including holdover, never to exceed 100,000 acre-feet. The 40,000 acre-feet of storage during the year is divided 25,000 acre-feet to Nebraska and 15,000 acre-feet to Wyoming.

2. Laramie River. In 1911, Wyoming started proceedings in the Supreme Court against Colorado to limit the Colorado diversions from the Laramie River. In 1922, the Supreme Court handed down its decree which allowed Colorado to divert annually for the meadow lands, 4,250 acre-feet, and by trans-mountain diversion 33,500 acre-feet plus "the relatively small amount of water appropriated..." from the headwaters of Deadman Creek, through theWilson Supply Ditch. In 1936, the Supreme Court of the United States stated that the record showed that the "relatively small amount of water" referred to actually amounted to 2,000 acre-feet of water per annum. Therefore the total annual diversion allowed Colorado was 39,750 acre-feet. In 1939 Wyoming secured an order from the Supreme Court of the United States restraining Colorado from diverting more than the 39,750 acre-feet annually that had been allotted to her. The Supreme Court stated that this amount should be administered according to Colorado laws. By stipulation between Colorado and Wyoming in 1957 the Supreme Court decreed that only 19,875 acre-feet of water per year could be diverted from the Laramie River Basin and that 29,500 acre-feet per year could be diverted by the meadow land users for the irrigation of certain lands described by map in the stipulation.

3. Teton and South Leigh Creeks. Conflict between the water users on Teton and South Leigh Creeks in Wyoming and Idaho was settled under decree of the United States District Court entered February 4, 1941, by what was known as the "Roxana Decree." This decree contains as a stipulation an agreement entered into between the Wyoming and Idaho water users. The stipulation sets forth that Wyoming users shall be unlimited in their diversions from Teton Creek and its tributaries until the flow diminishes to 170 cubic feet per second. After that, the Wyoming water users are limited to a diversion of 1 cubic foot per second for each fifty acres of land. When the flow further reduces to 90 cubic feet per second, the flow of Teton Creek and its tributaries is divided equally between Wyoming and Idaho water users. The Wyoming appropriators are permitted unlimited diversions from South Leigh Creek until the natural flow of the creek diminishes to a total of 16 cubic feet per second, after which time the Wyoming users are permitted to divert one-half of the stream flow and Idaho users the balance.

The following is an excerpt from:

Partial Interlocutory Decree and Supporting Documents Regarding the United States' Non-Indian Claim, Re: General Adjudication of All Rights to Use Water in the Big Horn River System and All Other Sources, State of Wyoming, Civil Docket #4993, 5th Judicial District Court.

QUANTIFIED WATERFLOW USES:

(a) In this matter the United States has claimed the right to pass certain amounts of water, measured in acre-feet, past specified points on certain natural streams in the Bighorn and Shoshone National Forests in order to achieve the purposes of those Forests under the Organic Act of 1897. The United States has also made a separate claim for the right to maintain certain levels of instream flows on those same streams to accomplish the additional purposes of the Bighorn National Forest under the Multiple Use-Sustained Yield Act of 1960. It is the Decree of the Court that, with the limitations stated herein, the United States shall have a water right to pass those amounts of water shown on the following pages past the points identified on the streams specified on the Bighorn and Shoshone National Forests during the periods shown. The United States shall have no other water right to the passage of any quantity of water or to the maintenance of any instream flows on the Bighorn and Shoshone National Forests except as specified by this Decree. Each of the following pages refers to a specific individual water right and defines the following elements of the right:

1. The name of the national forest on which the stream is located;
2. The name of the stream upon which the water right applies;
3. The priority date of the water right;
4. The point at which the water right is quantified, which is the point at which it may be enforced and maintained; and
5. The amount of the water right, in total acre-feet annually and monthly at the point of quantification.

Each of the foregoing elements of each water right is to be construed as a limitation on the right. Other limitations on the water rights granted herein are as otherwise specified in this Decree.

(b) The amounts shown for each of the water rights quantified on the following pages are displayed on a monthly basis. The monthly totals shall be considered to state a limitation upon the right decreed. The United States shall not be entitled in any month to the passage of a greater amount of water than as shown below for that month. Passage of a greater amount in any given month shall not, however, affect the amount to which the United States is entitled in subsequent months.

(c) The priority date of each water right shall be as shown in this Decree on the page pertaining to an individual water right.

(d) The water rights granted herein on behalf of the National Forests shall be in full and final satisfaction of all rights of the United States to the passage of any quantity of water past any point on any natural stream on the Bighorn and Shoshone National Forests and the right to maintain any level of instream flow on the Forests. Any other section of this Decree notwithstanding, the United States shall have no right to make any change of any kind in the water rights decreed by this section of the Decree. The water decreed herein shall be used solely as decreed, to pass those amounts of water shown past the points shown and in the amounts shown, on the stream in which the water naturally flows. The United States shall have the same rights as any other water right holder in Wyoming to assert injury to the instream flow rights decreed herein as a bar or defense to a change of a state-awarded water right.

(e) The Court is aware that the rights to the passage of water granted to the United States could, when exercised, adversely affect existing water rights permitted or certificated under Wyoming law. It is the Decree of the Court that all rights for the passage of water decreed herein to the United States shall be deemed to be and shall be administered and enforced as junior to any existing water right permitted or certificated under Wyoming law, if the exercise, operation, or use of the right to the passage of water conflicts with the exercise, operation, or use of the permitted or certificated water right.

(f) This Court recognizes that certain of the streams upon which a water right for the passage of amounts of water has been decreed have been studied as or planned for the construction of new or enlarged reservoir storage by the United States, Wyoming, or other public, quasi-public, or private parties.

1. Within the Bighorn National Forest, future new or enlarged reservoir sites have been identified on the following streams:

Porcupine Creek
Shell Creek
Medicine Lodge Creek
Paint Rock Creek
West Tensleep Creek

2. Within the Shoshone National Forest, future new or enlarged reservoir sites have been identified on the following streams:

- Brooks Lake Creek
- Warm Springs Creek
- E. Fork of the Wind River
- Wiggins Fork
- South Fork of the Little Wind River
- Louis Creek
- South Fork of the Shoshone River
- Clark's Fork of the Yellowstone River
- Sunlight Creek

It is the decree of this Court that if the construction or enlargement of any reservoir on the streams shown is authorized by an entity with authority to construct and/or fund the construction of such reservoir or enlargement, the water right decreed herein to the United States on that stream shall be deemed to be and shall be administered as junior to any such reservoir or enlargement.

(g) This Court is aware that, in addition to the potential future storage facilities noted above, there exists other additional, but as yet not specifically identifiable, potential for the development of water for beneficial use on the streams upon which a water right for the passage of water has been decreed. It is the Decree of this Court that all water rights for the passage of water decreed herein to the United States shall be deemed to be and shall be administered and enforced as junior to any water right or rights initiated under Wyoming law subsequent to the date of this Decree and having their point of diversion or place of storage all or partly upstream of the quantification point of the United States' right for the passage of water, when the exercise of the United States' right to the passage of water would conflict with the exercise of such water right or rights initiated under Wyoming law, provided however, that the United States' right to the passage of water shall be deemed to be and shall be administered as junior to such future water rights under Wyoming law only so long as all such rights annually use, in total, no more than the following amounts of water on the indicated streams:

Water Protected For Future Development Under Wyoming Law
Big Horn National Forest

Stream Name	Amount (acre-feet)
Trout Creek	1,130
Unnamed Northern Trib. of Trout Creek	229
Deer Creek	1,489
Porcupine Creek	11,534
Bucking Mule Creek	3,850
South Fork Cottonwood Creek	1,228
Elk Springs Creek	564
Five Springs Creek	365
Crystal Creek	1,830
Bear Creek	957
North Beaver Creek	1,984
South Beaver Creek	2,809
Hudson Falls Creek	613
Cedar Creek	1,370
Red Canyon Creek	2,223
Horse Creek	2,637
Dry Fork	531
Sunlight Creek	150
Shell Creek (mainstem)	43,773
Shell Creek above reservoir	11,051
Adelaide Creek above reservoir	2,261
Unnamed Trib. of Jack Creek	479
Trapper Creek	1,856
Mill Creek	614
Dry Medicine Lodge Creek	3,097
Medicine Lodge Creek	5,616
Allen Draw	1,518
Long Park Creek	3,362
Upper Paint Rock Creek	2,949
Unnamed Northern Trib. Paint Rock Creek	2,359
Unnamed Northern Trib. Paint Rock Creek	1,677
North Paint Rock Creek	17,700
Middle Paint Rock Creek	3,677
South Paint Rock Creek	7,591
Brokenback Creek	1,090
Willow Creek	2,697
Middle Tensleep Creek	8,062
Teepee Creek	1,251
West Tensleep Creek	6,528
Lake Creek	4,773
East Tensleep Creek	12,870
Leigh Creek	5,840
Childs Creek	417
Canyon Creek	2,394

Water Protected for Future Development
Under Wyoming Law
Shoshone National Forest

Stream Name	Amount (acre-feet)
Unnamed Trib. of Soda Butte Creek	1,688
Unnamed Trib. of Soda Butte Creek	1,230
Republic Creek	4,021
Hayden Creek	2,377
Rock Creek	6,602
Chain Creek	1,417
Wyoming Creek	2,224
Line Creek	3,184
Unnamed Trib. of Line Creek	181
Unnamed Trib. of Line Creek	67
Unnamed Trib. of Bennett Creek	215
Bennett Creek	5,034
Littlerock Creek	23,761
Unnamed Trib. of Lake Creek	124
Unnamed Trib. of Lake Creek	130
Clark's Fork River	
Dead Indian Gulch	178
Dead Indian Creek	30,742
Elk Creek	2,209
Beem Gulch	217
Huff Gulch	651
Gravelbar Creek	6,464
Jagger Creek	2,552
Sunlight Creek	38,335
Spring Creek	3,206
Gas Creek	2,552
Little Sunlight Creek	6,681
Trail Creek	925
Painter Gulch	2,903

RIPARIAN MANAGEMENT RESPONSIBILITIES AND ACTIVITIES IN THE ROCKY MOUNTAIN REGION OF THE FOREST SERVICE

Glen E. Hetzel[1]

The National Forest Management Act and its regulations require that Forest Plans contain specific direction on management of riparian areas. All Forest Plans for the Rocky Mountain Region have been approved and are now being implemented. Multiple-use is the guiding management principle in riparian areas, and necessitates an ecological approach, including vegetation, land, and water. Riparian areas often include aquatic ecosystems. The whole riparian area must be managed as a single, distinct unit. At the same time, influence of the condition of lands adjacent to the riparian area should be considered as well. These Forest Plans contain general direction for managing riparian areas within National Forests and National Grasslands, as well as a special multiple-use prescription to be applied to lands managed for riparian goals.

The Rocky Mountain Region has developed a score-card system for rating riparian areas. This system is used to rate the overall ecological condition of a riparian area, using vegetation, land, and stream characters. Another rating system is used to compare present stream condition against its potential for producing catchable fish.

The Rocky Mountain Region is embarking on an interdisciplinary, multi-resource effort to improve the rating of riparian areas through ecological classification; to demonstrate the possibilities for riparian improvement through management; to train field personnel in rating and managing riparian areas; to improve technology transfer within the Forest Service and with other agencies and public groups; and to work towards public consensus on riparian management goals.

Introduction

Concern for riparian areas and the values they represent in the Forest Service goes back many years, yet there has been a recent surge in interest. We certainly know more about riparian areas now than we once did, although there are still some missing pieces to the puzzle.

The Forest Service has recognized that we need to know more about the ecology and management of riparian areas, as exemplified by the number of recent symposia and workshops we have helped sponsor in recent years.

Riparian areas are highly valuable for range forage potential, wildlife habitat, fishery potential, watershed protection, and recreation. In many cases, a riparian area will have higher potential for these uses than an adjacent upland area of the same size. Riparian areas are where the interactions (some would say conflicts) between uses seems to be strongest. The policy of the Forest Service requires that range, watershed, and wildlife improvement programs give high priority to restoration of riparian areas. This policy requires that we:

1) recognize the importance and distinctive value of riparian areas during the land management process,
2) recognize the importance and distinctive value of riparian areas when implementing management activities,
3) manage riparian areas under the principles of multiple use and sustained yield, while emphasizing protection of soil, water, vegetation, and fish and wildlife resources, and
4) delineate and evaluate riparian areas prior to implementing any project activity (Peterson 1983).

Legal and Regulatory Framework for Land Management

The National Forest Managment Act of 1976 (P. L. 94-588) requires that all forest plans contain standards and guidelines that ensure that "timber will be harvested from National Forest System lands only where...protection is provided for steams, streambanks, shorelines, lakes, wetlands, and other bodies of water." This protection is to focus on protection from:

1) detrimental changes in water temperature,
2) blockages of water courses,
3) deposits of sediment,
4) serious adverse effects on water quality,
5) serious adverse effects on fish habitat (Sect. 6[g]).

The National Forest Management Act of 1976 (NFMA) mandated that regulations be written in order to carry out the goals stated in the act. In the case of riparian management, the regulations provide more detail for managers. "Special attention shall be given to land and vegetation for approximately 100 feet from the edges of all perennial streams, lakes, and other bodies of water. This area shall correspond to at least the recognizable area dominated by the riparian

[1]Director, Range, Wildlife, Fisheries, and Ecology, USDA Forest Service, Rocky Mountain Region, P.O. Box 25127, Lakewood CO 80225.

vegetation. No management practices causing detrimental changes in water temperature or chemical composition, blockages of water courses, or deposits of sediment shall be permitted within these areas which seriously and adversely affect water conditions or fish habitat" (Regulations in 36 CFR 219.27[e]).

There are some implications that can be drawn from NFMA and the regulations based on it, as they apply to riparian areas. First, the water body (stream, lake, pond, etc.), its banks, the riparian vegetation, the fluvial landform, soil water, sediment, and animals that live in the water or associated with riparian vegetation, are all inextricably connected, and the connections among these are very strong, usually stronger than the individual components themselves (Fig. 1). We can focus on one or another of these components of riparian ecosystems, but we cannot manage them separately. We must manage them together as the ecological unit they are. This principle was ap-parently understood well by the writers of the regu-lations, as shown by the carefully balanced mixture of terms relating to soil water, vegetation, unbound water, fish, and landforms. A typical riparian area and its surroundings shows these relationships (Fig. 2). In the Rocky Mountain Region of the Forest Service, the concept "riparian area " includes all of the components mentioned: floodplain, unbound water, ground water, distinctive riparian vegetation, fish, riparian-associated animals, 100-foot filter strip.

The first part of understanding the riparian situation is mapping and inventory, and in this case it is important to recognize that no one riparian component can be used to the exclusion of others. If we use landform alone, for example, to map riparian areas, the result will not be maximally useful to vegetation managers. If we use vegetation alone, we will cut across different stream reaches or changes in fluvial landforms, rendering the result less useful to fisheries biologists. On the contrary, the passage in the regulations contains direction for delineation of riparian areas using several different components, the approximate 100-foot strip and the outer edge of the distinctive riparian vegetation, at the same time. An ecological, multi-resource, multi-agency approach is necessary in the beginning, with mapping and inventory, and all through the process. We need the ecological approach to work towards improving our inventories of riparian areas, so that the resource manager can realize the scope of the situation.

The language of the regulations is strong. The word "protection" in the law (NFMA) is elaborated on in the regulations, as "[no] management...shall be permitted..." However, this strong language, even though negative and prescriptive, is limited to preventing the five adverse effects listed above. The law and regulations apply to all riparian areas, without apparent limitation.

Management of Riparian Areas in the Rocky Mountain Region

Management of riparian areas, as well as other areas within National Forests and National Grasslands, is described in the Land and Resource Management Plan for each. The Rocky Mountain Region of the Forest Service is responsible for the National Forests and National Grasslands in the part of Wyoming that lies east of the Continental Divide, in which there are parts of four administrative National Forests:

1) Bighorn National Forest, headquarters in Sheridan
2) Black Hills National Forest (part), headquarters in Custer, South Dakota
3) Medicine Bow National Forest and Thunder Basin National Grasslands, headquarters in Laramie
4) Shoshone National Forest, headquarters in Cody

The Land and Resource Management Plans (called the "Forest Plans" for short) for these have all been completed, and are now in the implementation phase.

In this Region, we have adopted a system of Region-wide standard prescriptions and Forest-wide management direction, that has been used in all Forest Plans. So you will find the treatment of riparian areas in the four Forest Plans from eastern Wyoming to be very much the same. By Regional policy, not all riparian areas are delineated on the management area map. For one thing, some riparian areas are too small to show up at the map scales we use. Also, all of the prescriptions are multiple-use prescriptions, with the idea that each parcel of land will have only one of these multiple-use prescriptions applied to it.

In each forest plan, direction for the management of riparian areas is contained in two places: (1) the general, forest-wide direction, that applies to all riparian areas, wherever they are and no matter how small; and (2) a special management prescription (number 9A) that applies to those riparian areas that are so important as to be managed for emphasis on riparian preservation. It is important to recognize that riparian areas, as with all areas on National Forests and National Grasslands, are multiple-use areas, but the mix of resources will differ from area to area.

The general, forest-wide direction in the forest plan directs that all riparian areas must be managed to reach the latest seral stage possible within stated objectives. This means that if, for example, livestock grazing is permitted within a riparian area, that it be managed to achieve the highest seral stage that also achieves the objectives set for that grazing use. Also, grazing systems and allotment management plans should state objectives for any riparian areas within the allotment, and they should plan to achieve

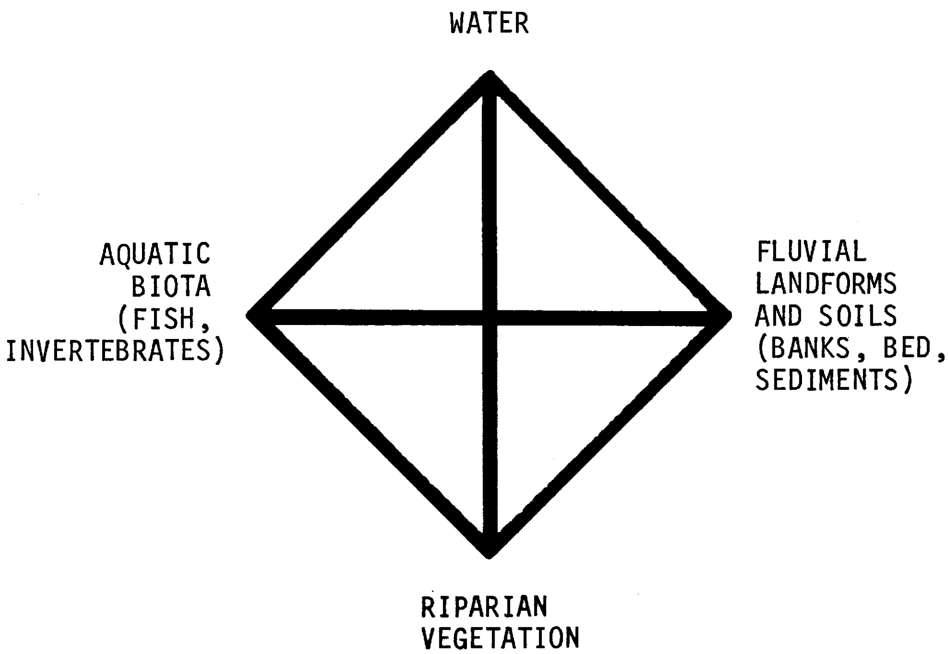

Figure 1. A simplified diagram of the components of the whole riparian ecosystem. The interactions (lines) are stronger than the individual components.

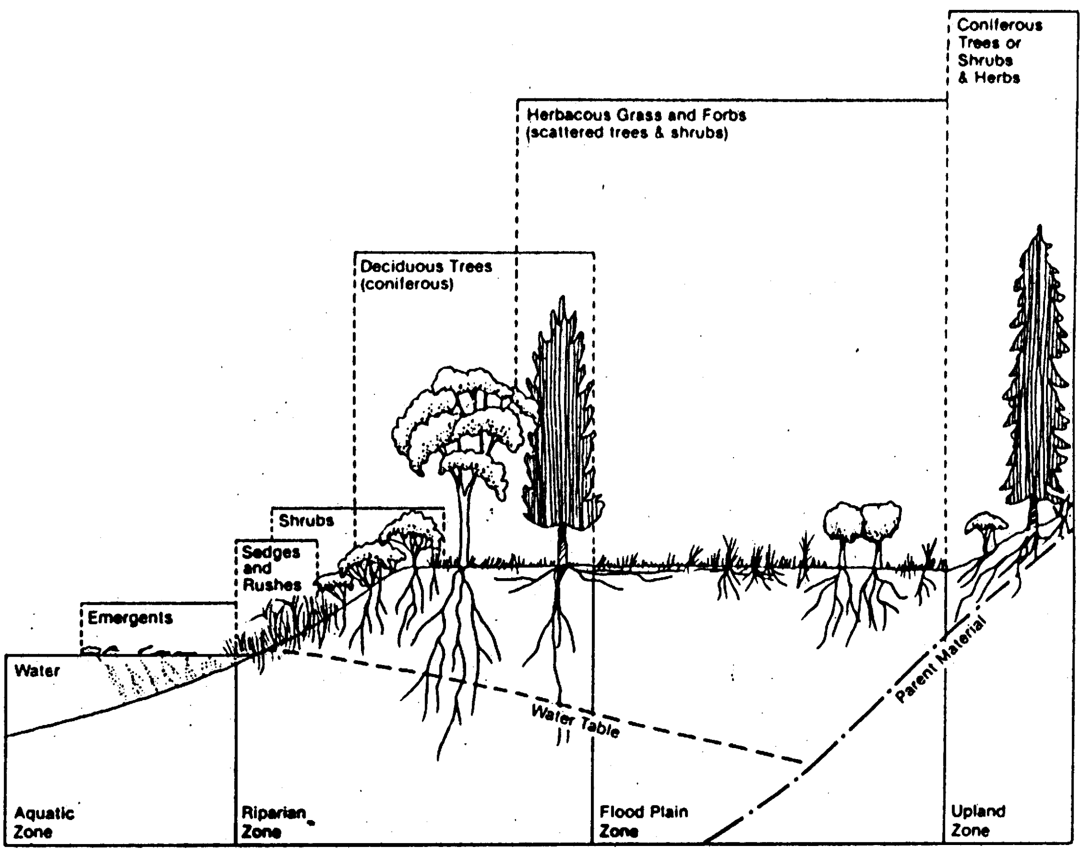

Figure 2. Cross section of a typical riparian area (From Skovlin 1984).

those objectives. Other parts of forestwide direction speak to road construction, timber management, and other vegetation and land management activities.

The special management prescription for riparian management (9A) puts emphasis on the management of all component ecosystems of riparian areas, including the aquatic ecosystem, the distinctive riparian vegetation, fluvial landforms, soils, and wildlife populations. These are to be managed together as a unit. The goals are to provide healthy, selfperpetuating plant communities, meet water quality standards, provide habitat for viable populations of wildlife and fish, and stable stream channels and shorelines. Although those goals restrict management severely, they do not mean that vegetation manipulation cannot take place. Nonetheless, careful and thoughtful management is indicated.

Although a riparian area is to be managed as an integrated unit, it is important to recognize the interactions that may occur between the riparian area and the adjacent upland sites, since management activities in those adjacent areas may well affect the riparian area significantly. Especially this is true with livestock grazing, where the riparian area and the adjacent upland may be in the same pasture. Also it is true in landscape management and wildlife managment, where the focus is on the whole landscape or watershed as seen or used as habitat. In addition, since riparian areas are often at the lowest positions in the watershed, ground water flow and natural erosion from adjacent uplands may control processes in the riparian areas, and management activities there that change ground water flow and erosion may have effects in the riparian area.

In designated areas for riparian management, that are included within the area covered by prescription 9A, livestock grazing must assure the maintenance of vigor and regeneration of riparian plant communities, and other uses such as recreation and roads must also work for the preservation of the natural features of the riparian area.

Rating Riparian Areas in the Rocky Mountain Region

In the Rocky Mountain Region of the Forest Service, riparian areas are rated using a system described in the regional range analysis handbook (Forest Service Handbook R-2 2209.21, chapter 900). This system applies both to the riparian areas that involve open, unbound water, and also to woody draws on the plains. Riparian areas, once delineated, are to be rated using one of seven scorecards:

1) Great Plains riverine
2) Great Plains lakes and reservoirs
3) Black Hills and Pine Ridge riverine
4) Foothills deciduous
5) Montane coniferous and deciduous
6) Alpine and subalpine
7) Woody draws

Each of these seven scorecards contains ratings for different components of the riparian area. After each component has been rated, the individual ratings are combined for a total score, which is expressed in number of total points, which is then translated into an ecological condition class and seral stage.

The score resulting from using one of the scorecards is an ecological score, that is, it does not carry with it any particular management direction, except that direction in the forest plan that we will achieve the highest seral stage possible within the stated multiple-use objectives. A high score does not necessarily imply that management is achieving anyone's goals (yours or ours), neither does a low score imply that we're not. Also, the score is necessarily combined from several components; two areas with the same score may look somewhat different. At the same time, the score does give a rating of the overall health and ecological condition of the riparian area. That will be useful to land and resource managers. An example scorecard, for the foothills deciduous riparian ecosystem, is shown in Fig. 3.

The Rocky Mountain Region's riparian scorecard system gives very valuable guidance to land and resource managers within the Forest Service, concerning what the most useful indicators of riparian condition are. Examples include different willow, grass, and sedge species, bank stability, indicators of streambed condition, and succession by tree species.

Progress and Future of Riparian Management

Many Forest Service personnel in the region are using a model called "COWFISH," which evaluates the relationship between grazing and fishery productivity.

The Rocky Mountain Region recognizes that the first step in describing management implications and writing management plans for riparian areas is better description of riparian ecosystems. This region, as well as adjacent regions, uses a vegetation classification system that emphasizes comparisons with the potential natural community for the site. A recent publication by the Intermountain Region of the Forest Service, describing riparian community types from western Wyoming, is a good illustration of such a classification system. With a system like this in place, results of past management can be more accurately applied to predict the effects of future management. The system also serves as a good framework within which vegetation inventory can be structured.

RIPARIAN AREA SCORECARD
FOOTHILLS DECIDUOUS
Less than 25% Trees Conifers

Stream or River ______	Stretch ______	Numeric & Ecological Rating ______
District ______	1/4 Section & Section ______	Date ______
Forest ______	Township & Range ______	Examiner ______

4	3	2	1	0
A. Tree Overstory Stands mostly discontinuous > 40% canopy, 4 or more size classes, deciduous trees dominant, occasional conifers, single species may dominate, light use, regeneration linear and vigorous ______	Stands discontinuous 25-40% canopy coverage, 3 or 4 size classes, deciduous trees dominant, conifers infrequent, light to moderate use on regeneration ______	Stand canopy 11-25%, interspaces partially filled with shrubs or grasses, 2-3 size classes of trees present, exotics a minor component, moderate use or damage, regeneration just adequate to replenish stand ______	Tree canopy 5-10%, 1 or 2 size classes, with only decadent stands common, heavy use, seedlings and sprouts sparse and heavily damaged, new stands not establishing, exotics invading ______	Canopy < 5%, trees very scattered or entirely lacking, very heavy use and damage, no regeneration of native trees, exotics often dominate ______
B. Shrub Midstory Shrub canopy > 50%, 2 or more palatable shrub species present, but a single genus, such as Salix may dominate, growth form linear, light browsing on most palatable species ______	35-50% shrub canopy, variety of species but single palatable species dominance more common, growth form mainly linear but some lateral branching from light browsing ______	Canopy coverage 21-35%, some weakened desirable species, intemediate species can dominate stand, lateral branching common from moderate use, regeneration limited ______	Canopy coverage 10-20%, single age classes and single species commonly dominate, browsing heavy causing clubbed appearance, little to no reproduction of desirable species ______	Canopy < 10%, only unpalatable shrubs present in sizeable numbers, or shrubs lacking, remnant desirable shrubs severely clubbed, no regeneration ______
C. Understory Desirable grasses and sedges dominate, forbs limited to those which are highly palatable, > 90% ground cover, plants vigorous with large seed heads, desirable seedlings filling bare spaces, or occupied by litter, light use > 5% ______	Some intermediate plants, up to 25% in composition but dominated by desirables, perennial forbs a component of the understory, ground cover 80-89%, seed heads common, trampling minimal, light to moderate use ______	Intermediate grasses and perennial forbs common, few least desirables, 65-79% ground cover, vigor down, some seed heads on less palatable grasses, soil trampling evident, use moderate to heavy ______	Intermediate plants dominant with a few remnant weakened relic desirable plants, invader plants common, 50-64% ground cover, vigor down due to heavy current use, soil movement evident ______	Intermediate and last desirable plants dominant, < 50% ground cover, bare spaces increasing, very heavy current use, overland erosion and soil compaction rampant ______
D. Stream Bottom Assortment of particle sizes, rocks angular, logs and rocks firmly embedded, bottom scouring < 5%, aquatic plant growth dark green ______	Most sized particles present, rocks angular to subangular, most logs and rocks firmly embedded, scouring 5-20%, depositions infrequent in pools, aquatic growth in slow water ______	Few particle sizes, rocks commonly subangular, obstructions usually embedded but new logs moving, scouring 21-35%, deposits occasional, aquatic growth pale green and only in pools ______	Rocks subangular to rounded and much same size, some rock and logs embedded but commonly move with the floods, scouring 36-65%, new bar formation common, aquatic plants rare ______	Rocks mainly rounded, obstructions unstable, scouring > 65% of bottom, accelerated bar development, aquatic plants absent ______
E. Streambank Stability Streambank damage < 5%, no evidence of mass wasting, plants of high vigor and with deep binding root systems, no channel enlargement or flooding outside banks ______	Streambank damage 5-15%, infrequent bank wasting at curves and constrictions, moderately high vigor plants which usually have strong root systems, channel overflows rare ______	Streambank damage 16-30%, bank failures at critical locations plantswith root systems barely effective in stabilizing banks, channel overflows infrequent ______	Streambank damage 31-59%, discontinuous bank failures with limited evidence of healing, low vigor plants incapable of preventing bank break down, channel inadequate for periodic peak flows ______	Stream bank damage > 50%, bank overhang failures frequent and yearlong, vegetation with weak, shallow often exposed root systems, channel inadequate for frequent peak floods ______
Column Totals ______	______	______	______	______

Rating Value:

Numeric	Ecological Condition
17-20	High
13-16	Moderately High
9-12	Moderate
5- 8	Moderately Low
0- 4	Low

Fig. 3. Example of a riparian scorecard (from USDA Forest Service 1985).

The Rocky Mountain Region is beginning to bring together an improved riparian vegetation classification system, and to use that system to add more scorecards to the excellent riparian scorecard system already in place. The improved vegetation classi-fication system will also include better definition of how to delineate and describe riparian areas. National Forests and National Grasslands in South Dakota and Nebraska now have projects in progress to describe and classify riparian ecosystems, and we hope to extend this to areas in other states within the region.

Beginning this year, this region is beginning to make scorecards to rate the range forage condition (not the same as ecological condition) of riparian areas, as part of a larger effort to improve the rating of all rangelands to include consideration for ecological condition. I expect the forage scorecards to follow the classifications, so they will most likely begin in South Dakota and Nebraska, and then spread throughout the region and I hope also to other regions. The classification of riparian habitat that Wyoming Game and Fish undertook several years ago (Olson and Gerhart 1983) needs some refining, and this could be done along the same lines.

The region is also cooperating with a livestock producers' group in Colorado to plan for a grazing allotment to demonstrate coordinated riparian and livestock management. We have high hopes that demonstrations such as that can increase the level of cooperation among user groups and the Forest Service, while also improving communications about all aspects of riparian management.

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RIPARIAN AREA MANAGEMENT

Hillary A. Oden[1]

Background

In fiscal Year 1985 the Bureau of Land Management undertook a riparian area initiative. The mitigation will focus approprate attention and commitment on the management of riparian areas which occur on, or are impacted by, management of BLM administered lands.

Definition

Riparian areas are zones of transition from aquatic to terrestrial ecosystems, whose presence is dependent upon surface and/or subsurface water, and which reveal through their existing or potential soil-vegetation complex the influence of that water. Riparian areas may be associated with features such as lakes; reservoirs; estuaries; potholes; springs; bogs; wet meadows; muskegs; and ephemeral, intermittent, or perennial streams.

Importance

Riparian areas are unique and among the most productive and important ecosystems on the public lands, affecting essentially all other resource uses and values. Characteristically, riparian areas display greater diversity of plant and animal species and of vegetation structure than adjoining ecosystems. Healthy riparian systems filter and purify water as it moves through the riparian zone, reduce sediment loads, and enhance soil stability, provide micro-climatic moderation when contrasted to extremes in adjacent areas, contribute to aquifer recharge, and enhance the stability and amount of base water flow.

In recognition of the importance of maintaining and improving the condition and productivity of these unique areas on the public lands, the Bureau of Land Management (BLM) has adopted the following policy:

Policy

The BLM is committed to the long-term, multiple-use management of riparian areas under the authority of various laws and Executive Orders.

It is the policy of the BLM to: (Not a priority listing)

1. Conduct and maintain on a continuing basis an inventory of all riparian areas, quantifying physical and biological condition and potential.

Current Status in Wyoming:

The BLM in Wyoming has conducted some riparian inventories of various types, levels of intensity, and area coverage throughout the State during the last two decades. Some of these inventories are of excellent quality and others are of lesser degrees of quality.

There presently are no statewide compiled statistics on the status of riparian areas and riparian inventory. Some of the Wyoming State agencies (State Engineer, Game and Fish Department, etc.) do keep limited basic resource data on riparian and water related natural resources.

2. Ensure that resource management plans identify riparian areas and prescribe proper management for their distinctive values.

Current Status in Wyoming:

Riparian issues are addressed in various degrees in the existing BLM land use plans in Wyoming. Most of the older vintage land use plans (pre-1980) did not specifically address riparian issues. Many of the Resource Management Plans (RMPs) from 1980-1984 imply some form of riparian area management, although it is often not explicit. Some of the most recent RMPs, such as Kemmerer, Lander, and Washakie, have explicit riparian issues stated in the RMP. Some of the recent RMPs also contain standards and guidelines incorporating riparian considerations in a fashion which could be interpreted as a listing of riparian "best management practices."

3. Tailor management of riparian areas to site-specific characteristics and settings.

4. Manage riparian areas to maintain or improve the quality and productivity of the soil and water and production of the vegetation.

Current Status in Wyoming:

The status of riparian objectives in activity plans throughout Wyoming varies considerably. As with the land use plans, many of the older activity plans do not specifically mention riparian areas as a management function. Many of the more recent activity plans include explicit riparian objectives as an integral part of the plan, including the incorporation of riparian areas as "key areas" in the plan.

[1]State Director, Bureau of Land Management, USDI, P.O. Box 1828, Cheyenne, Wyoming 82001.

During FY 86, efforts that will result in improvement to riparian areas will occur in 12 Habitat Management Plans, 3 Cooperative Management Agreements, and 2 Areas of Critical Environmental Concerns. In addition, special emphasis on riparian areas is being applied to an area under the Wyoming stewardship program. Livestock allotment management plans also improve riparian conditions.

5. Monitor and evaluate the effectiveness of management activities in meeting objectives.

Current Status in Wyoming:

Riparian monitoring is currently being conducted in Wyoming, mostly in conjunction with activity plans or as part of monitoring on range allotments. Various types of studies are being conducted related primarily to the specific monitoring goals and objectives.

6. Cooperate with all affected Federal, State, and private parties to share information, coordinate activities, and provide education on the value, productivity, and management of riparian areas.

Current Status in Wyoming:

Public awareness and participation have been an integral part of riparian efforts in this State. This has ranged from riparian CMA's to youth group assistance, professional society and public involvement, media articles and radio/TV programs, video tape development, and presentations at professional meetings outlining our programs and their results. Key efforts have also included community meetings and presentations at livestock grazing association meetings. We also cooperate very closely with private parties, in particular at the activity planning stage and implementation.

7. Conduct research and studies needed to ensure that riparian area management objectives can be properly defined and met.

Current Status in Wyoming:

Joint efforts with the University of Wyoming on watershed management and riparian desertification studies on Muddy Creek and Fifteen Mile Creek will pay long-term benefits in this area.

8. Retain riparian areas in public ownership, unless disposal is in the best public interest, or acquire significant riparian areas where needed to ensure the integrity of those areas that affect the public lands.

Current Status in Wyoming:

A field Solicitor's Opinion dated April 7, 1983, expands on this requirement with the following statement: The BLM can "authorize the sale of wetlands when:

1) The tract of public wetlands is either so small or remote that it is uneconomical to manage.
2) The tract of public wetlands is not suitable for management by another Federal agency.
3) The patent contains restrictions of uses as prohibited by identified Federal, State, or local wetlands regulations.
4) The patent contains restrictions and conditions that ensure the patentee can maintain, restore, and protect the wetlands on a continuous basis.

If any of these four requirements cannot be satisfied with respect to a particular wetlands tract, the tract must be retained in Federal ownership and administered by the Bureau in the manner set forth in BLM Manual, Part 6740."

Summary

Riparian area management is by nature a cross-cutting activity that will affect every Bureau program to some extent and which must be addressed by every activity associated with surface use or disturbance. All program managers must ensure that ongoing and proposed uses of the public lands are managed so that appropriate protection of riparian areas is provided. Costs of protective measures should be covered from the applicable program. Funding rehabilitation measures for currently degraded riparian areas should be based on program-specific benefits and values. Where benefits accrue to several activities, costs should be shared throughout the planning, implementation, and monitoring phases.

Some of the items previously mentioned indicate Wyoming BLM short-term riparian management actions. We do, however, recognize that for any effort of this nature to be effective requires a long-term commitment and dedication of time and manpower, as well as monetary resources. Therefore, we expect our riparian efforts to evolve in the years ahead and adjust to accommodate changing situations.

There has been concern expressed over the use of fences to exclude livestock from riparian areas. In the future, we will continue to use fencing as a tool in our management actions, but exclusion of livestock will only occur in those specific locations where other practices are not capable of providing the needed response.

THE USES AND NEEDS OF STREAMSIDE ZONES BY WYOMING MUNICIPALITIES

David T. Engels[1]

Abstract

Whereas the original siting location of towns and cities with respect to streamside zones was based primarily upon transportation and water supply, other benefits of the riparian location have become just if not more important. These benefits include waste-water conveyance and treatment, industrial development, recreation and aesthetic residential development.

Introduction

The streamside zone is important to Wyoming municipalities in many ways. The watercourse and streamside zone have historically been primary factors in the siting of towns and cities. Now those municipalities which have located upon the important streams and rivers have reaped other benefits than those for which the sites were originally chosen.

Discussion

The setting of a municipality with respect to a watercourse is one of the most, if not the most important reason that such a location was chosen. Most towns and cities both in Wyoming and throughout the world are situated near, at a minimum, a flowing creek and more typically, a major river. In many cases the original site of the town was chosen at the confluence of two major watercourses. Just a few examples of this are Pittsburgh--at the confluence of the Allegheny and Monongahela Rivers, St. Louis--where the Missouri River meets the Mississippi, and regionally the city of Denver--at the point Cherry Creek merges with the South Platte River. Navigation along these rivers was a primary means of transportation, thus the selection of the sites at key confluences. While there was not a major watercourse intersection at the site of Casper, the original Fort Casper was located at a point where a ferry existed to transport westward bound settlers across the North Platte River.

The need for a water supply was also an important criteria in the site selection of these towns and cities. Trappers, settlers, explorers--whoever carved out the original settlement--of course looked to a water supply as a basic requirement.

While transportation and water supply were the primary uses of streams originally, other uses have overtaken transportation as an important use, as well as rivaling water supply in importance. A "typical" city in Wyoming in regards to the use of streamside zones is the City of Casper. Here in Casper, the river and adjacent areas of course continue to meet the water supply need for the citizens. Casper uses a surface water treatment plant and shallow alluvial wells to meet the constant demand for water. Shallow wells are located within the riparian habitat. They are constructed to a depth of approximately 30-40 feet, and use the groundwater situated within the river's sands and gravels, the sands and gravels being used for filtration purposes (chlorination is all that is required for this water source). These facilities meet the demands of a domestic water supply which at times requires 35 million gallons per day.

The river and streamside zone also provide to Casper a means for wastewater conveyance and treatment. With the emphasis on gravity sewer systems, large trunk mains are usually installed directly adjacent to the river. Smaller mains serving the actual residences flow by gravity to these trunk mains, which convey the wastewater to the site. The plant site is also located directly adjacent to the river for two reasons: (1) again, because of gravity flow, and (2) the ultimate disposal of the treated wastewater is back to the river. Before sewage treatment facilities, the conveyance systems merely brought the sewage to the river for disposal purposes. The stream itself can act as a treatment system (witness the fact that State and Federal standards do not require perfectly clean effluent, but streams can be easily overloaded if too much sewage is discharged to them.

Recreation is more and more becoming an important use of the river and the streamside zone. Most cities and towns construct at least some of their park

Figure 1. Shallow wells within the streamside zone meet a portion of Casper's needs.

[1]Director, Casper Board of Public Utilities, 200 North David, Casper, WY 82601.

Figure 2. The Amoco Refinery is an important industrial use of the streamside zone.

facilities alongside watercourses. The City of Casper's park development plan in these riparian areas encour-ages two basic schemes--developed and undeveloped. Developed streamside zones include manicured lawns and parks, where picnicking grounds, athletic faci-lities and other recreational equipment are installed. There is the North Platte Park located along a mile stretch of the river just north of the city limits, which will include athletic fields and an executive golf course. The North Platte River Parkway is a scheme similar to other communities in which a public path is developed in the riparian area, oftentimes including adjacent irrigated landscaping.

Casper's second scheme on streamside parks includes leaving these areas in a undeveloped state. An example of this is the Morad Nature Park. These undeveloped parks meet needs other than those met by developed parks. Fishing, canoeing, and providing the opportunity to just get away from the hustle and bustle of city life are intended uses of the undeveloped riparian parklands.

Another significant use of streamside zones in towns and cities is the siting of industry. The Casper area has two major refineries, Amoco and Little America. Both are located directly adjacent to the North Platte. The refineries rely upon the river water for their industrial water demands. As with municipalities, the refineries also previously used the river as a disposal site. Recently they have recognized, or been forced to recognize, the value of a clean river, and have used other disposal mechanisms or sites to dispose of their effluent.

Sand and gravel mining operations also are an important industry in the riparian zones. With the large deposits of granular material usually located alongside the major rivers, these mining operations predominantly occur in these areas.

An ever-increasing use of the streamside zone is residential development. Previously, affluent individuals chose not to live next to the river for two main reasons, the previously mentioned fact that the river was being used for wastewater disposal, and the likelihood of flooding always remained in this area. Due to the fact that wastewater now is being properly treated or disposed of in other manners, as well as the fact that upstream reservoirs have greatly lessened the magnitude and frequency of flooding, the riparian areas are now looked upon as prime residential development areas. As the city of Casper grows to the west, many of the exclusive residential developments are located directly alongside the river.

The needs of municipalities for streamside zones will increase as both growth occurs (water supply, wastewater treatment, recreation, industrial use, and aesthetic residential development) and Americans continue to insist upon a clean, continually flowing stream for recreational purposes. Water supply will in particular become an ever-increasing need. Non-municipal riparian areas will play an increasingly important role in the ultimate development of these water supplies. Water developement now includes the provisions that the undeveloped riparian zones will require flushing flows to reduce sedimentation accumulation. Minimum flows are now required to enhance the fisheries (which of course are being extensively used by the municipalities' inhabitants). The protection of endangered species by supplying water for the migration and nesting purposes of these species (e.g., wetland mitigation) oftentimes requires additional water. All three of these environmental factors will limit the amount of firm yield which is deemed available for the municipalities' new water supplies. The Deer Creek Dam project is an example of this envimmental mitigation process, with its minimum flow requirements and potential impact upon the Whooping Crane.

Let us hope that these environmental requirements will make for wiser, more efficient use of the finite water source.

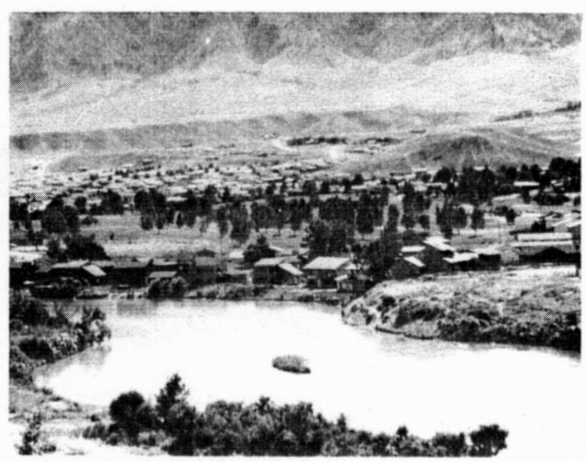

Figure 3. Aesthetic residential development has only recently become an important use of the streamside zone.

WYOMING'S USE AND NEEDS OF RIPARIAN AREAS: AGRICULTURE

Don Mieke[1]

Man and nature are friends, not enemies. Early diaries and records indicate that nature was having a hard time supporting a couple million people until the advent of western civilization. In Wyoming, riparian zones were some of the most disturbed areas because of uncontrolled runoff and thundering buffalo herds.

Man's efforts in water storage for livestock and irrigation has helped to control some of the extreme fluctuations of the rivers and streams.

Ranchers have no desire to see their land make Louisiana a larger state. They should be assisted in their efforts to help nature to cope with extremes. There is probably a place for EIS's and 404's, but it shouldn't be to restrict ranchers and other land owners from doing projects that help more than they could ever harm.

Keeping Wyoming's water in Wyoming means more than just not using any. Agricultural diversion of water has greatly enhanced the riparian areas and created a much larger water table than existed naturally. There were very few trees along most of Wyoming's waterways. Irrigation and grazing control has helped develop more riparian areas.

The citizens of Wyoming need to stress cooperation not regulation, education not legislation, and commendation not condemnation.

Poor irrigation and other agricultural practices need to be corrected, but we need to work on learning from past mistakes and not embrace a policy of doing nothing in fear of doing something wrong.

[1]Rancher-Irrigator, Sussex Route, Kaycee, WY 82639.

USES AND NEEDS OF RIPARIAN ZONES FOR RECREATION

David T. Taylor [1]

Abstract

Outdoor recreation is important to Wyoming for a number of reasons. From a business perspective, it attracts outside dollars to the state in the form of expenditures by recreational visitors. These dollars in turn generate jobs for Wyoming residents. From a public perspective, outdoor recreation is an important factor in the quality of life for many state residents. Riparian zones are an integral part of outdoor recreation from either perspective. In some cases, such as stream fishing, it is an essential input in the production of the recreational activity. In other cases, such as camping, it is an amenity that contributes, but is not essential, to the recreational activity.

The management of riparian zones often involves trade-offs between competing uses of the resource. In the absence of recreational considerations, the trade-off was typically between market commodities with known economic values. As recreational considerations have entered management decisions, the trade-off is often between market commodities with known economic values and recreation, a nonmarket good whose economic value is not directly observable. This means that alternative measurement methods need to be used to estimate the economic value of recreational use. Several alternative measurement methods have been developed to estimate the value of outdoor recreation activities.

In recent years, recreation's demand for natural resources, including riparian zones, has increased dramatically. On the supply side there is only a finite quantity of riparian zones in the state. Thus there will likely be continuing competition between recreation and other uses of riparian zones. Information on the value of recreation would be useful in determining the efficient allocation of the resource among these uses.

Introduction

In a recent newsletter Senator Malcolm Wallop describes outdoor recreation as basic to our country due to its contribution to the quality of life and because of its importance as a source of livelihood. The most recent National Outdoor Recreation Survey (NORS) estimates that 86% of the nation's population rated outdoor recreation very to somewhat important. On a state level outdoor recreation is important from at least two perspectives.

From a business perspective, outdoor recreation is a basic industry which attracts outside dollars to the state in the form of expenditures by recreational visitors. These new dollars in turn generate jobs for Wyoming residents. Senator Wallop's article indicates that, in 1984, estimated travel expenditures in Wyoming totaled approximately $700 million and directly accounted for about 21,000 jobs. The outdoor recreation industry represents a large proportion of these travel expenditures. The 1985 State Comprehensive Outdoor Recreation Plan (SCORP) estimates that an average non-resident recreational travel party spends about $440 during their stay in the state. This amounts to about $90 per day per stay in the area. Thus, the outdoor recreation industry makes a significant contribution to the state's economy. Recently this contribution has received considerable attention due to the current interest in diversification of the state's economic base.

From a public perspective outdoor recreation is important, not only as a source of employment, but also as a significant factor in the quality of life for most Wyoming residents. The SCORP report estimates that 54% of the state's population participate in camping, 55% participate in fishing, 56% participate in sightseeing, and 70% participate in picnicing. The SCORP report also indicates that Wyoming residents are willing to travel long distances to participate in outdoor recreation. For water-based recreation in mountain areas, the median maximum distance residents would be willing to travel to participate is 174 miles round trip.[2] For water-based activities in plains areas, the median maximum distance is 118 miles roundtrip.[2] The 1984 Fishing Pressure Survey (FPS) estimates that resident anglers averaged 17.6 days fishing in 1984. The willingness of residents to commit substantial amounts of leisure time to these activities highlights the importance of outdoor recreation to the quality of life in the state for the majority of Wyoming residents.

Riparian Zones

Riparian zoners are an integral part of outdoor recreation from both a business and a public perspective. In some cases, such as stream fishing, riparian zones are an essential input in the production of the recreational activity. In other cases, such as camping, riparian zones provide amenities that contribute, but are not essential to the activity. In

[1] Extension Specialist, Department of Agricultural Economics, Box 3354, University of Wyoming, Laramie, WY 82071.

[2] Calculated from grouped data presented in the report.

either case riparian zones are a signifcant part of the appeal of many outdoor recreation activities to both the resident and the nonresident.

The contribution of riparian zones as an amenity to other recreational activites is unclear due to the interrelationships between activities. However, some information is available on the use of riparian zones as direct inputs in recreation activities. Fishing is probably the best documented use. The FPS report indicates that 241,246 fishing licenses were sold in Wyoming in 1984. These license sales were associated with over two million resident angler days and over 500 thousand nonresident angler days. The FPS report estimates that about 45% of the days in both categories involve fishing on streams and rivers.[3] From a business perspective fishing activities result in an average expenditure of $508 per fisherman in 1984 (Wyoming Game and Fish Department, 1985). This amount includes expenditures for groceries, lodging, car and equipment maintenance, fees, entertainment, and rentals. From a public perspective 51% of the licenses sold and 81% of the riparian related fishing use involved resident anglers (FPS). Furthermore, the SCORP report indicates that fishing was ranked as the most enjoyable outdoor activity by Wyoming residents. Fishing rated nearly one-third higher than the second ranked activity--hunting.

Other recreational uses associated with riparian zones are less well documented, particularly on a statewide basis. Some information is available for float trip activities on a regional basis. In 1985, there were 194,000 float trip activity days on the Snake River in the Jackson area. About two thirds of the total days involved trips with commercial outfitters. From 16-18 commercial float trip outfitters operate in the area on a seasonal basis.[4] Commercial float trip outfitters also operate in the Cody and Saratoga areas of the state. On the Medicine Bow National Forest, other water craft activities (excluding power boats and canoes) accounted for 10,400 visitor days in 1984. While these numbers may not be representative for the whole state, they do indicate that there are other important recreational uses associated with riparian zones.

Trade-offs Between Competing Uses

The management of riparian zones and other natural resources generally requires that trade-offs be made between competing uses of the resource in the short run, since quantities of the resource are fixed. In the absence of recreation considerations, the trade-offs are typically between market commodities whose economic values are directly observable from the marketplace. However when recreation considerations are included in the management decision, the trade-off is often between market commodities with known economic values and recreation, a nonmarket good whose economic value is not directly observable. In order to make rational decisions regarding these trade-offs the economic value of the nonmarket good must somehow be estimated. Knowledge of economic value is necessary if the resource is to be efficiently allocated among the competing uses.

Recreation is classified as a nonmarket good since the charge for use of the resource, if any, is generally set by a government management agency rather than the marketplace. Thus recreation is not traded in an organized market and is not always sold to the highest bidder. Consequently, the true value of recreational use of the resource to the consumer is not reflected in the user fees established by the management agency. While this does not imply that the ownership of all recreational resources should be transferred to the private sector, it does mean that establishing the economic value of recreation is more difficult.

In the traditional market framework the interaction of supply and demand determines the equilibrium price at a point where the quantity that producers are willing to sell (i.e. supply) is equal to the quantity that consumers are willing to pay (i.e. demand). In this framework, price is a measure of the cost of the good and the demand curve is a measure of the total benefit of the good in terms of willingness to pay by the consumer. The difference between what individuals are willing to pay for the good (demand) and what they actually have to pay (price) represents net willingness to pay or the net benefit of the good. Net willingness to pay, sometimes referred to as consumer surplus, serves as a measure of the economic value of the good. Normally the demand curve is generated by observing changes in quantity demanded at various price levels and plotting the resulting points. In the case of recreation goods the demand curve cannot be easily derived since the expenditures for use, if any, are not determined in the marketplace. As a result, changes in quantity cannot be associated with variations in price and the demand curve cannot be estimated directly. Without a demand curve, net willingness to pay and hence economic value cannot be measured for the good.

Several alternative measures have been developed to estimate the value of outdoor recreation activities. The most common approaches are the Gross Expenditure Method (GEM), the Travel Cost Method (TCM), and the Contingency Valuation Method (CVM). A full description of each approach is beyond the scope of the paper; however, a brief

[3] Excludes fishing pressure by pioneer and youth anglers, nonresident elk license holders, and reciprocity stamp holders.

[4] Personal communication with Frank Ewing, Baker-Ewing Float Trips.

discussion of the basic premise and use of each follows. The GEM approach assumes that the value of the recreation activity is at least equal to the total dollar expenditure by the user to participate in the activity. Typically this would include the amount spent on travel, food, lodging, equipment, etc. This approach has been extensively used because of the relative ease in data collection and analysis. With two adjustments this approach can provide satisfactory estimates of the value of outdoor recreation to the state from a business perspective since we are only interested in the actual expenditures associated with the activity. One qualification is that the expenditures must occur within the state and must be by a nonresident. For example an expenditure by a Colorado fisherman in Colorado for equipment which is used to fish in Wyoming does not contribute directly to Wyoming's economy. Similarly expenditures by Wyoming residents on recreation only represent a redistribution of existing dollars to recreation and away from other uses, rather than a net gain to the state's economy. The other qualification is that the additional business activity generated by the respending of nonresident dollars in the local economy should be considered in estimating the total effect of outdoor recreation. This requires the use of economic multipliers to estimate the average amount of recirculation of a new dollar within the local economy.

The GEM approach is not an appropriate measure of the value of outdoor recreation from a public perspective for two reasons. The first is that the approach does not consider the additional value of the resource in terms of net willingness to pay over and above actual expeditures. The second reason is that the approach does not consider the value of resident recreation since this type of use does not result in the inflow of dollars from outside the area. For these reasons the GEM approach tends to underestimate the value of outdoor recreation from a public perspective. In order to correctly estimate the value of outdoor recreation from a public standpoint either the TCM or CVM should be used to indirectly derive the demand curve so that economic value (net willingness to pay) can be measured.

In the TCM approach travel costs are used as a proxy for price in estimating the demand curve. The basic assumption is that the number of trips to a recreational site will decrease as the distance to the site, and hence the cost of travel, increase. Specifications generally include adjustments for the cost of travel time, availability of alternative sites, and socioeconomic variables. The TCM approach has traditionally been preferred since it is based on observed market behavior to direct costs of participation.

The CVM approach is based on the maximum amount that users indicate that they would be willing to pay to use the recreation resource in response to hypothetical changes in user fees. The approach is essentially a bidding game based on a simulated market. The resulting measurement relies on individual estimates of their own net willingness to pay. The CVM is the preferred approach for valuing a change in the quality of the resource since the effect of the change can be measured before it actually occurs. A primary concern with the CVM approach involves the ability of users to relate to the simulated market.

The specific measurement technique chosen generally depends on the purpose of the analysis. If the purpose is to estimate the economic value from a business perspective then the GEM approach is most appropriate. If the purpose is to estimate economic value from a public perspective then either the TCM or CVM approach is most appropriate. In certain cases more than one technique may be required to obtain an accurate estimate of the true value.

Conclusion

Outdoor recreation plays an important role in our country and the state in terms of physical health, mental health, and economic activity. In recent times America's view of recreation has changed due to: (1) a higher standard of living; (2) expanded leisure time; (3) a higher proportion of young adults in the population; and (4) a redefinition of society's values. As a result outdoor recreation's demand for natural resources, including riparian zones, has increased dramatically, particularly the demand for wilderness related activities. The NORS report estimates that the proportion of the nation's population participating in fishing increased from 24% to 53% between 1972 and 1977. During the same time period camping participation increased from 16% to 51%. More specifically back country camping increased from 5% to 21%, between 1972 and 1977, making it one of the fastest growing outdoor recreation activities in the 1970's. It is unlikely that the dramatic growth in outdoor recreation activities will continue at its previous pace as the nation's population becomes older. However outdoor recreation demand for natural resources will certainly not disappear and will probably increase in absolute terms as the nation's population grows. This national trend will probably also apply to the demand for recreation use of riparian zones in Wyoming.

On the supply side we are dealing with a finite amount of natural resources. Nationally there are 3.25 million miles of rivers and streams of which a substantial portion are either unsuitable or not available for recreational use (U.S. Department of Interior, 1979). On the state level the SCORP report indicates that there are a total of 16,566 miles of streams and rivers available for fishing of which 6,806 miles are on private land where access may be questionable. Thus there will likely be continuing competition between recreation and other uses of riparian zones. The SCORP report estimates that 22% of the state's households are interested in increasing participation in fishing. The report also indicates that the primary reason for not participating in outdoor recreation activities, after lack of time and lack of maney, is that recreation areas are too crowded. Nationally this reason is the second rated deterrent to use of outdoor recreation areas (NORS). Thus it seems likely that there will be continuing pressure from outdoor groups to increase the quantity of riparian zones and other natural resources devoted to recreational uses.

Estimates of the economic value of recreation are needed in order to make rational decisions regarding the future allocation of the state's natural resources among competing uses. Establishing these values will not be easy due to the nonmarket nature of the recreation good. Since indirect measures must be used to estimate economic value from a public perspective, some error is inevitable. In addition recreation is not a homogenous good. Consequently, the value of a specific recreation site will vary depending on the quality of the resource, how close it is to users, and the availability of alternative sites. For example Sorg and Loomis (1984), in a survey of recreation valuation studies, found that the value of an activity day for cold water fishing ranged from \$8.58 to \$67.55. For a nonmotorized boating activity day values ranged from \$6.28 to \$150.00. The value of an activity day for a wilderness experience ranged from \$12.78 to \$73.93.

The variability in these estimates emphasizes the importance of developing site specific measurements of recreational use values for riparian zones in Wyoming. The variability also suggests a need to compare the results from alternative estimation techniques to accurately determine the true value of recreation use of the resource. Development of such measures is important if the state's goal is the efficient allocation of its natural resources between competing uses.

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WYOMING'S WATER: AN OVERVIEW OF WATER QUANTITY, WATER LAW, AND WATER ADMINISTRATION WITHIN THE STATE OF WYOMING

George L. Christopulos[1]

It is my pleasure to discuss with you briefly Water Quantity, Law and Administration in Wyoming. I shall present some statistics relative to water quantities in the State of Wyoming and follow with a brief outline of Wyoming water law and its administration though the Office of the State Engineer and conclude with a summary of the most recent addition to Wyoming's water law for the beneficial use of water, the newly-enacted Instream Flow legislation enacted by the 1986 Legislature.

Wyoming is the headwaters of four major water drainage basins. These are the Green River and Little Snake River in southwest Wyoming which form the headwaters of the Colorado River; the Bear River along the southwestern border of Wyoming which flows into the Great Salt Lake Basin; the Snake River and the Salt River in Jackson Hole and the Star Valley which are the headwaters of the Columbia River; and the Yellowstone River, Wind and Big Horn Rivers, Shoshone River, Tongue River, Powder River, Belle Fourche River, Cheyenne, Niobrara River and the North Platte and Laramie Rivers are all headwaters to the Missouri River. In this setting of Wyoming streams and rivers, the amount of surface water produced, (70% of which comes in the form of snow), amounts to an average of 15.8 million acre-feet of water per year. Added to this figure of 15.8 million acre-feet which flows into the state each year. Streams that bring water into the state include the Big Laramie and North Platte Rivers in southeast Wyoming; the Little Snake River in southern Wyoming; the Blacks Fork, Henrys Fork and Bear Rivers in southwest Wyoming; and the Clarks Fork River north of Cody in northern Wyoming. We have, therefore, a total available surface water supply of approximately 17.3 million acre-feet.

In addition to this surface water supply, water is also available from groundwater. Wyoming's supply of groundwater is stored in alluvium and bedrock with much of this water located very deep within the aquifer formations making it very costly to develop. Recharge to the aquifers is estimated to be approximately 5 million acre-feet per year.
Of the 17.3 million acre-feet of surface water supply, approximately 2.6 million is consumptively used within the State. By consumptive use we mean water which is used up or lost to further use. A major consumptive use of water each year is that used for irrigated agriculture. This amounts to about 2.2 million acre-feet of surface water and approximately 300,000 acre-feet of groundwater. Municipal, domestic, livestock and industry consume approximately 60,000 acre-feet of surface water and 100,000 acre-feet of groundwater annually. Reservoir evaporation amounts to about 400,000 acre-feet annually. This average annual depletion of 2.6+ million acre-feet leaves an approximate average of 14.7 million acre-feet of water which flows out of Wyoming into neighboring states each year. Some of this water leaving the state is utilized for such non-consumptive uses as recreation in lakes and streams, hydro-power generation, fisheries, etc. Included in the 14.7 million acre-foot figure is an amount of 2.8 million acre-feet which Wyoming is entitled to under the various Compact allocations as was discussed with you earlier in this Conference by Larry Wolfe.

The Wyoming Constitution declares that the waters of all natural streams, springs, lakes or other collection of still water within the boundaries of the state are the property of the state. Constitutional provisions allowed for the appropriation of water for beneficial uses and established the Office of the State Engineer and the Board of Control to supervise such appropriations. The State Engineer is charged by the Constitution with the "general supervision of the waters of the State and of the officers connected with its distribution." In carrying out this function, the State Engineer grants or denies applications for use of water, as well as being responsible for the distribution of the available water supply. Along with these duties and in concert "with the general supervision of the waters of the State," the State Engineer and his staff are also involved with water matters on an interstate and National level to protect Wyoming's interest in the utilization of her water resources.

Wyoming follows the Doctrine of Prior Appropriation. This means that a senior right receives water before a junior right. The Riparian Doctrine used in many midwestern and eastern states allows use of water only to those lands adjacent to the stream.

State statutes establish the procedure for the appropriation of water for beneficial use. First, a permit to use water must be obtained from the State Engineer. After the water has been put to use and proof of beneficial use is made to the Board of Control, the Board will adjudicate the water right. Priority of appropriation is based upon the relative date on which applications for permits are accepted in the State Engineer's Office. Again, "First in time is first in right" is the basis of Wyoming water law.

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[1]Wyoming State Engineer, State Engineer's Office, Herschler Building, Cheyenne, Wyoming 82002.

A water right cannot be acquired in Wyoming for either surface water or from groundwater without application to and the granting of a permit by the State Engineer. When a permit is granted by the State Engineer for either groundwater or surface water, conditions are imposed setting out time limits within which work must be commenced, completed, and beneficial use made under the permit and such work must be completed during those time frames. If, however, additional time is needed, an extension of time can be allowed by the State Engineer for good cause shown. Under this system of prior appropiation, all water rights are regulated in times of shortage to provide water to the earlier priorities.

After a water right permit has been completed, the final step is the adjudication or finalization of the water right. This adjudication is accomplished by the Board of Control. The Board of Control, as established by the Constitution, consists of the State Engineer and four Water Division Superintendents who are the Water Administrative Officials responsible for the administration of water in each of the four Water Divisions in the State. Water Division No. 1 consists of the North Platte, the Niobrara drainage and the Little Snake drainage in the southeastern portion of the state. Water Division No. 2 consists of all the drainage off the east slope of the Big Horn Mountains which includes the Tongue River and Powder River drainages and the Belle Fourche River and the Cheyenne River Drainages. Water Division No. 3 consists of the northwest portion of the state and includes the Big Horn drainage and Clarks Fork drainage. Water Division No. 4 is the southwestern portion of the state and includes the Snake River drainage, the Bear River drainage and the Green River drainage. The Board of Control functions as a quasi-judicial body in that water rights are adjudicated or finalized by the Board and all changes to adjudicated water rights are dealt with by the Board, such as changes in point of diversion, changes in lands to be irrigated, and in use and abandonment.

Water administration in the field is accomplished by Hydrographer-Commissioners who are full-time state employees skilled in the measurement of water and in water administration. The more complex water administrative areas are generally administered by Hydrographer-Commissioners. The balance of the water administration is handled by the Water Commissioners who are County employees paid by the County with some supplemental funds provided by the State, in certain instances.

As mentioned earlier, water rights are administered in order of priority so that during times of shortage, water rights with later priorities are regulated or shut down to provide water for the earlier priorities. This is true no matter what use is made of the water; priority strictly governs as to who gets the water during times of shortage, including water for municipal and domestic supplies. The amount of water appropriated for a direct flow right for irrigation is fixed at a statutory rate of 1 cubic foot per second for each 70 acres of land irrigated with an additonal cubic foot per second being available in times of surplus. Water rights for other purposes are fixed by reasonable use, based on the capacity of the facility.

A permit is required for any storage or diversion of water. There are thousands of reservoirs built in the State of Wyoming for stock purposes and a water right is required for these reservoirs as well as for the diversion of water for stock purposes. Storage water rights are adjudicated in acre-feet and in the case of an off-channel reservoir, a quantity of rate of diversion in cubic feet per second is also fixed for a supply ditch or pipeline to furnish the reservoir. A reservoir is limited to one fill per year and any water that is carried over from one year to the next counts against the next year's fill. For example, if a reservoir appropriation is for 100 acre-feet and 75 acre-feet is used in a year, with 25 acre-feet carried over into the following year, the reservoir is entitled to store 75 acre-feet to bring it back up to full capacity the following year. On-channel reservoirs oftentimes present problems in administration since inflows must be conveyed through the reservoirs to prior downstream appropriators. Aministration of such a reservoir requires the close monitoring of reservoir levels so that there can be an accounting for withdrawals from storage. If found necessary, the Superintendent may order a measuring device be installed in the stream channels above and below a reservoir in order to facilitate regulation of the reservoir. A Water Division Superintendent has authority to order headgates and measuring devices in all ditches or other points of diversion in order to allow for the proper regulation of the facility and also to determine the quantity of water that is being conveyed through the system.

The law requires that before a change in point of diversion or means of conveyance, is made or a water right is changed in any manner, a petition must be filed, generally with the Board of Control for all adjudicated water rights and to the State Engineer for unadjudicated water rights. Many factors must be considered before such a change in point of diversion, means of conveyance or changes in use, can be allowed. A change in use can only be granted by the Board of Control and can often be very complex. Such changes involve changes from irrigation to municipal or industrial use. A thorough review is necessary to make sure that there is no injury to other appropriators by the allowance of a change. Such a change cannot exceed the amount of water historically diverted, nor exceed the historic rate of diversion or decrease the historic amount of return flow or increase the historic amount of water consumptively used. The time period during which a right that has been changed can be diverted and used is fixed by the historic period of diversion. The Board in looking at such changes may also consider the economic loss to a community and to the state if the use of the right is transferred to some other use and as to whether the economic loss will be offset by the new use and whether other sources of water are available for the new use.

Through the years, sophisticated water regulation has occurred in many areas of the state. This is especially true in the southeastern portion of the state where the streams are most fully appropriated. This administration is accomplished by utilizing state-paid personnel on a year-round basis. This is also true to a more limited extent in other Water Divisions in the state. The most highly regulated stream in Wyoming, (and one of the more highly regulated in the nation), is the North Platte River which is regulated on a daily basis. Detailed records are kept of diversions and inflows, etc., on the total river system.

The requirement for regulation and administration of groundwater has not been done as extensively in Wyoming as it has been in many of the other states since the groundwater use is of more recent origin. We do have a provision in the law which allows for the establishment of "Ground Water Control Areas." These are areas where there are groundwater problems occurring or which may occur in the future. When a Ground Water Control Area is established under the procedure set out in the law, then no further permits for groundwater are allowed without a considerable review. Permits are only allowed if this can be done without injuring other appropriations in the control area.

All in all, the water administration in Wyoming has generally been satisfactory and the laws have been quite workable. They have been modified from time-to-time to modernize and update them, but as I have mentioned, they have worked very well up to this point and we expect that water administration will improve as years pass, and the competition for water becomes such that additional administration is needed.

After many unsuccessful attempts to enact instream flow legislation, the 1986 Wyoming Legislature passed Enrolled Act No. 53 which will be effective June 11, 1986.

The Act provides that the storage of water for providing instream flow purposes or for recreation is a beneficial use of water in Wyoming. The Act also privides that an appropriation of direct flow for an instream flow is a beneficial use of water, and allows for the conversion of existing water rights to instream flow purposes. The Act establishes how an instream flow is to be appropriated, by whom, (only the State of Wyoming), and establishes a procedure for the granting of permits by the State Engineer.

Instream flows can now be appropriated from the natural flow of an identified stream segment. The law also provides that reservoir appropriations can be made for instream flows or that storage water can be provided from existing reservoirs to maintain a minimum flow in an identified stream segment.

The Wyoming State Engineer's Office, the Game and Fish Commission, the Water Development Commission, and the Economic Development and stabilization Board are the State agencies who will be coordinating the implementation of this legislation.

Briefly, a description of how this legislation will work for appropriation of water is as follows: the Game and Fish Commission reports to the Water Development Commission on instream flow needs. Game and Fish conducts studies on the proposed segments, and Water Development investigates the feasibility of direct flow appropriation or of providing flows from existing or new storage. The Water Division of the EDS Board files applications with the State Engineer at the time the Water Development Commission study is initiated. Applications can be acted on by the State Engineer after appropriate advertising and public hearings and after all appropriate studies are done. For storage, Water Development requests the Legislature to authorize design and construction. The State Engineer may condition a permit to require a review of the continuation as an instream flow right.

Thank you for your attention and I shall be happy to address any questions you may have.

HYDROLOGIC IMPACTS IN RIPARIAN ZONES

Steve A. Mizell and Quentin D. Skinner[1]

Introduction

One dictionary defines riparian as "pertaining to, situated or dwelling on the bank of a river or other body of water." Working definitions have typically relied on plant assemblages that reflect significant water requirements to indicate riparian areas. A riparian zone is dependent, implicitly or explicitly, on the presence of water which is accessible to vegetation. This requirement for water suggests the very strong inter-relationship that exist between the hydrologic character of a stream system and the adjoining riparian areas.

Within this article inter-relationships between hydrologic features of the stream-riparian system will be conceptually reviewed. Significant hydrologic features will first be identified. Then their relationship to the riparian zone will be considered in light of a cycle of riparian zone degradation and regeneration. Finally, the impact of several hydrologic tools for managing riparian areas will be discussed.

Significant Hydrologic Features

The principal hydrologic features of a stream-riparian system include the following:

- Overbank flooding
- Water conveyance
- Flushing flow
- Subsurface water storage
- Infiltration and recharge
- Flow Regime
- Channelization

Most of these features are interrelated in that the existence of one may depend upon or promote the existence of another.

Overbank flooding is the spreading of water outside the normal stream channel. This phenomena is important in riparian areas because it provides new sediment deposits from which soil may develop, natural irrigation to plants on the floodplain, and waters to recharge soil moisture and storage in the stream-connected aquifer.

Water conveyance, that is the ability of a channel to transmit water, is related to the channel shape and to vegetation in the channel. The presence of vegetation in the channel and on the low banks of the stream, along with debris in the channel, will impede water conveyance. As a result overbank flooding occurs. Water conveyance during overbank flooding is retarded further because of the additional vegetation and the rough land surface on the floodplain.

Flushing flow requirements are reduced in stream reaches with well developed riparian zones. In such reaches the channels are narrower and less water is required to produce the energy necessary to flush fine sediments deposited during low flow.

Subsurface storage of water in the floodplain soils and the stream connected aquifer is important to the stream-riparian system. Water which enters subsurface storage during high stream flow and overbank flooding is temporarily removed from the steam and a lower peak flow results. Riparian zone vegetation is irrigated by water which infiltrates the soil. Recharge to the shallow aquifer may be released at a later time when lower stream flow reverses the hydraulic gradient of the stream-aquifer system (Figure 1). Stream bank recharge is an especially critical factor in determining low flow augmentation since waters recharged through the stream bank will not move far from the channel before stream flow subsides.

Infiltration is the mechanism by which waters pass from the stream into the soil and shallow aquifer. Infiltration occurs through the streambank under high flow and through the floodplain soils during overbank flooding. During high stream flow the water level in the stream is higher than in the soil or aquifer and water infiltrates the soil and recharges the aquifer. The volume of water which infiltrates through the floodplain soil is greater than the volume which infiltrates through the streambank for two reasons. The first is that the floodplain area is more extensive than the streambank area. Secondly, flood waters may be present on the floodplain longer than high flows are present in the channel.

Flow regime is the pattern of observed streamflow variation in response to the climate and the physical and biological character of the drainage basin. The magnitude of flow and the seasonal variation in flow are important factors in creating the stream channel. Dynamic equilibrium is the balance between channel characteristics and flow regime toward which nature is constantly moving using the tools of erosion and deposition.

Channelization is a change in the stream channel that permits it to convey greater amounts of water.

[1]Assistant Professor, Wyoming Water Research Center/Department of Geology and Geophysics, and Professor, Department of Range Management, respectively, University of Wyoming, Laramie,Wyoming 82071.

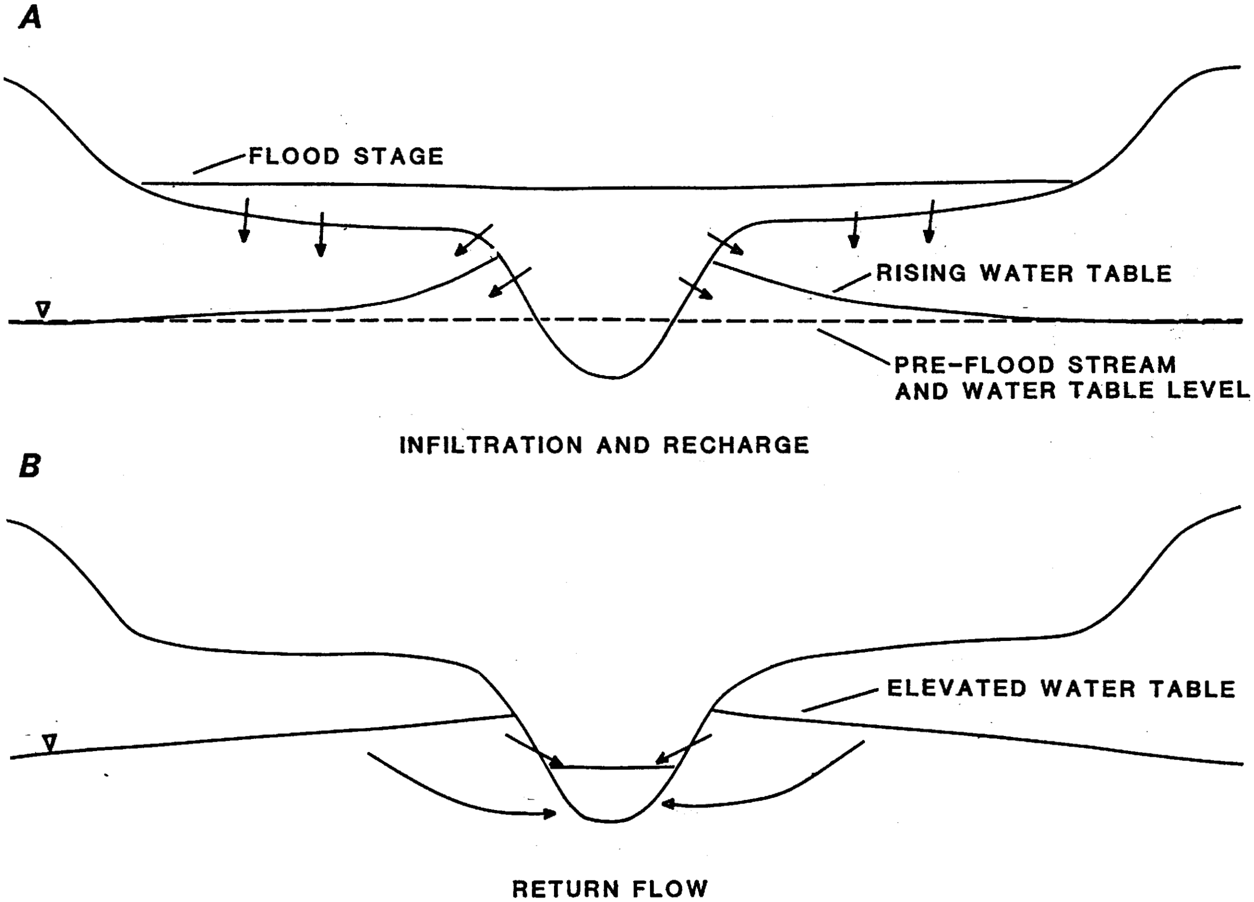

Figure 1. Schematic representation of stream stage and subsurface water storage relationships for (A) high flow, and (B) low flow conditions.

Channelization may involve intentional and engineered changes or it may result from natural events. The result usually includes an increase in channel volume.

All of these features of the steam-riparian system are interconnected. A change in one will cause a change in many of the other features. Consider, for example, that volume of infiltration is reduced. As a result the subsurface storage of water will be reduced, vegetation will lack an adequate water supply, and releases from ground water at low stream flow will be less.

While all the features listed above are important in understanding the riparian zone, flow regime and channelization are the basic features of concern. The active flow regime provides the water which in time, produces the riparian zone in dynamic equilibrium with the stream. Channelization on the other hand has the greatest portential for destroying the riparian zone because the resulting change in channel character and/or stream flow affect virtually every other hydrologic feature.

Flow Regime Impact

In northern latitudes, and where streams drain high elevation watersheds, the flow regime is typically dominated by snow melt runoff. The annual stream flow hydrograph exhibits minimum flow in winter, peak flow in the spring, and decreasing flow though the summer and fall (Figure 2). Minimum, or base, flows are determined by groundwater releases from springs in the watershed and from temporary storage in the stream connected aquifer underlying the floodplains. Streams draining basins with this kind of flow regime will run at bank full, or flood, stage during the snow melt period. At minimum flow the stream will be restricted to a low flow channel in the middle of the stream bed. In extreme conditions, flow may even be reduced to zero with water ponded in the stream bed.

Conceptually, a stream is thought to adjust its channel toward dynamic equilibrium with the average annual flow. Obviously then, some flows will exceed the capacity of the channel and produce overbank flooding. The overbank flooding is a critically important aspect of riparian zone development since it supplies water to recharge the soil moisture and the stream-connected aquifer storage and because it delivers fresh sedimentary material which enhances soil development. As mentioned previously, the temporary storage of water in the subsurface supports riparian zone vegetation and augments low stream flow. The encroachment of vegetation onto new sediment deposits stabilizes the deposits and contributes to devlopemnt of the riparian zone.

Channelization Impacts

Stream channelization is an important cause of riparian zone degradation. As the channel enlarges in response to large, more rapid flows the riparian zone is eroded. If channelization results from a change in the flow regime the erosion will continue until dynamic equilibrium is reestablished. If a catastrophic flow produced the channelization a greater portion of the natural high flows will be contained in the channel banks, so overbank flooding and recharge of subsurface storage will be reduced. Channelization may be initiated in a number of ways both natural and man induced. Some events that cause channelization are briefly discussed below.

The breeching of a dam which results in the sudden release of a large volume of water will cause channelization. The hydraulic head of the ponded water provides the energy that erodes the channel as the flood wave moves downstream. Failure of beaver dams or stock-pond dams may produce an unusually high flood wave on top of already high flows or catastrophic flows causing channelization.

Migration of head cuts up a channel result in channelization below the head cut. Head cuts may originate in several ways but the most dramatic channelization occurs when a main stream bed drops leaving the tributary channel higher than the main stream. Flow down the tributary causes this elevation difference to migrate upstream. If the head cut migration continues unchecked by nature or man it will move through the entire upstream drainage system.

Wildlife and livestock activity may cause channelization. In upland areas grazing activity may reduce vegetative cover which leads to increased overland flow since plants are no longer present to use the water or retard its movement toward channels. In the riparian areas grazing and browsing can eliminate some plant species and animal activity may damage the stream bank. Both situations damage the riparian zone and may increase the sediment load of the stream.

Ruts developed on animal paths, recreational trails, and off-road vehicle tracks will increase the feeder channels which deliver water from the upland contributing areas to the stream channel. Since water

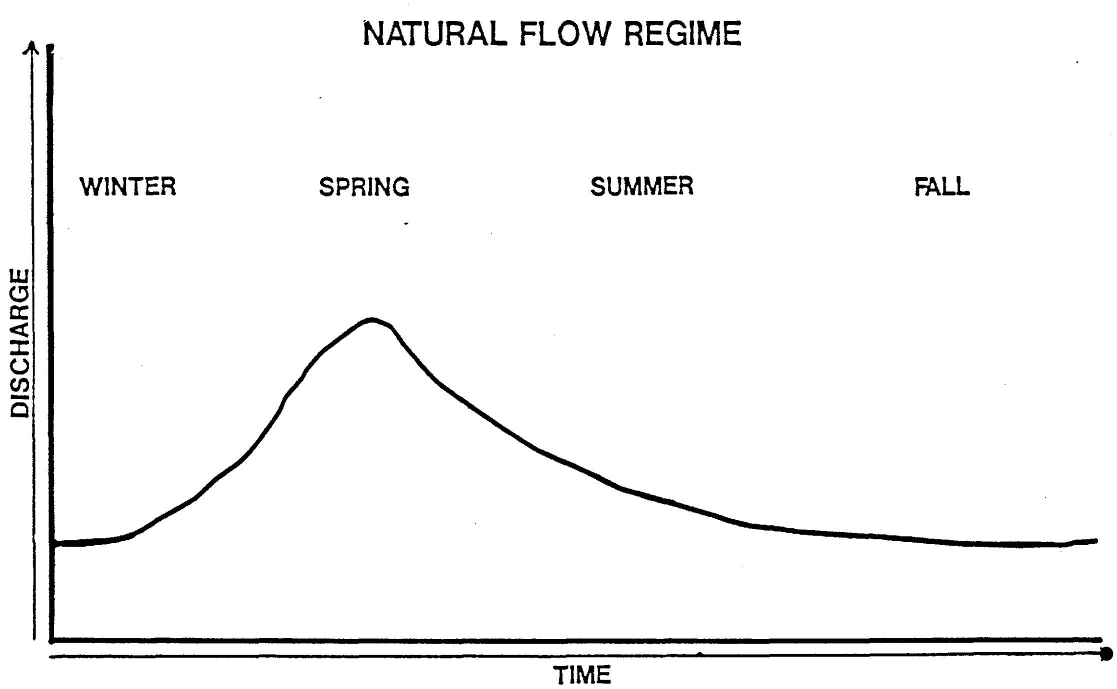

Figure 2. Typical annual hydrograph for flow regime dominated by spring snowmelt runoff.

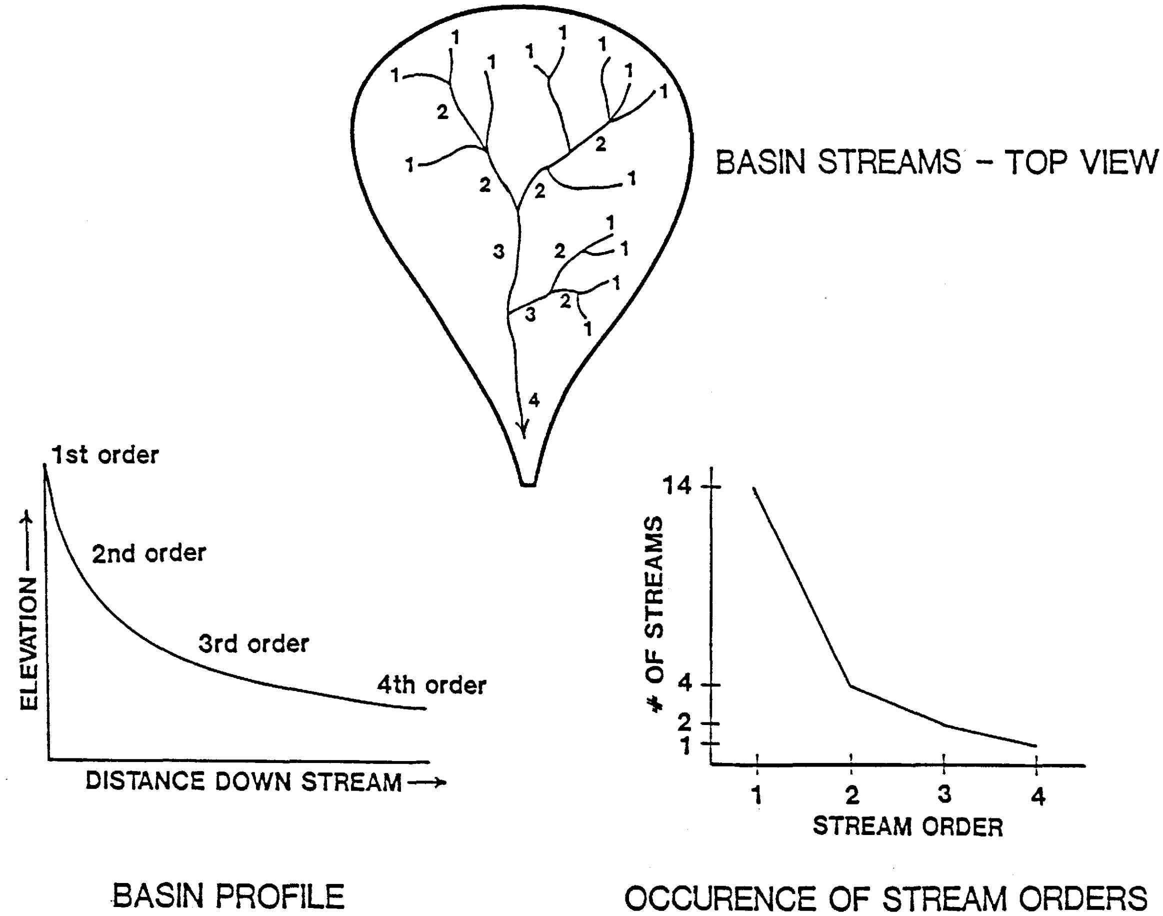

Figure 3. Stream order relationships in a typical drainage basin.

travels more quickly in channels and has more energy when concentrated, these feeder channels increase the magnitude and the speed of flows moving though the basin. Road construction may also lead to channelization. Poorly designed culverts, for example, may force water though a narrow pipe increasing its velocity and its erosive power. Access road layout and construction in areas of timber harvesting, oil and gas exploration, or other resource development may also result in channelization when overland flow is concentrated in the road as it flows toward the stream channel.

Channelization may also be intentional. For example, engineered channelization may be used to move a stream so that mining activities can continue or so that contamination points can be by-passed. While engineered channelization is carefully planned and implemented there is still potential for stream damage above and below channel modifications.

In upland areas channelization increases the number of small rills, gullies, and first order streams. Stream order is a drainage basin evaluation parameter that is indicative of channel development. First order streams are those which have no tributaries at the scale of study (Figure 3). Second order streams are designated when two first order streams converge. Third order streams are identified when two second order streams converge. The order parameter of stream segments is determined in this manner until the main stream order is determined at the outflow from the basin. First order streams are most common in the upstream, headwater areas of a basin and constitute the bulk of ordered stream segments in the basin.

The increased number of rills, gullies and first order streams has a significant impact downstream. These smaller channels partition contributing land area into smaller units (Figure 4). This partitioning means that snowmelt and precipitation reach channels more quickly than before. As a result upland infiltration is reduced, water is concentrated in channels more quickly, and peak flow events occur more quickly and last for shorter periods than before the increase in upland channels. Upland channelization effectively changes the natural flow regime, the seasonal variations and total runoff volumes remain the same but the magnitude and duration of events change.

Channelization which results from a downstream even, such as a head cut, migrates upstream changing the channel features without changing the flow

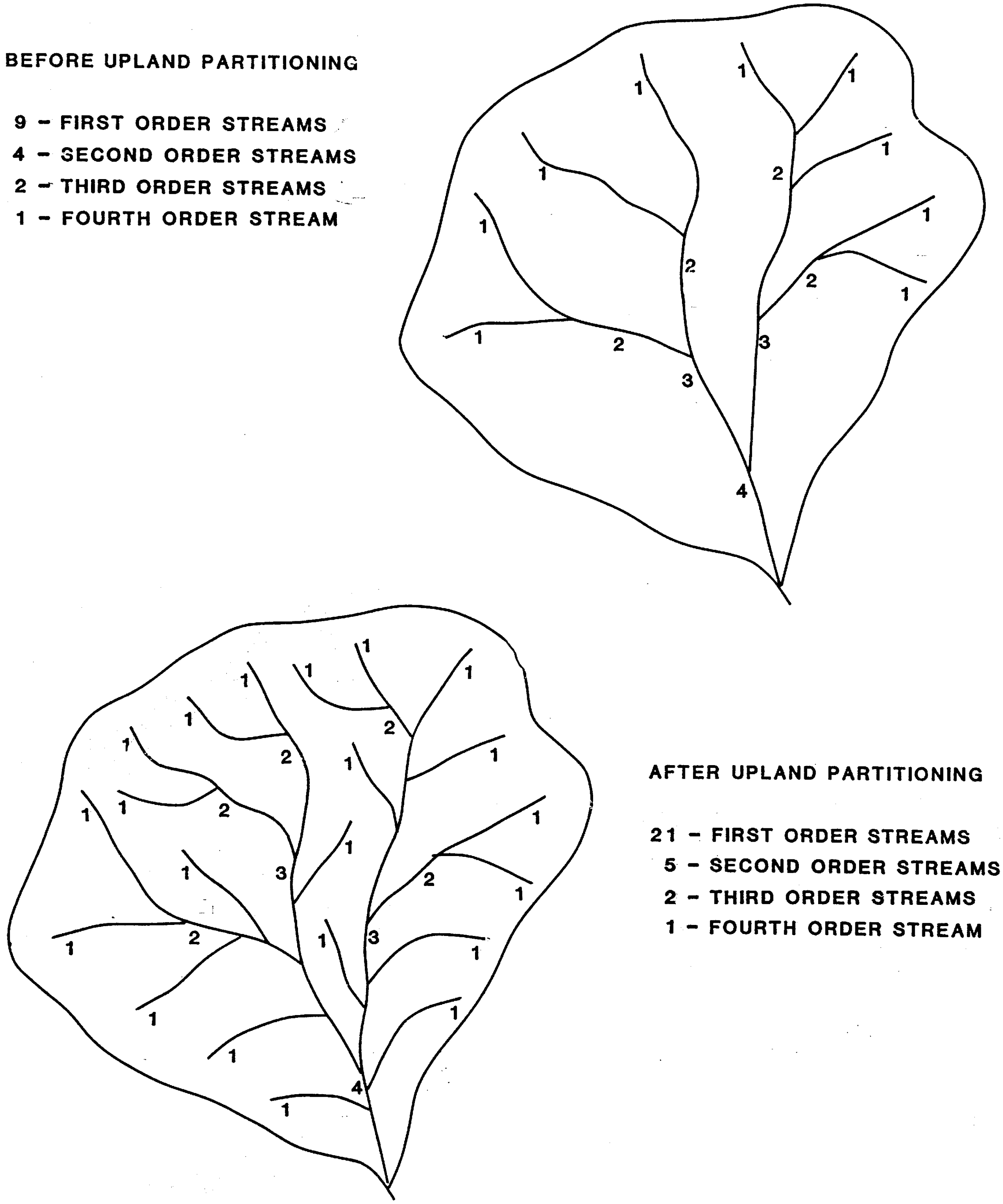

Figure 4. Partitioning of contributing areas as a result of upland channelization.

regime. As the channel widens by bank erosion and deepens from downcutting high flows are more frequently contained within the banks, overbank flooding is reduced and recharged to the soil and shallow aquifer is diminished.

Channelization, whether it originates in the uplands or in the lower basin, results in a larger channel with capacity to hold greater volumes of water. The reduction in overbank flooding means a reduction in soil infiltration and aquifer recharge. As a result the riparian zone dries out. The drying out is evidenced by changes in the riparian plant community. The number of plants that require considerable water may be reduced while the number of plants which can survive with less water increase.

Once a channelization event has cut though a stream channel nature immediately begins a maturing process to heal the cut (Figure 5). The process reflects the effort of nature to reestablish dynamic equilibrium between the active flow regime and the stream channel. As the stream matures, within the constraints of the flow regime and the channelization event, the riparian area is subjected to considerable change. The first effect of this maturing process is the widening of channel banks. This widening causes the steep banks created during channelization to be eroded to gentler slopes.

Two processes are particularly important at this point. They are piping of water though bank soils and periodic wetting and drying of the bank. Water piping occurs when macropores, large holes in the soil caused by animal burrowing or plant root growth, fill with water. These water filled pores exert higher water pressure than is present in the surrounding soil, and water is forced through the soil under pressure. When water fills macropores near the stream bank the water moving under pressure will erode soil along its flow path and cut off blocks of the stream bank which fall into the channel. The periodic wetting and drying of the stream bank has two effects. First, this cycle will cause clayey soils to swell and shrink. This action destroys the forces which hold the bank together. Additionally the accumulation of quantities of water in the bank soil may provide the added mass and lubrication which will cause the bank to fall under gravity.

As the flow regime and channel adjust toward dynamic equilibrium small areas of flood deposits develop inside the high channel banks. These deposits occur on the inside of meanders and in the stream bed. Under high flows bed deposits occur predominately at the foot of the stream banks. This is because the combined friction forces of the bed and bank slow the water causing some of the sediment load to be dropped. During low flow periods stream flow is

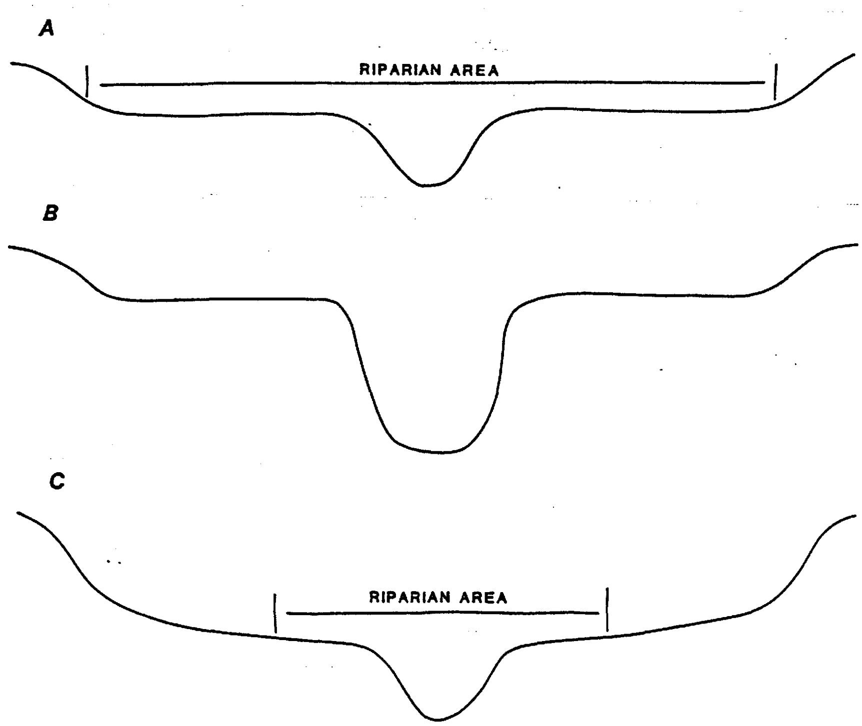

Figure 5. Schematic cross-sections illustrating the cycle of stream-riparian system change for (A) a well developed, fully mature system through (B) channelization impacts (C) a re-developing, matureing system.

typically confined to a small internal channel in the midst of the channel bed. Here sediment is deposited in the channel bed causing agradation of islands and infilling of channels between these low islands.

As vegetation encroaches and becomes established on these flood deposits inside the high banks the sediments are stabilized. The growth of vegetation in the channel shows water conveyance though the reach providing opportunity for increased infiltration into the banks and the underlying aquifer. The effect is to increase the rate of healing of the channelized stream reach. In time a single channel with its flood plain and good vegetation develop within the high banks and new riparian areas are formed. The repeated flooding of this new riparian area fosters growth of the vegetation and enhances development of the riparian system. The narrowed channel and well vegetated riparian zone provide opportunity for biological damming. Constriction of the channel by vegetation and biological dams slows water conveyance and causes overbank flooding. Constriction of channel width also causes overbank flooding. Overbank flooding provides the infiltration and recharge to subsurface water storage that fosters growth of the riparian zone. Overbank flooding also deposits sediments on which riparian vegetation may become established further contributing to the growth and development of the riparian zone.

Hydrologic Management Impact

There are three very significant hydrologic factors that must be recognized when riparian area management alternatives are considered. These key factors are: stream flow diversion, stream flow control, and evapotranspiration.

Figure 6 shows the impact of high flow diversions on the stream hydrograph. Clearly peak flows are reduced and, when diverted waters are used for local irrigation, some return flow is available to augment low stream flow at a later time. Diversion of stream flow to irrigate land along the stream duplicates the effect of natural overbank flooding. The irrigation waters infiltrate the soil where some water is utilized in crop growth. Excess water recharges the stream-connected aquifer where it is held in temporary storage until it flows back to the stream during low stream flow. Conversion to more efficient irrigation practices, which permit diversion of less water, will mean a change in the stream-riparian system. Since less waters are diverted higher peak flows will occur and the stream channel and riparian areas must adjust to the different flow regime.

Establishment of a reservoir on a stream will clearly effect the flow regime. The schematic hydrograph in Figure 7 shows the change in flow regime below a reservoir purposefully operated to control flow in the stream. Downstream of the reservoir the stream and riparian zone will adjust to the reservoir operation regime. In the case of the schematic hydrograph, this would mean the loss of overbank flooding as a source of recharge to subsurface water storage and probably the loss of riparian area. Riparian lands inundated by the reservoir would be lost, with new riparian areas developing along the reservoir shoreline only where variations in reservoir level are not extreme.

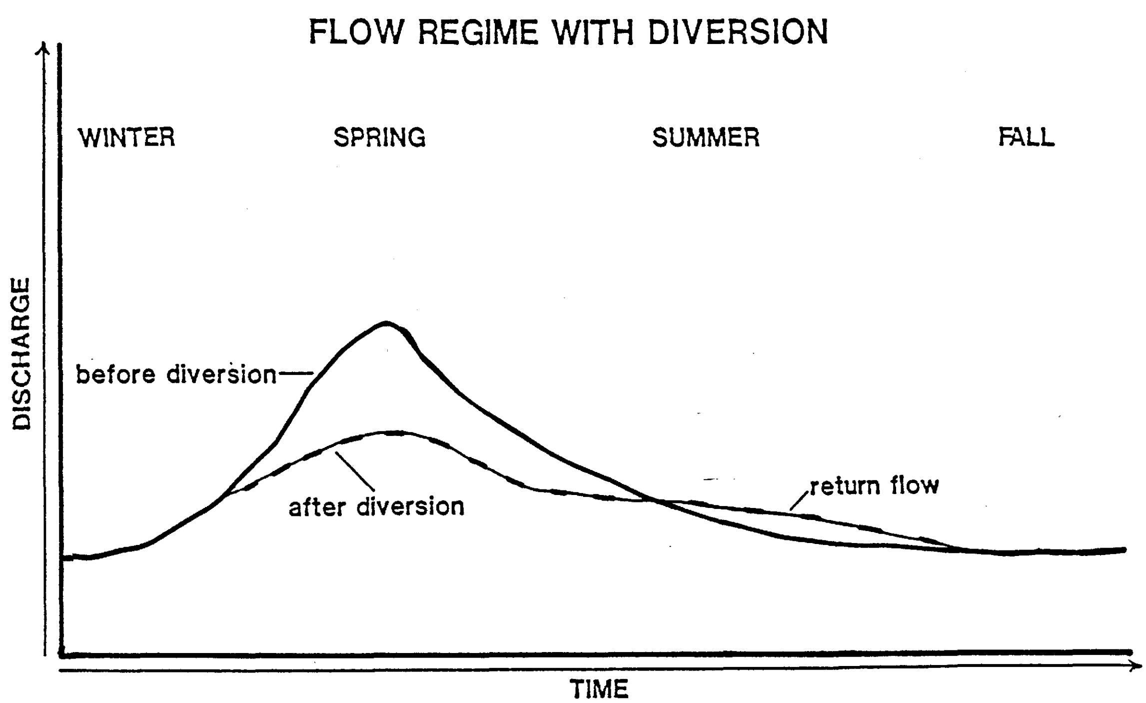

Figure 6. Effect of streamflow diversion on the typical annual hydrograph.

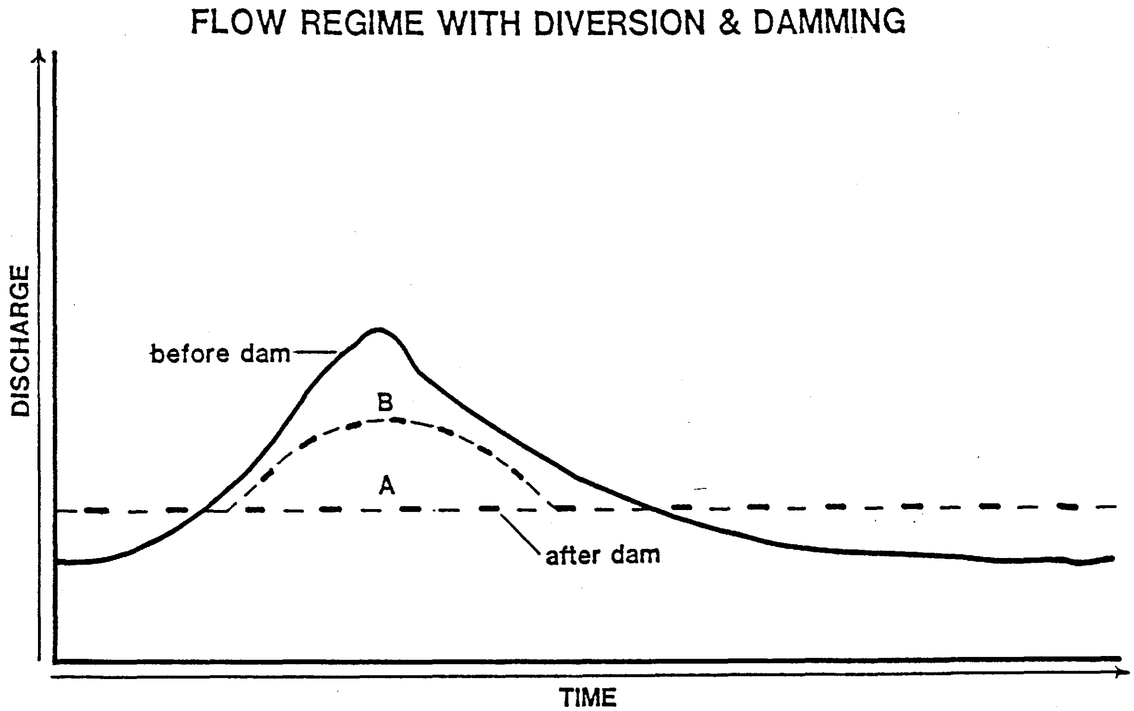

Figure 7. Hypothetical stream hydrographs showing the impact of reservoir operation to maintain stream flow.

The heavy vegetation of well developed riparian zones will withdraw water from subsurface storage by evapotranspiration. Vegetation control has been utilized as a management tool to control stream flow losses but the impacts of these efforts on the stream-riparian system as a whole have not been well documented.

Summary

Riparian zones are dependent upon the water provided by the associated stream. This dependence is extremely strong; a slight change in the character of the stream system will be reflected in the riparian zone. Just as a stream channel is adjusted by nature to a dynamic equilibrium with the active flow regime of the stream so, also, is the riparian zone adjusted.

MANAGING RIPARIAN STREAM HABITATS

William S. Platts[1]

Upon settling this great nation, European man soon recognized the potential of using the vast rangelands for livestock production. Cattle were initially stocked in the early 1500's with sheep arriving later. Animal numbers, however, did not peak until four centuries later. By the 1930's, livestock grazing was so heavy that many of these lands and the streams draining them were in poor condition. Since livestock are attracted to riparian areas adjacent to streams and lakes, that portion of the range was also heavily used.

As the land management agencies and private range owners implemented improved grazing practices after the 1930's, rangelands began to improve. Busby (1978) states that rangeland conditions today are far better than the denuded, deteriorated ranges that existed in the early 1900's. I agree that rangelands have improved greatly, but contend, however, that studies leading to the interpretation of the improvement were based primarily on data collected from drier upland sites, and often did not take into account the condition of riparian areas (Platts 1979). Riparian areas may have recovered to some degree since the 1930's, but not nearly to the extent of other rangeland types. The reason for this is that we were not concentrating on managing riparian habitats--we were managing conditions on a large scale.

Riparian habitats are productive and quite resilient. Even degraded habitats, under good management, can soon recover and contribute valuable multiple rangeland resources to the nation. The possibility exists to manage the nation's rangelands to increase fish populations by one order of magnitude during the next several decades. This article briefly, and in a generalized fashion, describes the past and present situation in riparian-stream management and offers some suggestions of methods to move toward better riparian management.

Situation

It is clear from the literature that improper livestock grazing can affect the riparian-stream habitat by eliminating riparian vegetation, widening stream channels, causing channel aggradation through increased sediment transport, changing streambank morphology, and lowering surrounding water tables.

Appraisals by the Bureau of Land Management (BLM) and Forest Service show that riparian lands are still in need of improved management. The BLM estimated that of their 536,825 acres of riparian habitat 447,473 acres (83 percent) were in unsatisfactory condition (Almand and Krohn 1978). Similarly, land use activities on the 2,300,031 acres of riparian wetlands on National Forest lands are exerting impacts that require prompt attention (Owen 1979). It is estimated that all land uses have eliminated 70 to 90 percent of all natural riparian ecosystems in the United States (CEQ 1978). We are fortunate that on rangelands a much higher proportion of the riparian habitats still exist.

Many authors have demonstrated that improperly managed grazing animals have the ability to alter riparian-stream habitats. A literature review by Gifford and Hawkins (1976) showed that no grazing system consistently or significantly increased plant and litter cover on watersheds. In an intensive review of this literature, Meehan and Platts (1978) and Platts (1981a) were unable to identify any widely used livestock grazing strategies that were completely capable of maintaining high levels of forage use while rehabilitating damaged streams and riparian zones. As this report will demonstrate, the remarks of Meehan and Platts no longer apply.

The high precipitation years of 1983 and 1984 resulted in flooding and high stream flows causing dramatic changes in many riparian-stream habitats in the West (Platts and others 1985). These authors showed that three basin-range streams in improperly managed watersheds were degraded by these storms, but in those reaches where streamside vegetation was in good condition, flood impacts were minimal. Floods are part of the reason that many of the nation's riparian-stream habitats are in their present condition, but probably more important are the small annual degrading effects which accumulate over time. A century of these small additive effects has resulted in major impacts on certain riparian-stream habitats. The nation's riparian habitats are in dire need of better management. To initiate the needed rehabilitation, methods of better management must be constantly sought.

Improved Methods

The stream and its watershed function as a unit. Therefore, management must be applied on a basin approach. In addition, riparian habitats are much different from their adjacent drier sites and require site-specific types of management. Each grazing system, species of livestock, and type of land needs to be considered together. Our research has begun to develop methods which are discussed here, but research must not stop here; it must move forward in developing better and more economical solutions to problems.

[1]Research Fisheries Biologist, U.S. Department of Agriculture, Forest Service Intermountain Research Station, 316 East Myrtle Street, Boise, Idaho 83702.

Riparian Pasture

One strategy we have tested that has excellent potential for bringing most allotments into successful management is the riparian pasture concept (Platts and Nelson 1985a). The riparian pasture is a smaller pasture within the allotment that encompasses the concerned riparian-stream area that will be managed independently to achieve the desired habitat responses. This pasture can also include the necessary amount of surrounding uplands to obtain a proper balance of riparian and upland forage. Advantages of the riparian pasture include better control over animal distribution, grazing intensity, and timing, as well as increased vegetation production, which in turn allows more management options for its use. Using the riparian pasture concept is expensive, and based on today's economy, may only be considered when valuable resources such as salmon and steelhead trout spawning and rearing areas need improved habitat management.

Stream Corridor Fencing

Platts and Rinne (1985), in an extensive literature review showed that riparian habitats benefited greatly after being fenced to eliminate heavy livestock grazing. Our studies have documented rehabilitation results on Tabor Creek, NV, Big Creek, UT; and Horton Creek, ID (Platts and others, 1983). In many areas, however, it is not economically feasible to fence every streamside corridor (Platts and Wagstaff 1984); therefore, successful grazing strategies that regulate animal distribution and forage use must be developed.

Specialized Grazing Strategies

The chief goal of a specialized grazing strategy (one that is more sophisticated than continuous grazing) is to maintain or improve livestock performance while improving or maintaining rangeland conditions by controlling the numbers, type, and distribution of livestock. Proper grazing of riparian vegetation requires controlled animal distribution. Conventional allotment management strategies, tailored to extensive areas, may not achieve acceptable animal distribution in the highly preferred riparian zones. Platts and Nelson (1985b) found that in 23 of 25 cases on study areas in Idaho, Utah, and Nevada, streamside vegetation use by cattle was twice as heavy as overall pasture use.

These studies showed that on conventionally managed allotments using rotation, rest-rotation, deferred, and season-long continuous cattle grazing strategies, cattle grazed riparian range types more heavily than the uplands.

Season Long Continuous

Under season-long continuous grazing, livestock generally concentrate in riparian areas. Roath and Krueger (1982) reported that although the riparian zone constituted only 1.9 percent of the area of one allotment in Oregon's Blue Mountains, it produced 81 percent of the vegetation removed by cattle. Eckert (1975) found on an allotment in northern Nevada that livestock obtained up to 88 percent of their diet on the wet meadow range site that occupied less than 1 percent of the allotment. Based on our studies that were in allotments using season-long continuous grazing (four study sites), it appears that this grazing strategy, under presently used intensities (60 to 95 percent), has little chance of success for improving riparian vegetation and fish habitats.

Winter Grazing

Based on our Otter Creek, UT, study results we believe that winter grazing has possibilities in the areas where winters are cold, but snowfall is light (Platts and Nelson 1984). We could find few detrimental streamside effects and believe that the reasons were because streambanks were usually frozen and vegetation was dormant.

Rest Rotation

Any grazing strategy that allows a period of rest for a riparian-stream habitat to rejuvenate has potential benefits. Success lies in applying the amount of rest needed to match the stream's capability to repair past damage and also to maintain a vigorous riparian habitat. We could find no adverse riparian-stream impacts from a well-managed, double-rest-rotation (graze early then rest 2 years, then graze late and rest 2 years) grazing strategy on our study site on Johnson Creek, ID. Rest-rotation systems with controlled grazing intensity can be quite successful in riparian habitats (Platts and Nelson, in press). Rest-rotation grazing by sheep can be very successful (Platts 1981b).

Species of Livestock

Different species of livestock graze watersheds in different ways. Herded sheep usually use slopes and upland areas, while unherded cattle prefer the lesser slopes or bottomlands. Our two Frenchman Creek, ID study sites are in an allotment programmed for sheep grazing using a three-pasture, rest-rotation strategy since 1967 (Platts 1984). After 8 years of study we found no significant changes in trends of any of the environmental factors measured. The stream and its riparian zone remained in a healthy condition and no significant changes were observed between the grazed and ungrazed pastures. Good management (proper herding, intensity, and timing) is undoubtedly the reason for the maintenance of the high-quality stream habitat. Herding allowed light forage use in streamside zones mainly after stream banks had dried out. This strategy could be useful throughout the Cascade, Rocky, and Sierra Nevada Mountains.

Riparian Rehabilitation

The restoration and rehabilitation of degraded riparian areas should receive the highest priority for future research. We have demonstrated at Big Creek, UT, that riparian areas can be artificially rehabilitated, though better techniques need to be developed (Platts and Nelson 1985c). Conversely, in other areas (Chimney Creek, NV, and Bear Valley Creek, ID) we have had little success with artificial rehabilitation. Research leading to successful rehabilitation of riparian-stream environments is in its infancy.

Summary

Much of the water that falls on a watershed eventually must pass through the riparian area to reach the stream. Therefore, as the nation's riparian habitats go, so go the nation's streams. These riparian-stream habitats must be managed as separate entities, but always within a watershed perspective. In riparian management, it is time to stop looking at a small exclosure or a stream reach. Successful riparian management requires a basin or watershed approach. We agree with Behnke (1977), who has stated that rehabilitating riparian habitats is the most efficient way to increase salmonids in the western United States.

We also need to look far into the future. Our streams, especially in the West, were not ready for the major storm events received in 1983 and 1984 (Platts and others 1985). Because many riparian habitats were in poor shape going into this period, the additional degradation could add many years to their recovery. Some of the latest research indicates that even more drastic climatic changes may come in the future. Thus, future large storm events could put our streams under even more stress than they received during the 1983-84 storms. Only healthy, well-managed riparian habitats will be able to withstand these conditions.

Most riparian habitats are extremely resilient (Platts and Nelson 1985b) and offer excellent opportunities for maintenance of good habitats as well as restoration and rehabilitation of degraded habitats. Livestock grazing under well-managed strategies can utilize riparian forage in compatibility with riparian-stream environments. We need to further develop and understand these compatible strategies and move toward their acceptance in rangeland management.

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WYOMING'S APPROACH TO NON-POINT POLLUTION CONTROL

Edward J. Fanning[1]

Abstract

Point source wastewater discharges (i.e., discharges from discrete conveyances such as pipes) have been regulated by the state NPDES (National Pollutant Discharge Elimination System) program since its adoption from EPA in 1975. The program currently administers 900 permits, 50 on which EPA retains some oversight due to facility size. NPDES permits regulate point source discharges by establishing permit specific numerical effluent discharge criteria directed at maintaining long-term instream water quality standards adopted in Chapter I of the Wyoming Water Quality Rules and Regulations, Quality Standards for Wyoming Surface Waters.

Violation of these standards by non-point sources of pollution attributable to the activities of man requires the development of best management practices (BMPs) which is addressed largely through the priorities established in the certified basin and statewide section 208 (Clean Water Act), Water Quality Management Plans, and the CPP (Continuing Planning Process) used to develop BMPs and incorporate them into plan updates.

In the absence of specific information on background erosion rates, and an instream sediment standard, the recommendations of the 208 plans have been to address the abatement of accelerated non-point pollution by the voluntary adoption of site-specific, land use-oriented BMPs on priority drainages that have been shown by monitoring to consistently impair instream water quality standards. The Fifteen Mile Creek and Muddy Creek riparian grazing-water quality studies are a result of this non-regulatory approach towards development and adoption of voluntary best management practices, which appear to be the selected alternative at this time in this state to more comprehensive land use regulation.

Introduction

The intention that water quality management planning should ideally be conducted on a comprehensive basinwide scale was admirably expressed in Section 208 of the 1972 Federal Water Pollution Control Act Amendments (P.L. 92-500), and the 1977 Clean Water Act (P.L. 95-217) including the most recent 1982 update (P.L. 97-117). Section 208 is entitled *Areawide Waste Treatment Management*, a concept which initiated the massive nationwide water quality planning effort of the middle to late 1970's, resulting in the production of basin and statewide "208 plans" which have served as guidance documents to the state Water Quality Division for implementing point and non-point source pollution controls on a priority basis. The unique feature of the 208 planning effort was that the identification of actual and potential water quality problem areas, and a possible abatement alternatives were accomplished at the local level within the context of a designated planning agency, which was responsive to the public at large. This "local level" approach to water quality management planning has provided local governments and constituents the opportunity to retain maximum control over their own affairs, with a minimum of intervention and oversight by state and federal governments. The Wyoming State Land Use Plan (July 1979) discusses the 208 planning process and emphasizes the attachment of Section 201 federal construction grants for publicly-owned wastewater treatment facilities to the development of areawide plans. A number of planning techniques for implementing land use planning are discussed in Section 3.2 and are generally applicable to managing growth within and on the fringes of urban areas. The use of a 20 year urban service area planning concept is a dual concern of both the State Land Use Plan and the Statewide 208 Plan in attempting to assess population growth, subdivision annexation, adequate sizing of new waste treatment plants, and construction of interceptor lines to bring peripheral developments into a central treatment facility. Within the planning area, non-point pollution originating from construction activities must be addressed, and the 1982 amendments make funding available to states which consider stormwater discharges a high water quality priority.

The State Land Use Plan establishes policy towards 208 planning, which is reiterated in the Statewide 208 Plan (1979), in a two-fold statement:

1. "State and federal agencies involved in 208 water quality mangement shall promote and assist local control and management of water quality programs."

2. "Federal requirements for 208 water quality planning shall be managed at the state as well as local level of government, integrating federal assistance as necessary."

In keeping with the policy of local control, section 3.1 of the State Land Use Plan summarizes the goals and policies of each of the 23 county land use plans within 14 areas of concern. Within the context of the current DEQ non-point pollution abatement program on rangelands, county policy has been tabulated for five of the more relevant areas, i.e., environmental

[1]Water Quality Soil Specialist, Wyoming Department of Environmental Quality, Water Quality Division, 125 West 25th Street, 4th Floor West, Cheyenne, WY 82002.

quality, water, agricultural lands, public lands, and natural hazards. In general, all counties favor integrating land use planning with the achievement of environmental goals and standards. Teton County stated a specific environmental quality goal of protection and enhancement of fisheries. Washakie County policy requires that county land use planning incorporate the recommendations of the BHB 208 Plan.

Under the "Water" category, 17 of the 23 counties provided policy responses. Thirteen of the 17 responses stated general goals of relating water use development to desired land use, and maintenance and improvement of water quality. A strong desire for the maintenance of agricultural water rights, as well as expansion of irrigated acreage, is expressed in several counties where irrigated agriculture provides the economic base. Fremont County is the only county in the state that suggested control of stream sedimentation by use of sediment control regulations. Also under the "Water" category, Park County adopted the BHB 208 Plan into its land use guidelines, and Teton County suggested protection of surface water quality from non-point sources originating from intensive agricultural activities, mineral resource extraction, timber cutting and construction. Under the "Agriculture Lands" category the overwhelming policy is to keep agricultural land use restrictions to a minimum. The policy consensus within the "Public Lands" category is to achieve maximum coordination of federal and state planning activities with county land use plans. Johnson County expressed special concern for the protection and/or restoration of alluvial valley floors disrupted by suface mining. Teton County suggested formation of a National Scenic Area Commission composed of all federal, state, and local entities involved in land use decisions.

Finally, in the "Natural Hazards" category, half of the 18 counties listing policy restrict development in the 10-100 year floodplain, on slopes with greater than 30 percent, and in other areas with unstable soils.

The functional local governmental unit for accomplishment of water quality management objectives is realized in the form of designated water quality management agencies as stated in signed Memoranda of Understanding (MOUs) with the State Water Quality Division of the Department of Environmental Quality. The signed MOU indicates acceptance on the part of the designated agency of the responsibility for identification and control of point and non-point sources of pollution originating from lands and activities under its jurisdiction. The designation of a management agency therefore recognizes the authority, willingness, and technical and financial capability of the agency to achieve compliance with state water quality standards within a predetermined time period. When considering control of point source discharges such as municipal wastewater, a municipality is usually the designated management agency. Where the concern is for the abatement of non-point pollution generated by land use, the land management agencies such as the Bureau of Land Management, the Forest Service, or, on private agricultural lands, the Wyoming Conservation Commission and the local conservation districts, are examples of designated management agencies. Ideally, a management agency must address both existing and future potential point and non-point sources of pollution.

Pollution Control Strategy - Water Quality Criteria and Standards

The control of municipal and industrial point sources of wastewater discharge has been the historical focus of water pollution abatement policy both nationwide and in Wyoming. The generalized approach to this control is the development of instream water quality standards, permit-specific waste effluent discharge criteria aimed at maintaining the instream standards, and development of a collection system and in-plant waste treatment process designed to meet the discharge criteria. Therefore, a regulatory program requiring regular monitoring of waste discharges is a logical and effective approach towards the control of point sources of pollution. Since non-point pollution is inextricably related to types and intensities of land uses, the approach towards the abatement of these structures has been the development of "best management practices" (BMPs). A working definition of a BMP is any conservation practice or management technique that is considered technically and economically feasible for realizing water quality goals while allowing a reasonable economic return on investment. BMPs may be applied to urban runoff situations, construction sites, and agricultural and forested lands. Abatement of non-point sources of pollution therefore lends itself to a non-regulatory, voluntary type of program.

Undoubtedly, non-point pollution, largely in the form of sediment and salinity, does violate the state instream turbidity standard and the state line total dissolved solids goal of 723 mg/1 in the Green River Basin at certain times of the year. Although instream monitoring of a given stream segment might establish, for instance, a turbidity violation, the usual regulatory approach would require the issuance of a discharge permit stating specific effluent criteria for a given runoff event. Since the origin of the non-point discharge is usually unknown, and may, in fact, be nothing more than natural erosion and sedimentation processes, a strict enforcement scenario is improbable and unworkable, especially in the absence of land use ordinances and an instream sediment standard. The voluntary approach to non-point pollution abatement therefore requires extended planning periods for problem assessment and prioritization on a stream segment basis, for establishment of proper institutional roles and financial capabilities for addressing problems, as well as the time required for BMP selection, or development by applied research, if necessary.

The 1979 Statewide 208 Water Quality Management Plan (Section 2.12) requires the development and testing of voluntary programs prior to consideration for mandatory compliance programs. Section 6, Standards Enforcement, of Chapter I of the Wyoming Water Quality Rules and Regulations states that "Violation of these standards by non-point sources shall be cause for development of best management practices". BMPs may already be listed in the certified 208 plans; if this is not the case, BMPs may be developed through the state's Continuing Planning Process (CPP).

The Process of Water Quality Standards Development, Water Uses and Surface Water Classifications.

Water quality criteria are technically based numerical values that are accepted in the scientific community as providing the necessary degree of protection for a specific organism, a group of similar organisms, or a specific water use. The data from which these criteria are developed may originate from long-term studies of aquatic communities, but are usually based on a 96-hour LC_{50} (lethal concentration) value derived from static or flow-through bioassays. This value represents the concentration of a given constituent in water which is lethal to 50 percent of the test organisms by the termination of the test period which is 96 hours. An application factor on the order of 10^{-1} to 10^{-2} may be judgmentally used to protect all the life stages of an organism. The numerical criterion is an expression of acute or short-term toxicity which usually results in death, as contrasted with chronic or long-term toxicity which is usually sublethal, although morphologically or physiologically debilitating.

A water quality standard is a legally adopted numerical value or narrative statement of condition, and, unlike exceedances of criteria, is enforceable with appropriate monitoring. Water quality standards are usually based on water quality criteria, but may be modified to reflect local ambient quality considerations and water uses.

Although the State of Wyoming recognizes six types of water uses, i.e., agriculture, fish and wildlife, industrial, public water supply, recreational, and scenic value, its surface water classification is based on the protection and propagation of fish, the use requiring the highest quality of water, and therefore maintaining the other stated uses. This approach is in direct alignment with the 1983 goal of the Federal Clean Water Act which was to achieve, where attainable, surface water quality which provides for the protection and propagation of fish, shellfish, wildlife and recreation in and on the water, and the 1985 goal to eliminate the discharge of pollutants into navigable waters.

Most surface waters of Wyoming have been grouped into four classes. Class I waters have the highest natural water quality and hydrologic potential to support game fish and are protected from further degradation by point source discharges. All Class I waters are specifically named in Chapter I and in so doing, the Environmental Quality Council (EQC) was required to consider all the regional values attendant to such a water in addition to water quality.

It is the goal of the state (Section 3.1.1, Statewide 208 Plan, 1979) to eventually classify surface waters based on all six types of uses and to develop numeric standards for protection of these uses.

The Utility of a Sediment Standard

The current Chapter I quality standards for surface waters include a narrative standard for settleable solids and numerical standards for turbidity. The settleable solids standard (Section 15) requires that "...substances attributable to or influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife, etc."

The turbidity standards (Section 23) require that "in all Class I and II waters, the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 10 NTUs (nephelometric turbidity units), and in Class III waters, in a turbidity increase of more than 15 NTUs". An exception is provided for the Guernsey silt run on the North Platte River.

A standard for total suspended solids concentration in surface water, which is largely a product of on-site erosion and sediment delivery to lakes and streams, has not been adopted in the Chapter I regulations. Nevertheless, it is obvious that land use activities contribute to a significant increment of the total suspended solids in surface water as a function of rainstorm or snowmelt runoff events. A certain fraction of suspended solids become bottom sediments as a result of instream particle flocculation and precipitation at a minimum critical current velocity. Consequently, even the fine clay particles of the total sediment load become settleable solids, as addressed in Section 15, which are deposited at some point downstream either at seasonal low flows or in an impoundment.

Turbidity is defined as the interference of light transmission through the medium by suspended substances causing it to be scattered and absorbed. According to Hammer (1975), an increase in turbidity above five units is noticeable to the average water consumer and represents an unsatisfactory condition for drinking water. Turbidity in "clear" lake water is approximately 25 units, and water is considered to be "muddy" if it exceeds 100 units, and may be perceived as unfit for primary body contact recreation such as swimming or secondary body contact recreation such as fishing. The layman's perception of water quality and useablility is therefore based on perceptions of visual clarity which can be quantitied by turbidity measurements. However, documentation of turbidity violations requires monitoring of background turbidity, since the numerical standards represent increments over background rather than total absolute values. In this context, the value of the turbidity standard is readily apparent. Contrasted with downstream sedimentation (the settleable solids standard), turbidity increases are immediate, although additive in the stream system, and closer to their source, whether point or non-point. If the increase is non-point in origin, it may then be defined on a stream segment basis, by turbidity unit increases per unit reach of stream.

From the standpoint of the scientist, whether he or she be a water quality specialist or a land manager attempting to determine the sources of the sediment, the value of the turbidity standard quickly wanes. Since the task of non-point pollution abatement ultimately involves not only the identification of sediment sources, but also the determination of the percentage of gross on-site erosion attributable to the involved land use, and the sediment delivery ratio to the subbasin confluence, quantification of the change in suspended sediment load carried by a stream segment throughout a storm event is desirable. By use of continuous pumping sediment samplers and stream flow recorders coupled with event-related monitoring of overland flow from selected small watersheds, the percentage of time that an instream sediment standard is violated is a determinable quantity. Although Hammer (1975) equates one turbidity unit to 1 mg/l of silica in water suspension, Standard Methods (1985) does not suggest an easy correlation of turbidity with the weight concentration of the suspended solids comprising turbidity due to the variable effects of particulate size, shape and refractive indices on the light-scattering properties of the medium. The acceptance of the instream use-based standard for total suspended solids is therefore useful, even for the current non-regulatory approach to non-point pollution.

The Southwestern Wyoming 208 Plan (CH2M Hill, 1978), utilized a fisheries use impairment criterion of 80 mg/l of total suspended solids as a sediment criterion in the absence of a Wyoming state standard. Its use in this plan was based on a review of four literature sources (page 2-22, SWW 208 Plan). The National Academy of Science listed three numerical criteria - 25, 80, and 400 mg/l of total suspended solids in its 1972 *Water Quality Criteria* as providing "ultimate, good and fair" levels of protection respectively for fisheries. EPA listed these same criteria in its 1975 draft of *Quality Criteria for Water*, but omitted them from its final 1976 "Red Book" publication. Instead, it combines turbidity with suspended and settleable solids into a single standard for protection of freshwater fish and other aquatic life. The standard states, "Settleable and suspended solids should not reduce the depth of the (light) compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life."

Non-Point Pollution Abatement Implementation Efforts, 1979 to Present.

Four local and one statewide 208 water quality management plans are certified within the state of Wyoming. In addition, an assessment of *Non-Point Pollution Sources in twelve Wyoming Counties* that were not part of designated planning areas was prepared in 1978 for the Wyoming Conservation Commission. The Statewide 208 Plan (1979) presented non-point pollution abatement implementation plans for various land use activities including road and bridge construction, recreation, silviculture, agriculture, urban runoff and mineral exploration and extraction, including oil and gas development. Since livestock grazing on rangelands is the predominant land use in the State of Wyoming, and sediment, nutrients and salinity from rangelands were identified as major water quality problems in the Green River and Big Horn basins, much of the implementation effort in the Department of Environmental Quality has been concentrated on this land use. Concurrent with the designation of the Wyoming Highway Department, the Wyoming Conservation Commission, The Wyoming Forestry Division of the State Land Office, the U.S. Forest Service and the Bureau of Land Management as water quality management agencies in signed Memoranda of Understanding (MOUs) in 1981, the first implementation efforts became apparent.

The Rural Clean Water Program

The development of the Rural Clean Water Program (RCWP) in Wyoming was listed as a first priority in the Statewide 208 Implementation Plan for agriculture. The Rural Clean Water Program, otherwise known as the Culver Amendament to Section 208 of the Clean Water Act, was enacted by Congress in 1979, with a $50 million appropriation for FY 1980. The intent of the program was to fund best management practices directed at water quality improvement on privately-owned agricultural lands. The program was administered by the U.S. Department of Agriculture through the Agricultural Stabilization and Conservation Service (ASCS), and was based on the ACP (Agricultural Conservation Practice) program. Funding of BMPs was made available to farm units or groups of units in a contract area identified as having significant non-point pollution problems originating from agricultural lands, in an areawide plan. A minimum of 75 percent of the farms or ranches in a contract area were required to participate, and funding of practices was available on a 50-50 cost share basis. The Soil Conservation Service was to provide technical assistance to the farmers, and the state water quality agency was to serve as a member of the Rural Clean Water Coordinating Committee (RCWCC). Although RCWP was available in Wyoming for several years, no noteworthy RCWP projects emerged. This may have been due to a combination of the inability of the ASCS to stimulate the necessary interest in a given project area, and the unwillingness of farmers to match federal monies for water quality improvement practices. Nevertheless, the SCS has achieved notable success in areas such as the Star Valley where it designed and installed dairy feedlot manure storage bunkers on 14 farms where runoff was affecting water quality in the Salt River. SCS also conducted the necessary water quality monitoring to demonstrate the associated reductions in nutrients to the stream system and ultimately Palisades Reservoir. Undoubtedly, numerous other on-farm practices and structures installed as a result of the Great Plains Conservation Program have produced measurable water quality improvement.

Meetings were held at the Wyoming Department of Agriculture in 1980 to consider development of a rangeland livestock grazing demonstration project aimed at reducing the salinity loading to the Green River from non-point sources. General disagreement with the technical adequacy of the study plan presented by a prospective contractor to meet the goals of the project by DEQ and the UW Range Management Division tabled the implementation of this effort.

Evolution of Improved Stream System Management Investigations

Several developments in the BLM, DEQ, and UW Range Management Division occurred independently, but almost simultaneously from 1979 to 1981 which would align water quality and land management efforts. Bruce Smith, a fisheries biologist in the Rock Springs district office of the BLM, had managed to construct a number of livestock grazing exclosures at various altitudes on stream systems that he felt were severely degraded by livestock grazing. Although data were not collected on changes in channel morphology, water quality and vegetation, total exclusion of a stream segment from grazing dramatically increased vegetation production within the following growing season, reversed channel downcutting, improved water quality, and in some cases, re-established trout spawning areas. Much of the improved trend was due to a combination of utilizing beaver dams to trap sediment, promote bank storage of water and improve bank stabilization by increasing willow and other riparian vegetative species. Dr. Quentin Skinner and E.J. Fanning, a soil specialist with the Water Quality Division of DEQ charged with the development of non-point pollution abatement implementation projects, toured the exclosures with Bruce Smith in August, 1981 and formed some basic study approaches towards stream stabilization from Mr. Smith's work.

Earlier in 1981, after failing to fabricate any substantial demonstration projects with the RCWP program or in the Green River area, the fourth priority in the Statewide 208 agricultural implementation plan was pursued. This priority was listed as the "Big Horn Basin Sediment Control Program" which was to address the significant rates of sedimentation in the basin from rangelands, a portion of which has been attributed to livestock grazing management practices.

Since the State Office of the BLM had accepted designation as the management agency for non-point pollution originating from lands under its control, a paper entitled "Evaluation of the Discharge and Suspended Sediment Load of Fifteen Mile Creek for the Period 1952-1972" was submitted for review to the Water Quality Division by Gary Rosenlieb, a hydrologist in the Worland District Office of the BLM. Since Fifteen Mile Creek was one of the three priority subbasins within the Big Horn Basin that were identified as having severe erosional problems, the others being No Water Creek and the Nowood River, a meeting was held with the District and State Offices to determine if Fifteen Mile Creek would be a feasible location for a non-point pollution abatement project addressing livestock grazing. Because of the substantial history of BLM efforts to control sediment on the drainage as documented in Mr. Rosenlieb's report, and due to the unique fine clay sediments delivered to the Big Horn River by Fifteen Mile Creek, this subbasin was selected as a project area.

By September 1981, a final cooperative watershed plan for management of the Fifteen Mile Creek drainage emerge. The plan consisted of five elements which included structural repair and improved maintenance techniques, continued water quality monitoring at selected points on the drainage, initiation of further hydrologic and riparian grazing management studies, performance of economic analyses of the costs and benefits associated with structural works versus improved grazing management and land treatment techniques, and finally, provision for a continuing extension and public information effort.

The BLM proceeded immediately to implement its structural repair and maintenance program on degraded detention dams and waterspreading systems on the North Fork. DEQ arranged a meeting in March 1982 with the University of Wyoming Range Management Division to explain the watershed plan and solicit a study proposal to satisfy the riparian grazing portion of the third element. The general intent of the first and third elements was to compare the use and cost-effectiveness of traditional engineering structures versus grazing management and land treatment techniques for controlling sediment yield to the Big Horn River.

By this time, Range Management had become a division of the College of Agriculture at the University of Wyoming, administratively separate and distinct from the Plant Science Division, which formerly administered it as a section. Dr. Quentin Skinner, a new faculty member, was charged with watershed teaching and research duties, since he had a substantial background at the University's Water Resources Research Institute in this area.

The University study proposal entitled "The Effects of Selected Grazing Treatments on Channel Morphology and Sediment Within the Riparian Zone of the Fifteen Mile Creek" was reviewed and accepted in June, 1982. Work was initiated in August of 1982 with 75 percent federal funding from the balance of DEQ's 208 grant. A study exclosure consisting of five cells including a control, three season of use grazing treatments, and a bank manipulation cell, was constructed on the Middle Fork of Fifteen Mile Creek in 1983 by the BLM. This site was chosen since it represented a structurally unmodified segment of the system as contrasted with the North Fork.

The major areas of effort in data collection within the University study have consisted of annual channel morphology measurements above, below and within the exclosure, vegetative baseline and trend data, documentation of livestock spatial and temporal grazing behavior within spring, summer and fall grazing trials, potential stocking rates, soil moisture and groundwater monitoring, and precipitation monitoring. Three entire field seasons of data have been collected at this time, and the annual report for 1985 activities is now under review, with the hope that certain trends in channel morphology as related to the grazing treatments may be emerging. The Federal 208 grant was totally expended by September 30, 1983 and the project has been funded by state appropriations in the amount of $190,807 since that time, with approximately 100 percent match by the BLM in the form of materials and in-kind services. The Water Quality Division has maintained a monitoring role in the project, and has suggested some modifications such as the initiation of paired small watershed studies to assess the effects of upland hydrology on channel flows, with and without land treatments.

A similar study has been developed by the UW Range Management Division and the Rawlins District office of the BLM on the Muddy Creek drainage which is tributary to the Little Snake River above Baggs, Wyoming. Muddy creek is a perennial stream system with certain sections that have been degraded by a combination of factors including livestock grazing and road crossings. It is an ideal complement to the Fifteen Mile Creek Study, and funds from that project have been utilized for the work on Muddy Creek. DEQ maintains a monitoring role in this project also.

Future Scope of the Non-Point Pollution Abatement Effort in DEQ

The Water Quality Division has originally perceived the development of riparian demonstration projects in each of the four BLM divisions. Indeed, initial efforts were made in February 1985 by Dr. Skinner and E.J. Fanning to identify potential study sites on Bates Creek in the Casper district. However, assessment of financial and staff capabilities probably will limit the future effort to the two existing projects.

The Section 401 (Clean Water Act) State Certification of Army Corps of Engineer Section 404 Dredge and Fill Permits remains a very important program for non-point pollution abatement in that the process requires recommendation of best management practices for instream modifications involving the discharge or deposition of dredged or fill material into stream channels having a flow of 5 CFS or greater. In a very real sense, this program provides the more immediate, day-to-day, site-specific mitigation needed to maintain the integrity of the state's stream systems while longer term watershed studies continue. Michael Carnevale provides a complete review of this program in an accompanying paper.

EIS and scoping statement review and comment on Forest Service and BLM projects remain as an ongoing staff function. More significant involvement in silvicultural activities may occur in FY 87 as time allows.

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THE ROLE OF THE 404 PROGRAM IN RIPARIAN WETLAND PROTECTION

Michael A. Carnevale[1]

Historical Perspective

The 404 permit program is the most expansive attempt by the U.S. Congress to regulate dredging and filling activities in the nation's waters. The first program of this type was authorized in 1899 when Congress passed the River and Harbor Act. This act protects interstate navigation and the navigable capacity of American rivers and harbors for commercial activities. The waters regulated by this statute are those subject to the ebb and flow of the tide shoreward to their mean high water mark and/or waters that are, ever have been, or ever could be used for interstate or foreign commerce. Among the activities regulated by the act are the construction of dams, dikes, piers, breakwaters, bulkheads, revetments, navigational aides, and on-shore facilities which could impact navigable capacity. The United States Army Corps of Engineers (COE) was given the responsibility of administering the permit program established pursuant to Sections 9, 10 and 13 of the River and Harbor Act.

It was not until the explosion of environmental consciousness in the late 1960s that environmental factors were considered in this Corps of Engineers permit process. In 1968, the Corps of Engineers revised its policy with respect to the review of permit applications. The new policy allowed other factors, in addition to navigation, to be included in the permit process. These additional factors included fish and wildlife, soil and water conservation, pollution, aesthetics, ecology, and general public interest concerns. The National Environmental Policy Act of 1969 also required that all federal agencies give full consideration to environmental concerns.

In 1970, the Corps of Engineers expanded its operating regulations to require a public interest review on all activities landward of the established harbor lines. The harbor line was usually construed to be the seaward edge of the piers and bulkheads that make up navigational and commercial facilities.

Congress, recognizing that adverse water quality impacts were resulting from uncontrolled dredging and filling in all the nation's waters, strengthened the role of the federal government in regulating these activities on October 18, 1972 with the passage of the Water Pollution Control Act (P.L. 92-500). A significant cause of concern was the loss of wetlands in the United States, which has been estimated to be as much as 50% of the total which existed prior to the colonization of North America by European peoples (Council on Environmental Quality, 1978). Swift and Barclay (1980) concur with this appraisal and further state that most remaining riparian habitats in the contiguous 48 states have been seriously affected by man's activities. P.L. 92-500 was enacted with the announced purpose of restoring and maintaining the chemical, physical and biological integrity of the nation's waters. Section 301 of the Water Pollution Control Act prohibits the discharge, from any discernable conveyances (i.e. point sources), of pollutants into the navigable waters of the United States unless the discharge is in compliance with 402 or 404 of this Act. According to Section 502(6) of the Act, dredged spoils or fill material are considered to be pollutants capable of causing pollution of the waters of the United States. In 1977 Congress amended the Water Pollution Control Act and strengthened the provisions of Section 404. The amended Act (P.L. 95-217) is commonly referred to as the Clean Water Act (CWA).

The provisions of the Clean Water Act requiring the U.S. Army Corps of Engineers to issue permits for discharges of dredged or fill materials into waters of the United States are commonly referred to as the 404 Permit Program. Section 404 establishes a permit system to regulate these discharges and authorizes the Secretary of the Army to issue permits for the disposal of dredged or fill materials into the navigable waters of the United States. According to Thompson (1977), the intent of Congress was to define navigable waters to mean any waters of the United States (i.e. any place where water normally flows). This permit system is currently administered by the U.S. Army Corps of Engineers with environmental guidelines developed by the U.S. Environmental Protection Agency (EPA).

The regulatory program authorized by Section 404 has been extensively litigated in the courts (Want, 1984). The statutory protection afforded wetlands, stream channels and shorelines has generated considerable passion within the regulated community which has generally been opposed to the program. Objections raised by dissatisfied permit applicants have focused on perceived government interference with the rights of private property owners, the jurisdictional limits of the Corps to regulate dredging and filling activities in all waters of the United States and costs suffered as a result of program processing, delays, modifications and lost opportunities (Congress of the United States, Office of Technology Assessment 1984).

Lawsuits brought by environmental groups have generally questioned the amount of environmental protection given waters of the United States by the Corps. The adequacy of regulations promulgated by the Corps to enforce the provisions of the Clean Water Act have been frequently challenged in the courts. The court battles have, nearly unanimously, strengthened the role of the federal government in protecting stream channels, shorelines and wetlands. There has been much controversy regarding the limits

[1]Planning Supervisor, Wyoming Department of Environmental Quality, Water Quality Division, Herschler Building, 4 West, Cheyenne, Wyoming 82002.

of Corps jurisdiction over waters in the United States, and the issue is still being argued. Virtually all waters, including wetlands, are potentially regulated by the Section 404 Program. The Corps also has jurisdiction over man-made wetlands provided they were not created by the Corps *(Track 12, Inc. vs. District Engineer, U.S. Army Corps of Engineers).* The level of protection afforded isolated wetlands and streams above the headwaters is less than that given to other waters of the United States and wetlands contiguous or adjacent to them. The headwaters are defined as "the point on a nontidal stream above which the average annual flow is less than five cubic feet per second." The definition of wetlands which is used by the Corps, and was recently upheld by the U.S. Supreme Court in a historic 9-0 decision *(United States vs. Riverside Bayview Homes),* is "Those lands that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted to life in saturated soil conditions." This definition of wetlands is broad enough to include most riparian zones in Wyoming. Some riparian habitats, especially those on ephemeral drainages, would not be classified as wetlands using either the definition of the Corps of Engineers or the U.S. Fish and Wildlife Service's system (Cowardin 1979). Riparian wetlands are classified as either riverine (emergent non-persistent wetland) or palustrine (emergent persistent or scrub-shrub wetlands) (Cowardin 1979).

In 1974, following the enactment of the Water Pollution Control Act, the Corps of Engineers promulgated regulations pursuant to Section 404 that limited the 404 permit program to the same waters regulated under the River and Harbor Act of 1899. The Natural Resources Defense Council and the National Wildlife Federation went to court challenging this limitation as being inconsistent with the intent of Congress *(NRDC, et al. vs. Callaway).* On March 27, 1975, the United States District Court for the District of Columbia ordered the Corps of Engineers to rescind that part of the 404 regulations "which limits the jurisdiction of the Corps...to other than (all) the waters of the United States." Numerous subsequent legal decisions have since upheld this challenge by finding that it was not the intent of Congress to restrict the definition of navigable waters to the definition established in the River and Harbor Act of 1899 (Rosenbaum 1979).

The United States District Court (Western District of Louisiana, Alexandria Division) in the case of *"the Avoyelles Sportsman's League, Inc. et al. vs. Clifford L. Alexander, et al."* on March 12, 1981 found, in regard to the intended scope and coverage of the 404 program, that the:

> "Congress was acutely aware...in drafting Section 502(7) of the Federal Water Pollution Control Act (now CWA), (and) deliberately moved away from the earlier restrictive definitions of navigable waters. The conferees fully intended that the term 'navigable waters' be given the broadest possible constitutional interpretation unencumbered by agency determinations which have been made or may be made for administrative purposes."

Although section 101(a)(1) of the Clean Water Act refers to the discharge of pollutants in the navigable waters, it is clear that Congress was not referring to navigable waters in the usual physical sense. In fact, the statutory definition mentions no physical characteristics such as width, depth, volume or flow. It mentions none of the characteristics normally associated with navigability such as ebb and flow of tide or highwater mark or low water mark. The CWA defines navigable waters in terms consistent with Congress' stated objective to restore and maintain the chemical, physical and biological integrity of the nation's waters. The report of the House Committee on Public Works which accompanied the House bill defined integrity to mean a condition in which the natural structure and function of ecosystems is maintained... In enacting the 1972 Amendments to the Federal Water Pollution Control Act (now CWA), Congress intended to extend the Act's jurisdiction to the Constitutional limit.

Section 404 offers the most comprehensive statutory protection to the nation's waters from dredging and filling activities, however, some activities are not specifically regulated. Dredging is only questionably covered by the provisions of the Clean Water Act (Want, 1984). The Corps program exempts dredging if the dredged materials are removed by equipment that does not enter the water body (i.e. draglines, backhoes, etc.) and the dredged spoils are deposited above the ordinary high water mark. A regulatory guidance letter of the U.S. Army Corps of Engineers (1981) states that the Corps is not authorized by the Clean Water Act to regulate "De minimis discharge occurring during normal dredging operations, such as drippings from a dragline bucket." However, dredging may result in water quality standards violations which are regulated by the Wyoming Department of Environmental Quality.

The regulatory program authorized by section 404 will, undoubtedly, continue to be refined in the courts and the federal agencies charged with program administration will be forced to revise their regulations to reflect court rulings. Congress may, in the future, choose to clarify the enabling legislation. Reauthorization of the Clean Water Act is presently being debated by Congress and bills have been passed in the House and Senate. The two bills contain no significant changes to section 404. It is the opinion of this author that significant weakening of the dredge and fill permit program is unlikely. Environmental advocacy groups have clearly made a strong 404 program a priority issue and will continually monitor and challenge any perceived relaxation of program requirements. Want (1984) and Nagle (1985) present excellent papers addressing the legal impacts of the 404 program and are highly recommended for those desiring additional information.

404 Program Administration and Permit Processing in Wyoming

Presently, the 404 program in Wyoming is administered by the U.S. Army Corps of Engineers. The Corps is responsible for developing regulations, issuing permits and enforcing the provisions of the Clean Water Act. The Omaha, Nebraska District Office has the authority to regulate discharges of dredged or fill materials in Wyoming waters. The Omaha regulatory office operates two field offices in Wyoming. These are located in Cheyenne and Riverton. The field office staff provides assistance to applicants, liaison with state agencies and interest groups, investigates complaints, performs compliance monitoring and issues Nationwide 404 permits. Nationwide permits authorize specific classes of activities which have been determined to have minimal environmental impacts. For example, nationwide permits have been issued for minor stream crossings, minor bank stabilization projects and pipeline crossings. In addition, nationwide permits are authorized for a number of other minor projects. Activities which have the potential to cause significant, adverse environmental impact require individual or general permits which are issued from the Omaha office. PRIOR TO INITIATING ANY WORK IN A STREAM CHANNEL, WETLAND, LAKE OR RESERVOIR, THE CORPS OF ENGINEERS SHOULD BE CONTACTED.

The U.S. Environmental Protection Agency (EPA) oversees and monitors the Corps of Engineers' administration of the 404 permit program. The EPA Region VIII office oversees the program in Wyoming and is located in Denver, Colorado. EPA provides oversight in order to ensure that the physical, chemical and biological environment is protected and proper precautions are taken for all permits issued. Because of limited staff, the normal EPA procedure is to review public notices issued by the Corps and to respond only to those applications for activities which may cause significant degradation of the environment. EPA can initiate the conflict resolution process set down in a memorandum of understanding between the Corps and EPA if major problems or conflicts are present. The EPA prepares environmental guidelines mandated by Section 404.b.1. of the Clean Water Act which the Corps must abide by when issuing 404 permits.

In Wyoming, the agency responsible for implementing the state's water quality management program is the Water Quality Division of the Department of Environmental Quality (DEQ). In the dredge and fill permit process, DEQ provides the applicant with state water quality certification required by Section 401 of the Clean Water Act. Section 401 of the Clean Water Act states that: "Any applicant for a...permit to construct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into the navigable waters, shall provide the licensing or permitting agency a certification from the state...that any such discharge will comply with the applicable (water quality) provisions..." In the event that a state chooses not to provide water quality certification, the EPA regional office will review and certify projects.

The state's 401 certification assures that the proposed activity is in compliance with the established state water quality standards and will not cause a degradation of the water quality. The 401 certification process involves evaluation of the project by several state agencies including the Game and Fish, State Engineer and Highway Department. DEQ has Memoranda of Agreement with the Game and Fish and the Highway Departments to provide comments on 401 certification applications. The DEQ frequently provides liaison between permit applicants and the other state and federal agencies involved in the permit review process.

In order to assure timely issuance of 404 permits and water quality (401) certifications, the applicant should file the necessary forms with the Corps and the Wyoming DEQ concurrently. The most frequent causes of delay in permit issuance or outright denial are incomplete applications, poor project designs or inadequate environmental safeguards.

The U.S. Fish and Wildlife Service (FWS) also plays a significant role in the review of proposed 404 permits and enforcement notices. The Corps has entered into a Memorandum of Agreement with the FWS to ensure that wildlife concerns are given full consideration whenever 404 permits are issued. The FWS is responsible for coordination of comments from all the agencies within the Department of Interior. Recommendations made by the FWS to mitigate expected fish and wildlife losses must be incorporated in the 404 permit when issued by the Corps. In the event the Corps does not choose to abide by comments provided by the FWS, a conflict resolution process is initiated.

Comments provided by the Wyoming Game and Fish Department also receive special consideration pursuant to the Fish and Wildlife Coordination Act of 1965. Concerned citizens or interest groups may comment to the Corps during the public interest review period.

When issuing 404 permits in Wyoming, the Corps of Engineers is required to consider the impact of the proposed activity relative to several other federal statutes. Proposed projects must comply with the provisions of these acts which include:

1. Endanger Species Act (P.L. 96-159). this statute protects endangered and threatened species.

2. Federal Land Policy and Management Act (P.L. 94-579). This act applies to lands owned by the Federal Government and promotes the protection of lands, fish and wildlife conservation and recreation.

3. Fish and Wildlife Conservation Act (P.L. 96-366). The act extends protection of fish and wildlife to nongame and nonthreatened species including their habitat

4. Fish and Wildlife Coordination Act (P.L. 89-727). This legislation mandates that federal agencies consult with the U.S. Fish and Wildlife Service prior to initiating an action that may have adverse impacts

on fish and wildlife resources. The act requires that recommendations for conserving fish and wildlife resources be given full consideration in the decision making process.

5. National Environmental Policy Act (P.L. 94-83). This law established a systematic, multi-disciplinary approach to minimize damage to the environment and applies to all federally permitted, funded, or sponsored projects.

6. National Forest Management Act (P.L. 94-588). This statute protects stream banks, streams, shore-lines, lakes, wetlands and other natural bodies of water from degradation resulting from activities occurring in national forests.

7. National Resources Planning Act (P.L. 93-378). This act provides direction to the U.S. Forest Service for enhancement of fish and wildlife resources.

8. Wild and Scenic Rivers Act (P.L. 95-625). This law provides protection to designated river reaches and their surrounding environment (Simpson, et. al., 1982).

Dredge and fill projects must also comply with executive orders 11988 (Flood Plain Management) and 11990 (Wetland Protection). The purpose of these executive orders are to minimize flood damage and wetland destruction.

Strine (1981), describes the process that the Corps staff follow to issue a permit as consisting of six basic steps which occur after an applicant submits an application. The steps are:

1. initial review of the application;
2. preparation and issuance of a public notice;
3. screen and forward to the applicant comments submitted by reviewers in response to the public notice;
4. review applicant response to any comments or issues;
5. preparation of a draft permit and environmental assessment;
6. issue permit.

After receiving an application, the Corps staff reviews the application for completeness according to 33 CFR Part 325 (Processing of Department of the Army Permits). An application is considered complete when all necessary drawings, sketches or plans; the location, purpose and intended use of the proposed activity; the names and addresses of adjacent property owners; the location and dimensions of adjacent structures, and the approvals required by other federal, state or local agencies for the work are submitted with a signed application. The requirement for a completed

In the Omaha district, the 401 certification is not considered part of a completed application and is applied for concurrently with the 404 permit. The state also prefers this procedure in order to minimize delays in permit issuance. According to the Omaha office, the common standard used to determine the completeness of the application is whether they can complete the public notice. When the application is completed, a number is assigned. If there is not enough information, the Corps will contact the applicant and advise them of the deficiency. The public notice is not prepared until all required information is available.

Once all the necessary information is available and a number assigned, the Corps prepares a public notice to inform any interested agencies or parties of their intent to issue a permit and requests comments. Corps personnel review comments (including 401 certification letters) submitted in response to the public notice for objections or any mitigation measures that should be incorporated into the permit. If determined to be appropriate, mitigation measures are included in the permit. If no significant comments are received, a draft permit is prepared.

The applicant is given an opportunity to respond to the issues raised during the comment period. The original commentors may review the applicant's response to the issues that were raised during the comment period. The issue is usually resolved by amending the application, mitigating the project, conditioning permit, dropping the issue, or denying the permit. According to Corps guidelines on increasing efficiency, all permits must be issued or denied within an average processing time of 60 days. This potentially results in more permit denials since no time is available for conflict resolution or extended discussion.

The last step is a consolidation of the information provided by the applicant, with comments and conditions provided by reviewers into a 404 permit. An environmental assessment is prepared stating that the project will not have a significant adverse impact on the environment. Is is assumed (by the Corps, DEQ and EPA) that if a project is permitted, it will not have a significant impact upon the environment. The environmental assessment of a project for which an Environmental Impact Statement (EIS) has been prepared usually references data presented in the EIS if the Corps of Engineers agrees with the statements.

The proposed permit is sent to the applicant for his concurrence and signature. The signed permit and fee payment is then returned to the Corps office. After the permit is returned to the Corps district office, it is signed by the district engineer and issued. The applicant can now proceed with the activities stated in the permit.

The Corps of Engineers has received a considerable amount of criticism from environmental groups and permit applicants relative to the 404 permit program. A disappointing track record including promulgation of inadequate regulations, a minimal public information and assistance program, the lack of a coherent enforcement policy, delays in permit issuance and numerous unauthorized activities which remainnresolved has led to widespread skepticism of the Corps' ability to effectively operate the program.

Nagle (1985) states:

"Another barrier to effective wetland protection under section 404 is the Corps' inability or unwillingness to adequately monitor for violations and to bring enforcement actions. The Corps field-checks, on the average, only about half of all authorized projects for compliance with permit conditions. Some Corps districts field-check only if they receive reports of violations from citizens or other agencies. In a 1982 survey of section 404 compliance in the Corps' Charleston District, the NMFS found violations of permit conditions in thirty-three percent of completed projects.

Even when the Corps detects illegal fills or violations of permit conditions, it rarely prosecutes violators. After discovering illegal fills, the Corps commonly grants "after-the-fact" permits to violators. In other cases, the Corps may order restoration of damaged wetlands, but violators often fail to comply with such orders. Compounding the problem is the reluctance of local U.S. Attorney's offices to prosecute violators, particularly in cases involving only a few acres.

Central to all the problems of the section 404 program is the Corps' unenthusiastic attitude toward wetlands protection. The Corps does not accept the view that section 404 is a wetlands protection law and has consistently sought to reduce its own responsibilities in that area. This is evident in the Corps' recent regulatory changes, particularly the attempted expansion of the nationwide permits, and in legislative lobbying efforts by Corps officials to reduce the scope of section 404 jurisdiction to waters meeting the traditional definition of navigability. Ultimately, the fate of any regulatory program depends on whether those who administer it are committed to its success. Thus far, the Corps has failed to show such a commitment."

Recently, the Corps has taken steps to improve the administrative and regulatory aspects of the 404 program in Wyoming. In 1984, field offices were opened in Riverton and Cheyenne which have improved the ability of the Corps to provide asistance to applicants and information to the public. The field office personnel issue nationwide permits, inspect project sites, investigate unauthorized activities, answer questions and provide information and application forms. They also provide liaison between reviewing agencies, the applicant and the Omaha Corps office. Prior to 1984, all inquiries, permit issuance, and enforcement investigations were processed through the Omaha office.

Recently, the Omaha Corps of Engineers regulatory office has demonstrated a greater resolve n pursuing unauthorized activites and protecting wetland resources. The increased regulatory activity has, in part, resulted from the court decisions supporting the jurisdiction of the Corps relative to the 404 program and wetland protection.

These efforts by the Corps to improve the permit system have resulted in an increase in permit processing efficiency. Better communication between the Corps, other state and federal agencies and permit applicants has also been realized. Investigations of unauthorized activites are now completed in a more timely manner. Enforcement actions have also been more effective. Although the U.S. Justice Department has never pursued any legal actions in Wyoming involving 404 violations, the Corps has denied several permits to applicants who requested after-the-fact authorization of dredge and fill projects. Where after-the-fact authorizations were denied, the Corps issued restoration orders, and for the most part, restoration and/or mitigation is being, or has been, completed. A few are still being negotiated.

Unauthorized activities usually generate a great deal of paperwork and cost the state and federal agencies investigating the activity a considerable amount of time and money. A more streamlined enforcement system is needed to circumvent much of the present public interest and environmental review of after-the-fact requests. The Corps should be able to deal with unauthorized fills quickly and effectively without requesting comments from interested agencies or individuals.

Confusion related to permitting procedures and activities requiring permits is still abundant. Some propsective applicants are unsure which agency issues 404 permits. The Water Quality Division receives numerous requests for information pertaining to Section 404. These requests are usually referred to the appropriate Corps office for response.

The Clean Water Act contains provisions for state administration of the 404 program and EPA has written regulations stipulating requirements for transfer to the states. However, because no federal funds have been specifically allocated for states to operate the program, only Michigan has assumed primacy at this time. Inflexible EPA requirements have also deterred state assumption.

The Rationale for Adequate Riparian Zone Conservation

Stream channel alterations and wetland destruction are activities which have the potential to significantly degrade water quality and riparian zones. Section 404 is a powerful tool for protecting Wyoming's stream channels and riparian lands. The Corps' definition of wetlands is broad enough to regulate mechanical alterations of most riparian zones. There are a number of benefits to maintaining stream channels and riparian lands in optimum condition and rehabilitating degraded channels and riparian zones. Included are social benefits that are only now being recognized and quantified. We are becoming more cognizant of the water quality, water storage, wildlife, forage production, and groundwater benefits provided by riparian lands in Wyoming. The narrow ribbons of lush vegetation adjacent to Wyoming streams serve as oases in the state's dry environment and despite occupying a small percentage of land area, provide disproportionate benefits to citizens of the Cowboy State. Brown et al. (1978) and Kusler (1983) present excellent overviews of riparian wetland values.

The beneficial effects of wetlands on water quality have been expansively addressed by Lee et al. (1975), Boto et al. (1979) and Council on Environmental Quality (1978). Healthy riparian wetlands serve as natural water purification systems. Sediments are trapped in the abundant vegetation and stabilized by plant growth. Nutrients deposited with the sediments are used by plants. In this way, riparian zones are capable of continually building and enriching soils. Preventing or slowing the downstream transport of sediments and nutrients improves water quality by reducing turbidity and minimizing the potential for growth of aquatic weeds (Kadlec and Kadlec, 1979). Wetland vegetation adjacent to streams may reduce the rate of eutrophication in downstream lakes or reservoirs (James and Lee, 1980). The abundant plant growth and extensive biomass of roots in well managed streamside areas holds the soil in place and reduces water velocities during floods, significantly reducing the potential for soil erosion and sediment transport. Recently, researchers have investigated the potential for using wetlands to treat domestic wastewater (Boyt et al., 1977) and the U.S. EPA considers wetland treatment a viable alternative for nutrient removal from wastewaters. Several municipalities are using wetlands to remove nutrients and further reduce suspended sediments and biochemical oxygen demand.

Researchers from the University of Wyoming have been investigating the water storage capacity of riparian zones (Brosz, 1986). Water stored in the soil and alluvium adjacent to streams subirrigates riparian vegetation enhancing plant growth. Riparian areas serve valuable functions as buffers for flood waters and act almost like a sponge with the capacity to absorb large quantities of water. Additionally, during periods of flooding, water velocities are slowed by frictional forces as the water encounters vegetation. Because water is stored in the soil or slowed by contact with vegetation, downstream flood peaks are reduced and the potential for economic loss is minimized. Water stored in the soil and shallow aquifers during periods of high stream flow is often available for slow release back to the stream during dry periods. Water returned to the stream from groundwater storage is important for maintaining aquatic life. Healthy riparian zones reduce the amplitude of stream discharge volumes, providing more even distribution of stream flow throughout the year (Carter et al., 1979). Notitzki (1979) documents the value of Wisconsin wetlands in flood control, sediment removal and streamflow regulation.

The above ground biomass of plants within Wyoming's riparian areas is noticeably greater than the grassland or shrub/grass steppes characteristic of the plains and intermountain basins. Riparian wetlands have the capability to provide from 4 to 700 times more vegetation per acre than upland ranges (Brinson et al., 1981). The extraordinary production of plant biomass provides forage and cover for domestic livestock and wildlife. During the latter part of the growing season, when upland range grasses have withered, forage produced in riparian zones may be critical for livestock and wildlife nutrition. Abundant riparian vegetation provides escape, nesting and rearing cover for wildlife and supplies shade to domestic stock. Wildlife, including economically important species such as moose, whitetail deer, waterfowl and many furbearers are highly dependent upon the habitat provided by riparian zones (Schamberger et al., 1979, Schitosky and Linder 1979).

Fisheries benefit from the overhead cover provided by riparian plant growth and reap a windfall of additional food as hapless terrestrial insects inadvertently fall from overhanging grasses and branches into the water. Shade provided by the vegetation and inflow from groundwater storage keep water temperatures cooler in the summer. Groundwater stored in the adjacent alluvium during spring snowmelt and summer storms flows back into the stream during fall and winter and contributes significantly to maintenance of stream flows and fish survival. In the winter, riparian vegetation helps provide thermal protection to the stream by trapping drifting snow. If sufficient snow is captured by the vegetation to cover the stream, formation of frazzle and achor ice is prevented. Frazzle ice (suspended ice crystals) and anchor ice, which is formed on the substrate, are extremely damaging to stream dwelling fish and their primary food supply of aquatic invertebrates. Riparian root masses lessen erosion of stream banks and encourage development of overhung banks which further reduce water velocities and provide cover for fish.

Because water stored in healthy riparian zones is in contact with the land for a relatively long period of time, there is increased potential for percolation into aquifers. Although the groundwater tables that are recharged are usually shallow alluvial aquifers, they play an important role by acting as reservoirs for later release to the stream during dry periods. Occasionally, contact is made with outcrops of porous geologic formations and recharge of deeper aquifers occurs.

In most cases, stream channel alterations are now regulated by the provisions of the Clean Water Act and require authorization through the 404 permit process. Bulldozers, dump trucks and draglines have destroyed many miles of Wyoming stream channels and numerous acres of riparian habitat. Mechanical alterations of stream channels not only change the hydraulic characteristics in the immediate vicinity of the affected area but have profound upstream and downstream effects. Until recently, it was thought that the best way to prevent flooding and channel erosion was to improve the hydraulic capacity of the channel. It was reasoned that a channel that presented little resistance to flow and allowed a greater discharge of water was more desirable than that found in nature. Thus, many miles of Wyoming streams were diked, straightened and dredged in an effort to increase the flow volume that the channel could carry. The secondary impacts of these actions on water quality, channel stability, downstream flood peaks and wildlife resources were seldom considered.

Generally, most proposed stream channel alterations are intended to alleviate flooding or reduce bank erosion. Although channel straightening, diking and channel widening may reduce flood hazards in the immediate vicinity of the structure or channel change, increased flooding may result downstream as water from higher reaches is transported more quickly to lower points in the watershed. There are many options available to landowners for rectifying chronic erosion and flooding problems without initiating large scale channel changes. Streambank and flood protection structures should be designed (or the design reviewed) by a hydrologist or civil engineer who specializes in sedimentation and stream mechanics. Poorly designed and/or improperly constructed projects may result in additional, unanticipated flooding and/or bank erosion. The U.S. Army Corps of Engineers (1980) has published *Streambank Erosion Control Methods* (1980) and *Streambank Protection Guidelines for Landowners and Local Governments* (Keown, 1983) to assist applicants with project design. Thronson (1979) describes mitigation and best management practices to minimize water quality standards violations for dredge and fill activities.

Increased water velocities cause most of the problems associated with stream channel alterations. Typically, when channel cleaning, dredging, channelization or bank sloping is undertaken without installing erosion control or energy reducing structures, water velocities are increased as a result of decreased bed roughness. Vegetation is often destroyed increasing the potential for bank erosion. Stream channels are often shortened by these activities resulting in steeper streambed slopes and additional increases in water current speed. Water moving at higher velocity is capable of transporting a greater sediment load. Accelerated bank erosion and substrate scour frequently occur. Sediments scoured from the streambed are eventually deposited downstream in reaches with lower water velocities resulting in aggraded streambeds below the altered reach. Aggradation by sedimentation causes additional reductions in water speed and encourages further disposition of sediments. Eventually, because the channel has filled with sediment, lateral (bank) erosion occurs and the channel widens destroying riparian vegetation. Bank erosion is a result of hydraulic factors working to maintain sufficient channel capacity to discharge water during storms and snowmelt (Leopold et al., 1964).

While aggradation is occurring downstream, down cutting in the altered channel often stimulates head cutting which proceeds upstream from the altered reach. Head cutting results in degradation of the stream bed and may lower the water table leaving riparian vegetation without an adequate water supply (Barclay 1980; Taskey and Hinckley 1977). Without water, the riparian vegetation dies and further erosion takes place. As the bed is being cut and sediments are eroded, additional substrate materials are available for deposit in downstream reaches exacerbating what may already be a serious problem. Once the natural stream channel equilibrium is lost, it may take decades or centuries to reestablish a more stable channel.

The adverse impacts to wildlife associated with stream channel alterations are well documented. The November 1978 issue of Wyoming Wildlife magazine presents a good overview of the effects of stream channelization on fish populations. Wiley and Dufek (1978) and Simpson et al. (1982) report severe reductions in the numbers and biomass of game fish in channelized streams. Avian species, mammals and reptiles and amphibians are all adversely impacted by stream channelization (Simpson et al., 1982).

Summary

The Federal Clean Water Act of 1977 (P.L. 95-217), which revises the Water Pollution Control Act of 1972 (P.L. 92-500), authorizes the Secretary of the Army to issue permits for the disposal of dredged or fill materials into the nations waters. Commonly referred to as the 404 Permit Program, this section of the Clean Water Act has been extensively litigated in the courts by interest groups intent on strengthening or weakening the regulations that have been developed pursuant to the enabling legislation. The court battles have, nearly unanimously, reinforced the federal government's role in stream channel, wetland and shoreline protection.

Presently, in Wyoming, the Dredge and Fill (404) Program is administered by the U.S. Army Corps of Engineers with U.S. Environmental Protection Agency oversight. The Wyoming Department of Environmental Quality issues water quality certification of 404 projects pursuant to Section 401 of the Federal Clean Water Act. Certification by the State is required to ensure water quality standards will not be violated by proposed activities. The Corps gives special consideration to comments received from the U.S. Fish and Wildlife Service and State Wildlife agencies.

Section 404 can be a powerful tool for protecting our stream channels and riparian lands. The current definition of wetlands used by the Corps of Engineers is broad enough to regulate mechanical alterations of most riparian zones in Wyoming. The definition of wetlands which was recently upheld by the U.S. Supreme Court in a 9-0 decision is "those lands that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted to life in saturated soil conditions." Riparian zones are classified as palustrine or riverine wetlands.

Riparian zones serve valuable functions in Wyoming where they serve as natural water treatment systems, valuable flood buffer zones, critical wildlife habitats, water storage areas, and forage production areas. Riparian zones support lush vegetation when compared to the dry uplands characteristic of much of Wyoming. Riparian zones have the capability to produce between 4 and 700 times more vegetation than upland ranges.

Stream channel alterations, now regulated by the 404 Program, have the potential to destroy riparian zones. Unregulated channel changes undertaken in the past have impaired some riparian areas.

The 404 program in Wyoming is hampered by minimal staffing, logistical problems and the absence of a coherent enforcement policy. Greater public awareness and concern for stream channel alterations and riparian land destruction is needed.

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FISHERY HABITAT IMPROVEMENT

Robert Pistono[1]

Since 1973 the Wyoming Game and Fish Department has been involved with an aquatic habitat improvement program. Nine specific projects have been chosen to depict the various types of methods used and to show the various types of funding sources for these projects. This program has been successful in terms of increasing trout populations and benefiting the riparian zone by reducing bank erosion and raising the water table. Low profile, properly installed structures have required little, if any, maintenance on these projects.

Project: Beaver Creek

Location: Black Hills National Forest (S27, R63W, T53N) about 10 miles north of Sundance and three miles upstream from Cook Lake. Good access by graveled road. Beaver Creek is tributary to the Belle Fourche River. Beaver Creek was the pilot project for the Game and Fish Department and the work lasted from 2-4 weeks per year from 1973-1977.

Fisherman Use: Popular in early season when water flows are up. Estimated use near Cook Lake is 109 fisherman days per mile annually, but the stream in the treated area probably receives less than that amount of pressure. Prior to 1975, planted with catchable brook trout to provide a put-and-take fishery. No stocking at present.

Habitat Problems: Severe stream bank erosion, with considerable silt in the stream, riffle-pools ratio very poor with few deep pools. Stream was wide, shallow and lacked shelter for trout. Water flows limited in some years, especially late summer.

Purpose of Project: (1) Stabilize stream banks, (2) provide deep pools to over-winter trout, and (3) increase shelter and holding areas for trout. This stream was also used to test some stream improvement devices developed in Wisconsin to see if they would work under the fluctuating flow conditions found in Wyoming streams. A total of 106 structures were installed and 2152 ft. of eroding bank was stabilized.

Project Benefits: After habitat improvement devices were installed in 1978 at the upper study area, the trout population increased steadily over a seven year period. Standing stock increased from 50 fish/mile of planted trout in 1973 to 1090 fish/mile of wild trout in 1980, a 2,080 percent increase. (Figure 1)

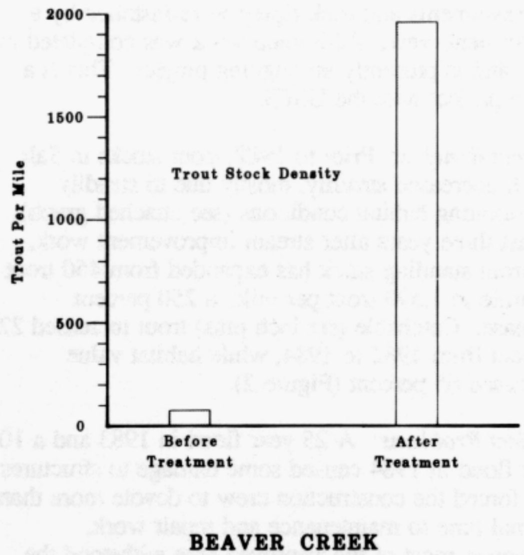


Figure 1. Trout Density - Beaver Creek.

Perhaps more important, the additional shelter and deep pools provided by the devices allowed trout to overwinter and a resident, reproducing population became established. Thus, a self-sustained wild brook trout fisher replaced a put-and-take fishery.

Project: Salt Creek

Location: Bridger-Teton National Forest, about 20 miles south of Afton at Allred Flat, immediately downstream from the U.S. Forest Service campground. Elevation 6,650 feet. Tributary to Thomas Fork Bear River. Good access by walking from Highway 89, which parallels the stream.

Fisherman Use: The stream is well used by fishermen from the campground and nearby towns in Wyoming and Idaho. The fishery is wild, relatively pure strain, Bear River cutthroat trout. No hatchery fish are stocked. The stream supports an estimated 40 fisherman days per mile per year.

Habitat Problems: Severe stream bank erosion with serious down cutting. Poor riffle-pool sequence and deep pools are widely scattered. Trout shelter and holding areas limited.

Purpose of Project: (1) Stabilize eroding stream banks, (2) increase trout carrying capacity of stream by providing more shelter and holding areas and (3) increase resident stocks of the rare Bear River cutthroat trout without using expensive hatchery trout.

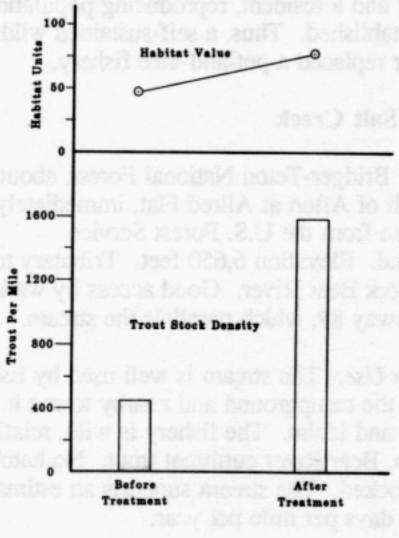
Treatment: In 1981-84, 22 instream structures (check dams, deflectors and cover devices) and 1,540 feet of

[1] Assistant Habitat Biologist Supervisor, Wyoming Game and Fish Department, 260 Buena Vista Drive, Lander, Wyoming 82520.

tree revetments and rock riprap were installed by a Department crew. Additional work was completed in 1985 and is presently an ongoing project. This is a co-op project with the USFS.

Project Benefits: Prior to 1982, trout stocks in Salt Creek decreased steadily, mostly due to steadily deteriorating habitat conditions (see attached graph). In just three years after stream improvement work, the trout standing stock has expanded from 450 trout per mile to 1,590 trout per mile, a 250 percent increase. Catchable (six inch plus) trout increased 22 percent from 1982 to 1984, while habitat value increased 65 percent (Figure 2).

Project Problems: A 25 year flood in 1983 and a 100 year flood in 1984 caused some damage to structures and forced the construction crew to devote more than normal time to maintenance and repair work. However, most of the improved area withstood the flood waters quite well, especially when compared to the flood caused devastation in untreated downstream areas.



SALT CREEK

Figure 2. Trout Density - Salt Creek.

Project: Clarks Fork River

Location: BLM and state land downstream from the Clarks Fork Canyon (S22, R102W, T56N), about 22 miles northwest of Cody. Good access to entire area by dirt roads from State Highway 292. Elevation 4,330 feet.

Fisherman Use: Estimated use prior to treatment was eight fisherman days per mile per year. While no up-to-date creel census data are presently available, fisherman sightings and other evidence suggest that angler use of the area has increased considerably since the structures were installed.

Habitat Problems: Very poor riffle-pool ratio prior to stream improvement work. Deep pools very rare and channel U-shaped with long, shallow riffles. Few boulders, wood debris or other objects to slow fast currents and thus provide shelter for trout. Trout stocked in past years generally vanished from the area.

Purpose of Project: Provide additional shelter and holding water for both wild and stocked trout. Increase stock level of wild trout and increase return to creel of stocked trout by holding them in the area longer.

Treatment: In 1983-85, 16 boulder structures were built in about 1 1/2 miles of river. Each structure generally incorporated about 100 large boulders in a configuration designed to manage river currents to the best advantage of trout. The rocks were obtained from nearby BLM land.

Project Benefits: The standing stock of wild trout increased 1,800 percent (1.1 trout/mile to 21 trout/mile) after the structures were installed (Figure 3). Usage of the structures by stocked trout is excellent and most planted trout appear to be staying within the treated area instead of drifting out as in previous years. Angler reports indicate satisfaction with the improvement work. Fishing was good in 1984-85, with a catch rate of better than one trout per hour for those fishermen checked. The project is being evaluated in 1986 by electrofishing and scuba diving to better assess benefits.

Project Costs:

Manpower and Time: Private contractor from Powell, using large frontend loaders and dump truck, worked about 20 days in 1983-84.

Funding:

Park County Recreation Board	$18,422
Wyoming Game and Fish Department (Biologist to supervise rock placement)	$ 2,428
Total Cost of Project (1983-84)	$20,850

Project: North Tongue River

Location: Big Horn National Forest, about eight miles west of Burgess Junction (S15, 22, R90W, T56N), elevation 8,450 feet. Good accessibility from Highway 14A, as the road parallels the stream.

Fisherman Use: The upper North Tongue River is very popular with fishermen and the stream supports considerable fishing pressure. Estimated fisherman usage in 1984 was 635 fisherman days per year. The stream is stocked annually with small (five inch) cutthroat trout because natural reproduction is insufficient to provide a fishery with existing fisherman usage.

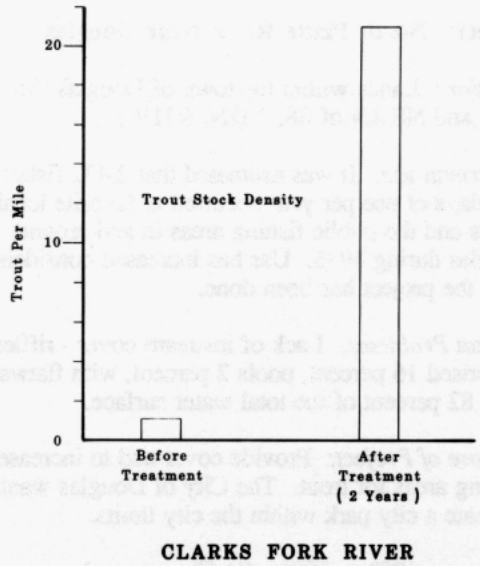


Figure 3. Trout Density - Clarks Fork River.

Habitat Problems: Prior to treatment, the riffle-pool ratio was poor with only a few, widely scattered pools. Pools deep enough to overwinter trout were rare. Pocket pools, undercut banks, patches of woody debris and other habitat features that provide shelter to trout were generally lacking.

Purpose of Project: (1) Provide deep pools to overwinter trout, and (2) provide holding and rearing areas for summer use by planted trout.

Treatment: In 1982-83, 15 log or tie overpours, six rock plunges, eight deflectors, 775 feet of tree revetment and 125 feet of rock riprap were installed by the Wyoming Game and Fish Department. This was a co-op project with the U.S. Forest Service.

Project Benefits: The standing stock of trout overwintering one or more years after being stocked increased from 74 trout per mile prior to treatment to 190 trout per mile two years after structure installation (Figure 4). Numbers of catchable trout (over six inches long) increased 156 Percent. The trout stock decreased slightly in 1985, possibly due to increased angler awareness and use of the improved area. Habitat value, as measured by the Habitat Quality Index, increased 17 percent after the improvement project. Young trout planted in 1984 were very common and well distributed throughout the treated area a month after stocking.

Project: Salt River

Location: Lincoln County. The section of river treated begins at the first Highway 89 bridge (Sl, Rll9W, T33N) south of Thayne and ends 3.2 river miles below County Road 111 (S33, Rll9W, T36N).

Fisherman Use: Unknown

Habitat Problems: Loss of riparian habitat (willows) allowed the river to cut new channels. This resulted in a wider and far more shallow river with many raw unprotected banks.

Purpose of Project: (1) Stabilize streambanks - increase shelter and holding areas for trout. The Soil Conservation Service and local conservation districts desired to protect the agricultural fields.

Treatment: Tree revetments and rock riprap in selected areas throughout the project section noted here.

Project Benefits: The revetments have provided overhead cover which was lacking. From 1978 to 1981 the number of trout increased by 658 on a 3.7 mile section where 4,841 feet of revetments had been constructed. The revetments also allowed the streambanks to revegetate. Landowners in the area have been exposed to the basic principles and concepts of hydrology and the need to allow the river to maintain natural meander patterns.

Unfortunately, two record water years did considerable damage to the revetments. During 1983 and 1984, the maximum flow exceeded the previous peak flow (3,800 cfs) by 800 to 1,000 CFS. Revetment loss was estimated to be 38 percent. Damage was highest in the middle section where the gradient was greater and channel alterations were common. However, it is assumed that more changes would have occurred had the tree revetments not been in place.

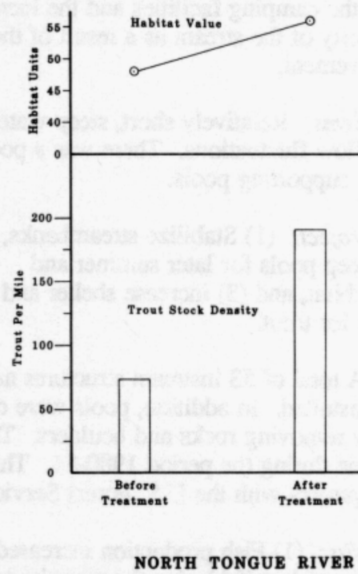


Figure 4. Trout Density - North Tongue River.

Project Costs: 1978-1984.

Manpower and time: Game and Fish.
Approximately 200 days.
(Field Crew)

Funding:

*1)	Game and Fish (Includes funds from State Conservation Commission and Governors Office)	$ 43,776
	A) Materials	
	B) Salaries (Approximately)	$ 24,000
2)	Soil Conservation Service	$131,329
		$199,105

*The Game and Fish Department provided one person to assist in supervision during construction and 25 percent of the construction funds. The Soil Conservation Service provided engineering and 75 percent of construction funds. The local conservation district provided access and were responsible for maintenance.

Project: LaBonte Creek

Location: Medicine Bow National Forest (S10, 13, 14, 17, 18 and 23, R78 and 73W, T28N) about three miles upstream from Curtis Gulch Campground. Good access by graveled road.

Fisherman Use: The U.S. Forest Service indicated 1,660 days visitor use-angler days use in the canyon in 1979 (prior to improvement). The U.S. Forest Service estimated 4,060 visitor use-angler days in 1984 (after improvements). The increase was presumed to be a response to improvement and expansion of the camping facilities and the increased carrying capacity of the stream as a result of the habitat improvement.

Habitat Problems: Relatively short, steep watershed and extreme flow fluctuations. There was a poor ratio of larger, fish supporting pools.

Purpose of Project: (1) Stabilize streambanks, (2) provide deep pools for later summer and overwinter habitat, and (3) increase shelter and holding areas for trout.

Treatment: A total of 53 instream structures and rock riprap were installed. In addition, pools were created by selectively removing rocks and boulders. This work was done during the period 1980-84. This was also a co-op project with the U.S. Forest Service.

Project Benefits: (1) Fish production increased by 74 percent (wild, resident fish) plus the capacity to accommodate 834 hatchery sub-catchables per mile, and (2) recreational use increased by 59 percent.

Project: North Platte River Near Douglas

Location: Lands within the town of Douglas (SE 1/4 of S5 and NE 1/4 of S8, T32N, R71W).

Fisherman use: It was estimated that 2,432 fisherman days of use per year occurred at favorite local access and the public fishing areas in and around Douglas during 1976. Use has increased considerably since the project has been done.

Habitat Problems: Lack of instream cover - riffles comprised 16 percent, pools 2 percent, with flatwater areas 82 percent of the total water surface.

Purpose of Project: Provide cover and to increase holding areas for trout. The City of Douglas wanted to create a city park within the city limits.

Treatment 1982 to 1985: (1) Cleanup and enhancement in riparian zone, (2) asphalt pathway constructed, and (3) approximately 2,031 tons of large granite boulders were placed through a 2.73 mile stretch in the Douglas city limits -- 47 picnic pavillions, barbeque pits, etc.

Project Benefits: In 1984, an estimated 3,505 trout were harvested per mile as compared to 16 trout per mile in 1976. The multi-facet potential of the project had made it especially attractive. The asphalt pathway provides access to the fish habitat areas with a smooth surface for the handicapped and the elderly. It also provides safe travel for people in a 1,500 family unit sub-division to a shopping center and schools by passing under busy street bridges. The project furnishes opportunity as an outdoor classroom to observe wildlife and help protect the riparian zone by preventing development in the flood plain.

Project Cost:

Manpower and time: 1 Biologist 15 days

Funding:

1)	City of Douglas (includes grant and/or matching money from the Wyoming Recreation Commission and Soil Conservation Service)	
	Rock Placement	$ 20,000
	Recreational Facilities	82,085
		$102,170
2)	Game and Fish Salaries, (Approximately)	1,950
	Total	$104,120

Fish - approximately 7,500 catchable and brood culls per year. (Catchable and brood cull plants coincide with heavy use periods such as State Fair, hunting seasons, etc.)

Project: Three Channel Spring Creek

Locations: Teton County - enters the Snake River about 1/4 mile north of the Gros Ventre River - S5, R116W, T41N, and S32, T42N.

Fisherman Use: Not applicable in this case. Three Channel Spring Creek is a spawning tributary for the wild Snake River cutthroat from the Snake River.

Habitat Problems: Lack of spawning gravels. The spawning gravels were either cemented in with silt and/or too shallow to allow the expansion of the spawning population.

Purpose of Project: Excavate holes in the streambed and either wash the gravel or place commercial washed gravel in the holes. Trees were installed to provide overhead cover for spawning trout and cover for fry and fingerlings after hatching. This would allow more eyed egg plants and increase the wild fish population in the Snake River.

Treatment: During 1979 and 1980, 277 tons of washed gravel were placed on 18 constructed and natural riffles by the Fish Division equipment operator.

Project Benefits: The number of sqawning cutthroat had increased from 149 in 1970 to 350 in 1980 (135 percent increase).

Project: Huff Creek

Location: On BLM land about 24 miles south of Afton (S27, 34, R119W, T28N), elevation 6,430 feet access by fair dirt road from Highway 89. Tributary to the Thomas Fork Bear River.

Fisherman Use: Light (13 fisherman days annually). Some use by people from Evanston and Montpelier, especially on weekends. Fishery is for wild Bear River cutthroat trout. No stocking.

Habitat Problems: Considerable stream bank erosion, with a high silt load in stream. Shelter for trout rated very poor prior to treatment. Riparian vegetation in poor condition, resulting in little shading of stream and high water temperatures.

Purpose of Project: (1) Reduce bank erosion and silt load of stream, (2) increase shelter areas and trout holding water, (3) increase stocks of the rare Bear River cutthroat trout, and (4) improve stream side vegetation by removing livestock grazing and by raising water table with grade controls.

Treatment: A 1.25 mile long area was fenced by the BLM to exclude livestock in 1979. In 1981 to 1983, 68 small check dams and other instream structures were installed. Some 3,760 feet of eroding stream banks were armoured with rock riprap. The instream structures were built by a department crew. A private contractor built the fence. This was a co-op project with the BLM.

Project Benefits: From 1978 (pre-treatment) to 1984, the stock of trout increased 1,100 percent (36 trout per mile to 436 trout per mile) (Figure 5). Numbers of catchable trout (over six incles long) increased drastically. Habitat value improved 18 percent.

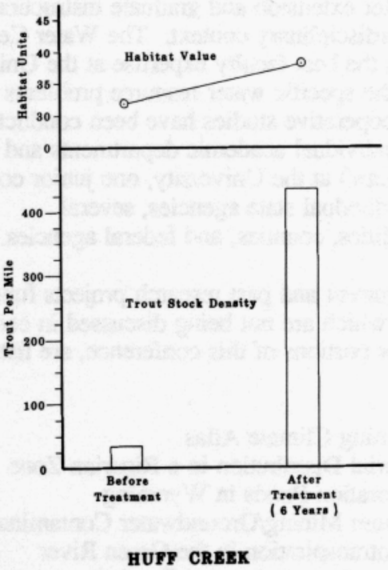


Figure 5. Trout Density - Huff Creek.

WYOMING WATER RESEARCH CENTER

Victor R. Hasfurther [1]

The 1982 Wyoming Legislature provided funds to establish a water research program at the University of Wyoming. The Wyoming Water Research Center (WWRC) conducts a comprehensive, multidisciplinary water research program that specifically addresses the development, management and preservation of Wyoming's water resources. The Center is required to coordinate, conduct and sponsor water research on a state, regional and national scope; to provide numerous State agencies an applied service function; and to offer extension and graduate instruction -- all in an interdisciplinary context. The Water Center mobilizes the best faculty expertise at the University to study the specific water resource problems of the State. Cooperative studies have been conducted with thirteen individual academic departments and one college (Law) at the University, one junior college, twelve individual state agencies, several municipalities, counties, and federal agencies.

Several current and past research projects funded by WWRC, which are not being discussed in connection with other portions of this conference, are listed below.

- Wyoming Climate Atlas
- Bacterial Distribution in a Riparian Zone
- Evaporation Ponds in Wyoming
- Uranium Mining/Groundwater Contamination
- Evapotranspiration in the Green River
- Furrow Compaction and Erosion
- Input-Output Model for Economic Development
- Optimal Consideration of Municipal Waste Loads
- Microbiological Causes of Tastes and Odors in Drinking Water
- Assessment of Water Research Needs in Wyoming
- Stream-Aquifer Interactions on Horse Creek
- Geothermal Potential
- Satellite Imagery for Snowmelt/Runoff
- Thermal Hot Springs Evaluation
- Groundwater Flow Distortions
- Water Development Costs and Benefits
- Water Development Recreational Benefits
- Center Pivot Irrigation Analysis
- Organic Contamination in Surface Water, Ground Water and Sediments
- Watershed Eutrophication Study (Flaming Gorge)
- Transpirational Water Loss from Streamside Vegetation
- Phreatophytic Water Relationships
- Contaminant Groundwater Flow Models
- Acidic Deposition in Wyoming
- Winter Stream Habitat Studies
- Wyoming Integrated River System Model
- North Platte River Management Model

[1] Acting Director, Wyoming Water Research Center, Box 3067, Laramie, Wyoming 82071.

GRAZING EXCLOSURES AND NATURAL REHABILITATION OF ERODING STREAMS[1]

Bruce H. Smith[2]

Introduction

Recently, a certain degree of controversy has arisen over the use of "exclosures" as it were, in the management of streams for riparian recovery efforts in not only Wyoming, but throughout the west. But, in all honesty, we must really ask ourselves, "What's the Beef?" Exclosures are nothing new in the science of range or land management...they've been used for decades, in fact. Small "exclosures" are often referred to as "utilization cages" or "browse cages"; larger units are referred to as "range trend study plots" (several dozen of which have been funded and studied by numerous agencies and the University of Wyoming Range Management Department, for the last twenty years or more); even larger units are often referred to as simply "pastures," for in the true meaning of the word, whenever you fence something **out** of one area, you fence it **in** to another. In any intensive grazing management system, cattle are typically fenced into one pasture (the enclosure) and out of the others (the exclosures). So, "Where's the Beef?" (Unless properly managed, it's usually in the riparian zone!) And the basic rub of the issue of exclosures in riparian zone recovery or management is usually one of politics, rather than applied management techniques.

Methods

For most people, seeing is believing. It's human nature. It's applied research. It is, in total, improved scientific based management. The role of the control group in experiments, or the function of ledger accounts and balance sheets in business; people want to, need to, see, smell, taste, feel,...the difference! Nothing sells like results, and results oriented management can be hard to find these days. It may in fact, be right there in front of us, but how can we know what the results are, if we can't see the difference?

For most of us in the Rock Springs District, these realizations came about through the trials and tribulations of the Sandy Grazing Environmental Statement. To our consternation, all of our surveys, studies and references were to little avail, when compared to all of the OTHER surveys, studies and references, cited in opposition to the recommended management practices. An besides, studies in Montana or Colorado meant little to people in Wyoming. Especially when, during numerous field reviews, they just couldn't really see any **DIFFERENCE!** Streams and gullies today appeared to be eroding just like they were twenty or thirty years ago. Few people were around who could remember that many of these areas actually were quite different in the past, but that was eighty or more years ago (Figure 1).

What did evolve out of all the public participation in the Sandy and many other similar projects around our district, was an extensive system of riparian and stream management "compromises." Call them "exclosures" if you like (several were actually designed as "enclosures," or grazing study mini-systems, a point many people don't seem to realize). But their purposes were as varied as the areas for which they were designed. They vary in size from three feet, to thirty acres, to three miles and are for monitoring site potentials; comparing these results to the progress being achieved in adjacent grazing systems; trying special management techniques on a limited scale; testing different ideas, independent of general management prescriptions; and finally working towards full scale improved rangeland management grazing programs. All of this through programs where the public is a **partner** in the process of change. Today, people cannot only see th

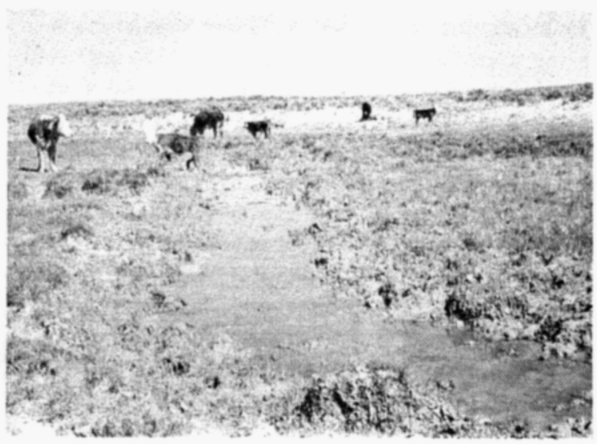


Figure 1. Conversions in many areas from past sheep use to cattle, combined with differences in behavior, season-long use, concentrations in riparian areas, and insufficient rest for recovery, have contributed to riparian decline, bank erosion, stream sedimentation, and losses in rangeland productivity. (Bone Draw)

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[1]Slide presentation of riparian special management units in the Rock Springs District, Wyoming.

[2]District Wildlife Biologist and Program Leader, Rock Springs District, Bureau of Land Management, P.O. Box 1869, Rock Springs, Wyoming 82901.

difference, but they are personally involved in helping to **make** the **difference**, in striving towards improved riparian land management practices in southwest Wyoming (Figure 2).

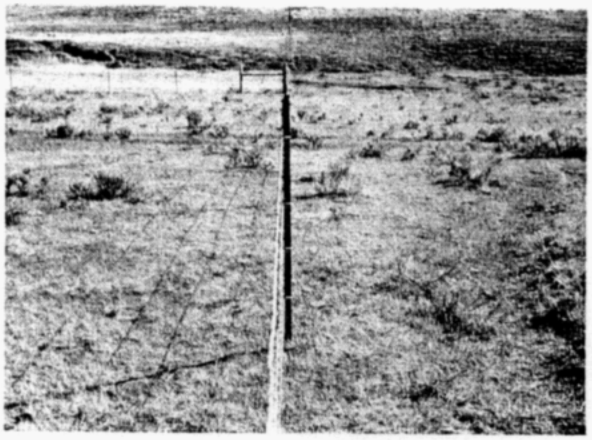

Figure 2. Riparian exclosures are management tools for improving grazing systems. Control exclosure notes site potential through time with ongoing rest (far left). Present season-long use (near left) can be compared with modified use response in a riparian test pasture (near right). Special management units can be utilized to test, compare, and experiment with different grazing techniques for recovery of degraded riparian sites or use adjustments, without impacting the entire allotment system. A "try it, before you buy it" approach to initiating changes in management. (Little Muddy Creek)

Results

As mentioned earlier, you will often hear so much about what CAN be accomplished through improved grazing management programs, but may find it yet another situation to actually see some hard and fast results. So, don't take my word for it, come and see for yourself what our Resource Area Managers and their staffs have been able to accomplish in their various riparian management initiatives. And don't forget, anyone who wins along the way, took their losses too. We've had our successes and failures, just like anyone else. But, even the failures have been learning experiences, leading us on to other newer ideas and techniques. Some of the things we have been able to accomplish and demonstrate to the public, often with participation from respective range users, or other agencies and interested groups, include the following:

1. Through the use of monitoring "exclosures" [Huff Creek Study, for example (Figure 3)], riparian wet meadow streamside zones could be expanded from less than one acre per mile of stream, to several acres per mile, illustrating site potentials for recovery throughout the allotment. (The objective was to rest the area and allow maximum vegetative recovery and vigor.)

2. In conjunction with the above expansion of riparian zone vegetation, herbaceous forage production increased 45 percent over the existing, highly compacted and depleted site conditions.

3. Serious riparian problems can be solved through recovery of vegetation, without impacting the adjacent grazing system or allotment operation, simply by putting the area into a special management "pasture."

4. Cooperative Wyoming Game and Fish studies have found:

    a) Where complete rest from livestock grazing and the construction of stream habitat structures provided the maximum improvement, several hundred percent, in rare trout populations.

    b) Simply rest alone with abundant riparian vegetative recovery, will achieve about 85 percent of the maximum efforts, with stream improvements.

    c) Improved grazing management, leading to riparian vegetative recovery and bank stabilization, can achieve about 80 percent of the maximum improvement effort.

5. Through the application of special management techniques, beaver and natural regenerative processes can be employed to accelerate riparian recovery and erosion control in gullied out drainages.

6. Through the testing of site specific mini-grazing systems, management prescriptions can be developed within an allotment, prior to, and avoiding the risks of, changing over the entire management scheme.

7. Ecosystem oriented riaprian management programs can be utilized to diversify the economic prospects of not only individual ranch operations, but small rural communities as well.

8. Much of the latent, natural, buffering capacity within a watershed to control flooding and extend late season stream flows, can be achieved through riparian systems recovery management.

Conclusion

So, when you go home tonight and find that your investments are not doing well, do you plan to shoot your banker? Or, if your business is in a negative cash flow situation, will you fire your accountant, dump your attorney, burn your books and deny yourself any of the management tools by which to judge your successes, failures and potentials for future improvements? Hopefully not. For these are the very tools and support skills you'll need to survive and succeed. And so it is with riparian management. Management which focuses on **results**, not politics. I'll listen to anything anyone has to say, but will only believe them when I see their results. And so should we all...for in this era of quick turnovers, corporate raiders, fast buck artists, short-term exploitation at the expense of the long-term productive basis of many of our ecosystems, those who most often pay the price of accountability are the people left holding the Old Maid card. The many abandoned homesteads, standing in alkali/greasewood bottoms, or perched on the edges of deep gullies, give mute testimony to their accountability, throughout the West today. They paid dearly for their, or our, mistakes. If one but reads the study of Lowdermilk (1953) in evaluating the downfall of civilizations over the past 7,000 years, it soon becomes evident that the symptoms of decline in our water related renewable resource bases are all about us. And if one could make any predictions about the future of riparian management in the arid west, they might be similar to the following.

1. Riparian recovery management will be a key to the future stability of life in the West, as we know it today.

2. Much of this future will be determined though the actions and initiatives taken within this generation.

3. The future belongs to those individuals who can work together, to once again build value into our renewable resource bases, most specifically, riparian and streamside zones.

Mother Nature plays no favorites.

Figure 3. Ultimately riparian exclosures can **prove** your accomplishments of better management! It is hard to tell a difference between the outside (left) and the inside (right) control unit. This is grazing management for rangeland recovery and riparian production. (Huff Creek)

Reference

Lowdermilk, W.C. 1953. Conquest of the land during 7,000 years. USDA-SCS Agricultural Information Bulletin No. 99. (Revised August 1975.)

BEAVER, WATER QUALITY, AND RIPARIAN SYSTEMS

Michael Parker[1]

Abstract

Studies are discussed which show that a complex of beaver dams can improve the quality of water flowing through them. Compared to stream sections above or below the dams, export from the complexes was estimated to be less by 50-75 percent for suspended solids, less by 20-65 percent for total phosphorus and total Kjeldahl nitrogen, and less by 20-25 percent for nitrate-nitrogen. Next, work is summarized which suggests that the presence of beaver dams also can protect riparian areas from erosive perturbations, if these perturbations are not too great.

In general discussions about riparian areas, climate and herbivory normally are mentioned as the important factors affecting riparian systems, and in altering them. However, data are reviewed which strongly implicate beaver as another significant regulatory factor in riparian systems; the removal of beaver during the past several centuries may have had unappreciated and far-reaching consequences. Thus in terms of management, almost any work enhancing our understanding of beaver and their interaction with the riparian system is of potential use. In some cases management using this knowledge or other can be inexpensive, but not always. Therefore, a major challenge associated with riparian areas in the coming decades is to politicians; they must devise mechanisms that 1) will allow use of initially expensive management schemes, 2) minimize "abuse" of the land, and 3) also will yield long-term profits.

Beaver Ponds and Water Quality

To test the hypothesis that beaver ponds improve the quality of water flowing through them, Currant Creek, a second order stream in southwest Wyoming, was sampled (see Maret et. al., submitted, for details). Located 48 km south-southwest of Rock Springs, Currant Creek flows into the northeast corner of Flaming Gorge Reservoir. The drainage area is 132 km^2, and a 12.9 km section of the stream's 32 km length was designated as the study area. The reservoir lies 3.2 km downstream from the lowermost point sampled on the creek.

During the period of study (May-August, 1984; April-June, 1985), the maximum and minimum discharges measured were 0.07 and 1.07 $m^3\ sec^{-1}$. A portion of the study area contained three large complexes of beaver ponds, with numerous individual ponds in between. Associated with the ponds there are areas of marsh and willow thickets. In addition to this riparian zone, the valley has irrigated and subirrigated hay meadows, and areas of sagebrush and greasewood. Water samples were taken upstream from, within, and downstream from the complexes of beaver ponds.

During periods of high flow in the spring and summer of 1984 and 1985, concentrations of suspended solids (SS), total phosphorus (TP), sodium hydroxide-extractable phosphorus (NaOH-P, an index of biologically available P) and total Kjeldahl nitrogen (TKN) were reduced in water flowing through the beaver ponds (See Figure 1). The ponds had less effect on these parameters during low flow. Nitrate nitrogen (NO_3-N) was reduced during both high and low flows, but ortho-phosphate (ortho-P) did not appear to be affected by beaver ponds. SS appeared to explain a large portion of the variation in TP, TKN, and NaOH-P, and ortho-P often was significantly correlated to TP. Particulates were more important in contributing to biologically available P (NaOH-P) than were soluble sources.

Estimates of the export from beaver dam complexes were made for several parameters. Compared to stream sections above or below the dams, export from the complexes was less by 50-75 percent for SS, less by 20-65 percent for TP and TKN, and less by 20-25 percent for NO_3-N.

In summary, the beaver dam complexes clearly improved the quality of water flowing through them for many of the parameters measured. However, most parameters increased in concentration below the area with dam complexes, apparently reflecting input from bank and channel erosion (Figure 1). Thus the location of beaver ponds and/or the erodibility of the downstream channel are important when considering ponds as a tool for improving downstream water quality.

The Role of Beaver in Resisting Perturbations to Riparian Areas

Next consider a more general hypothseis: in lower order drainages the activity of beaver can provide resistance to perturbations of a stream's dynamic equilibrium (e.g., downcutting) if the perturbation is not too great. The thermodynamic basis for this hypothesis can be understood by realizing that, literally, the statement "water flows downhill" is false. If we are able to put energy into a system (e.g., by burning gasoline in a pump to make water flow uphill), then the system may be able to resist changes which otherwise would occur.

Beaver put energy into riparian systems when they build and maintain dams, and dams can be thought of as continually-renewed, erosionally-resistant

[1]Associate Professor, Department of Zoology and Physiology, University of Wyoming, Laramie, WY 82071

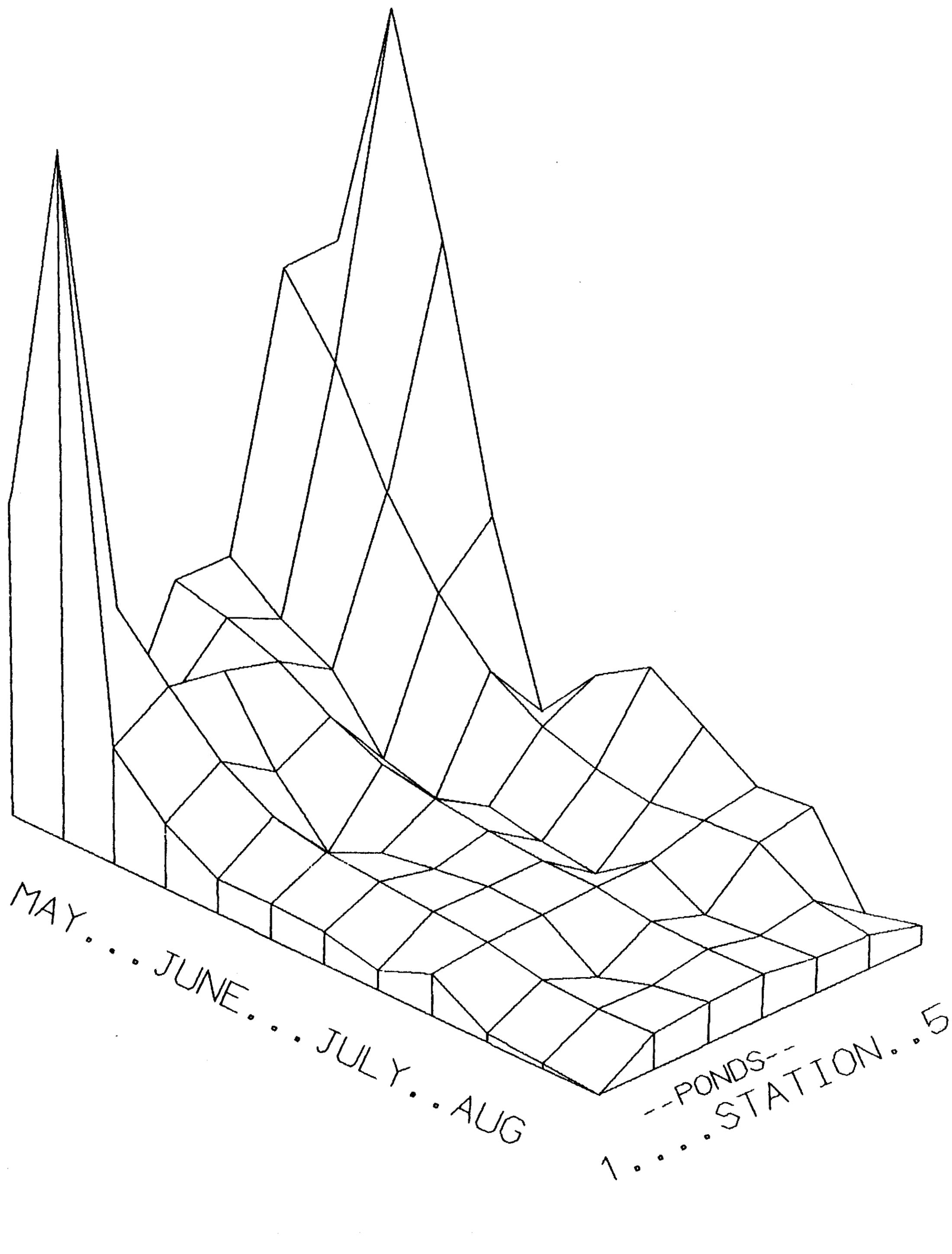

Figure 1. Data from Currant Creek on concentrations of total phosphorus. Height of the surface represents the concentration of total phosphorus, date of sampling is indicated from left to right (May to August), and flow of water is from station 1 to station 5 (this axis not to scale).

substrates. Thus an important perturbation against which dams provide resistance is erosion.

The power of water to erode is a function of velocity, which in turn is related to the depth of a stream. To understand why periods of great discharge may lead to erosion, note that as discharge increases so will depth (Figure 2), and as depth increases velocity becomes greater. Thus, as discharge increases, the power to erode becomes greater. And because beaver dams tend to spread water in thin, shallow, horizontal layers, depth and erosive power increase relatively little during high-discharge events in areas with dams (e.g., compare (A) and (B) in Figure 2).

Using the relations between discharge, velocity, and erosion, Parker et al. (1985) developed a simple theoretical model which: quantifies, in the same units used to measure discharge, the ability of beaver to withstand erosional perturbations; theoretically provides the ability to assess whether a perturbation might be "too great" to withstand, and; considers the effects of vegetative cover, which can be altered greatly by herbivores (e.g., beaver themselves, wildlife, domestic stock).

In summary, there is good reason to expect that the presence of beaver dams can protect riparian areas from erosive perturbatons, if these perturbations are not too great. This resistance to perturbaion is made possible by the input of energy by the activity of beaver. Simplistically, the mechanism involved is a reduction of water velocity and hence a decreased potential for erosion.

Riparian Systems in Overview

Factors Affecting Riparian Systems.

Climate is a dominant force affecting the biomes of earth. Precipitation is an important climatic component, supporting vegetative growth and contributing directly and indirectly to the discharge of streams and rivers (Figure 3). A second factor affecting the composition, structure, productivity, and amount of vegetation is herbivory. A variety of studies, including some discussed at this Symposium, show the effect of grazing by domestic stock on rangeland and riparian vegetation (e.g., Meehan and Platts 1978; Chew 1982; Gibbens et al. 1983; Platts et al. 1983; Apple 1985).

These two factors, climate and herbivory, commonly are considered as the major forces responsible for the changes which have occurred in the rangelands and riparian zones of western North America over the last few centuries. However, Neilson (1986) argues that changes in both climate and grazing pressure were required, and sufficient, to bring about the floristic alterations observed in the southwestern U.S.

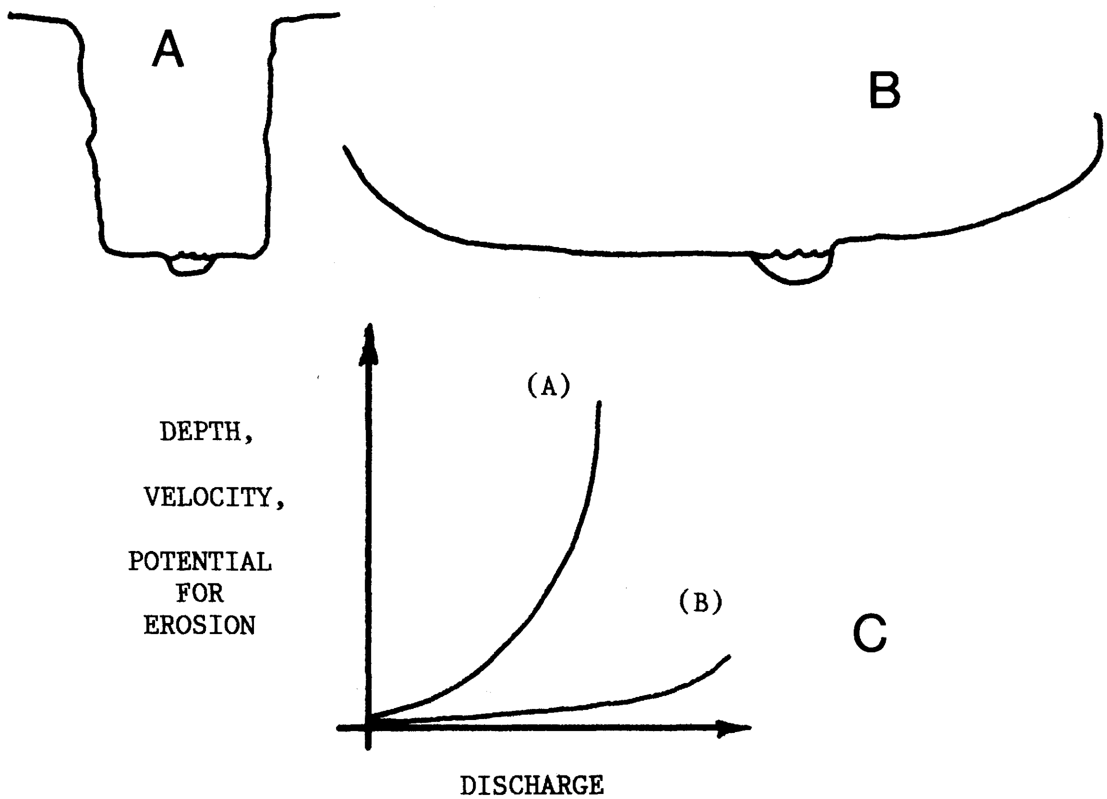

Figure 2. Schematic cross sections of an entrenched stream (A) and a stream with a wide flood plain (B). (C), a schematic representation of how depth, velocity and the potential for erosion increase in streams (A) and (B) as discharge increases.

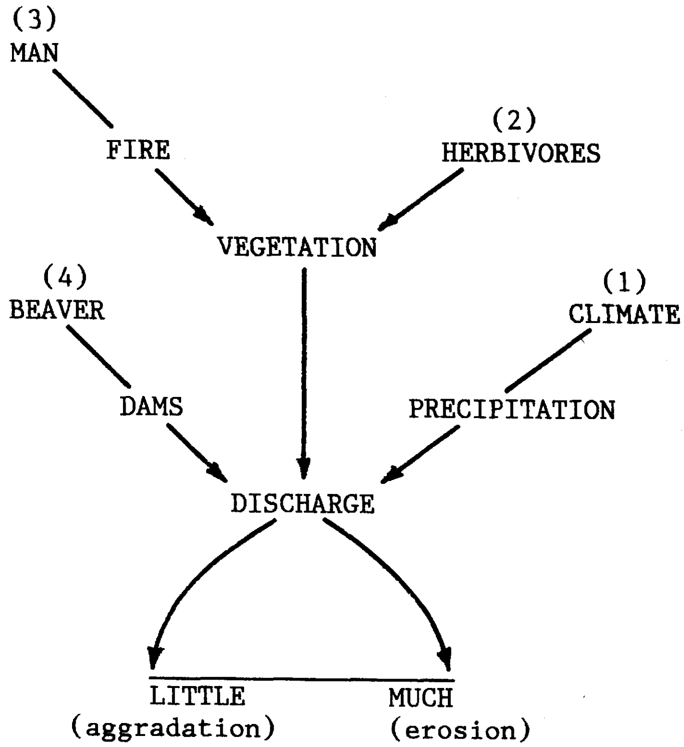

Figure 3. Simplified diagram of how (1) Climate, (2) Herbivory, (3) Man and Fire, and (4) Beaver affect riparian areas, especially in terms of erosion, via discharge.

At least on a local or regional basis, two other factors probably should be considered, fire and beaver (Figure 3). Dobyns (1981) suggests that data concerning the occurrence of fires in the southwestern U.S. have been incorrectly interpreted. He argues that American Indians regularly used fire when hunting in the southwest, and that these frequent and widely distributed fires were a major factor in controlling vegetation prior to the presence of Europeans. Their cessation removed this control and the vegetation subsequently has changed in response to other factors, now more important that fire. Dobyns also implicates removal of beaver in causing the downcutting which occurred in the Gila River drainage during the late 1800s.

Those of us alive today probably cannot conceive the extent to which riparian areas used to be affected by beaver. Prior to European man there are estimated to have been 60-400 million beaver in North America (Seton 1929), or about 6-40 beaver per km (4-25 per mi). Note that this means there likely were 6-40 beaver on every km of every stream and river in the U.S.

While none of us have experienced such a distribution on a continentwide basis, we can appreciate how greatly beaver alter riparian habitat simply by looking at streams with and without beaver. For example, in the Mackenzie River Delta, Northwest Territories, beaver play a role in creating a distinct type of habitat (Gill 1972). In West Virginia they appear to have altered the structure of forests (Lange and Weider 1984), and Milne has found beaver to be the single factor most affecting the overall state of riparian landscapes (Dahm, personal communication).

In Oregon portions of streams influenced by beaver appear to support faster-growing salmonids than other sections of the same stream (Duncan 1984), and a review of the literature suggests that in the western U.S. beaver have a generally positive effect on fisheries (Dahm, personal communication). Twidale (1976) in his book "Analysis of Landforms," comments on the role of beaver in causing alluvial deposition. Beaver also are expected to affect hydrology in several beneficial ways (see discussion above and below; Figure 3).

Changes in Riparian Systems During the Past Several Centuries.

Tremendous changes have occurred in riparian systems during the past few centuries. For example, in Oregon the Willamette River has been drastically altered by the Corps of Engineers, and today there is markedly less standing water with the main channel containing almost all of it (Sedell and Froggatt 1984). While the associated changes in marsh, etc. were not documented, they must have been considerable. Similar changes have been noted elsewhere, for example on the Missouri (Hallberg et al. 1979).

In Wyoming many people are aware of changes in riparian systems which have occurred in their lifetimes, changes that have involved not just the elimination of marsh and riparian meadow, but which have involved remarkable downcutting. In southwestern Wyoming, Shute (1981) estimated that approximately 80 percent of the stream sections studied have become badly downcut during the past century or so. In 1910 at Muddy Creek, Dad, Wyoming, one had to stoop when walking under the bridge. Today the creek is in a trench 3-6 m deep.

Because downcutting lowers the water table, riparian vegetation is eliminated. For example, on the section of Muddy Creek mentioned above, data from aerial photographs suggest that today the area occupied by riparian vegetation is 25-35 percent less than that occupied in 1938. On Sage Creek, in southwest Wyoming, one can observe an abandoned hay lift in what once was a meadow irrigated by diversion from the stream flowing though it. Today the stream is downcut 3-5 m, and no hay is produced. Of course when this vegetation is eliminated the capacity to support stock and wildlife decreases.

What has caused these changes? Changes in climate and grazing clearly are implicated (e.g., Nielson 1986). But perhaps we also should consider the consequences of removing beaver from the riparian system. Beaver dams are a continually-renewed, erosionally resistant substrate, and we have seen that the activity of beaver potentially can resist erosional perturbations if these are not too great. This occurs in part from the effect of dams on hydrology (Figure 3).

For example, while a single dam will detain only a small amount of water during a runofff event, collectively a large number of dams thoughout the watershed will have a much larger effect. This is important because such detention will reduce the peak discharge, and therefore also will reduce the erosive power of the event. In addition, it also is reasonable to think that large numbers of beaver dams will lead to greater flows during late summer. Collier (1959) provides an anecdotal account of this phenomenon.

Management of Riparian Systems

While theorectically interesting, the preceding observations also have obvious implications for managing riparian areas. A variety of statements about beaver have or can be made; some of these are true, others merely wishful thinking (Table 1). In terms of management, a major point to be made is that almost any work enhancing our understanding of beaver and their interaction with the riparian system is of potential use.

Finally, while I don't consider myself a political animal, I am an academician living in an ivory tower and I'll make several comments about what I think I can see from that tower. Increasingly, issues related to managing riparian systems are making their way into the arena where upper-level administrators and politicians play, and pressures seeking to change the status quo are being brought to bear. For example consider the issue of instream flow, recent discussion related to increasing grazing fees, and the discussion of a riparian tax incentive in Colorado. At a recent meeting I attended there was debate about whether

STATEMENT	VERACITY	PRESENT USEFULNESS TO MANAGERS	PRIORITY FOR KNOWLEDGE
Beaver improve water quality	G	F	G
Presence of beaver drastically affects riparian areas	G	F	F
Beaver affect the hydrology of streams	F	P	G
Beaver prevent erosion	F	F	G
Beaver enhance fish habitat and productivity	F	P	G
Reintroducing beaver will solve all problems with riparan habitat--free	P	P	P

Table 1. Some statements about riparian areas followed by ratings of the statement's veracity, present usefulness to managers, and the priority for acquiring more knowledge concerning the statement. Abbreviations used are: G, good; F, fair; P, poor.

individuals should be allowed to "abuse" their own or public land. A societal precedent for not allowing "abuse" of private land was suggested to be that fact that if one "abuses" one's children, society will remove the children from your care.

There are several points to be made. The first is that the only thing which doesn't change is change itself, and that the attitude toward managing the resources of public, and even private, lands may be changing. Second, in some cases management appropriate for this changing societal attitude can be employed inexpensively, but not always. Third, legislation enforcing such a changed attitude is being discussed, but I have a different suggestion. Consider the following.

- •Change WILL occur in the way society allows land to be used and managed
- •Those living on the land know most about that land, and must make a long-term living from it
- •Some appropriate management schemes are relatively inexpensive, but others are not
- •Our economic system is based on short-term profit, making it difficult for an individual to consider initially expensive management which yields long-term profits.

Therefore:

- •Politicians must devise mechanisms that 1) will allow use of initially expensive management schemes, 2) minimize "abuse" of the land, and 3) also will yield long-term profits.

I suggest that, to politicians, the last statement represents the prime challenge associated with riparian systems. To meet this challenge they will need to talk and work with managers, who in turn may find academicians of some help.

Acknowledgements

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REVERSING DESERTIFICATION OF RIPARIAN ZONES ALONG COLD DESERT STREAMS

Quentin D. Skinner, Michael A. Smith, Jerrold L. Dodd, and J. Daniel Rodgers[1]

Abstract

Instream flow structures (trash collectors), willow and beaver are being used to reclaim riparian habitat along a degraded cold desert stream in Wyoming. It is hypothesized that trash collectors will decrease stream flow velocity thus causing sediment to be deposited bank first and as channel bed material. Willow (Salix sp.) growing and planted along banks will be used to stabilize new channel bank deposition by roots. Willows will further reduce stream flow velocity and cause additional entrapment of sediment during flood runoff events. As a narrow channel, raised bottom and willow habitat develops more frequent overbank flooding should occur and cause conditions favorable for increasing new riparian zone habitat. Willow will provide structural materials for beaver dams thus replacing the need for installing trash collectors. Sixteen sets of three or four trash collectors have been installed during 1984-85 along 7 km of stream on straight reaches between meanders. Second year growth sprigs, pole plants, and containerized willow stock have been planted on degraded stream channel reaches to test survivability and root development. A surface and groundwater monitoring system is nearly complete to measure change in the riparian zone water balance. Preliminary results show (1) trash collectors slow stream velocity and increase channel bed material, (2) ninety percent of planted willows survived during their first summer growing season, and (3) beaver are using trash collectors as support for dams.

Introduction

Riparian Zones Characterized

Riparian zones are areas supported by a high watertable because of proximity to surface or subsurface water. They are characterized by distinct soils and more productive and diverse plant communities and animal species than adjacent more xeric areas. They normally occur as an ecotone between xeric and aquatic ecosystems (4). Riparian zones exist because water is available to plants during their entire growing season. The water promotes dominance of plant species that need a watertable near their root zone during their entire growing season. If the watertable near the root zone of water-loving plants is removed over extended periods of time, they may be replaced by plant species normally found where no permanent watertable exists. Loss of water tables and replacement of water-loving plants may be referred to as desertification.

Importance

Riparian zones are used by a wide variety of interest groups (5, 18, 38, 21). Apparent causes for concentration of multiple uses in riparian zones are the vegetation species diversity, productivity, and proximity to open water. High species diversity in riparian zones is reported by Campbell and Green (6), Brown et al. (4), Ewel (11) and Kauffman et al. (19). The vegetation of this zone stabilizes stream channels by creating a rough surface thereby reducing stream flow velocity while roots hold bank material together (24, 14, 31, 2). Lowrance et al. (25) show how interflow between bank waters and streams in riparian zones improves water quality. Increase in water quality promotes diverse aquatic habitat and thus improves fisheries (9, 10, 32). As well, riparian habitat value to wildlife is well documented (8, 37). Increased edge effect for area occupied (28) and vegetation structural diversity compared to surrounding plant communities are often characteristic of riparian zones (1). Both edge effect and structural diversity are important for habitat to maintain diverse wildlife species composition (29). In addition, high vegetation production, free flowing water, flat terrain and shade are cited as reasons livestock use riparian habitat (21).

User Impacts:

Users of riparian zones may cause soil compaction, slough off undercut stream banks, and denude vegetation along channels. These actions can increase erosion which often causes stream channel widening, downcutting, or both (30, 35, 27, 37). This erosive action may result in loss of: (1) floodplain water tables, (2) floodplain soil moisture, (3) aquatic habitat quality, (4) fisheries, (5) plant vigor, and (6) plant species diversity (17, 7, 26, 33). Examples of stream degradation and channelization with impact as above are noted by Busby (5), Meehan and Platts (27), Roath and Krueger (34), and Kauffman et al. (20). Recovery of stream channels, aquatic habitat, fisheries, and riparian vegetation after livestock have been removed has been demonstrated by Keller et al. (22), Duff (10), Bowers et al. (3), Platts (32), and Kauffman et al. (19). These researchers have used exclosures to eliminate grazing along stream reaches

[1]Professor and Associate Professors, Range Management Department, University of Wyoming, Box 3354, Laramie, Wyoming 82071.

within areas having different grazing management strategies to hopefully document which strategy best conserves riparian and aquatic habitat. This paper discusses a research effort designed to test procedures to reclaim a degraded cold desert stream using trash collectors, vegetation, and beaver. Pertinent questions to be answered from this study effort are:

1. Does water storage differ between degraded, natural, and improved riparian zones of a cold desert stream?
2. Do different stream reaches have different water storage capabilities along this improved cold desert stream?
3. Do improved riparian zones change a flow regime and, if so, is there a prolonged release of water for downstream users?
4. What are the hydrologic responses associated with riparian zone improvement practices on a cold desert stream such as: damming by beaver and instream flow structures, willow and grass establishment, brush control, and fertilization?
5. Can riparian zone improvement practices initiated on old desert streams reduce nonpoint source pollution downstream?
6. What functions of improved riparian zones of a cold desert stream control and abate nonpoint source pollution?
7. What are the hydrologic responses associated with grazing of improved riparian zones of a cold desert stream by livestock and wildlife?
8. What are the economic costs and benefits of improving degraded riparian zones of a cold desert stream?

Methods

Site Selection Criteria

Criteria used to select a stream reach for reversing desertification of riparian zones were: (1) the stream reach gradient must be low, (2) the stream reach should have a mature meander pattern, (3) the channel morphology of the stream should have a developed or developing flood plain, (4) stream flow should be losing water to surrounding alluvium during high flow, (5) channel damming within the selected stream reach should cause maximum response upstream, (6) a high potential exists for water spreading over adjoining flood plains as reclamation progresses and, (7) the stream reach selected should be typical of those found and similarly managed for grazing in the immediate area.

Hypotheses

Instream flow structures, vegetation, and beaver to reclaim degraded streams cause overbank flooding of former riparian floodplains that are now xeric plant communities. These xeric communities are now isolated from a permanent watertable because channel bottoms have been downcut, stream channel width has increased, or both. Flooding can promote riparian zone area because: (1) water is spread over floodplains and flow velocity decreases because of increased width of channel characteristics and a rough surface caused by vegetation, (2) water on the soil of the floodplain percolates down becoming groundwater, and (3) groundwater returns slowly to the stream channel after flood flow subsides. Flooding can create an underground reservoir which provides a watertable near the soil surface and plant root zone. Stored water, released slowly, prolongs instream channel flow during periods of less than flood stage.

Reclamation efforts on a stream reach following above site selection criteria promotes opportunity for producing overbank flow and of maximum area which will support riparian vegetation. Low gradient stream reaches are potential zones for deposition of sediment because of reduced stream flow velocity. Meandering channels increase: (1) stream length per length of valley, (2) time of travel for flow, (3) valley width, (4) alluvial valley fill as floodplains, (5) streamside storage capacity for groundwater, and (6) potential riparian zone area. Developed floodplains provide stable sites for installation of instream flow structures and beaver dams. Flood water applies less strain on these structures because overbank flow and decreased water depth dissipates velocity over a greater channel area. Established riparian vegetation further reduces flow velocity and also provides root biomass to keep instream structures in place.

Stream channel transmission loss of water downstream can occur during a flow event to surrounding alluvium in desert streams (23). Loss in flow to channel banks should cause aggradation of sediment and thus channel filling. Glymph and Holton (12) show loss of stream flow in desert areas from any one runoff event should be maximum near the mouth of a drainage basin and in larger basins if channel transmission loss occurs. Location of instream flow structures based on loss of flow and aggradation of sediment should therefore be locations of maximum water travel time.

Damming by instream flow structures, like check dams or trash collectors, and biological damming by beaver or constrictive channel dams created by encroaching banks and riparian zones cause (1) reduced flow velocity, (2) stable bed material and, (3, storage of water in banks proximal to the dam. Heede (15, 16) discusses reclamation of gullies by raising a local base level of ephemeral stream reaches to decrease gradient slope upstream using check dams. The lower gradient reduces sediment transport. Deposition occurs upstream in a wedge shape. Following Heede (15, 16), dams should be placed just above a tributary junction. Additionally, to achieve restoration of riparian habitat the dam should also be located on a stream reach having a low gradient, and on straight reaches between meanders where stable floodplains exist. The dam should then cause bank deposition of sediment and maximum filling within the upstream drainage network. Established riparian vegetation and narrowing of the channel may then eventually increase the height of the bank water table, and cause water to spread over banks more frequently because of decreased channel size (13).

Study Area

Muddy Creek, a perennial stream, located between Rawlins and Baggs, Wyoming was selected for this research program. This creek is tributary to the Green-Colorado River system and is typical of those draining cold desert foothills in Wyoming. Muddy Creek is approximately 170 km long. The downstream 100 km is mostly downcut and the channel gradient is 0.2 percent or less based on 7 1/2 minute USGS maps. Because of the low channel gradient and several different stages of channel degradation, research was initiated during 1984 in the lower 100 km of the basin.

Peak channel flow is caused by spring melting of basin and foothill snow pack and summer thunderstorms. Outcrops of sedimentary parent material and low vegetation cover cause high sediment yield in flow during peak runoff periods. Deep, old and recent alluvial fill covers bedrock in the valley bottom. Additional sediment reaches Muddy Creek because wet-dry cycles cause debris loading of channels during low flow and flushing during high flow.

Study Design:

Hydrology

Six consecutive downstream hydraulic response units (a stream reach with a characteristic channel condition and response to yearly stream flow regime) were selected within 66 km of stream distance where treatments will most likely reverse impacted channel conditions. Two of the units, Unit 2 upstream and Unit 6 downstream, were selected for use of instream flow structures (trash collectors) to trap sediment, raise the channel bottom, induce willow (Salix sp.) growth and beaver damming, create a narrow channel, cause overbank flooding, and backfill a degraded reach upstream. Stream reaches in these units are each 7 km long. Unit 2 is going to be used as a control initially and later as a replication for treaments now being applied in Unit 6.

Stream gauging stations have been installed above and below Unit 6 and are planned during 1986 on Unit 2. Sixty-eight of 90 planned groundwater monitoring wells, placed in nested designs to different depths, have been installed at selected permanently marked cross-sections along 19 straight reaches between meanders in Unit 6 and at 5 straight reaches in Unit 2. Wells have also been placed across the valley from wall to wall at each gauging station location. Stream gauging stations and groundwater wells will allow gathering water balance information as related to treated and nontreated degraded stream channel conditions.

Trash Collectors

Sixteen sets of 5 stream channel cross-sections located on straight stream reaches between meanders within Unit 6 are being used to monitor deposition of sediment caused by installed trash collectors. Fifty-two trash collectors located in groups of 3-4 at the 16 cross-section locations are presently in place and are approximately evenly spaced, as allowed by the occurance of straight reaches, along the 7 km stream length of Unit 6. Installation occurred during June 1984, August 1984, and June 1985.

Various trash collector designs using: (1) 10 cm woven wire, 90 cm wide, 0.6 cm cable, discarded tires, steel posts, and brush, (2) woven wire, cable, tires, 0.6 cm wire mesh, 90 cm wide, steel posts and brush, and (3) woven wire, cable, synthetic cloth, tires, steel posts, and brush were installed during spring 1984 at each of 16 sets of 5 cross-sections. Selection of a best design was carried out during July and early August 1984 and this design was used for trash collectors installed during late August 1984. These were installed downstream from those constructed during June 1984 but were still within the 16 cross-section areas. The August 1984 design was also used for trash collectors installed June 1985 between those installed in 1984. The latter trash collectors were placed on top of trapped sediment. Three additional sets of cross-sections downstream without trash collectors serve as controls for treatments initiated in Unit 6.

Our best trash collector design is constructed in the following manner:

1. A field measurement of the width of the active channel was recorded.

2. The field measurement was doubled to determine the length of woven wire, 90 cm in width, needed for the face and trench dug into banks on either side from the trash collector (wing sections) were 1/2 the channel width each.

3. An additional length of woven wire equal to the channel width was centered on the collector face and wired to it with a 20 cm overlap to form an upstream apron.

4. Synthetic cloth, 90 cm wide, was secured to the upstream apron surface by sewing with pliable wire. A 20 cm fold was overlapped onto the dam face as a sediment trapping lip.

5. Synthetic cloth was attached to each wing section with loose 20 cm overlap onto the collector face for side bank protection.

6. The collector face was cut down 45 cm at channel bank edges and the face section doubled down upon itself shortening the dam face and leaving the wings full width.

7. The upstream apron was then bent to form a 90° angle to the collector face forming (a) a collector face the width of the channel which is 45 cm high and has a lip of cloth 20 cm high along its bottom edge, (b) an upstream apron, faced with synthetic cloth to lay on the channel bottom, and (c) wing panels 90 cm wide faced with synthetic cloth for reinforcement of bank trenches.

8. A 0.6 cm steel cable approximately 2 1/2 times the channel width in length, was then laced through the top of the collector face leaving equal lengths on either side.

9. Trenches 20 cm wide on each bank were dug to the channel bottom and into the bank 90 cm the distance across the channel.

10. Two steel anchor posts were set in each bank trench, one at the stream edge and one at the back, and driven to 45 cm above the trench floor. A line of 180 cm long support posts, centered on the trenches, spaced at 1/5 channel width intervals, and driven to 45 cm of the channel bottom, was then installed in the channel bed.

11. 90 cm wide synthetic cloth was attached on its' upstream edge and located in the channel downstream of the posts in the channel. The cloth was then forced to the channel bottom. This cloth provided resistance to erosion of the bottom downstream apron.

12. Discarded tires were wired together edge to edge to match channel width plus one tire on each end to extend onto the banks. Tire centers were then stuffed with brush. This row of tires was then placed over the downstream cloth apron and wired to the bottom of the support posts.

13. The trash collector was then inserted by floating the dam face downstream against the support posts. Wings were inserted into the trenches and the upstream apron was then forced to the bottom and stamped into the channel bed material. The face was wired to the support posts.

14. The cable was then fastened to the anchor post at the back of one trench and stretched from the anchor post in the second trench. Trenches were back filled from the channel edge first and brush was placed on the face of the uptstream side of the dam. Willow or brush was intermingled with backfill especially at channel edges to increase resistance to erosion.

Vegetation

Vegetation type varies upstream to downstream in Unit 6. Upstream is grasslike, middle is grasslike forb-willow, and downstream is forb-willow. Total standing crop by species at the edge of the riparian-xeric transition zone, middle of the riparian zone, and channel edge of floodplains is being measured using harvest and weight estimate procedures. Measurements are being recorded at each cross-section on both banks of the channel and will be used to follow plant response to stream modifications caused by trash collectors.

Willow planting trials using containerized stock, second year stem growth and old woody stems of willows placed as deep as possible in bank sediment are being initiated to evaluate their potential use for accelerating vegetation community development on degraded floodplains and channels. Willow provides: (1) structural material for beaver dams, (2) winter food for beaver, (3) deep root systems for channel bank stabilization, (4) resistance to overbank flow during flood events, and (5) structural diversity for wildlife.

Preliminary Results

Hydrology

Preliminary surface flow records show Muddy Creek has three periods when peak flow can cause overbank flooding. Low elevation basin snow melt during March and April first floods Unit 6. Low flow resumes until higher elevation foothill snow melt occurs from mid-May to mid-June. Periodic flood events occur during July and August because of convective thunderstorms

Trash Collectors

Fifty-one of 52 trash collectors have withstood flood events. Thirty-one of 32 have survived one full year including spring ice flow and most are filled with sediment. Twenty, installed during 1985 are filling and should be full by late spring 1986. At a minimum, 45 cm of sediment has been added to the channel bottom over the entire stream distance in Unit 6.

Brush placed in the trash collector to slow flow and screen channel debris causes increased strain on the sides of the dam. When bank material is wet this strain can cause bank sluffing and piping of water around the structure. Trenches dug in banks to hold the trash collectors should be placed perpendicular to the channel to relieve strain caused by water storage behind the dam. In addition, rapid filling of the trash catcher with brush and debris immediately after placement of structures causes overflow and plunge pools to develop. Less or no brush decreases stream flow velocity but allows water to flow through the dam. This flow pattern deposits sediment both up and down stream of the trash collector thus eliminating plunge pools. In one year or less trash collectors are buried by bed material. Trash collectors placed on top of each other after one is full of sediment seem to increase channel filling and are stable. Hopefully using this procedure will allow us to fill the channel in 45 cm increments per year.

Tires in banks within trenches used by other investigators (36) to increase stability failed because voids around tires after trenches were filled caused piping and flow around the structure. Synthetic cloth placed upstream of side aprons within trenches stabilized fill while it was in a quick condition caused by flooding and bank water recharge. Synthetic cloth over the channel bed woven wire apron upstream from the dam eliminated undercutting of the structure and kept sediment in place to hold the apron on the channel bottom. Synthetic cloth immediately downstream from the dam plus a row of tires stuffed with brush over it: (1) held the cloth on the channel bottom (2) dissipated velocity of overdam flow, (3) stabilized bottom material next to support posts used for holding the structure in place, and (4) moved any plunge pool downstream from the dam.

Vegetation:
Willow establishment using containerized, second year growth sprigs, and pole plants stock harvested on site can be accomplished on new deposition with degraded stream reaches. Containerized willow plants require several preparatory steps and greenhouse facilities to ready them for planting. At least 90 percent of second year growth sprigs and pole plants survived and no preparation was needed before planting. Second year growth sprigs and pole plants spaced every foot forms an interlace of roots that may keep deposited sediment in place during flood producing runoff events. Second year growth sprigs should be cropped to about 16 cm above the soil surface to increase survivability.

Conclusions

Preliminary conclusions are:

1. Trash collectors have survived 1 1/2 years.
2. Trash collectors do trap sediment and channel bed material is increasing.
3. Beaver will build dams on trash collector sites.
4. Willow second year growth sprigs and pole willow plantings have survived summer stream flow conditions. Containerized willow plantings have survived two years.

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RESEARCH ON STREAMSIDE ZONES IN FISH AND WILDLIFE ECOLOGY

Wayne A. Hubert and Stanley H. Anderson[1]

Abstract

Fish and wildlife projects associated with streamside zone ecology or management, which have been conducted by the Wyoming Cooperative Fish and Wildlife Research Unit at the University of Wyoming since its establishment in 1980, are summarized.

Introduction

The Wyoming Cooperative Fish and Wildlife Research Unit was established 1980. The cooperating organizations are the University of Wyoming, Wyoming Game and Fish Department, Wildlife Management Institute, and U.S. Fish and Wildlife Service. The Unit was established to focus its research efforts on problems in fish and wildlife habitat management associated with energy, mineral, and water development in Wyoming. The Unit is housed in the Department of Zoology and Physiology. It has three professional staff members, a unit leader and two assistant leaders, who serve as University faculty members. These three staff members administer the Unit's research program, direct graduate students, teach graduate-level classes, and carry-out extension and continuing education functions at the University. The Unit employs numerous graduate students, research associates, and technicians through the University to perform the various aspects of its research program. In addition, the Unit staff collaborate with other faculty and staff from around the University to conduct multidisciplinary research projects.

The purpose of this paper is to summarize the Unit projects, which have been completed or are currently underway, that focus on streamside zones and their relation to fish and wildlife. The projects have been supervised by the Unit Leader (Dr. Stanley Anderson) and the two Assistant Leaders (Drs. Fred Lindzey and Wayne Hubert). Graduate students who have conducted several of the projects are acknowledged, but the projects could not have been completed without the help of many technicians, research associates, and volunteers who are too numerous to mention.

Wildlife Projects

Bird Response to Width and Patchiness of Riparian Vegetation. This study was done in mountain meadow habitat (elevation 8,000 feet) on the Snowy Range to better understand relations between nongame birds, shrub-willow streamside vegetation, and cattle grazing. It was found that many birds require shrub-willow vegetation and that the greater the variation in shrub density within a meadow the more bird species are likely to occur. Results suggested that beaver ponds have a positive influence on birds by increasing aquatic insect production and food availability for birds. Cattle were found to alter the shrub density and structure; moderate grazing created more habitat diversity and increased the number of bird species present. The results of this study are presented in a Ph.D. thesis by Dr. Henry Krueger (1985) and a paper by Krueger and Anderson (1985).

Cavity Nesting Birds and Their Habitat Needs. Many birds utilize cavities of trees in the streamside zone to build their nests. In this study the characteristics of trees used by birds were identified along the North Platte and Laramie Rivers in Platte and Goshen Counties. It was found that cottonwood-willow stands serve as islands of bird habitat in plains areas. Results showed that managers would maintain these tree stands interspersed with clearings to harbor the greatest diversity of cavity nesting birds. Different size classes of trees which support a variety of cavity openings are important for bird communities in the plains of Eastern Wyoming. The results of this study are currently available in a Ph.D. thesis by Dr. Kevin Gutzwiller (1985).

Overthrust Industrial Association Cooperative Wildlife Project. The impact of oil and gas development on wildlife in the Overthrust Belt of Western Wyoming is of concern to many people. The Overthrust Industrial Association, a consortium of three oil-producing firms, funded a project to address these concerns. The Unit participated in the project in two phases. First, it coordinated a detailed literature review on the effects of human activity on wildlife, with emphasis on oil and gas development, forest and range management, and recreation. Secondly, the Unit constructed vegetation and wildlife habitat maps for a five-county area in Wyoming, Utah, and Idaho. The maps are for use by management agencies and private firms in planning and assessing proposed developments. Results of these studies are available in reports submitted to the Overthrust Industrial Association (Meyer et al. 1983, Cook et al. 1985a and 1985b).

[1]Assistant Leader and Leader, respectively, Wyoming Cooperative Fish and Wildlife Research Unit, P.O. Box 3166, University Station, Laramie, Wyoming 82071.

Impacts of Water Division on Birds and Mammals. This project is being conducted to assess the influence of water diversions resulting from the Cheyenne Water Project, Stage I and II, on streamside habitat of nongame birds and mammals. Comparisons are being made above and below diversion structures in the Little Snake River Drainage on the western slope of the Sierra Madre Mountains. This project is being conducted by Mark Shields, a Ph.D. candidate at the University of Wyoming.

Activity Patterns of Bald Eagles. Bald eagles are nesting and breeding along the North Platte River in the vicinity of Saratoga, Wyoming. Use of the river by people who are fishing, floating in boats or canoes, or pursuing other activities can alter the activity patterns of birds using the streamside zone. This study was conducted to ascertain the normal activity patterns of bald eagles along the river and the extent to which activities are altered by various types of human use. The work was conducted by Liza Cuthbert-Millett as her master's thesis research.

The Effect of Invertebrate Abundance on High Mountain Birds. Many species of mountain-dwelling birds depend upon invertebrates produced in streams and streamside zones as their food source. This study focused on the relations between shrub-willow habitat structure, food availability, and food use by birds in mountain meadows above 8,000 feet in elevation. The results demonstrate the selectivity of birds for certain invertebrate types, as well as the value of the streamside zone to birds. This study, which provides further insight into the management of mountian meadows, is being described by Cathy Raley in her master's thesis.

Survey of River Otters in Wyoming. River otters were once widely dispersed, but their distribution has become limited in Wyoming, probably related to man's activities. Otters are associated with aquatic habitat and streamside zones, therefore changes in aquatic-riparian habitat have potential impacts on otter populations. The Wyoming Wildlife Federation has provided funding to describe the current distribution of river otter, in order to consider impacts of proposed land uses being studied. The study is being conducted by Dr. Steve Buskirk (University of Wyoming), Dr. Fred Lindzey (Assistant Unit Leader), and Bill Rudd (Wyoming Game and Fish Department) during this summer (1986).

Fishery Projects

Brown Trout Habitat Suitability Index. This project was conducted to determine the habitat features that influence brown trout abundance in streams of Southeastern Wyoming and to convert the insight into a method to assess habitat quality. This project utilized data gathered by Thomas Wesche and his associates at the Wyoming Water Research Center over the last 15 years. We found that the degree of water level fluctuation, overhead bank cover, and amount of deep pool area had the greatest influences on brown trout abundance. All of these habitat features are influenced by streamside and drainage basin management practices. Results of this project were summarized in a report to the U.S. Fish and Wildlife Service (Goertler et al. 1985).

A Rapid Method for Assessing Trout Stream Habitat. The Bureau of Land Management has responsibility for stream habitat management over a large area of Wyoming. This project was undertaken to develop a tool for BLM biologists. The study determined that instream habitat, streamside features, and the underlying geomorphology of the drainage basin all have influence on trout abundance. While many instream habitat features are influenced by human uses of the stream and streamside zone, geomorphological features, independent of man's activity, have strong influence on habitat quality. The resultant assessment methods are described in a master's thesis by Robert Lanka (1985), and a report to the Wyoming Water Research Center (Lanka et al. 1985).

Winter Habitat Conditions in Mountain Streams. This project was conducted to determine the winter conditions in brook trout streams above 9,500 feet in the Snowy Range, Southeastern Wyoming. We found that winter conditions are quite stable under the deep snow accumulations at high altitudes. It was observed that deep, narrow channels are important because they allow snow bridges to form over the streams and streamside uses that lead to a widening of the channel, such as overgrazing or trampling by humans, can be detrimental to winter fish habitat quality. We further found that maintenance of instream flows during the winter is important at high altitudes, but even more critical in downstream reaches of mountain streams. Results are available in a master's thesis by Ian Chisholm (1985) and a report to the Wyoming Water Research Center (Chisholm et al. 1985).

Fish-Habitat Relations in the Medicine Bow National Forest. This project is being conducted to determine the relation between instream and streamside habitat features, fish abundance, and forest management practices. It is part of a national program being conducted by the U.S. Forest Service. We are in our second year of field work and have already determined the importance of channel shape and large logs to fish habitat quality and fish abundance in this forest. First documentation of this project will be available in the master's thesis by Steve Kozel expected to be completed in spring 1987.

Beaver Pond Habitat Quality Index. The Wyoming Game and Fish Department has a technique to measure trout stream habitat quality that is widely used and accepted by managers. A limitation of the technique is that it is not applicable to streams impounded by beaver. The goal of this project is to develop a similar technique for beaver-impounded stream reaches. This project is being initiated this summer (1986) by two master's degree students at the University of Wyoming, Paul Winkle and Shawn Johnson.

Predicting Sediment Impacts on Trout Reproduction. A common impact associated with a variety of human developments in Wyoming watersheds is increased erosion and sediment deposition in streams. Sediment can make spawning gravels unusable and destroy fisheggs and embryos while they incubate in the gravel. The purpose of this project is to determine how various amounts and kinds of sediment influence the survival of Colorado River cutthroat trout and brown trout during the incubation phase. The project is being done in cooperation with the U.S. Forest Service, Wyoming Game and Fish Department, and Wyoming Water Research Center. Initial phases of the project will be conducted by Michael Young, a Ph.D. student at the University of Wyoming.

Flow Enhancement Effects on Fish Habitat. The South Fork of Middle Crow Creek in the Pole Mountain Recreation Area of the Medicine Bow National Forest was an ephemeral stream that did not support fish. In an attempt to mitigate fish habitat losses resulting from the Cheyenne Water Project, a constant flow of water has been added to the headwater portion of this drainage to create a perennial stream. To assess the changes in the hydrologic conditions, riparian vegetation, and fish and wildlife habitat resulting from this management action, a multidisciplinary team has been assembled at the University of Wyoming. The team leaders include Thomas Wesche (Wyoming Water Research Center), Dr. Victor Hasfurther (Civil Engineering), Dr. Quentin Skinner (Range Management), and Dr. Wayne Hubert. One aspect of the project is to assess the quantity and quality of fish habitat gained by the enhanced flow. This portion of the project is being funded by the Wyoming Game and Fish Department and Wyoming Water Research Center, and is being carried out by Steve Wolff, a master's degree student.

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SIMILARITIES IN RIPARIAN BIRD COMMUNITIES AMONG ELEVATIONAL ZONES IN SOUTHEASTERN WYOMING

Deborah M. Finch[1]

Abstract

I examined trends in bird species richness and overall bird abundance in riparian habitats among elevations varying from 6740 ft. to 9800 ft. in southeastern Wyoming. Bird species diversity ranged from a low of three bird species and 23 pairs in subalpine shrub willow habitat to a maximum of 21 species and 101 pairs in lowland cottonwood habitat. Bird communities were less diverse at higher elevations probably because of the reduced vegetational complexity and increased environmental severity at high elevations. Few bird species found in subalpine riparian habitats contained unique (but depauperate) avifaunas. Despite loss of a tree overstory, bird species composition on mid-elevation shrub sites was more similar to lowland cottwood habitats than to subalpine shrub areas. Similarity in bird species composition was greatest within elevational zones. Based on these results, general recommendations for managing riparian habitats in different elevational zones are offered.

Introduction

In the central Rocky Mountains, the distributional ranges of riparian plant species are partitioned into elevational zones (Johnston 1984, Cannon and Knopf 1984). Cottonwoods (Populus spp.) typically dominate riverine floodplains at lower elevations, whereas a variety of shrub species, in particular willow (Salix spp.), occupy streamside communities above 8000 ft. (2600 m). In the Medicine Bow National Forest of southeastern Wyoming, riparian vegetation in the subalpine spruce-fir zone is typically comprised of one willow species which forms a structurally simple community. Above timberline, streamside habitats are dominated by boggy Carex - Deschampsia meadows and shrub thickets composed of S. glauca.

Although riparian habitats contain highly diverse faunas and are critical to the survival of many rare and uncommon species (see review, Johnson and Jones 1977), few studies have examined animal distributional patterns along riparian elevational gradients. By determining the extent of faunal variation associated with elevational changes, habitat management strategies can be more accurately recommended for dissimilar riparian zones. Knopf's (1985) comparison of upland bird communities to riparian bird communities along an altitudinal cline in Colorado showed that on a local basis, number of bird species was highest at lower riparian sites but that regionally, birds were most diverse in upland sites. Knopf (1985) also found that riparian bird communities were most unique at the extremes of the elevational continuum. Although other studies of elevational gradients have revealed that bird communities became simpler at higher elevations, with decreases in rare species and increasing dominance by a few species (Able and Noon 1976, Sabo 1980), Knopf's (1985) study did not support such trends.

Because plant species composition and habitat structure in riparian communities are highly variable within, as well as across, elevational zones (Johnston 1984, Olson and Gerhart 1982), I examined patterns of bird species richness and abundance along a cline similar to that of Knopf's, but differing with respect to location, plant species associations, and elevational range. Knopf's study areas began as low as 3650 ft. and ranged to 8350 ft. My study sites ranged from 6740 ft. 9800 ft.; thus they encompassed a narrower range, but began and ended at higher elevations. By concentrating on a shorter vegetational spectrum and increasing the number of study sites, trends in bird species numbers may be found that were lacking in Knopf's wideranging regional study. In this study, I asked the questions: (1) are there trends in bird species richness and overall bird abundance related to plant association patterns, and (2) how similar are bird communities among different riparian plant associations along an elevational cline? Based on my results, I also provide general recommendations to maintain and improve riparian habitats for bird populations.

Methods

Study Area. Ten study grids of 20 acres (8.1 ha) each were established in the summer of 1981 in riparian habitats in (or within 10 km) of the Medicine Bow National Forest of southeastern Wyoming. Study sites were distributed over an elevational range of 3060 ft. (933 m), encompassing a continuum of riparian plant species and plant associations (Table 1). Based on preliminary surveys, three to four plots were established in three elevational zones: Zone 1 = low-elevation cottonwood plots (sites 1, 2, 3,); Zone 2 = mid-elevation mixed shrub plots (sites 4, 5, 6); Zone 3 = high-elevation willow plots (sites 7, 8, 9, 10). Within each zone, plant associations were similar or identical and were regarded as replicate sites for each zone. Johnston's (1984) plant association guide was used to classify habitats on each site based on

[1]Research Wildlife Biologist, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, 222 South 22nd Street, Laramie, Wyoming 82070.

Table 1. Plant associations and elevation on each bird-censusing site.

Site	Elevation (ft.)	Plant association[a]	Dominant vegetation
1	6,740	Poan3/Saex-Befo	Populus angustifolia/Salix exigua - Betuala fontinalis
2	6,980	Poan3/Saex-Befo	Populus angustifolia/Salix exigua - Betula fontinalis
3	7,400	Poan3-Potr/Sali[b]	P. angustifolia - P. tremuloides, mixed tree and shrub willow (Salix sp.)
4	7,500	Alte-Befo/Sali	Alnus tenuifolia - Betula fontinalis/mixed shrub willow (Salix spp.)
5	8,100	Sage-Sali/Caca	S. geyeriana - other shrub willow (Salix spp.)/Calamagrostis canadensis
6	8,300	Sage-Sali/Caca	S. geyeriana - Salix spp./ C. canadensis
7	8,500	Sapl/Dece	S. planifolia - S. wolfii/Deschampsia caespitosa, Carex spp.
8	9,150	Sapl/Dece	S. planifolia/D. caespitosa, Carex spp.
9	9,750	Sapl/Dece	S. planifolia/D. caespitosa, Carex spp.
10	9,800	Sapl/Dece	S. planifolia/D. caespitosa, Carex spp.

[a]Where possible, plant associations were listed according to Johnston (1984)
[b]Plant association is similar to site J51 in Olson and Gerhart (1982:141).

dominance of understory and overstory plant species. Dominance of shrubs and trees was computed using the point-centered quarter method (see Mueller-Dombois and Ellenberg 1974). Forty random sampling points established at grid intersections on each plot were used in these analyses. Because some plant associations could not be classified according to Johnston (1984), I also referred to Olson and Gerhart (1982) for further information on Wyoming riparian habitats. Plant associations and elevations at each site were listed in Table 1. Willow species were identified using the taxonomic keys of Argus (1957) and Nelson (1974) as well as University of Wyoming herbarium facilities.

I used the following criteria to select sites: (1) the stream bottom was large and level enough to establish a 20 acre grid (thus habitat types specifically adapted to steep narrow stream courses were excluded); (2) each study area was accessible by road in June so that enough time was permitted for a sufficient number of bird counts; (3) there was little or no evidence of livestock grazing or browsing based on presence of manure, foraging effects, or livestock themselves; (4) little or no human recreational activity was apparent; and (5) each site had similar topography and year-round running streams. Flooding was an additional disturbance, but because the degree of flooding was unpredictable, it was not used as a criterion in selecting plots. Not all the above criteria were met on each plot, particularly with respect to livestock disturbance. Four of the ten plots were grazed to some extent. Sites 5 and 6, which were located in plant associations dominated by mixed shrub willows (Table 1), were on a rest rotation grazing system; on site 2, winter grazing was permitted with cattle removed in May; and on site 4, the riparian edge was moderately grazed and browsed. Recreational fishing was also common on some sites but was considered a minor disturbance because effects on vegetational structure and bird territories were not detected. Sites 1 and 3 were severely flooded in 1983 so that bird

Table 2. Mean species richness and mean total number of breading pairs (all species) on each study site, 1982-84. Homogeneous subsets of means determined from Duncan's multiple range tests share common underlines ($P < 0.05$).[a]

Species Richness									
Site 1	Site 2	Site 6	Site 3	Site 5	Site 4	Site 7	Site 8	Site 10	Site 9
21.0	20.7	19.3	17.0	15.3	13.0	9.3	4.5	3.3	3.0

Number of Pairs									
Site 1	Site 2	Site 6	Site 3	Site 5	Site 7	Site 4	Site 10	Site 8	Site 9
116.3	100.7	96.0	79.3	78.0	67.1	61.0	29.0	26.3	23.0

[a]See Table 1 for description of plant associations on each site.

censusing was halted for two weeks. Although a few ground-nesting birds lost their nests in the floods, they retained their territories and built new nests when water levels dropped, and thus no effects on bird numbers were evident.

Bird Censusing. Bird populations were counted on the ten study grids using the spot-map method (Robbins 1970). Breeding birds were counted from mid-May to late July of 1982, 1983, and 1984. A minimum of eight visits were conducted on each study grid each year. Abundance was estimated as the number of territorial pairs per species on each 20 acre (8.1 ha) plot. Species richness was reported as the number of species known to be breeding on each study site based on nest searches and territorial data. Bird census data for each species will be reported elsewhere (Finch, in prep.). In this paper, abundance data was used to estimate overall number of breeding pairs.

Analysis. Jaccard similarity index (Goodall 1978) was used on presence-absence data (years averaged) to calculate percent similarity in bird species composition between all pairs of plots. One-way ANOVA with *a posteriori* pairwise comparisons was performed on bird species richness and overall abundance data to determine if numbers of species and pairs differed significantly among plots. Pairwise comparisons were computed using Duncan's Multiple Range Test. Data for each year were used as plot replicates in the ANOVA's. The Bartlett-Box F-test was used to test the assumption of homogeneity of variances in the sample data. Bartlett-Box's test was not significant for either the species richness or the abundance data so the assumption of homogeneity was met.

Results and Discussion

Numbers of Species and Pairs. Bird species richness and total number of pairs were highest on low-elevation sites dominated by narrowleaf cottonwood (P. angustifolia) and coyote willow (S. exigua) (Table 2). The three-year mean values on the cottonwood sites ranged from a low of 17.0 bird species and 79. 3 pairs on site 3 to a high of 21 species and 116.3 pairs on site 1. During the three-year study, species richness reached a maximum in 1982 of 23 breeding species on site 2, and overall abundance peaked at 130 pairs in 1982 on site 1. Of the three cottonwood sites, numbers of species and pairs were significantly lower ($P < 0.05$) on site 3 than on sites 1 and 2 (Table 2). Water levels were regulated for irrigation purposes upstream from site 3, and consequently site 3 was severely flooded for prolonged periods during the summer. For example, in 1983 (a peak flood year) site 3 was under water for three weeks. Site 3 hosted a decadent cottonwood community with little evidence of cottonwood rejuvenation. Heavy, prolonged flooding, as well as loss of cottonwoods due to flooding, may explain the decrease in bird numbers compared to the other cottonwood sites.

Mid-elevation shrub habitats (sites 4, 5, 6) ranged from a mean low of 13 species and 61 pairs on the plot dominated by thin-leaf alder (A. tenuifolia) (site 4) to a high of 19.3 species and 96 pairs on a mixed shrub willow area (site 6). Bird numbers on this latter site were not substantially different ($P > 0.05$) than those on the severely flooded cottonwood site indicating similar habitat potential to support birds on the two sites. Although this study was not designed to evaluate the effects of rest-rotational grazing on the two mixed shrub willow sites (5 and 6), Duncan's test demonstrated that these moderately

Table 3. Percent similarity in bird species compositon between pairs of study sites.[a]

Zone[b]	Plant Association [c]	Site	Site 1	2	3	4	5	6	7	8	9
1	Poan3/Saex-Befo	1									
1	Poan3/Saex-Befo	2	64								
1	Poan3-Potr/Sali	3	42	44							
2	Alte-Befo/Sali	4	36	33	35						
2	Sage-Sali/Caca	5	29	27	48	35					
2	Sage-Sali/Caca	6	26	10	40	25	61				
3	Sapl/Dece	7	15	11	14	18	30	26			
3	Sapl/Dece	8	0	0	5	0	11	9	44		
3	Sapl/Dece	9	0	0	6	0	5	5	33	75	
3	Sapl/Dece	10	0	0	6	0	5	5	33	75	100

[a]Jaccard's Index was used to compute similarity values based on presence or absence of bird species.
[b]Elevational zones are 1 = 6,740 - 7,400 ft.; 2 = 7,500 - 8,300 ft.; 3 = 8,500 - 9,800 ft.
[c]See Table 1 for descriptions of plant associations.

grazed sites contained significantly greater ($P < 0.05$) numbers of birds than ungrazed sites at higher elevations. Thus, mixed shrub willow communities, regardless of livestock effects, had greater capability to sustain birds than subalpine willow habitats. Habitat structure and plant species composition were more diverse in mid-elevation shrub willow communities than in subalpine communities, and avian numbers were higher as a response (Finch 1985). More bird species preferred to breed in habitats with larger shrub size, canopy height, and number of vegetation layers. Subalpine habitats were probably avoided by most riparian bird species because preferred habitat features were not available.

Plant communities above 8500 ft. (Sites 7, 8, 9, 10) were heavily dominated (> 90% shrub cover) by S. planifolia and were simple in habitat structure and plant species diversity. Within this elevational zone, bird numbers were highest on site 7, the lowest S. planifolia site. Species richness on this site was greater than sites above it ($P < 0.05$), but bird abundance was comparable to the alder-dominated site (site 4) ($P > 0.05$). Areas above site 7 were highly homogeneous ($P > 0.05$), being consistently low in both species richness and bird abundance. Lincoln's sparrow (Melospiza lincolnii) dominated these subalpine sites (52% of all birds), followed by Wilson's warbler (Wilsonia pusilla) (28%), and white-crowned sparrow (Zonotrichia leucophrys) (20%).

Similarity Among Sites. In general, percent similarity in bird species composition was higher within elevational zones than between zones (Table 3). Similarity values were highest in Zone 3 ranging from 33 percent to 100 percent shared species among the four S. planifolia plots (Table 3). These subalpine sites shared fewest bird species with cottonwood sites in Zones 1 (range = 0-15%). The three cottonwood sites were also highly similar among themselves (range = 42-64%), as were the three mid-elevation shrub sites within Zone 2 (range = 25-61%). Mid-elevation shrub sites shared more species with cottonwood sites (range = 10-48%) than with subalpine willow sites (range = 0-30%). For example, species that foraged and nested in lower canopies (i.e. shrubs) such as yellow warbler (Dendroica petechia), veery (Catharus fuscescens), and American robin (Turdus migratorius) reached highest densities in cottonwood habitats but were common in mid-elevation shrub willow as well (Finch 1985). Most of these species were absent in subalpine habitats presumably because of low habitat diversity (Finch 1985). Nevertheless, although depauperate in number of species, subalpine willow was unique because it shared few species with other riparian habitats.

Zone 1 and Zone 2 sites had about 85 percent more species than Zone 3 sites. Therefore, homogeneity among low and middle sites is less likely because more combinations of different species were possible.

In addition, many rare and uncommon species occurred only once in some low and mid-elevation plots, causing similarity values to decrease when presence/absence data were used. Thus, similarity values as low as 30 percent were more probable for pairs of low- or mid-elevation plots than for high elevation pairs.

Conclusions and Recommendations

Samson and Knopf (1982) indicated that between-habitat (beta) diversity comparisons were more important in assessing habitat significance to birds than within-habitat evaluations. My investigation demonstrated that bird species richness and composition, as well as total avian abundance, were more similar within riparian habitat zones than between habitat zones. Of the plant associations examined in this study, low-elevation cottonwood habitats contained more bird species, but subalpine habitats were also important because they contained bird species that did not occur in other zones. Thus, I concur with Knopf (1985) that riparian avifaunas were most unique at elevational extremes in the Front Range of the Rockies. Contrary to Knopf's (1985) findings, this and other studies (Finch 1985, Finch in prep.) have revealed that rare species were lost at higher elevations, replaced by increased dominance of a few species (Lincoln's sparrows, Wilson's warblers, and white-crowned sparrows). Greater severity of environmental conditions and reduced habitat diversity at my higher elevation sites probably explains the consistent trend toward community simplicity that was lacking in Knopf's study.

Habitat management models designed for the Rocky Mountains that assume similarity in bird species diversity and composition among different riparian shrub associations are too simplistic. For example, habitats dominated by S. planifolia contained a unique but depauperate assemblage of bird species that differed greatly from all other riparian habitats, and thus should be managed differently. Elevation alone is an excellent predictor of bird species composition, as well as number of birds and species in streamside habitats of southeastern Wyoming, and can be used to predict appropriate management designs along a riparian altitudinal gradient.

At high elevations (> 9000 ft.), severe winters and short growing seasons create a difficult environment for most plant and animal species (Kuramoto and Bliss 1970, Douglas 1972). Riparian plant communities specifically adapted to high altitudinal conditions may be irreparably damaged from man-made disturbances, and experiments designed to test the effects of various disturbances such as livestock grazing and browsing should be conducted before a management scheme is instigated. However, "improving" habitat to increase species diversity is probably an inappropriate goal in subalpine riparian communities because harsh environmental conditions form a natural barrier to wildlife immigration and plant establishment.

Because many bird species were shared in common between Rocky Mountain shrub willow and cottonwood sites at elevations below 8500 ft. (note that elevational limits are variable), management of shared species should be similar. To increase density and diversity of lower canopy birds like yellow warbler, MacGillivray's warbler (Oporornis tolmiei), and song sparrow (Melospiza melodia), riparian shrub densities and structure can be manipulated via cattle grazing (Knopf and Cannon 1982, Cannon and Knopf 1984, Krueger and Anderson 1985a), introduction of native shrub species (e.g., in Southwest, Anderson and Ohmart 1985), and beaver dam management (Apple 1985). Along high velocity streams in Colorado and Wyoming, checkdams can be used to widen and deepen the floodplain, thus providing enough soil nutrients and moisture for shrub (and tree) establishment. Dams built by beavers serve the same purpose, as well as reduce bank erosion (Parker et al. 1985).

In riparian habitats that have lost a cottonwood or aspen overstory, revegetation practices are recommended (Anderson and Ohmart 1985). Because several years must elapse before revegetated sites are suitable for high canopy bird species, temporary wildlife improvements can also be made. For example, nest boxes can be attached to large shrubs to attract secondary cavity-nesting species that may already forage on such areas (e.g. northern flicker Colaptes auratus, house wren Troglodytes aedon, and black-capped and mountain chickedees, Parus atricapillus and P. gambeli, respectively). Introduction of nest platforms can also improve treeless riparian areas for some raptors and waterfowl. Improvement practices are recommended specifically for sites in need of restoration because they have been damaged by mining, overgrazing, flooding, etc., or because they have lower wildlife diversity than the potential for that specific habitat type. In healthy non-degredated riparian ecosystems, the best management action is habitat protection rather than alteration because the most suitable plant and animal species are those that are already present.

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CROP WATER USE STUDIES

Larry Pochop, Robert Burman and Greg Kerr [1]

Abstract

Two studies of mountain meadow water use have been conducted recently along the Little Laramie River and in the Upper Green River Basin of Wyoming. The objectives of the studies have been to develop technical data and calibrate models for evapotranspiration of mountain meadow vegetation. Field measurements of water use and climatic data were taken in the Little Laramie River study during 1979 through 1982 and in the Upper Green River study during 1983 through 1985. Water balance lysimeters were used to measure water use in each study with those in the Little Laramie River Valley being placed on a line across a valley while those in the Green River Basin were placed along a 20 mile stretch of Horse Creek. Results of the field measurements and analyses of data show a high rate of vegetative water use, with values near those of pan evaporation rates. Measurements show a tendency for actual water use to vary depending on available water supplies and irrigation practices. Estimation of maximum water use can be accomplished through use of a number of different models, however, local calibration is necessary.

Introduction

A large portion of the irrigated land located in the high altitude areas of the Western U.S. is referred to as "mountain meadows." The vegetation on this land is usually harvested as hay or by grazing livestock. The irrigation of mountian meadows is usually quite variable, involving land which has not been leveled and few water control structures. With limited water control, and often short supplies, much of the area upon which mountian meadows are located is partially dry for at least part of the growing season. Irrigation water is usually removed from the fields to dry the fields for harvest or often when the natural stream flow becomes low and irrigation water right priorities are imposed.

Much of the mountain meadow vegetation grows in the presence of high water tables, similar to the conditions found for vegetation along streams. Differences do occur in the type of irrigation encountered, since most mountain meadows are flood irrigated while vegetation along streams usually obtains its water through sub-irrigation. Thus, water use rates may differ somewhat. Maximum use rates for given climatic and soil conditions should be defined through measurements of well-watered mountain meadows.

Many reasons exist for defining water use rates. For example, the Upper Green River Basin of Wyoming contains the headwaters of the Green River, one of four major tributaries to the Colorado River. The basin is subject to the terms of the Upper Colorado River Basin Compact of 1948 which directs the signatory states to assess their current water uses. Other needs for water use estimates include planning decisions concerning future uses and management of current uses. Applications of special concern regarding streamside vegetation include definition of conveyance losses and determination of return flow components.

Previous studies of mountain meadow water use have been conducted in surrounding states, especially in Colorado. Transfer of water use estimates from location to location using information from previous studies is difficult. Most studies, as part of the experimental procedure, have included climatic measurements which are not available at other locations, or at the same location for times beyond the study period. Local calibration of evapotranspiration estimation methods is generally recommended, yet data for calibration is not available. Finally, previous studies have generally considered individual fields or small regions. Basin-wide studies have seldom been undertaken.

Data Collection

Instrumentation. Non-weighing water-balance lysimeters are usually used to measure mountain meadow evapotranspiration (ET) because of the remote locations involved and the high cost of weighing lysimeters. Simple square non-weighing lysimeters 3.25 feet on a side and approximately 5 feet deep were used to measure ET from mountain meadows in the Little Laramie River Valley and the Green River Basin. Climatic measurements were made to provide data needed for modeling. Changes in soil moisture were measured using a neutron probe. Water added or removed from the lysimeters was measured and a water balance was used to estimate weekly ET from the data collected. Water table depths both inside and outside the lysimeters were measured, with the depth inside maintained at a level that was approximately the same as that of the surrounding fields.

Little Laramie River Study. A series of 9 lysimeters were located on a transect located across a typical mountain meadow approximately 23 miles west of Laramie, and were operated during the summers of 1979 through 1981. Temperature, humidity,

[1] Professors, Agricultural Engineering Department, Box 3295, and Research Associate, Wyoming Water Research Center, Box 3067, respectively, University Station, Laramie, Wyoming 82071.

and precipitation data were measured at a central location using standard weather service instruments. Four of the lysimeters represented conditions which were similar to those in nearby irrigated fields producing forage. An objective of the Little Laramie River study was to investigate the variation in water use with variations in water supplies (that is, river flows). Streamflow records were available from the Wyoming State Engineer's local hydrographer and represent streamflow approximately four miles from the lysimeter sites. For three of the seasons, the winter snowpack was near normal, resulting in near normal streamflows. However, in 1981, winter snow accumulations were low resulting in streamflows of less than half of that of other years (29,900 acre feet versus 81,000 acre feet).

Green River Basin Study. Fourteen water balance lysimeters were installed in the Green River Basin and operated for three years to obtain water use measurements for mountain meadows, alfalfa, and alta fescue. Ten of the lysimeters are located along a 20 mile stretch of Horse Creek between Merna and Daniel and consist of eight with mountain meadow vegetation and one each of alfalfa and alta fescue. The other four lysimeters were one each of alfalfa and alta fescue located at Farson and Seedskadee. The alfalfa and alta fescue are used as reference crops.

Automated weather stations measuring temperature, wind run, solar radiation, relative humidity, and precipitation were installed at each of the four lysimeter sites listed above and at three other sites in the Basin. Evaporation pans were installed, and operated during 1984 and 1985 at Merna, Daniel, and Seedskadee.

Lysimeter operation during 1983 versus 1984 and 1985 differed somewhat due to crop establishment and other factors. Regular weekly irrigations were provided all lysimeters except for four of the mountain meadow lysimeters during 1984 and 1985 which were not irrigated after irrigation in the surrounding fields was stopped for the year. This usually occurred between mid-July and mid-August. Operation in this manner allowed measurements depicting both maximum and actual water use of mountain meadows.

Results and Discussion

Results of the Little Laramie River study are shown in Table 1 and Figure 1. It is obvious that ET increases as available irrigation water increases. Relatively high water tables are associated with mountain meadow irrigation. When stream flow is high, water tables in the area are near the surface while with low stream flow, irrigation water is only available in the early summer. Hence, the ET in the irrigated areas is shown to be related to stream flow (Figure 1). In the Little Laramie River area, each additional 10,000 A.F. of stream flow is associated with an increase of approximately one inch of ET.

Eight mountain meadow lysimeters were operated in the Upper Green River Basin of Wyoming in 1983, 1984, and 1985. During the last two years, four of the eight lysimeters were managed so that they were allowed to dry out at the time irrigation water on surrounding fields was removed in preparation for haying operations. This is referred to as "actual" ET. Four of the eight lysimeters were operated so that regular weekly irrigations were applied until the end of the growing season. This is referred to as the "maximum" ET. This should not be considered as being maximum in the sense that all factors influencing ET were operating at a maximum level, but merely that the water use rate was maximum under the existing conditions.

The results of the paired Green River lysimeters are shown in Table 2 and in Figure 2. In both years, the majority of the difference in water use between the acutal and maximum treatments occurred after the time that irrigation was discontinued. The difference was slightly greater in 1985. This was probably due to a combination of factors, but especially the fact that less precipitation was received in 1985 as compared to 1984. The comparisons show that actual seasonal consumptive use for mountain meadows averaged about 20 percent to 30 percent less than maximum consumptive use.

Accumulated water uses at Daniel for 1984 and 1985 are shown in Figures 3 and 4. These sample results show a high rate of water use, with both mountain meadows and alfalfa having water use rates approximately the same as that of an evaporation pan. Mountain meadow water use at the three sites along Horse Creek for 1984 and 1985 are in Figures 5 and 6. Results indicate some variation with location as well as variation between years.

Comparisons of measured ET rates with estimated rates using empirical models are not shown herein. However, preliminary analyses indicate that local calibrations are needed for accurate estimates of ET.

Summary

Field measurements of consumptive use of mountain meadows have been taken in the Little Laramie River Valley and the Green River Basin. The measurements provide a source of data for definition of water use rates for mountain meadow vegetation in Wyoming and for calibration of equations for estimating ET. The studies should provide a reliable source of consumptive use data for mountain meadow vegetation. Analyses of the data is currently underway, thus, all results reported herein are tentative.

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Table 1. Seasonal ET, Little Laramie River - May 16 through September 15.

	Stream Flow (1000 AF)	TYPE OF SITE: Interm. Irrig. Saline	Irrig. Hay	Irrig. Hay & Pasture	Irrig. Pasture	Avg. of Four Sites
1979 ET	93.7	19.8	26.4	23.8	18.0	22.0
Rain		5.3	5.5	5.8	5.3	5.5
Water Table		20.0	23.0	17.0	34.0	24.0
1980 ET	75.6	21.5	19.1	21.4	19.1	20.3
Rain		2.5	3.0	3.1	3.0	2.9
Water Table		26.0	26.0	18.0	40.0	28.0
1981 ET	29.9	11.6	16.6	18.2	15.0	15.3
Rain		7.0	6.3	6.4	6.6	6.6
Water Table		28.0	28.0	20.0	32.0	27.0
1982 ET	74.5	14.1	18.3	22.8	17.2	18.1
Rain		5.8	5.7	5.8	5.5	5.7
Water Table		23.0	26.0	22.0	28.0	25.0
ET Averages		18.5	21.3	22.7	18.1	20.1
ET Std. Dev.		4.7	4.3	2.4	1.7	2.2

ET equals rain + water added or removed + change in soil water. (Rain is assumed to be 100% effective.)
All ET, rainfall, and water table depth values are in inches.

Table 2. Seasonal ET in the Green River Basin of Wyoming.

No.	Location	Lysimeter Descrip.	Type	Seasonal ET (inches) 1984	1985
3A	Merna	MtnMeadow	Maximum	23.6	20.9
3B	Merna	MtnMeadow	Actual	21.4	17.6
3C	HorseCr	ImproveMdw	Actual	15.4	12.6
3D	HorseCr	MtnMeadow	Maximum	20.0	15.8
3E	HorseCr	ImproveMdw	Actual	16.6	16.2
3F	HorseCr	ImproveMdw	Maximum	20.4	21.0
4C	Daniel	MtnMeadow	Maximum	26.9	21.3
4D	Daniel	MtnMeadow	Actual	20.3	17.5
		Average Actual		18.4	16.0
		Average Maximum		22.7	19.7
		Reduction		4.3	3.7

Seasonal totals are from May 23 through October 18.

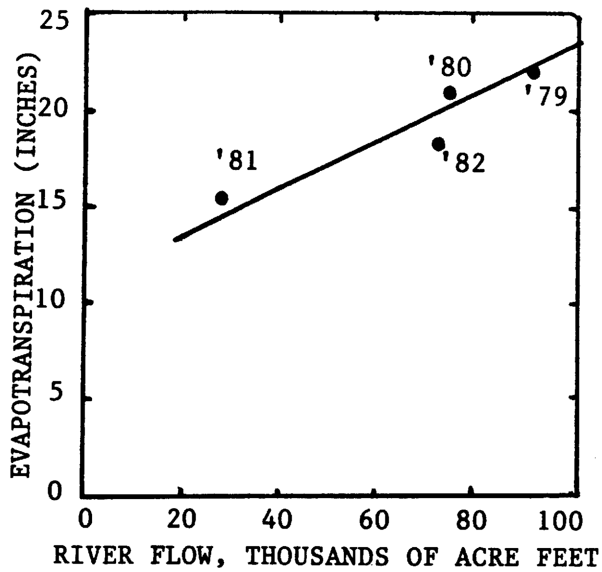

Figure 1. Relationship between ET and summer stream flow in the Little Laramie River.

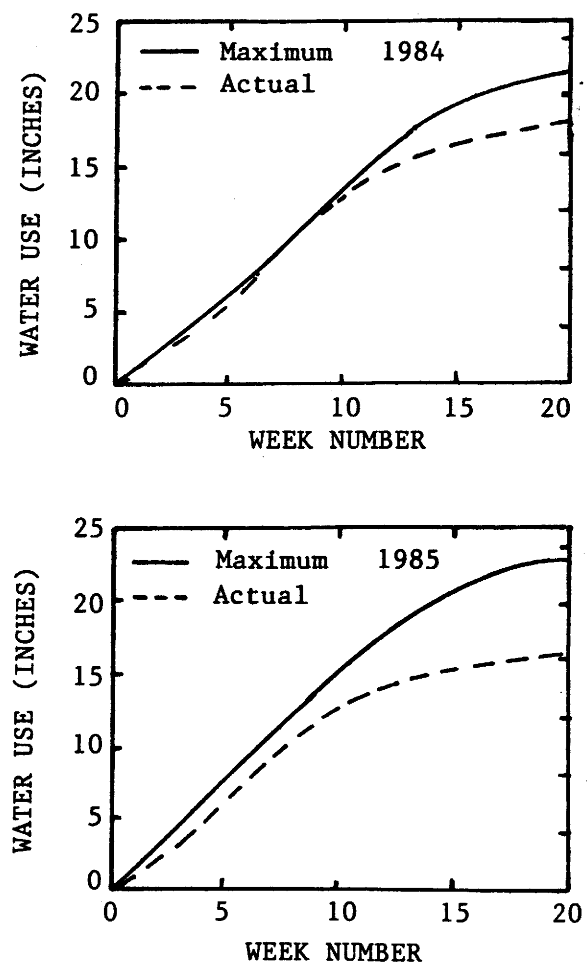

Figure 2. Maximum versus actual mountain meadow accumulated water use, 1984 and 1985, in the Green River Basin.

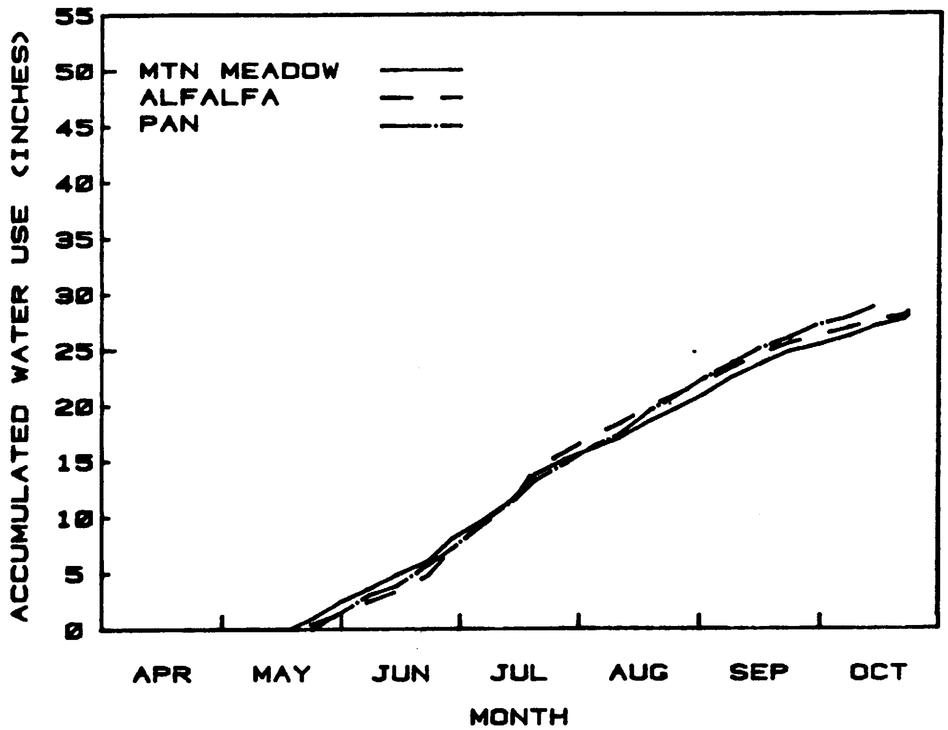

Figure 3. Accumulated water use at Daniel during 1984.

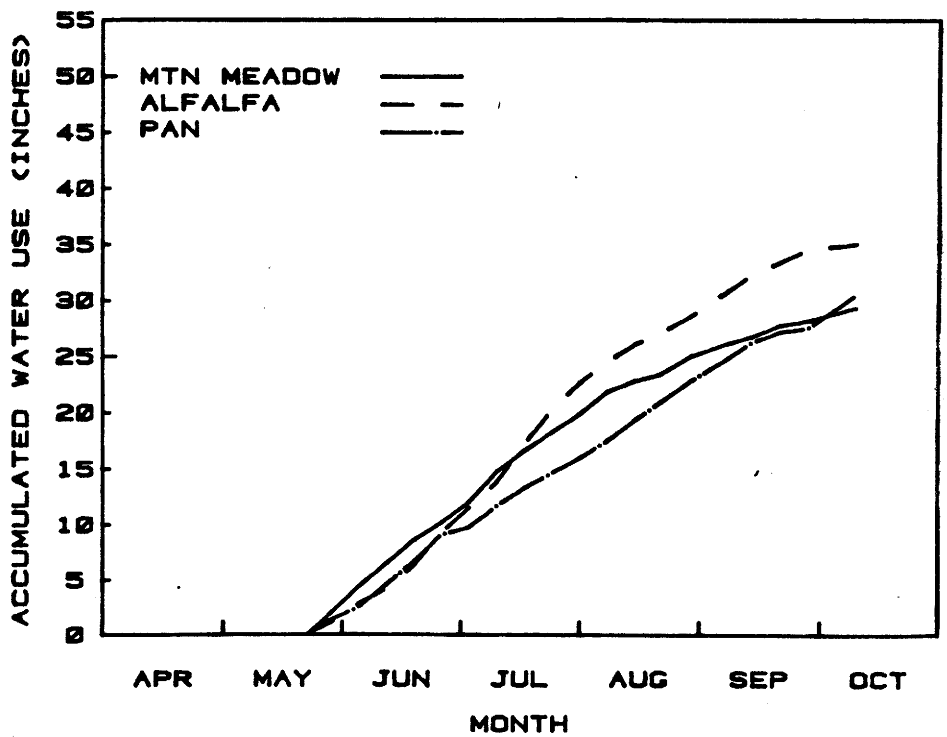

Figure 4. Accumulated water use at Daniel during 1985.

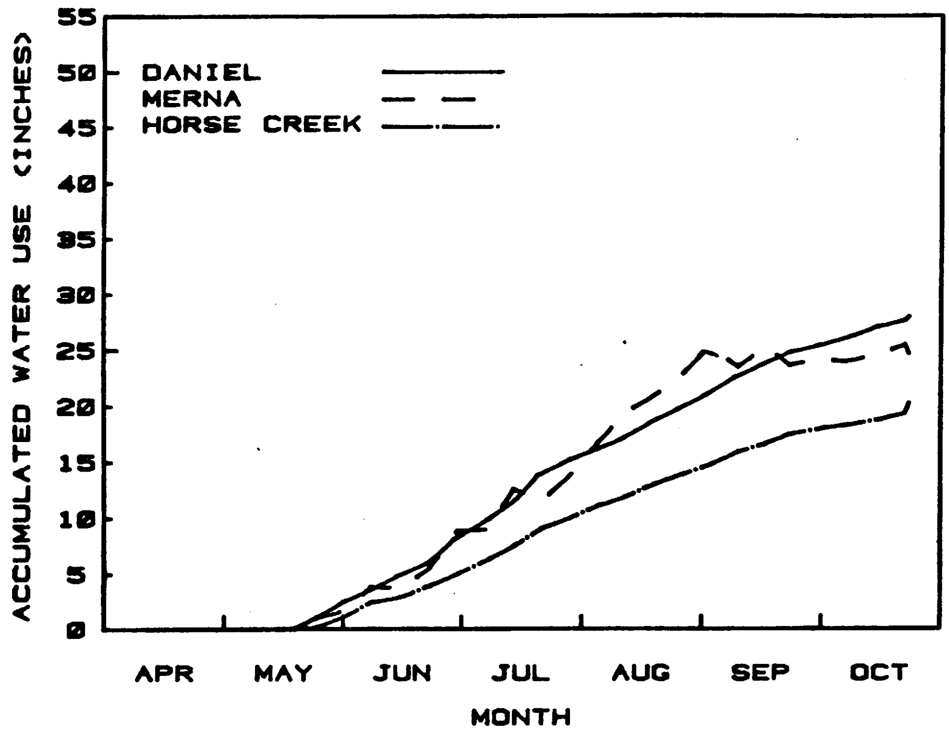

Figure 5. Mountain meadow water use during 1984.

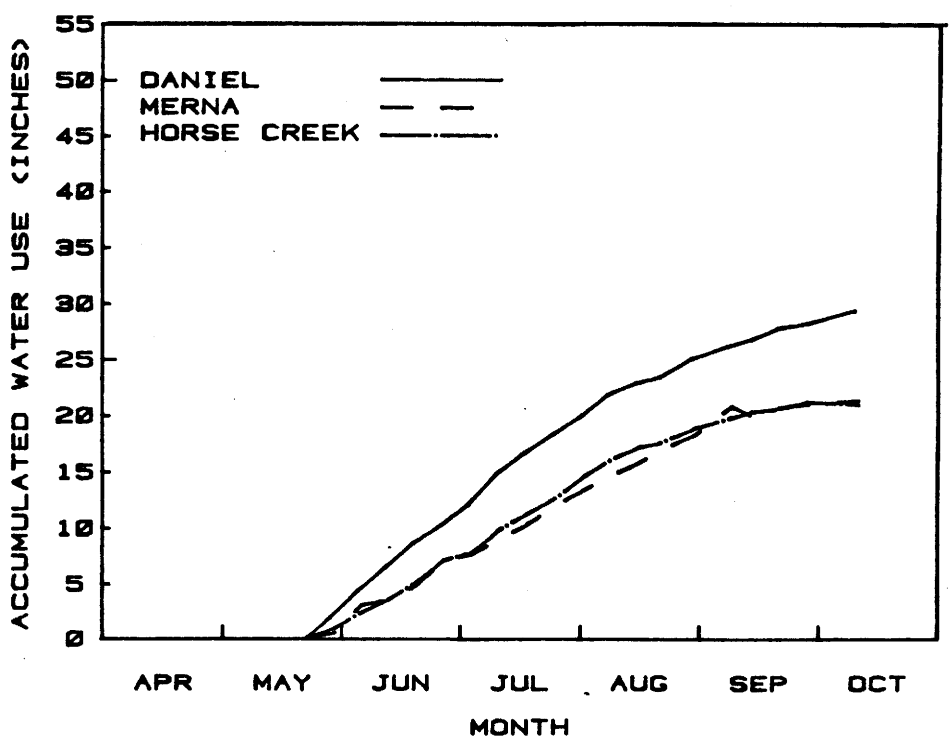

Figure 6. Mountain meadow water use during 1985.

EFFECTS OF MONTANE FORESTS AND RIPARIAN WOODLANDS ON WATER YIELD IN WYOMING

Dennis H. Knight, Jeffrey R. Foster, William K. Smith, and Howard E. Haemmerle[1]

Abstract

Streamflow is affected significantly by riparian vegetation as well as by upland forests. While manpulation of this vegetation can sometimes be a useful tool for increasing water yield, other resource values must be considered as well and often there is insufficient information for making decisions in specific localities. Ongoing research in the Department of Botany at the University of Wyoming is addressing questions such as: (1) What proportion of the water in annual snowfall is consumed by plants on montane watersheds? (2) How do vegetation cover, snowpack water equivalent, soil waterholding capacity, and climatic conditions interact in determining water yield from specific areas within single watersheds? (3) Under what conditions is water yield from a forest stand reduced to zero? (4) What is the effect of timber harvesting on water yield from specific sites? and (5) To what degree do different kinds of riparian vegetation affect water flow in streams of different sizes? Answers to these questions depend on many factors and generalizations are difficult. A summary of results for the Medicine Bow Mountains is presented.

Introduction

The vegetation of Wyoming provides many familiar benefits including wildife habitat, forage and shade for domestic livestock, erosion control, recreational opportunities, and aesthetically pleasing landscapes. But, from one perspective, these benefits are not cheap. The cost of maintaining that vegetation is water consumption. Larger amounts of forage or wood require larger amounts of water, as do larger amounts of shade and more effective erosion control. Some of the figures are rather startling, e.g., to produce one pound of dry plant tissue may require more than 400 pounds of water (Jensen and Salisbury 1972). Ninety-nine percent of the water entering plants via the root system is lost from the plant via transpiration (evaporation) from the leaves, and some have pondered how much more streamflow would result if transpiration could be reduced. Of course, reducing transpiration also means reducing plant growth and eventually plant cover.

Despite this dilemma, there are opportunities for management that could reduce water consumption by plants. For example, it may be possible to reduce plant cover and still maintain adequate vegetation for erosion contol and habitat. Or it may be possible to modify the species composition of the vegetation, favoring those species that require relatively less water per unit weight of plant tissue. It is known that some species consume water at greater rates than others. Furthermore, watershed scientists with the U.S. Forest Service have shown how the size and shape of timber harvests can lead to a redistribution of snow by wind (Leaf 1975, Troendle 1983). If the cuts are designed properly, the snow is blown into forest openings where it melts earlier and at a time when relatively few plants are available to use the water. This research, and other research of a similar nature, suggests that a good opportunity for augmenting water yield may be in manipulating the vegetation mosaic of watersheds, perhaps in a way that is similar to the kinds of mosaic shifts resulting from natural disturbances, whether they be fire, pest outbreaks, or wind storms.

Manipulating vegetation to increase water yield can be a sensitive issue, especially in the riparian zones that are valued so highly for wildlife habitat and agricultural purposes. While some groups think in terms of cutting or spraying a willow shrubland or cottonwood grove to increase streamflow, or to provide more hay meadows, others defend the importance of the woodlands for wildlife habitat, livestock shade, or maintaining streambank water storage, arguing that the amount of additional water consumed by plants is a small price to pay for these and other benefits. In fact, we usually don't know how much water is consumed by riparian vegetation in Wyoming. How do the various types of woodlands differ with regard to water consumption, and will the costs of cutting the woodlands be worth the additional water yield? Our research is designed to gather information that is relevant to such questions. Because of the high value of water in Wyoming's semi-arid lowlands, we think that the answers to these questions are important.

Some Results

For this presentation we can only provide an overview of some of our results thus far. First we present some data for the upland coniferous forests of the Medicine Bow Mountains, an area which is representative of other montane forests in Wyoming, and then we present some information pertaining to riparian vegetation. Our research has focused on montane and riparian woodlands because that is where the vegetation cover is most dense and, consequently, where water consumption is highest.

[1]Professor, Research Associate, Associate Professor, and Graduate Student, respectively, Department of Botany, University of Wyomng, P.O. Box 3165, Laramie, Wyoming 82071.

Montane forests: Water yield from most Rocky Mountain forests is a function of snow accumulation over a period of about six months. Because of that accumulation, and the rapidity of snowmelt, only a small proportion of the water can be stored or utilized on the watershed. A large amount of streamflow results. But how much water is consumed by the forests, and how does one forest type vary from another?

To answer these questions we studied a series of five contrasting two to five acre (0.8 - 2.0 ha) stands of lodgepole pine forest, one of the most widespread forest types in Wyoming. We found that actual evapotranspiration (ET) for the period from early spring to late fall ranged from 21 to 53 cm, which was 33 to 95 percent (average 73 percent) of total annual precipitation (Knight, Fahey, and Running 1985). For all stands and years of study, transpiration accounted for 50 to 61 percent of ET, and 9 to 44 percent of the transpiration that occurred during the spring drainage period (vernal transpiration). Outflow beyond the rooting zone, which contributes to streamflow, occurred only during the snowmelt period; summer rains are almost always too light to cause water flow from the upland forests into the streams. Figure 1 illustrates the annual hydrologic budget for a representative stand and year in lodgepole pine forest.

As the above numbers indicate and as illustrated in Figure 2, there is considerable variability from one forest to the next, variability which depends on (1) the amount of storage capacity for water within the litter, plant, and soil components of the forest ecosystem; (2) the amount of leaf area available for transpiration; (3) the amount of snow which accumulates; and (4) the climatic characteristics of the spring snowmelt period. Some stands store or evapotranspire nearly all of the snow water, while others contribute over 80 percent of the snow water to deep drainage beyond the rooting zone--water which could potentially contribute to streamflow or groundwater recharge. Keep in mind that these numbers apply to tracts of lodgepole pine forest that are two to five acres in size, not to whole watersheds or mountain ranges.

As part of our data analysis, we used computer simulation techniques to estimate the effect of a clearcut on water outflow from two contrasting stands (Figure 3). The most striking result of this exercise, reported in Knight et al. (1985), was the much greater increase in water outflow from one stand (Nash Fork) than the other (Albany). Outflow increased by only 36 percent at Albany (from 36 to 49 cm), whereas outflow at Nash Fork increased by 277 percent (from 13 to 49 cm). Outflow at Nash Fork was 20 percent (13 cm) of the total annual precipitation (66 cm) before the simulated harvest and 74 percent (49 cm) the second year after harvest, whereas outflow at Albany was 55 percent (36) of annual precipitation prior to harvest and 74 percent (49 cm) after.
A post-harvest decrease in total ET was indicated for both stands, from 80 percent to 26 percent of annual precipitation at Nash Fork and from 45 percent to 26 percent at Albany.

What is the best explanation for the different responses of the two stands to clearcutting? While these two stands differed noticeably in tree density, tree size, and soil water-holding capacity, we suspect that the most significant difference was in leaf area. Whereas the Nash Fork stand had a leaf area index (LAI, i.e., leaf area per unit ground area) of 10, the Albany stand has an LAI of 4. Since transpiration occurs from the leaves, deep drainage should increase in proportion to the amount of leaf area removed.

Recognizing that leaf area is an important parameter for predicting the water yield benefits to be gained from timber harvesting, we have been engaged in research desinged to simplify the estimation of forest leaf area. One of our studies demonstrated that stands with very different tree densities and biomass could have the same leaf area (Knight et al. 1981), and another study (Haemmerle and Knight, in review) provided regression equations for estimating LAI from two forest characteristics that are relatively easily measured--stand age and site index. As Figure 4 illustrates for the subalpine fir/dwarf huckleberry habitat type, projected LAI increases to a maximum of about 20 with stand age (at least for about 200 years) and better site conditions. Determining the leaf area of a stand being considered for timber sale may be as important as measuring other stand characteristics, and our research should make leaf area measurement more feasible.

Riparian woodlands. Our research on water consumption by riparian vegetation was initiated in 1984 and is still underway. The work is being done in the Medicine Bow Mountains at high and low elevation sites; only preliminary results are available.

One of our first interests was to determine whether or not there are differences between various riparian shrubs in the relative amount of water that they consume. Thus far we have found all of eight species studied to be about the same in this regard (Young, Burke, and Knight 1985; Foster and Smith, in preparation), but more work remains to be done. At this time we are inclined to think that the total amount of shrub leaf area is more important than the species composition of the shrubs.

Unlike the evergreen forests, which maintain leaf area all year, the riparian woodlands usually are deciduous and transpiration cannot occur when the plants are without leaves. Thus, little consumptive water use occurs before the leaves are fully expanded, usually in late June or early July in the mountains, and transpiration by the shrubs ceases with leaf fall in the autumn, usually early to mid September. Indeed, some have observed increased streamflow following leaf fall. Transpiration is further restricted by heavy dew accumulation on the leaves, which often persists until 10 A.M. in the mountains.

One of our primary objectives is to answer the question, "By what percentage is streamflow reduced due to phreatophyte transpiration? The answer to this question is not easily determined and depends on the size of the river or stream and the time of year. As illustrated in Figure 5, the larger the river, the smaller will be the proportion of streamflow consumed by phreatophytes (plants with roots in groundwater). Similarly, the proportion of streamflow transpired by phreatophytes will be less in the spring, when flow rates are high and leaves are still expanding, than in late summer when flow rates are lower, the leaves are fully expanded, and transpiration is occurring more rapidly due to warmer and drier conditions.

Our research is not far enough along to make credible estimates of streamflow reduction due to phreatophytes, but some preliminary values suggest reductions of 0.01 percent to 2.0 percent in June, and from 0.2 percent to 48 percent in late August (Jeff Foster, personal communication). Thus far the relationships hypothesized in Figure 5 seem to be valid.

Summary

As with many resource management questions, it is difficult to generalize about the effect of woody vegetation on streamflow. Water consumption by plants varies from one place to another, whether in mountain forests or riparian woodlands. More is known about the effect of mountain forests, and management opportunities surely do exist there, but less is know about riparian ecosystems. The amount of leaf area available for transpiration is an important consideration in all ecosystem types and, in the case of riparian vegetation, the proximity of the leaf area to the stream could be another important feature of the ecosystem. In other words, shrubs located on the streambank could be influencing streamflow more than those back on the floodplain. Further research is necessary to determine if this is true.

The unsettling observation that generalizations are difficult is confounded by the impracticality of studying every tract of forest or every stretch of stream in the State. To overcome this problem we believe that research should be focused on processes such as transpiration, seepage, and environmental controls as much as on specific localities. As these processes become better understood, it should be possible to extrapolate to unstudies areas.

Finally, there is a clear need for interdisciplinary studies. It may be possible to increase water flows by manipulating the vegetation, but are the direct and indirect costs of that manipulation worth the amount of water gained? Will the costs of reducing transpiration be worth the additional water? Will the short-term benefits be worth the long-term losses or costs, whether they be losses in wildlife habitat, livestock forage, or bank storage? Answering such questions will require the collaboration of investigators from various disciplines as well as farmers, ranchers, and agency personnel.

Acknowledgements

We are especially grateful to the Wyoming Water Research Center and the National Science Foundation for financial support.

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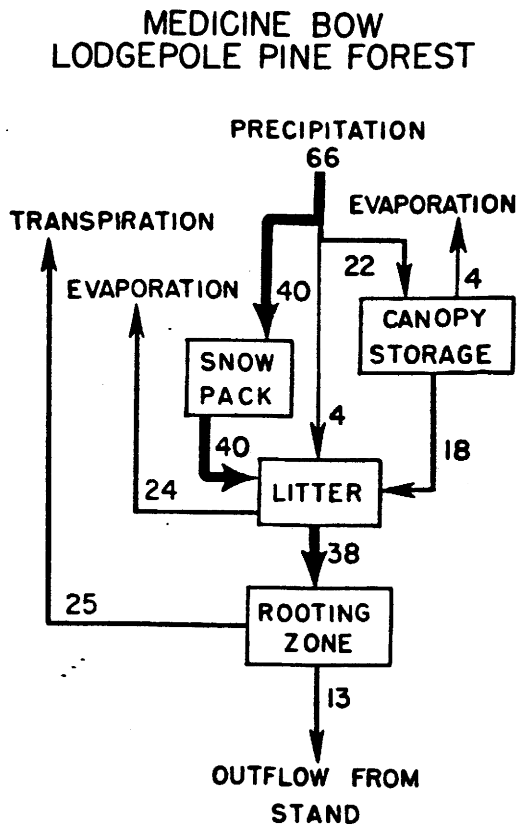

Figure 1. The annual hydrologic budget for a representative, 100-yr old stand of lodgepole pine forest in the Medicine Bow Mountains, Wyoming. The numbers are cm of water. As illustrated in Figure 2, the water budget may vary considerably from one area in the forest to another.

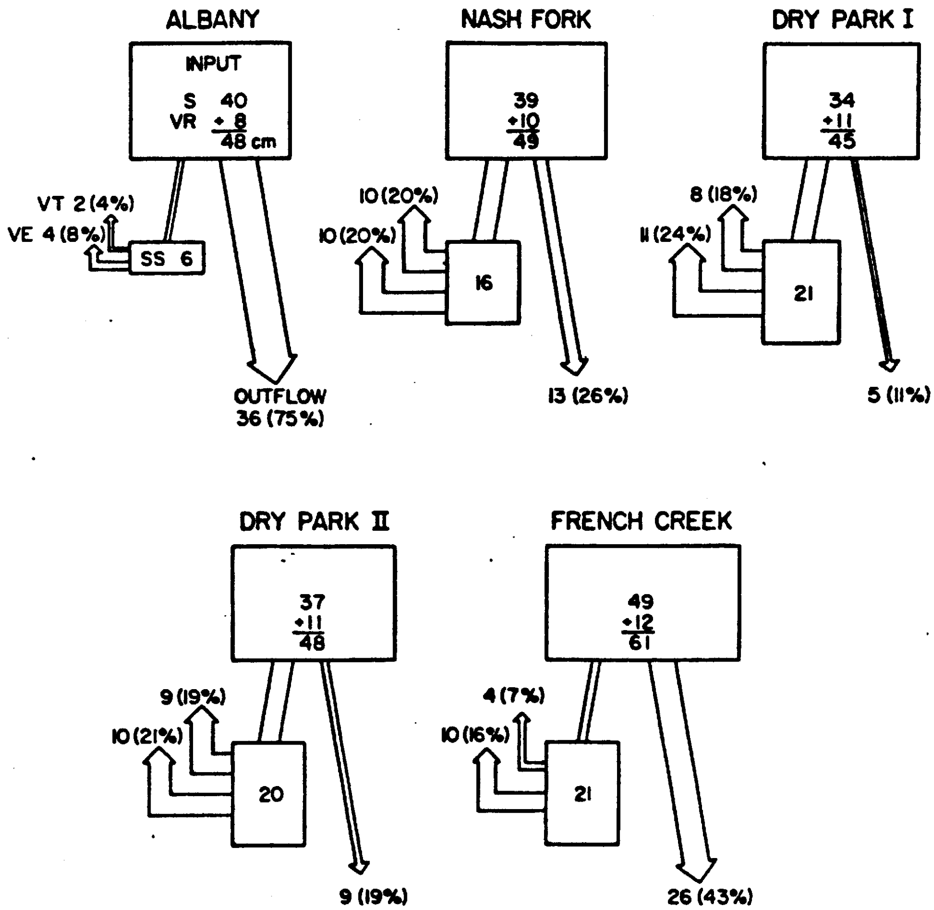

Figure 2. Diagram depicting the water budgets of five contrasting stands of lodgepole pine forest during the 1980 outflow period (from the initiation of snow melt until the end of drainage). The numbers are cm of water. See Figure 1 for a representative annual budget. The amount added to the value for maximum snow water equivalent (S) is vernal rainfall (VR), i.e., rainfall that occurred during the snowmelt period. The smaller boxes represent soil storage (SS), which is at a maximum at the end of the outflow period when the soils are saturated, and the percentages in parentheses indicate the proportion of S + VR flowing via outflow, vernal transpiration (VT), and vernal interception (VE) by the litter on the forest floor and the forest canopy during the outflow period. From D.H. Knight et al. (1985), with permission from the Ecological Society of America.

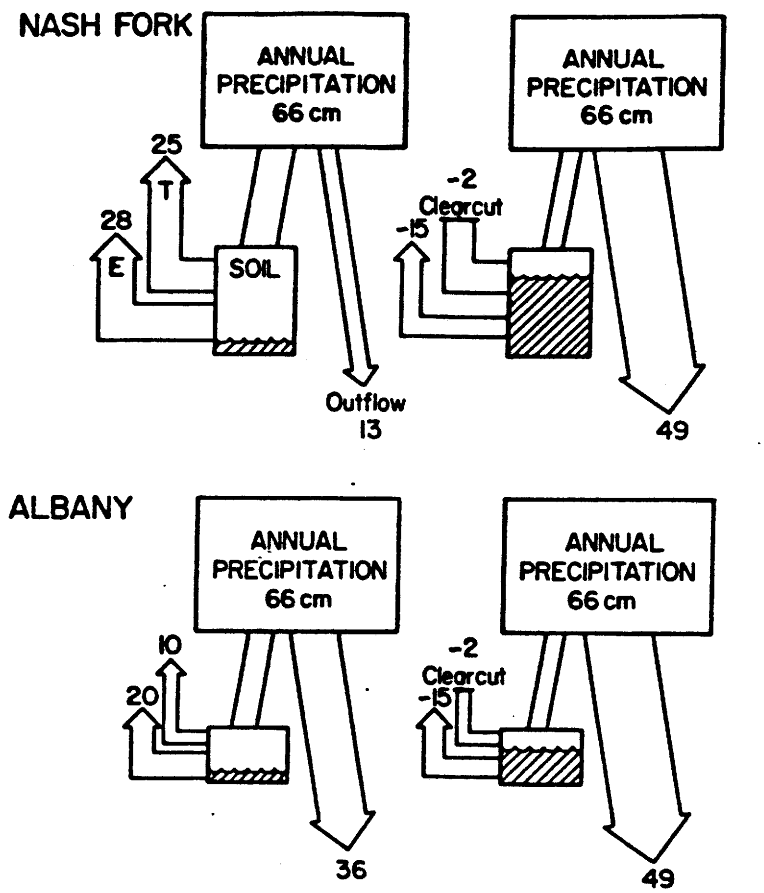

Figure 3. Estimated water outflow from two contrasting stands before and after a computer-simulated clearcutting experiment. The annual hydrologic budget for two stands is illustrated, with returns to the atmosphere being transpiration (T) and evaporation (E). Evaporation includes interception by litter on the forest floor and by the forest canopy. the hatching in the soil compartment suggests differences in soil water storage capacity, with greater storage capacity before the clearcut (left) than in the second year after harvest. From D.H. Knight et al. (1985), with permission of the Ecological Society of America.

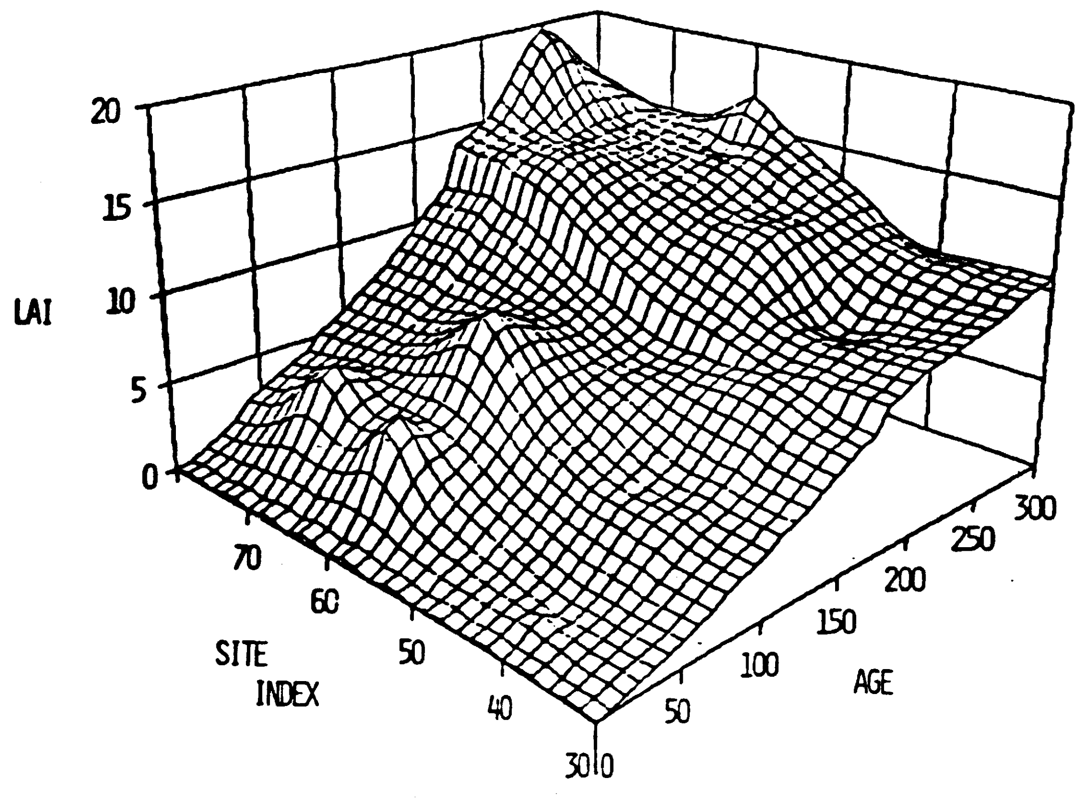

Figure 4. A three-dimensional figure showing the relationship between site index, forest age, and leaf area index (LAI) in forests dominated by lodgepole pine, Engelmann spruce, and subalpine fir in the Medicine Bow Mountains, Wyoming. Site index was calculated using tree height and age data (base age of 100). LAI is square meters of leaf area per square meter of ground area and, in this case, is calculated as projected leaf area (i.e., half of the total leaf surface area). Data for this figure were gathered from the subalpine fir/dwarf huckleberry habitat type. From Haemmerle and Knight (in review).

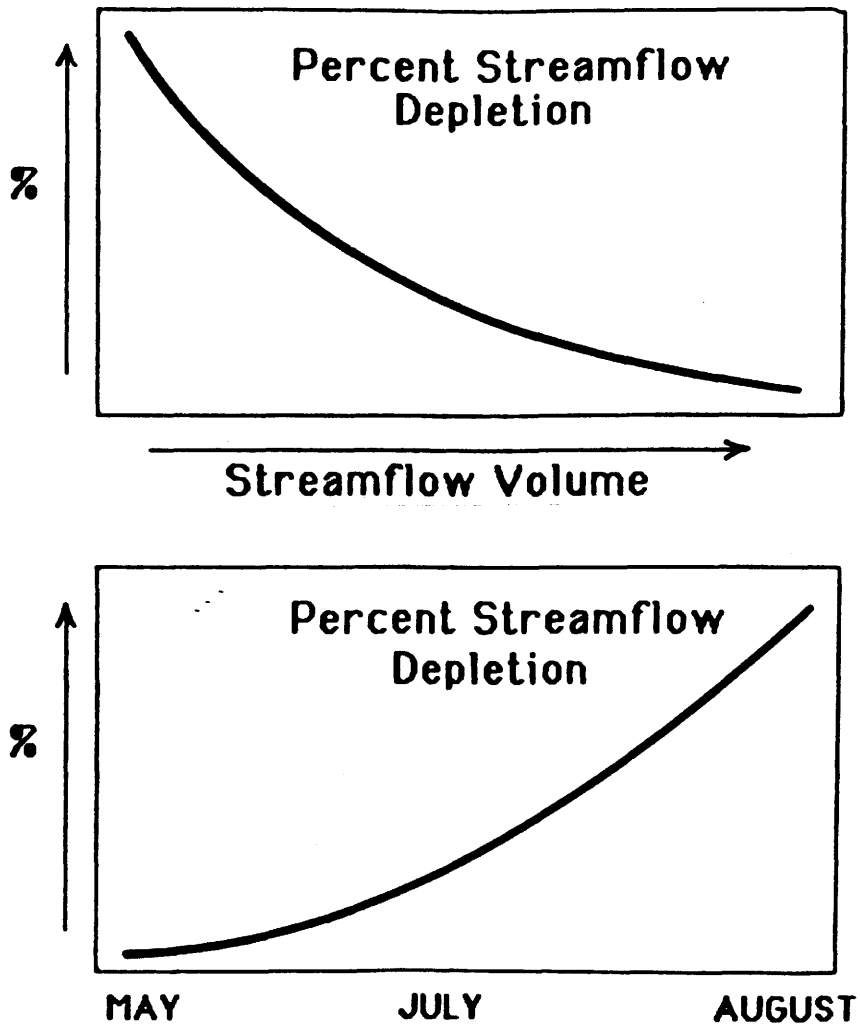

Figure 5. Two diagrams that illustrate hypotheses being tested. The upper figure suggests that the percent streamflow depletion by riparian plants will be much greater when streamflow volume is low, and the lower figure suggests that the percent depletion by plants will be greater later in the summer. Data are not yet available to quantify the axes.

FLUSHING FLOW RESEARCH

T.A. Wesche, V.R. Hasfurther, W.A. Hubert and Q.D. Skinner[1]

Abstract

The effectiveness of flushing flow recommendations for the North Fork of the Little Snake River was assessed in response to sediment deposition which occurred in 1984 as a result of construction activity in the watershed. Results indicate that three spring runoff flushes meeting or exceeding the magnitude and duration of the recommended flushing flow were somewhat successful in reducing the quantity of deposited material. Quality of deposited material, in terms of trout habitat, was very low but showed an improving trend in response to the runoff hydrograph in stream areas most severely effected. Methodology for quantitatively assessing the effectiveness of flushing flows is presented as well as mitigative recommendations for 1986.

Introduction

Alteration of stream flow regime and sediment loading from water development activities can result in both short- and long-term changes in channel morphology and conveyance capacity. Subsequently, the condition of the aquatic habitat can be affected. In recent years, much research and development effort has been directed toward the determination of suitable instream flows to maintain fisheries habitat in regulated streams (Stalnaker and Arnette, 1976; Wesche and Rechard, 1980). However, there are several facets of the instream flow problem which have not been adequately investigated, one of which involves the recommendation of flushing flows to simulate the peak runoff hydrograph characteristics of most unregulated streams (Reiser et al., 1985).

Limited research has been conducted to develop methodology for determining the magnitude, timing and duration of flushing flows needed to maintain channel integrity and associated habitat characteristics through the movement of sediment deposits. Of the 15 methodologies identified by Reiser et al. (1985), a majority were not designed specifically to assess flushing flows, but rather were approaches for studying sediment transport problems. The several formal methodologies currently available (e.g. Wesche et al., 1977; Environmental Research and Technology, Inc. 1980; Rosgen, 1982) were developed in response to immediate management needs and are relatively untested in terms of accuracy and reliability.

During 1984, the Wyoming Water Research Center initiated a research project entitled, "Development of methodology to determine flushing flow requirements for channel maintenance purposes." Objectives of this project are to (1) document the rate of change of various channel characteristics resulting from aggradation/degradation processes under altered flow regimes; (2) quantify the physical and hydraulic properties needed to transport deposited sediment through natural channels; (3) test the predictive capabilities of existing sediment transport models against field data; and (4) develop methodology to predict conditions of flow needed to flush sediments to maintain given streams in prescribed hydraulic, physical and biologic conditions.

One stream selected for study in response to these objectives was the North Fork of the Little Snake River (North Fork), a steep, rough, regulated, headwater stream. Wesche et al. (1977) recommended both maintenance and flushing flow regimes for the North Fork in light of the proposed expansion of water diversion facilitities in the drainage by the City of Cheyenne, Wyoming, as part of their Stage II water development program. Construction of Stage II began in 1983. During the late summer of 1984, intense rainfall in the construction area resulted in the deposition of a broad size range of sediments in that section of the North Fork where flushing recommendations had been made. At the request of the Wyoming Game and Fish Department and in cooperation with the United States Department of Agriculture, Forest Service, the authors initiated a study of the North Fork. The objectives of this paper are to (1) describe the methods used to assess the extent of the 1984 sediment deposits; (2) present preliminary results summarizing the response of the deposited sediment to the 1985 spring runoff flow regime; (3) evaluate the effectiveness of the 1977 flushing flow recommendations in relation to the 1984 sediment deposits, and (4) present mitigative flushing recommendations for 1986.

[1]Sr. Research Associate, Wyoming Water Research Center; Acting Director, Wyoming Water Research Center and Professor, Civil Engineering Department; Assistant Leader, Wyoming Cooperative Fishery and Wildlife Research Unit and Department of Zoology and Physiology; Professor, Range Management Division; respectively, University of Wyoming, Laramie, Wyoming 82071.

Description of Study Area

The North Fork of the Little Snake River is a steep, rough, regulated tributary of the Little Snake River located in the Green River sub-basin of the Colorado River basin in southwest and southcentral Wyoming. The headwaters of the North Fork rise on the west slope of the Continental Divide at an elevation of 10,000 feet above mean sea level (msl) and flow southwesterly 12.4 miles to the confluence with the Little Snake River at an elevation of 6,990 feet. Average gradient is 4.6 percent. A United States Geological Survey (U.S.G.S.) streamflow gaging station (#09251800) located 1.5 miles below the study area was in operation from 1957 to 1965 and recorded a maximum discharge of 516 cubic feet per second (cfs) on June 7, 1957. Average discharge over the period of record was 25.8 cfs. Prior to initial water diversion in the mid-1960's, the North Fork hydrograph was typical of unregulated mountain streams in the central Rocky Mountain Region, with the majority of runoff occurring in the May to late-June period, as a result of the melting snowpack.

The North Fork and its tributaries support the largest known, essentially-pure, naturally-reproducing endemic population of Colorado River cutthroat trout (Salmo clarki pleuriticus Cope) (Binns, 1977). For this reason, management of the popoulation is a high priority for the Wyoming Game and Fish Department. Wesche, et al. (1977) also report the collection of mottled sculpin (Cottus bairdi Girard).

Transbasin diversion of water from the North Fork drainage has occurred since 1964 when the City of Cheyenne, Wyoming completed Stage I of its water development program. Approximately 8,000 acre-feet per year have been diverted (Banner Associates, Inc., 1976). During 1983, construction began on Stage II collection facilities. When completed in 1986, a total of 23,000 acre-feet per year will be conveyed from the upper Little Snake drainage to the east slope of the Continental Divide (U.S.D.A., Forest Service, 1981).

The study area on the North Fork is located in Section 27, Township 13 North, Range 85 West at an elevation of 8,580 feet above msl, within the boundaries of Medicine Bow National Forest, 1.5 miles below the Stage I diversion structure. Under Stage II, this structure is being modified to increase the amount of water diverted from the North Fork proper. Within the study area boundary, a stream section 0.3 miles in length, construction of a bridge and pipeline crossing was underway in the late summer of 1984 when heavy rains precipitated the sediment spill that led to the intiation of this study. Gradient through this area is 4.4 percent while the predominant natural substrate is boulders and cobbles. Wesche et al. (1977) reported a mid-July 1976 water temparature range of 55 to 63° F, a total alkalinity range of 25 to 32 ppm, a pH of 7.1, and clear water conditions for this section of the North Fork. Standing crop estimates for Colorado River cutthroat trout ranged up to 14.0 pounds per surface acre. Instream flow recommendations developed by Wesche et al. (1977) called for a minimum flow of 3.0 cfs or the natural flow, whichever is less, and a three-day annual release of 60 cfs for flushing purposes during the spring runoff period.

Methods

During the Fall of 1984, four reaches were selected for study in cooperation with personnel from the Wyoming Game and Fish Department and the U.S. Forest Service. Reach 1, the uppermost site, was located just above the confluence of Second Creek, approximately 1,300 feet upstream from the North Fork bridge and pipeline crossing. Reach 1 served as the control station above the construction area from which the sediment spill originated. Reaches 2, 3 and 4 were located in descending order below the North Fork crossing area and were within the zone of immediate deposition from the spill. Given the intensive nature of the sampling to be conducted, study reaches were kept short in length, with Reach 2 being the longest, 50 feet. Also, study reaches were located close to one another to avoid compounding the access problems involved with early spring sampling in a remote, high elevation area.

Two recording streamflow gage stations were installed within the study area in early May, 1985 to monitor the spring runoff hydrograph. One station was located at Reach 1 while the second was installed at Reach 3. As no tribuatries entered between Reaches 2, 3 and 4, this lower station served to define the hydrograph for the three downstream reaches. Each station consisted of a stilling well constructed from 12-inch diameter perforated plastic pipe, a Leopold and Stevens Type F water stage recorder, a steel platform on which the recorder was seated, and an outside staff gage for measuring stream stage. A rating curve for each gage station was developed following standard U.S.G.S procedures (Buchanan and Somers, 1969). Eight stage-discharge measurements were made at each station to determine the rating curves. The correlation coefficient (r) for each curve was 0.99. Recording thermographs to measure water temperature were installed in conjunction with each stream gage station.

Four equally spaced cross-channel transects were established during October, 1984 within each study reach. Field data collected along these transects were used to quantify changes in response to the runoff hydrograph of (1) hydraulic characteristics, including discharge, channel width, top width, water depth, cross-sectional area, wetted perimeter, hydraulic radius, mean water velocity, bottom water velocity, and intergravel permeability; (2) bedload transport; (3) suspended sediment transport; (4) quantity and distribution of deposited sediments; and (5) quality of the deposited sediments. Given the scope of this paper, analysis will focus primarily on data types 4 and 5 listed above. The hydraulic and sediment transport data collected is presently undergoing analysis and will be presented in future project papers and reports. Field sampling began in late October, 1984, was then discontinued over the winter months, and was reinitiated in early May, 1985 as spring runoff began. Sampling continued on approximately a weekly basis through early July, 1985.

The quantity of deposited sediment within each study reach was determined by the following procedure:

1. Along each transect at each sampling time, the depth of deposited material (Dd) was measured at 1.0 foot intervals to the nearest 0.05 foot by gently driving a 0.5 inch diameter round steel depth rod into the substrate until it came into contact with the underlying boulders and cobbles.

2. Mean Dd for each transect was determined by summing the individual depth measurements and dividing by the number of measurements taken along the transect (usually about 20 measurements).

3. The mean Dd for each of the four transects in a reach were then summed and divided by four to obtain the mead Dd for the reach at that sampling time.

4. Multiplying the mean reach Dd (feet) by the mean channel width (feet) and by the length of the reach (feet) yielded the volume of deposited material (feet^3) in the reach at that time.

5. To determine the density of the deposited material (pounds/feet^3), three core samples were collected along each transect in October 1984, early May 1985 and early July 1985 using a McNeil-Ahnell sample (McNeil and Ahnell, 1964). To standardize weight measurements, all core samples were oven-dried for at least 24 hours at 140 F before weighing. Volume measurements for each sample were made by water displacement technique. The mean density of each reach was calculated by dividing total weight of the 12 cores for that reach by their total volume.

6. Total weight of deposited material within each reach at each sampling time was determined by multiplying the volume of deposited material by the mean density.

7. To allow comparison of study reaches having different surface areas, the total weight was divided by reach area to obtain pounds of deposited material per square foot.

The composition and quality of the deposited material within each reach over time was assessed by the following procedure:

1. As described above, 12 core samples were taken at each study reach at each of three sampling times.

2. Particle size distribution by weight within each core sample was determined by dry-sieve analysis at the University of Wyoming's Division of Range Management Watershed Laboratory. A series of 10 sieves ranging in mesh size from 3.0 to 0.008 inches were used (Reiser and Wesche, 1977).

3. The mean particle size distribution for each reach at each sampling time was determined by averaging the results from the 12 individual core samples. Distribution plots of particle size versus percentage (by weight) finer than the given sieve sizes were then developed.

4. Quality of the deposited material by reach over time was assessed by:

a. the median particle size read from the distribution plots described above;

b. the geometric mean particle size (d_g) calculated by the equation,

$$d_g = (d_1^{w1} \times d_2^{w2} \times \ldots d_n^{wn}),$$

where d_n is the midpoint diameter of particles retained by the nth sieve and w_n is the decimal fraction by weight of particles retained on the nth sieve (Platts et al. 1983);

c. The Fredle Index (f) calculated by the equation,

$$f = \frac{d_g,}{S_o}$$

where S_o is the sorting coefficent defined as the ratio of d75 to d25 where the particle size diameters are 75 and 25 percent finer on a weight basis of the sample (Lotspeich and Everest 1981).

Results and Conclusions

Response of Sediment Deposits to 1985 Hydrograph

A summary of hydraulic characteristics for each study reach is presented in Table 1. As indicated by these data, Reach 2 had the steepest gradient, the highest water velocities, and shallowest water depths. Reach 4, the lowermost site, consisted primarily of pool habitat having the lowest gradient, deepest water and slowest velocities. Reaches 1 and 3 were similar in hydraulic characteristics and represented more moderate conditions.

Spring 1985 runoff hydrographs for the two streamflow gaging stations are presented in Figure 1. While the magnitude of the runoff was greater at the lower station due to the tributary which entered the North Fork immediately below Reach 1, timing and duration were similar. Also shown on Figure 1 is the magnitude of the flushing flow recommended by Wesche et al. (1977) for the North Fork in the vicinity of the three lower study reaches. This recommendation, 60 cfs for a duration of three days, was based upon field measurement of bankfull dishcarge and the findings of Eustis and Hillen (1954).

Three major runoff peaks occurred during 1985 which equalled or exceeded the magnitude and duration of the recommended flushing flow (Figure 1). Each peak had a maximum instantaneous discharge of 105 cfs while the maximum mean daily peaks ranged from 73 to 80 cfs. Based upon maximum instantaneous discharge, the earliest peak lasted three days (May 10 to 12), the second peak extended over eight days (May 23 to 30), and the third peak exceeded the recommended discharge on five consecutive days (June 6 to 10). A fourth peak occurred in late June during which the maximum flow approached the 60 cfs level, but only for a portion of one day.

The quantity of deposited material within each study reach at each sampling time is presented in Figure 2. Deposition was consistently lowest in Reach 1, the upstream control, and Reach 2, the uppermost study section below the construction area. Quantities in these two reaches varied from 16.1 to 31.2 pounds/feet^2. The high gradient through Reach 2 probably explains the relative lack of deposition in this area. Based upon the October 1984 and the July 1985 data, Reach 2 experienced a net export of 7.3 pounds/feet^2 through the spring runoff period. Reach 1, a moderate gradient section, realized a net gain of 5.7 pounds/feet^2 by early July 1985. As there was additional construction activity in the North Fork drainage during 1984 above Reach 1, a small increase, such as that observed, was not expected.

The quantity of deposited material sampled in Reach 3 ranged from 29.5 to 46.9 pounds/feet^2. From October 1984 to early July 1985, no net gain or loss was observed in this moderate gradient reach. The trend of the data, while greater in magnitude, did parallel that found for Reach 1, a section having similar hydraulic characteristics.

Reach 4, the lower gradient pool section, was found to have the greatest magnitude and variation of deposited material. Measurements indicated 31.6 pounds/feet^2 were present during October 1984. By early May the amount of deposition had increased to 82.1 pounds/feet^2, indicating considerable pool aggradation had occurred as a result of the first peak in the hydrograph. The effects of the three later peak runoff events on the quantity of deposited material in Reach 4 are evident from Figure 2. In total, these flushes reduced the amount of deposition from 82.1 to 50.5 pounds/feet^2. Through the entire sampling period, Reach 4 realized a net import of 18.9 pounds/feet^2.

The relative quality of deposited material in each of the study reaches over time is provided in Figure 3. As median particle size data were similar in both magnitude and variation to the geometric means, they are not presented.

The geometric mean particle size was consistently larger in Reaches 1 (range 0.39 to 0.51 inches) and 2 (range 0.39 to 0.55 inches) than in the lower two sections. Data for Reach 3 varied from 0.16 to 0.28 inches while the range for Reach 4 was 0.13 to 0.20 inches. Geometric means for both Reaches 3 and 4 increased in response to the runoff peaks.

Fredle indices for deposited material in all study reaches appear to be quite low when compared to the preliminary relationships presented by Platts et al. (1983) between index values and percent survival-to-emergence of eggs from several salmonid species. However, the trend of our data is similar to that for geometric mean particle size and indicates improvement of deposition quality in Reaches 3 and 4 in response to the spring runoff hydrograph.

Table 1. Mean hydraulic characteristics of the four North Fork study reaches at a low and a high discharge.

		Hydraulic Characteristics				
Reach	Discharge (cfs)	Top Width (ft)	Cross-Sectional Area (ft^2)	Mean Depth (ft)	Mean Velocity (ft/sec)	Water Surface Slope (percent)
#1	3.5	19.0	7.1	0.36	0.56	2.6
	39.6	21.6	21.2	0.98	1.90	--
#2	4.2	20.9	4.3	0.20	1.08	4.5
	64.7	23.6	20.5	0.89	3.18	--
#3	3.5	19.8	6.5	0.33	0.52	3.0
	74.6	24.6	26.1	1.08	2.89	--
#4	3.2	16.0	6.8	0.43	0.49	0.4
	101.1	28.1	48.1	1.74	2.23	--

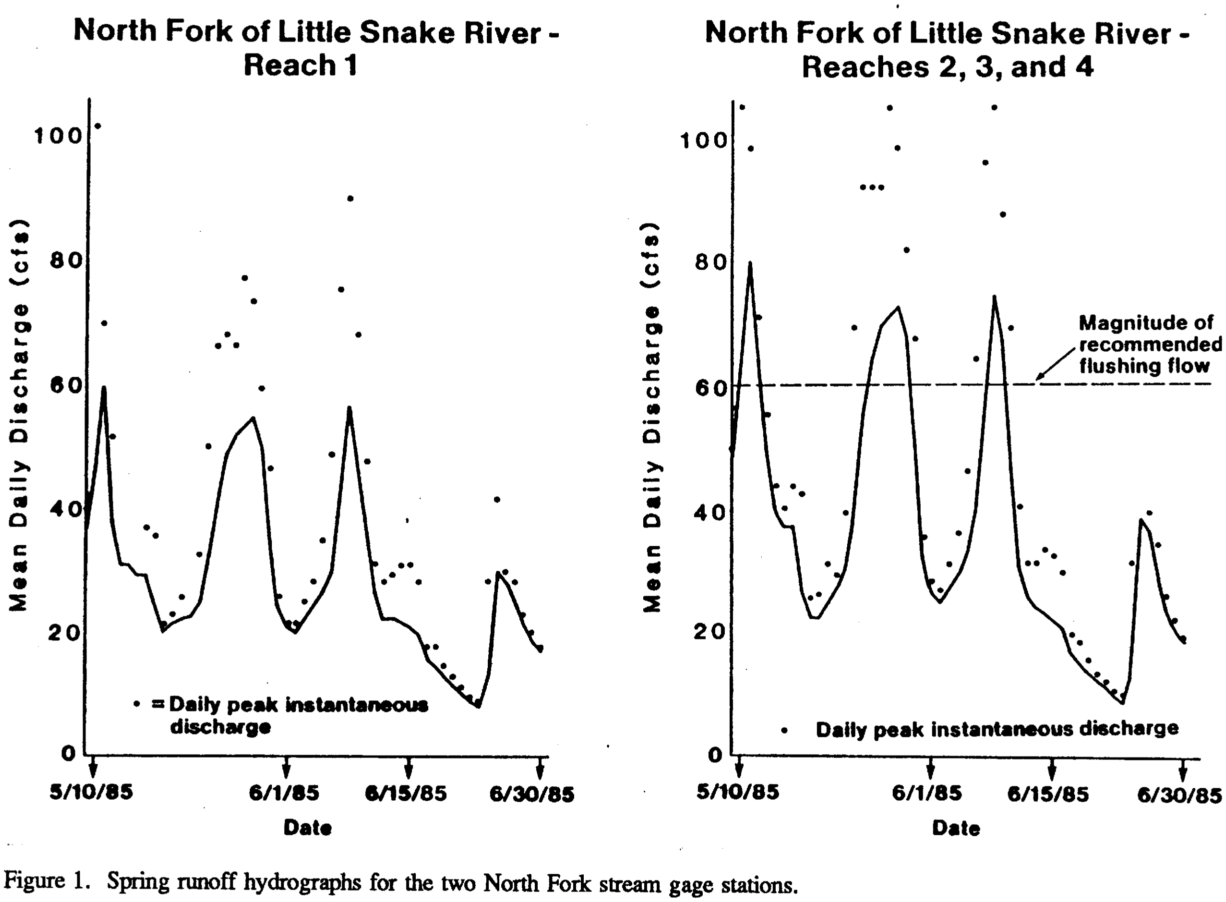

Figure 1. Spring runoff hydrographs for the two North Fork stream gage stations.

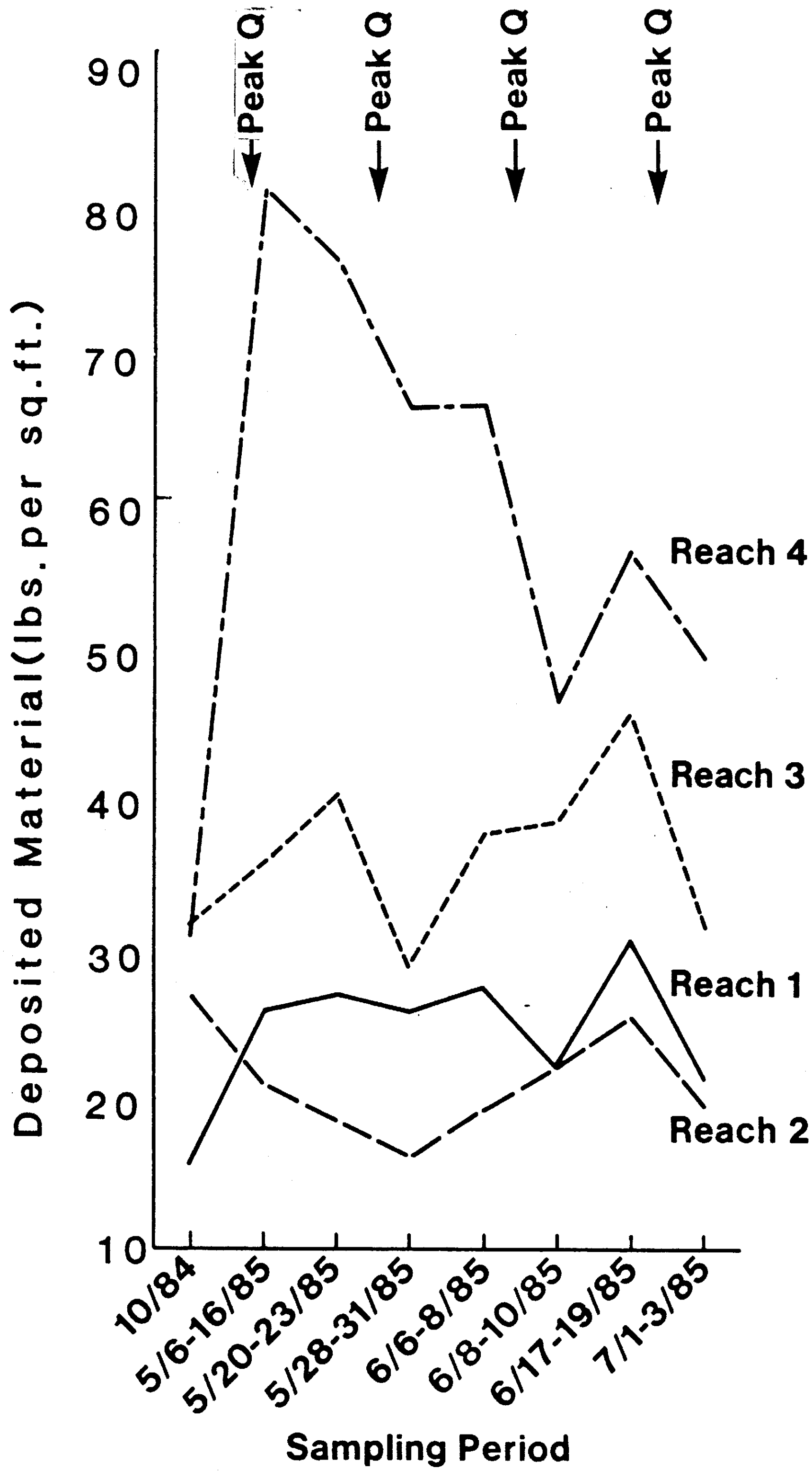

Figure 2. Comparison of deposited material in the four North Fork study reaches in relation to the spring runoff peak discharges.

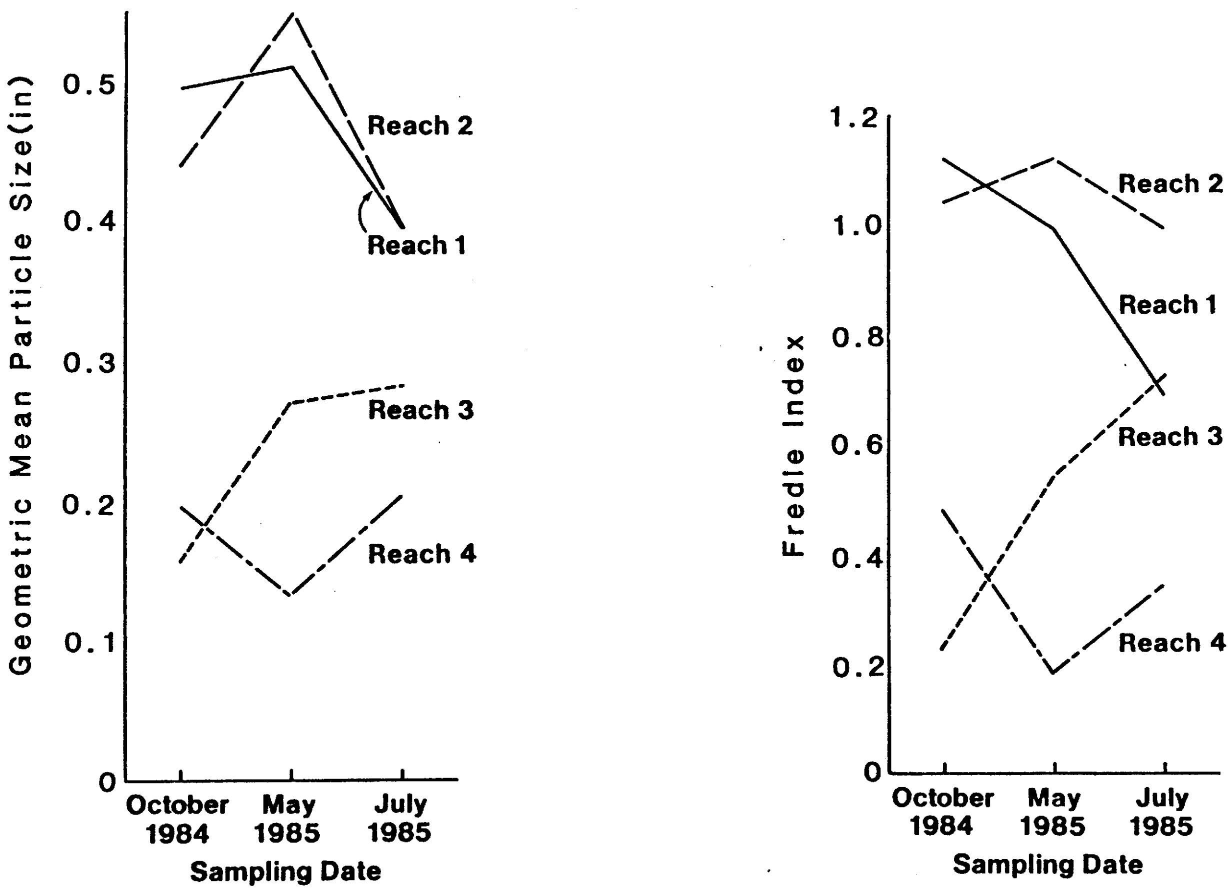

Figure 3. Quality of deposited material in the four North Fork study reaches over time.

Based upon these data, the following conclusions could be drawn regarding the response of the deposited material to the 1985 spring runoff hydrograph:

1. Three spring runoff flushes meeting or exceeding the magnitude and duration of the recommended flushing flow for this section of the North Fork of the Little Snake River were somewhat successful in reducing the quantity of deposited material.

2. Flushing was more effective in steeper gradient reaches, while results regarding duration of the individual flushes are at present inconclusive.

3. As indicated by the Fredle Index, quality of the deposited material was very low throughout the study area.

4. Quality of deposited material showed an improving trend in response to the runoff hydrograph within those study reaches having the largest quantities of deposition.

1986 Flushing Flow Recommendations

In response to a request from the Wyoming Game and Fish Department, mitigative flushing flow recommendations for the North Fork of the Little Snake River during 1986 were developed. The primary basis for these recommendations were: (1) the assumption that the maintenance of pool quantity and quality in stream sections such as Reach 4 is essential to the well-being of Colorado cutthroat trout; and (2) the relationship of the 1985 instantaneous hydrograph to the time series sediment deposition data for Reach 4 (Figure 4). Secondary information also used to justify the recommendations included: (1) flow duration curves for the four 1985 peak runoff events; (2) grain size distributions of deposited materials; (3) grain size distrubutions of sediment moving as bedload; (4) historic runoff patterns from U.S. Geological Survey records; and (5) channel cross-section plots over a range of flows. The recommendations and our justification for them will be found in Appendix A. (At the end of this paper, page 134)

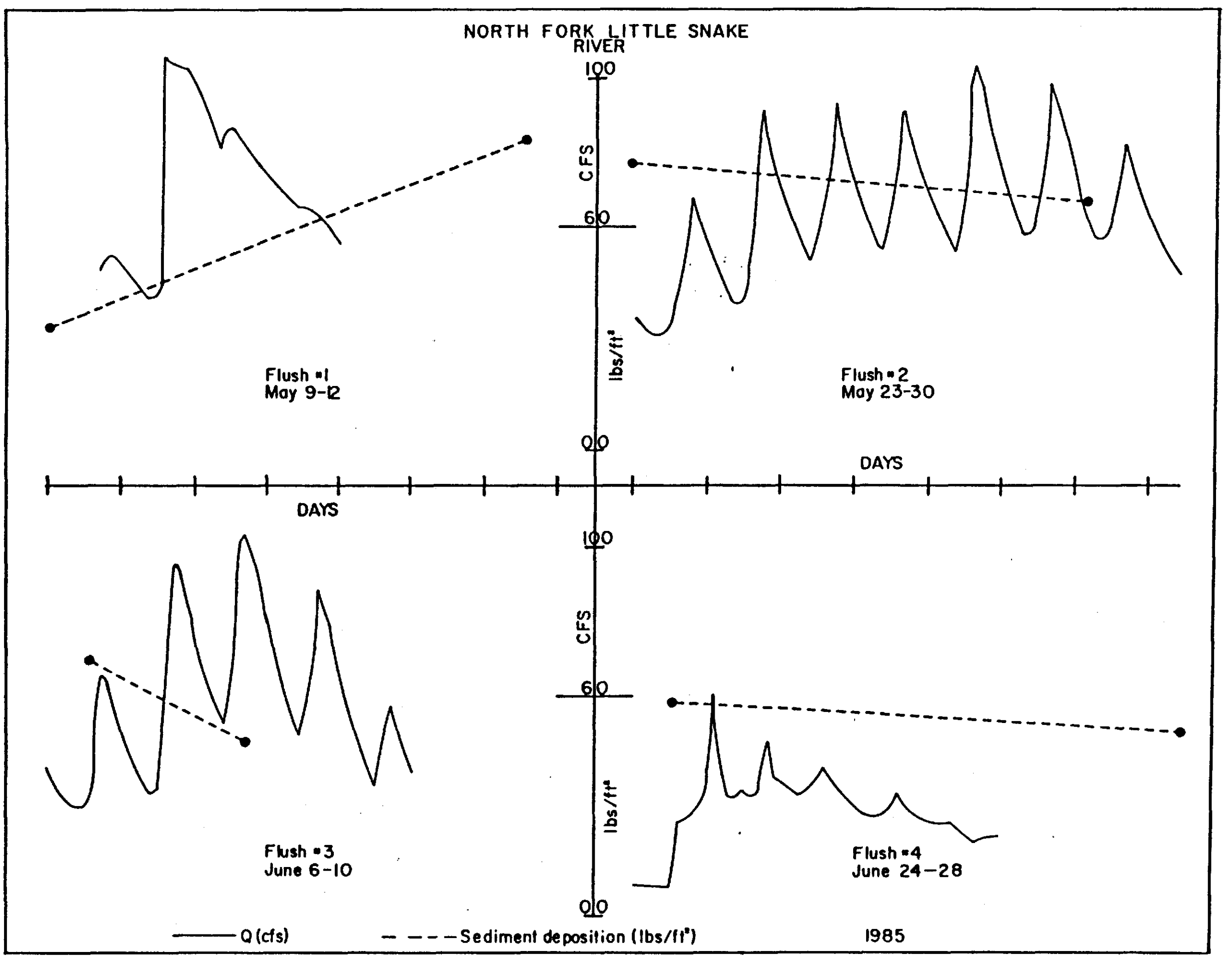

Figure 4. Relationship of 1985 instantaneous hydrograph to Reach 4 sediment deposition over the four runoff events.

Acknowledgements

The authors wish to acknowledge the cooperation of the USDA Forest Service, Medicine Bow National Forest, and the Wyoming Game and Fish Department in the conduct of this research. Special appreciation is extended to the field and laboratory technicians at the Wyoming Water Research Center who participated in the project.

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APPENDIX A

RECOMMENDED 1986 FLUSHING FLOW REGIME FOR NORTH FORK OF LITTLE SNAKE RIVER

Recommendation

Three (3) flushing flow events are recommended for the North Fork of the Little Snake River during the spring-early summer period of 1986. Each event should have a peak discharge equal to or greater than 60 cfs, as measured at the Wyoming Water Research Center stream gage station located on the right streambank at an elevation of approximately 8580 ft above msl, and should have a duration of at least three days from initiation to conclusion. The first flushing event should begin on or about May 19, 1986 and conclude on or about May 22, 1986. The second flush should occur from approximately June 2 to June 5, 1986 and the third event should run from June 16 to June 19, 1986. It should be emphasized that these dates can be slightly flexible depending upon weather and runoff patterns. At the initiation of each flushing event, water should be released at a sufficient rate to achieve a rise of at least 10 cfs per hour in the hydrograph at the Water Center gage station. To best accomplish this, the initial release for each event should be made in mid-afternoon.

Justification

Number of Flushing Events

The assumption is made that the maintenance of pool quantity and quality is essential to the well-being of the Colorado cutthroat trout population in the North Fork of the Little Snake River.

Data collected during 1985 on Reach 4 (low-gradient, pool habitat) indicate that the latter three flushing events were successful in reducing sediment deposition from 82 to 51 lbs. per ft^2 over the period from May 21 to July 1. The first flushing event, May 10-12, resulted in the import of 50 lbs/ft^2 into Reach 4 (32 lbs/ft^2 in October, 1984; 82 lbs/ft^2 on May 15, 1985), 60 percent of which was removed by the latter three flushes.

The 1985 data indicate that three flushing events are necessary in 1986. The first event will serve to concentrate any additional surplus sediments from the upstream steep and moderate gradient reaches in the pools, while the second and third events should be effective in reducing the aggraded material. On the average, the latter three 1985 flushes each removed 10 lbs/ft^2 of aggraded material. If we assume that the target deposition level in Reach 4 is approximately 30 lbs/ft^2 (the October 1984 level), and that material from the early fall 1984 sediment spill had not reached this study section to any great extent prior to our October 1984 sampling, then the result of the latter two 1986 flushes should approach our target level.

Magnitude

The 1985 flushing events were somewhat successful in removing deposited sediments and increasing median grain size of bed material. The peak instantaneous flow during each of the four flushes equaled or exceeded 60 cfs, while for Flushes 1, 2 and 3, 60 cfs approximated the median flow, based upon flow duration analysis. Inspection of cross-section plots indicates that a discharge of 60 cfs covers the active low flow channel in both steep and low gradient sections, paralleling the results reported by Wesche et al. (1977), who recommended 60 cfs as the flushing flow for this portion of the North Fork. Analysis of 1985 bedload composition data indicates that the vast majority of the material being transported at flows greater than or equal to 60 cfs is less than 0.5 inches in diameter. Thus, we would not expect severe disruption of quality spawning gravels given flushing flows of this magnitude.

Duration

Inspection of the instantaneous hydrograph-sediment deposition plot for 1985 indicates that Flush #1 (three day duration) and the first three days of Flush #3 were the most successful that we measured for morning bed material. In contrast, deposition measurements taken after six consecutive days on which peak daily flows had exceeded 60 cfs indicated that Flush #2 was not as effective.

Based upon our 1985 findings regarding diurnal flow fluctuation on the North Fork and our understanding of how the diversion structures will be operated to provide flushing flows (i.e., bypass gates will be completely opened to allow passage of the entire natural flow for a specified duration), we would not expect that flows during each flush would equal or exceed 60 cfs for the entire three-day duration.

Rate of Hydrograph Rise

Clearly, magnitude and duration of events are not the only variables which determine flushing success.

Inspection of the 1985 instantaneous hydrograph-sediment deposition plot indicates that the flushes which moved the most bed material, #1 and #3, also had the steepest slopes on the ascending limbs of the hydrographs. Flush #1 had a rate of rise of 16.4 cfs/hour while Flush #3 rose 10.2 cfs/hour. Flush #4, the smallest event in terms of magnitude and duration, resulted in a net export of 7 lbs/ft^2 from Reach 4, only 30 percent less than that exported by Flush #2. However, the rate of hydrograph rise for #4 exceeded 13 cfs/hour for the main portion of the ascending limb compared to less than 7 cfs/hour for the steepest portions of the hydrograph for Flush #2.

Timing

As water storage is not possible on the North Fork, flushing flow events must be timed in accordance with the spring snowmelt runoff period. Inpsection of the 1985 hydrograph and the discharge records from USGS gage station No. 09-2518 (North Fork of Little Snake River near Encampment, Wyoming; 1957-1965) indicates that the probability of having sufficient streamflow available for the three flushing events is greatest from mid-May to mid-June. As cutthroat spawning activity begins on the North Fork during the latter part of June (Quinlan, 1983), all flushing should be completed prior to this time to prevent egg deposition in areas soon to be dewatered.

The trend of the 1985 sediment deposition data indicates that moderate pool filling occurs between flushing events, but that the peak amount of deoposition between successive non-flushing periods decreases over time. Because of this and also to attempt to coordinate flushing events with normal work week patterns, we have recommended a 10-day non-flushing period between each successive flush.

To achieve the recommended rate of hydrograph rise, flushing events should be initiated during mid-afternoon. Inspection of the 1985 instantaneous hydrographs indicates the most rapid rise in the hydrograph occurs at this time due to snowmelt runoff.

INCREASING IRRIGATION WATER USE EFFICIENCIES AND RESULTING RETURN FLOWS

Donald J. Brosz[1]

Abstract

Improving upon irrigation water use efficiencies and adopting water conservation practices are receiving increasing attention as a solution to problems of inadequate water supplies. These methods are being pursued in lieu of more traditional methods of meeting growing water requirements through construction of more water supply facilities such as dams, conveyance facilities and wells. Since irrigated agriculture accounts for about 80 percent of all the water consumed and 50 percent of the total water diverted or withdrawn in the United States, it is assumed that by increasing irrigation water use efficiencies that substantial increases in the available water supply will result.

The Salt River Drainage Basin (Star Valley) as an agricultural watershed of 829 square miles in western Wyoming provided the opportunity for a study to determine the effects of increased irrigation efficiencies. Starting in 1971 several irrigation projects were completed that converted surface irrigation systems to sprinkler irrigation systems on approximately one-half of the irrigated acres in the valley. This conversion of irrigation systems resulted in less total water being diverted from streams for the sprinkler systems than was the case for the surface systems on the same irrigated acres.

Salt River stream flows were hydrologically analyzed and a comparison made of the flows prior to and after conversion to sprinkler systems. Significant impacts were identified. The mean monthly spring flows in the Salt River increased by 58.7 percent following the conversion to sprinkler irrigation. The study also showed substantially lower flows in the fall and early winter months. Analysis of annual flood peaks revealed that the mean annual flood peak flows increased by 47 percent.

Thus, this study shows that the primary effects of increasing irrigation efficiencies in areas where there is no storage above the irrigated area results in higher flows in the spring months, higher peak annual flow discharges and lower fall flows due to decreases in groundwater recharge. Large increases in spring flows also are causing bank erosion and damages of existing stream structures. The quantity of water available to the area essentially is unchanged but the time it is available has hanged substantially.

The study indicates that a careful analysis of resulting impacts within a watershed needs to be considered before major changes are made in the management of irrigation waters. Negative impacts upon the streamside zone land area and upon the quantity and quality of water may result.

Introduction

In parts of the semiarid West, the availability of sufficient water is one of the primary factors limiting agricultual production. For this reason, the development of irrigation systems with increased water application and conveyance efficiencies has been desirable to make better use of the limited available water. However, increases in irrigation efficiencies may affect stream flows by causing higher flows during the spring months and lower flows during the fall months (Interagency Task Force on Irrigation Efficiency, 1979). These can be undesirable effects especially to the lower portion of watersheds where no storage reservoirs are available in the upper watershed area.

Developments in the Salt River drainage basin (Star Valley) in Wyoming presented an opportunity to document some of the overall hydrologic impacts of increased irrigation efficiencies (Sando, 1985). Between 1971-1974, several irrigation projects were completed which resulted in a conversion from flood irrigation to sprinker irrigation. After the completion of these projects, approximately one-half of the 60,000 irrigated acres in Star Valley were irrigated with sprinkler systems. Those farms that converted to sprinklers increased their on-farm irrigation system efficiencies by an estimated 50 percent. The previous earthern conveyance canal systems were also replaced with underground pipelines on the sprinkler projects. The increased efficiency for delivering water to the farms thus, also increased substantially.

The Salt River has a drainage area of 829 square miles. The area is located on the west central edge of Wyoming. The Salt River flows northerly through the Star Valley for about 50 miles before flowing into the Palisades Reservoir at the lower end

[1]Associate Director, Wyoming Water Research Center, P.O. Box 3067, University Station, Laramie, Wyoming, 82071. Acknowledgements are given to Steve Sando, former University of Wyoming, Agricultural Engineering graduate research assistant who conducted this research for his masters degree thesis and to Dr. John Borrelli, advisor to Steve Sando and former University of Wyoming professor of Agricultural Engineering, now professor, Agricultural Engineering, Texas Tech. University, Lubbock, Texas.

of the watershed near Alpine Junction, Wyoming. The waters forming this river flow out of the Salt River Mountain Range on the east, the Caribou and Webster Ranges on the west, and the Gannett Hills to the south. Peak discharges in the area result from snowmelt runoff in the spring months; flooding due to thunder storms is a rare occurrence.

The Star Valley is a narrow, agricultural valley about 50 miles long and about 15 miles across at its widest point. It is one of the main dairy farming centers in Wyoming. Alfalfa hay and barley are the two main crops produced. The irrigation season typically lasts from late May to early September. Most of the soils in the valley are shallow, gravelly and well drained. Average annual precipitation is between 18-20 inches.

Many of the analyses in this study involved comparison of Salt River flows with the flows of the Greys River. The Greys River flows through a narrow drainage area 448 square miles in size immediately adjacent to Star Valley. The Greys River is essentially devoid of agricultural influence with less than 500 acres being irrigated from this river.

Analysis of Stream Flow Data

As many hydrological and statistical tests as were relevent and practical were employed in this study in an attempt to properly interpret streamflow changes on the Salt River. In all analyses, the period October, 1953 through April, 1971 was assigned to represent the pre-sprinkler period. The period May, 1971 through September, 1982 represents the sprinkler period.

Monthly Flow Comparisons

The double mass analysis was used to test the consistency of the stream flow observations on the Salt River. In this procedure, for each month, yearly accumulated streamflow values of the Salt River were plotted against those of the Greys River. A consistent record will generate a relatively straight line of constant slope. A record in which streamflow changes have occurred will yield a broken line with two or more segments of different slope. The double mass plots for the months of December-April and for the month of July yielded relatively straight lines of constant slopes, indicating little change in Salt River flows relative to Greys River flows during these months after the sprinkler systems were installed.

The double mass plots for the months of May and June showed an upward break in slope in 1971, indicated that during these months Salt River flows increased in the sprinkler period relative to those of the Greys River. The double mass plot for May (Figure1) is representative of the early season plots.

In the late season months (August-November), the double mass plots showed a downward break in slope in 1971, indicating a decline in Salt River flows in these months during the sprinkler period relative to those of the Greys River. The double mass plot for August (Figure 2) is representative of the late season plots. This test is very valuable in discerning the effect of the conversion to sprinklers upon the Salt River streamflow. The close proximity of the Greys Rivers to the Salt River provides that other factors including climatic influences are most nearly identical

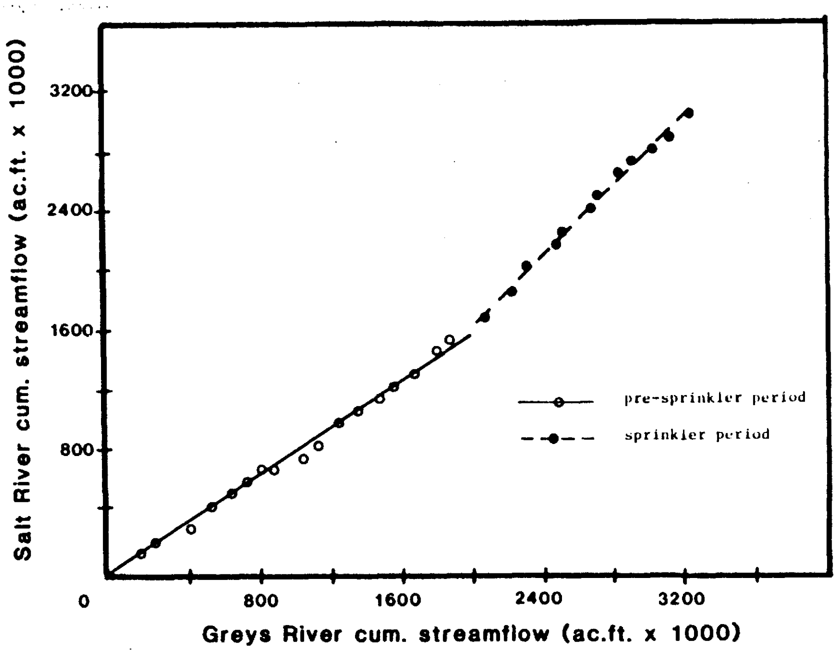

Figure 1. Double mass plot of Salt River flows versus Greys River for the month of May.

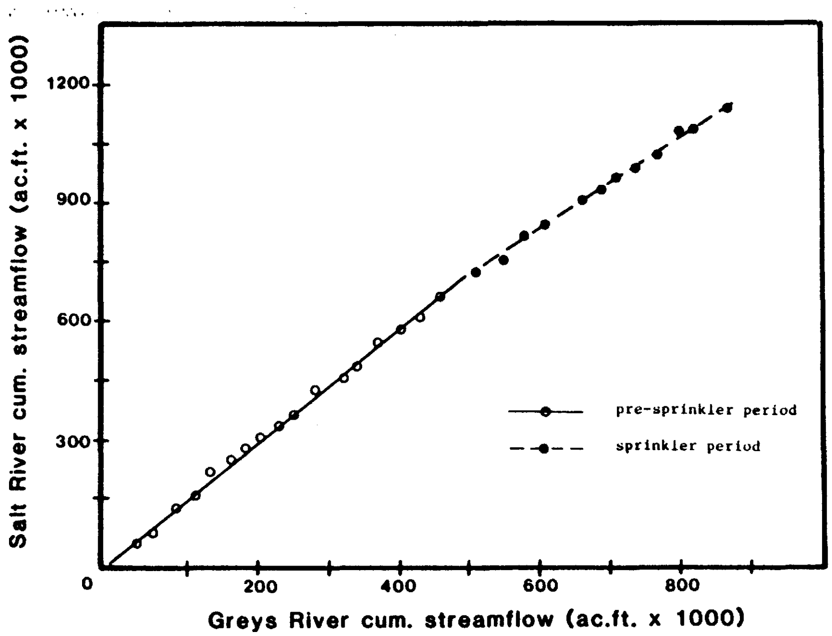

Figure 2. Double mass plot of Salt River flows versus Greys River for the month of August.

between these two drainages. Therefore, this double mass procedure tends to factor out the influence of climatic trends upon changes in the streamflow of the Salt River.

Mean Monthly Flows

The analysis of the mean monthly stream flows for the period of 1953 through 1982 show that during the months of May and June the streamflows were significantly higher since the sprinklers have been installed. The average increase for these two months was 58.7 percent.

A synthetic streamflow procedure was used to simulate what flows for the Salt River might have been in the sprinkler period if the sprinklers had not been installed. This procedural analysis substantiates the trends shown in the double mass analysis as discussed above. The synthetic procedure showed that the Salt River significantly lower in the fall months since the change to sprinkler irrigation. All other months (December-April, July) showed no significant differences.

Annual Flood Peaks

A test procedure was also used to determine whether the peak annual discharges changed significantly following the change to sprinkler irrigation. Using the pre-sprinkler flood frequency distribution, the 50 year recurrence interval flood is calculated to be 2891 cubic feet per second (cfs). This peak discharge was exceeded seven out of the twelve years during the sprinkler period. The hydrologic probability of exceeding the 50 year recurrence interval flood seven out of the twelve years is approximately one chance in 225 (4.45×10^{-3}). This is a very remote possibility which indicates that a significant change has occurred between the pre-sprinkler and sprinkler periods. Several other tests of data indicate the same change in flood peak flows.

Analysis of Other Factors

Where changes were observed in the Salt River flow between the two periods, it was necessary to consider the possibility that other factors besides the irrigation change may have contributed to those changes. Three primary influencing factors were identified and analyzed to determine their contribution to streamflow changes. These three factors were climatic trends, changes in crop water use due to increased crop production following the conversion to sprinklers, and urban construction trends.

Climatic data (mean temperature and precipitation) from Star Valley was analyzed similarly to the streamflow analyses, employing mean comparisons between the two periods and double mass analyses with data from surrounding stations. None of the tests employed revealed significant trends that would have contributed to the streamflow changes. In fact, the climatic trends that were observed tended to be opposite to those expected from the streamflow changes and therefore, the climatic trends may have served to obscure some of the effects of the sprinklers. This is especially true during the fall months where an increase in precipitation of 22.7 percent in the sprinkler period may have obscured the expected decline in streamflows during these months.

The effect of changes in crop water use was analyzed by estimating yield increases following the conversion to sprinklers and then employing a crop water function based on yield (Hill, 1983) to estimate the increase in crop water use. This increase in crop water use was then compared with the deviation in observed streamflow from the expected streamflows determined by the synthetic flows analysis. This procedure gave an estimate of the portion of reduced streamflows in the late summer and fall months that might be attributable to increases in crop water use. This analysis was performed for the months of August and September when the influence of crop water use on streamflow would be most pronounced. The results of this analysis indicated that increases in crop water use accounted for approximately 40 percent of the streamflow decline in August and approximately 30 percent of the decline in September. While these are relatively large contributions, the biggest factor contributing to the streamflow decline during these months was the reduction in groundwater inflow due to less groundwater recharge with the sprinkler systems.

The impact of urban construction trends was also considered as possibly contributing to streamflow changes. Wyoming Highway Department and Lincoln County personnel were interviewed to determine whether major increases in road or building construction occurred during the study period. The interviews revealed that no significant construction had occurred which might have contributed to the observed changes in streamflow.

Irrigation and River Basin Hydrology
(Interagency Task Force Report on Irrigation Water Use and Management, June 1979)

Basic principles of irrigation water diversions, application, and utilization need to be considered in relationship to efficient use of such water. Figure 3 shows the relationship between irrigation diversions, water use, and river basin hydrology.

To deliver a given amount of irrigation water to an irrigated crop, it is necessary to divert from the supply source (7) (numbers are located on sketch on Figure 3) in amounts of water greater than that to be consumed by the crop. This diverted water may include return flows from other areas.

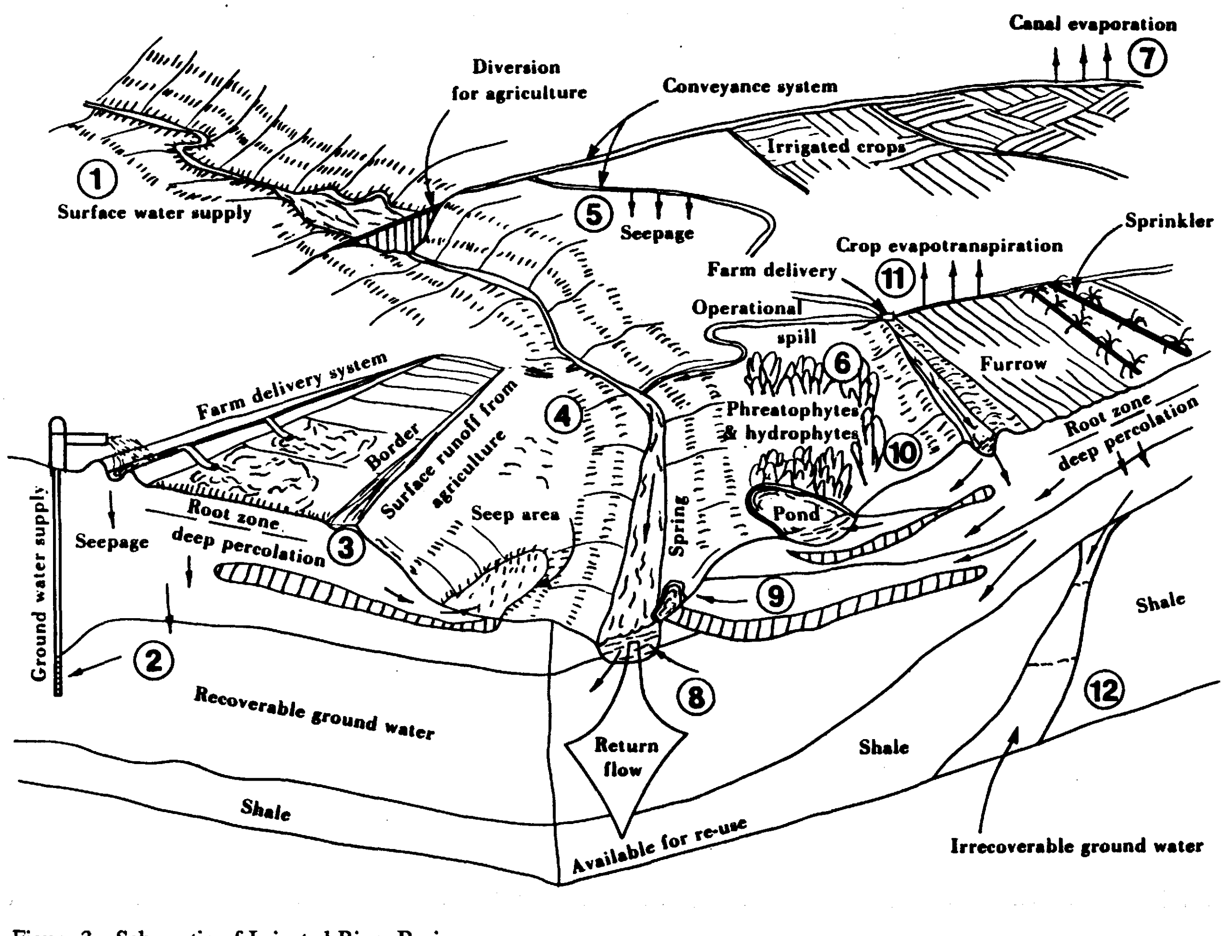

Figure 3. Schematic of Irrigated River Basin

Diverted water may leave the irrigated area as crop evapotranspiration (11), seepage (5) from the conveyance system (canals and on-farm ditches), operational spills (6), deep percolation (3), (water moving deeper into the soil than the crop roots), tailwater runoff (4) (water running off the end of the field), evaporation (7), or as phreatophyte and hydrophyte consumption (10).

Seepage varies depending on the condition of the canals and on farm ditches. Piped or lined conduits have lower seepage amounts than earthen unlined canals and ditches. Most seepage and deep percolation waters return to natural stream systems either directly via drains or indirectly through groundwater aquifers (9). Tailwater runoff, often referred to as return flows, which reach natural stream channels again become available for instream or downstream diversion (8) as do the returned seepage and percolation waters. However, the return flow water quality may be degraded. The recharge to aquifers can result due to irrigation practices which serves to maintain groundwater supplies (2).

High early-season streamflows from snowmelt are diverted near the headwater. The entire diversion, irrigation, and return flow process may take from a few hours to a few months. The delays occur when a significant amount of flow returns through the groundwater system. These returns supplement the later season low flows that normally occur. The net effect is similar to reservoir storage in the basin. Thus, large increases in system efficiencies of "upstream" irrigation projects may require additional water storage to provide the same downstream water supplies later in the season.

Operational spills (6) result from a reduction in demand for water within the system after the water has been withdrawn from the supply source. These spills usually return to the natural stream channels via wasteways and become available for instream or downstream uses.

Phyreatophyte or hydrophyte consumption (10) is noncrop vegetative transpiration of water that may occur adjacent to streams and channels, or in areas of shallow water tables. The existence of such vegetation often provides or enhances wildlife habitat.

A small quantity of deep percolation (3) (movement of water downward below crop root zone) is necessary to remove salts that would otherwise accumulate within the root zone, hampering and eventually prohibiting plant growth. This water is referred to as the leaching requirement and the quantity depends on soils, crops grown, climate, and water quality. Depending on geologic conditions, deep percolating water may slowly flow to deep aquifers or may enter stream systems through natural or manmade drainage systems. Deep percolation is often excessive as a result of poor irrigation management or nonuniform application inherent in many irrigation systems.

Filling the root zone on graded irrigation systems results in tailwater runoff (4) at the lower end of a farm field. The amount of runoff depends on soil conditions, irrigation system design, and water application methods. Some tailwater runoff may be unavoidable when graded surface irrigation systems are operated to achieve adequate infiltration and water application uniformity. Tailwater may evaporate, percolate, be consumed by phreatophytes, or reach stream channels as surface or groundwater return flow. Runoff may be collected on-farm and pumped back into the deliver systems for reuse, or may be intercepted by other users as a supplemental or primary water source.

Diverted irrigation water that recharges a groundwater aquifer (2) through seepage or deep percolation adds to the water supply available to groundwater users. Some farms and small communities depend on these replenished supplies. In some cases aquifers are used to store and distribute excess surface supplies. "Irrecoverable groundwater" (12) is groundwater resulting from seepage or deep percolation that is not recoverable or usable.

Return flows (4, 6, 9) to natural stream channels resulting from tailwater runoff, drainage flows, operational spills, or groundwater discharge may provide all or a portion of a downstream user's water supply. Return flows from irrigation sources often increase the sustained flow in smaller streams to the extent that the stream can support limited fisheries not otherwise available.

Diverting less water for irrigation would generally not change the consumptive use on the irrigation project significantly. Additional water would be available for nonconsumptive instream uses between the points of diversion and return flow. The water would be available during the time the diversion would have been made, in the absence of reservoirs to store it.

Many irrigation projects have been developed, at least in part, in consideration of return flows and reuse. The streamflow in the lower reaches of most streams does not consist of new water, but of return flows of water previously diverted from the system in the upstream reaches. Thus, the system of storage and return flow provided by current irrigation practices affects other water-related development. Any irrigation improvements which alter this system need to be carefully considered.

Additional Studies

Irrigation and return flow studies are also underway by University of Wyoming faculty on the New Fork River, a tributary of the Green River in the Pinedale, Wyoming area. The purpose of this study is to evaluate the effects of irrigation diversions and their resultant uses on the flow dynamics of the stream system. Within this content, the importance of the interaction and it attendant return flow characteristics to the stream system are being evaluated in some detail in terms of storage and release within the aquifer system. A surface water-groundwater accounting model is being developed to evaluate the irrigation practices and yearly flow of the stream system. The study is being conducted under the direction of Dr. Victor Hasfurther through the Wyoming Water Research Center located at the University of Wyoming.

Conclusions

This study has described some of the hydrologic effects of increased irrigation efficiencies. As hypothesized, the primary effects of increasing irrigation efficiencies are higher flows in the spring months, higher peak annual discharges and lower fall flows due to decreases in groundwater recharge. Large increases in spring flows can cause bank erosion and can affect structures designed according to hydraulic variables. The possibility that increased spring streamflows higher peak annual discharges and decreased fall streamflows may result from projects designed to increase irrigation efficiencies should be considered in irrigation project design. Where these effects appear likely to occur, procedures to alleviate the problems may be considered and be incorporated into the project design.

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CONVEYANCE LOSSES DUE TO RESERVOIR RELEASES

Victor R. Hasfurther and Randy A. Pahl[1]

Abstract

Three natural streams in Wyoming were studied in order to estimate incremental conveyance losses associated with incremental increases in stream flow. For each study area, all surface water inflow and outflow was measured before, during and following a significant reservoir release. With this data, conveyance losses were determined for the control period using a water budget analysis. The major losses were attributed to bank storage and a decrease in groundwater inflow. The conveyance loss results for the three study areas ranged from 0.34 to 1.66 percent per mile. Duration of release, of five times (3 days to 15 days), resulted in a decrease of the conveyance loss by over 50 percent (0.76 to 0.38 percent per mile).

Introduction

The recent growth in the areas of energy development and, to a lesser extent, agriculture and municipalities has increased pressure on available water resources throughout the U.S., and especially the Western U.S. and Wyoming with its prior appropriation doctrine (first in right, first in use). In order to satisfy these increased needs, it has become necessary to develop unappropriated water or to transfer water already appropriated for other uses. Energy development companies and municipalities have found it necessary to purchase agricultural water rights and then petition for a change in use, a change in place of use, and a change in the point of diversion of these water rights. Wyoming water law allows these changes to occur, provided the Board of Control feels that certain conditions stated in the State statutes are met. The Wyoming State Statutes, Section 41-3-104(a) declare:

> "...The change in use, or change in place of use, may be allowed, provided that the quantity of water transferred by the granting of the petition shall not exceed the amount of water historically diverted under the existing use, nor exceed the historic rate of diversion under the existing use, nor increase the historic amount consumptively used under the existing use, nor decrease the historic amount of return flow, nor in any manner injure other existing lawful appropriators..."

In order to protect downstream prior appropriators when water is transferred to a point downstream, conveyance losses need to be assigned to the transported water. However, there is a scarce amount of technical data available to aid the State Engineer and Board of Control in Wyoming in determining values of conveyance losses that would be equitable to all parties concerned. Many decisions in the past have been based on the best estimates of the people managing the stream in question. This is not unrealistic, and in many situations the only reasonable method available, but better quantification of conveyance losses would be more desirable from a technical and administratively defensible position.

Factors Affecting Conveyance Losses

When discussing conveyance losses in a stream, it is first necessary to define the term "losses." There are losses associated with the total flow in the stream that will exist year round. There are also losses associated with an incremental increase in the natural flow that will only exist when the increase exists. This increase may be the result of a reservoir release or a change in the point of diversion of an existing water right. In a case involving an incremental increase in flow due to a water transfer or reservoir release, the problem arises as to which "losses" the water user should be responsible. There are those who feel that a percentage of the total losses should be assigned to the increase, while others feel that the incremental losses associated with the increased water in the stream should be used. The amount of the increase in relation to the natural flow will partly determine which loss is the greatest. The incremental loss approach was taken in this paper due to the difficulties involved in determining total losses and the fact that if the conveyance losses associated with the increased water are completely borne by the party involved then no injury should result to any prior right appropriator of the water in the stream.

A large number of factors (> 15) affecting conveyance losses complicates the determination of the losses. M.C. Hinderlider, former Colorado State Engineer, discussed the difficulties involved in determining conveyance losses. Hinderlider states: "These factors alone, through hundreds of different combinations and changes daily imposed by the elements of nature, may produce a million different results having a direct bearing on this complicated problem....All of these factors are seriously affected from time to time by periodic changes in the hydrologic cycle, and in the

[1]Professor, Civil Engineering and Acting Director, Wyoming Water Research Center, P.O. Box 3295, University of Wyoming, Laramie, Wyoming 82071; and Hydrologist, Western Water Consultants Inc., 611 Skyline Road, Laramie, Wyoming 82070.

normalcy of the rate and amount of precipitation, which have profound effects upon the underground water table of a drainage basin, and the rate and amount of return flow tributary to any natural water course" (Wright Water Engineeers, 1970).

In an effort to simplify its quantification, Colorado's administrators and engineers have split the conveyance losses that are chargeable to reservoir releases into four major components: evapotranspiration, inadvertent diversions, channel storage, and bank storage (Livingston 1973; 1978; Luckey and Livingston 1975; Wright Water Engineers 1970; 1982). In addition to these components, this paper includes a fifth component of loss which results from a decrease in groundwater inflow. These five components, to a large degree, include the effects of the many factors important to incremental losses in a perennial stream. Changes in any one of these five major components can influence the amount of the incremental conveyance losses. Several studies have been performed in an attempt to define the extent to which some of these components influence the hydrologic cycle of the stream and concurrently influence losses.

Studies on incremental conveyance losses in stream systems have resulted in loss estimates from 0.35 percent per mile to essentially zero for small incremental amounts of flow on large stream volumes on perennial streams (Livingston 1973; 1978; Luckey and Livingston 1975; Wright Water Engineers 1970; 1982). It was found that ephemeral type streams could produce much higher losses, 11.5 percent per mile (Wright Water Engineers, 1980), on the average, compared to perennial streams.

In Wyoming, very little information and essentially no detailed field studies on conveyance losses had been made in the past. In the future, it is expected that more transfers of water from upstream locations, either through building of reservoirs or transfer of water rights, will occur to downstream locations because of increased development. Since the mode of transportation will most likely be the natural stream channel, a study on incremental conveyance losses was undertaken, and the results are presented in this paper.

Study Areas

The initial studies were to test a method of analysis on reservoir releases to be conveyed to downstream owners of the reservoir storage. Three study sites were selected on perennial streams. These study sites were:

1. A portion of Piney Creek that extended from a point where Lake DeSmet discharge water enters Piney Creek to the confluence of Piney Creek and Clear Creek near Ucross, Wyoming. This stream reach traverses a total of 22 miles through a narrow valley comprised of alluvial deposits.

2. A portion of the Laramie River from Wheatland Reservoirs Nos. 2 and 3 to the confluence of the Laramie River and Sybille Creek near Wheatland, Wyoming. This stream reach is a total of 51 miles. The first ten miles of the study reach traverses through a wide valley containing alluvial deposits, and then cuts through the Laramie Mountains in a narrow precipitous canyon consisting of Precambrian rock for a distance of 27 miles. The river then exits the canyon and traverses approximately 14 miles in a narrow valley containing flood plain deposits.

3. A portion of the New Fork River near Pinedale, Wyoming, was studied from New Fork Lakes to a point approximately eight miles downstream. In this reach, the river traverses a distance of approximately one mile through glacial deposits, and then enters an narrow valley consisting of alluvial deposits.

Methodology

At each study site, a network of stream gages was established at all locations of surface water flow into and out of the main stream system. Some flows were not monitored since they remained fairly constant during the study periods and were generally small. Continuous stage recorders were installed at all flow measurement locations, and stage-discharge rating curves were developed.

With the recorders installed, the system was then monitored for a period of time to insure that the surface flows in and out of the system were relatively stable; i.e., gains into the creek from groundwater, irrigation return flows, and ungaged surface flows were constant. Once a stable condition was maintained, additional water was released from reservoir storage to provide an incremental increase in flow. This increased flow was then maintained for a period of several days (short, 3 days, to longer time periods 15 days), after which time the flow was reduced to approximately the same rate that existed prior to the reservoir release.

The hydrologic budget approach was used in the analysis of the collected streamflow data. This method required a comparison of the quantities of inflow and outflow in order to determine conveyance losses. In general terms, the water budget relationship can be written as

$$O = I - D + G \quad (1)$$

where: O is the servace flow out of the system,
I is the surface flow into the system,
D is the surface flow diverted out of the system, and
G is the gain or loss in the flow in the entire system.

In the above equation, the 'G' term is a lumped variable which conatins the effects of groundwater flow and all sources of loss, such as surface evaporation, evapotranspiration, etc., and can be either positive or negative in sign. All of the rivers discussed in this paper were gaining at the time of the data collection, so the 'G' term was considered to be positive in the analyses. However, if a stream is losing, the approach discussed here is still applicable.

Incremental losses in the system due to the reservoir release are defined by this approach as the decrease in the gains or the increase in the losses during an increase of surface flow. The incremental loss can be calculated by manipulation of Eq. (1).

$$L = [\Delta I - \Delta D] - \Delta O \quad (2)$$

where: L is the incremental loss due to the release,
ΔI is the increase in the surface inflow due to the release,
ΔD is the increase in diversions during the release, and
ΔO is the increase in the surface outflow due to the release.

All of the components of Eq. (2) are in the same units (i.e., cfs or acre-feet)

Eq. (2) provides a simple means for determining the losses associated with a reservoir release based solely on surface flow records. With this relationship, losses can be computed either in terms of the flow rate or the volume of the reservoir release by solving Eq. (2) in units of c.f.s. or acre-feet, respectively. Some adjustments need to be made to account for travel times. Certain limitations exist on the use of Eq. (2).

In the first place, all sources of loss are lumped together into one value. Included in this value are losses due to bank storage, channel storage, a reduction in the groundwater contribution, and an increase in surface evaporation and evapotransiration. Determination of each of these separate losses would require more field data than was collected in this study.

Secondly, use of Eq. (2) is limited to time periods when meteorological conditions are fairly consistent. Precipitation and its effect upon the surface and subsurface flows are not accounted for in this relationship. In most of the cases studied, there was negligible rainfall during the study periods; so this was not a problem.

Perhaps the most important limitation on the use of Eq. (2) pertains to the stability of the study area. Since this relationship determines the change in gains during a reservoir release, it is necessary that the flow regime in the study area is in a stable condition with relatively constant gains. This will ensure that the calculated decrease in gains is mainly due to the introduction of additional water into the stream. Any large changes in activities, such as irrigation, during the study period could affect the amount of return flows which, in turn, could affect the gains measured before, during and after the reservoir release.

The rating curve for each gage within the system was used to develop hydrographs which formed the basis for the determination of the conveyance loss. It became apparent from the measured losses that they were small enough to be affected by the degree of accuracy of the established rating curves. As a result, 95 percent confidence limits were place on rating curves in an attempt to better quantify the accuracy of the conveyance losses.

Results.

The analysis of results will be shown only for the Piney Creek study area, but all three study area results will be summarized at the end of this discussion. More details on both the methodology and results of the study areas can be found in Pahl (1985) and Hasfurther, et al. (1985).

Fig. 1 indicated the results of one of the two reservoir releases on Piney Creek. The hydrographs shown have not been adjusted for travel time. In order to make this data more understandable, the diversion hydrograph was first adjusted for travel time and was then subtracted from the inflow hydrograph, with the results indicated on Fig. 2. This plot is easier to read, and it clearly shows the relatively constant gains that existed in the system prior to the reservoir release. As discussed earlier, a stable system with constant gains is one of the prerequisites for the analysis technique used.

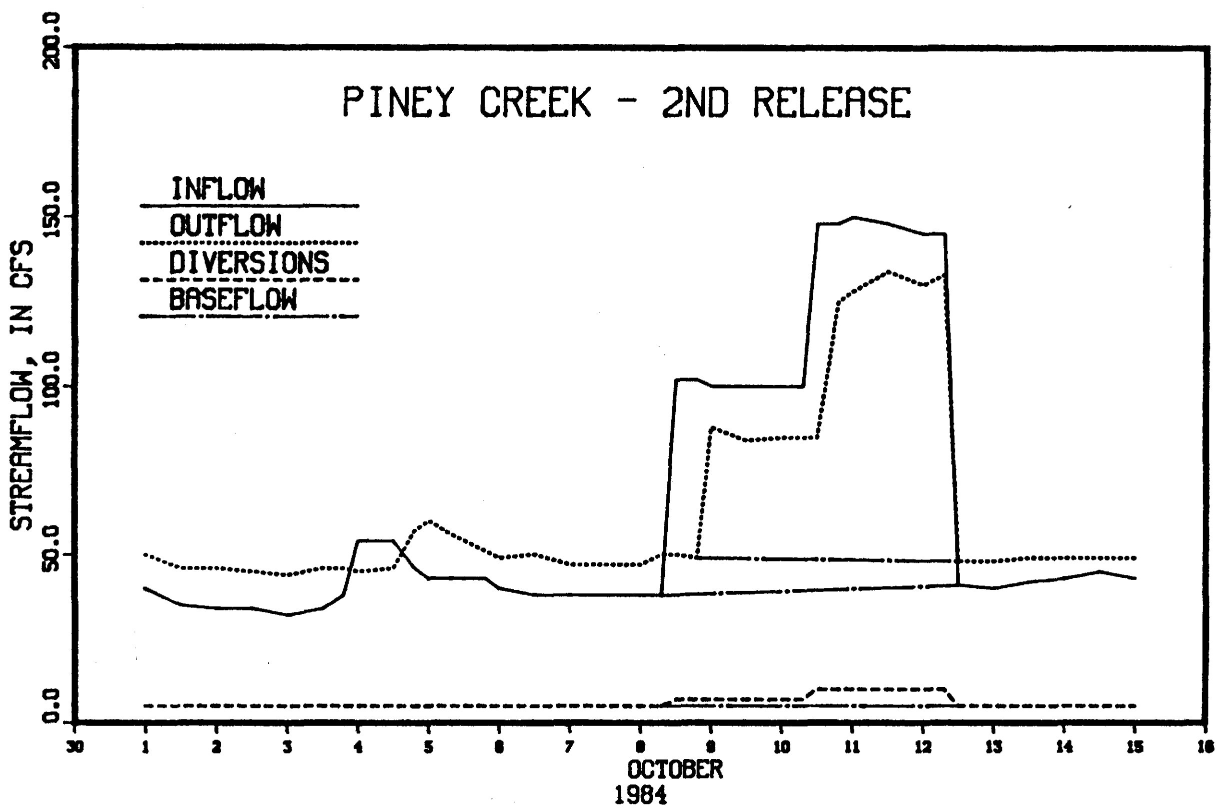

Fig. 1. Piney Creek Inflow, Outflow, and Diversions, 2nd Release.

With the stability of the system confirmed, Eq. (2) was utilized to estimate the conveyance loss associated with the release. Changes in the diversions during the release were significant; however, the amounts were not due to inadvertent diversion and, thus, the increase in the diversion term was accounted for in the analysis. It was, therefore, not included as part of the conveyance loss value. The ΔI and the ΔO terms were defined as that amount of additional flow in and out of the system, respectively, due to the reservoir release. To determine quantities for these terms, it was first necessary to estimate the base flows that would have existed had there been no release. This was accomplished using the most simple base flow separation technique which results in a straight line, on the hydrograph, connecting the flow prior to the release to the flow following the release (Fig. 1). The flow above these lines was then used to determine values for ΔI, ΔO, and ΔD. Losses were determined in terms of flow rate and volume.

Using this approach, the increase in the inflow was calculated to be an average of 84.6 c.f.s. for a period of 4 days, or a total volume of 670 acre-feet, while the average increase in the outflow was calculated to be 56.3 c.f.s. for a period of 3.66 days, or a total volume of 408 acre-feet. The average increase in the diversions was estimated to be 3.7 c.f.s. for a period of 4 days, or a total volume of 30 acre-feet.

With these values, the average conveyance loss was calculated to be 24.6 c.f.s. or 232 acre-feet. These loss figures were then converted to as percentage of the net inflow; i.e., the inflow minus the diversions. Due to the difference in the time bases of the inflow and outflow hydrographs, the volumetric loss was larger than the loss based upon the flow rate, with values of 1.66 percent per mile (volumetric) and 1.39 percent per mile (flow rate). Using volumetric values, the conveyance loss calculations were repeated with the 95 percent confidence limits placed on the hydrographs. Use of these limits resulted in a range of possible conveyance losses from 1.31 percent to 1.99 percent per mile of river. The results of these calculations are summarized in Table I, along with the other analyses made on all study areas.

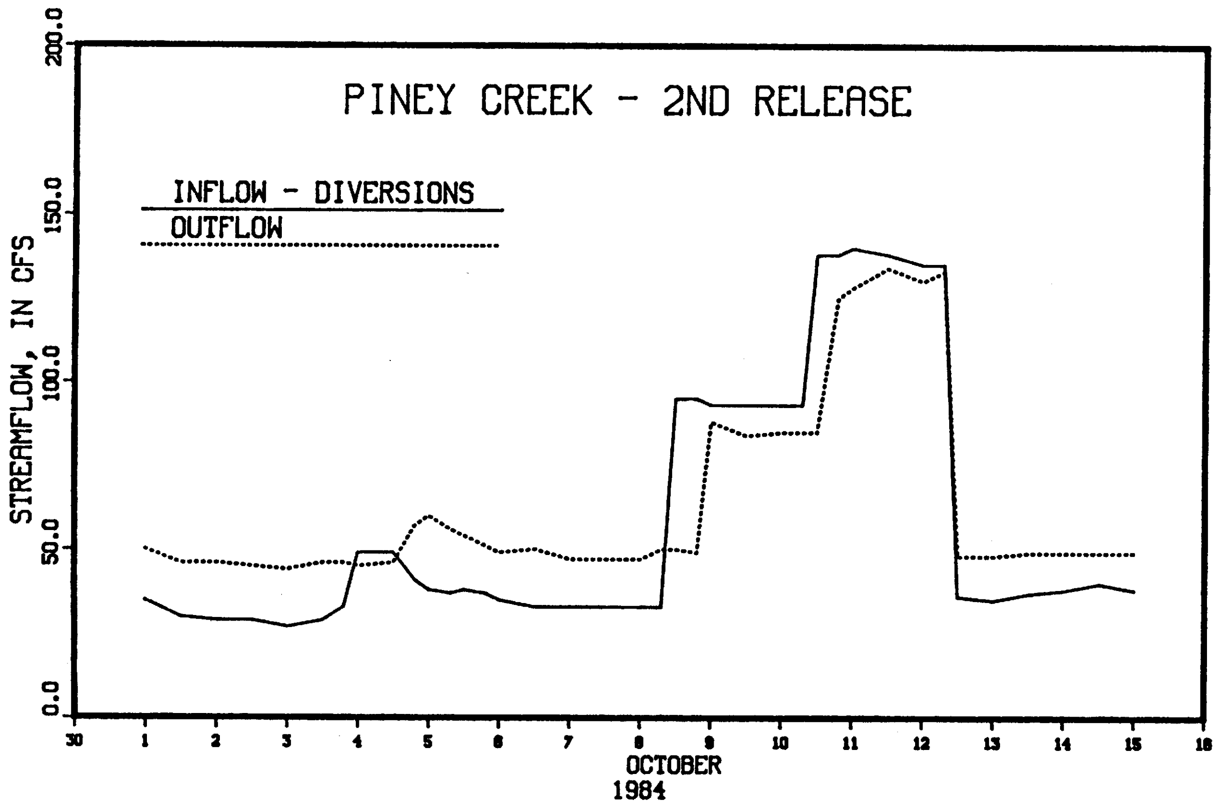

Fig. 2. Piney Creek Net Inflow and Outflow, 2nd Release.

The release shown for Piney Creek indicates that the majority of the measured loss is due to bank storage and a reduction in the groundwater inflow. During this release, the stage of the river rose an average of 0.47 feet. This increase temporarily forced water into the banks and prevented the surrounding groundwater from entering the creek. As the hydrographs on Fig. 2 show, the creek because influent during the release, losing water to the subsurface system. However, near the end of the release, the losses due to a decrease in groundwater inflow to the stream approached zero. This suggests that the stream was approaching a condition where the losses were negligible had the duration of the release been of sufficient length.

Several other releases were made on Piney Creek to try and determine the effect of time duration on the percentage of conveyance loss. Table II illustrates the results obtained when increasing the time duration from 3 days to 15 days.

This illustrates the fact that over time the groundwater system adjusts to the new flow regime and the amount of decrease in groundwater inflow and bank storage resulting from the initial increase of flow in the system is decreased with time duration as suggested by Fig. 2.

Summary

With all of the releases that were studied, it was assumed that evapotranspiration and channel storage had a minimal effect on the measured conveyance losses. This assumption agrees with the results obtained by Livingston (1973) in his study of the Arkansas River. Bank storage and reductions in the groundwater inflow were considered to be the major source of losses in the streams discussed in this paper.

The data collected for the Piney Creek study area demonstrated the high rate of loss that is typically experienced at the beginning of a reservoir release. However, in a perennial stream such as Piney Creek, the rate at which water is lost will decrease with time. As the groundwater table rises in response to the release, it is possible for the losses to continue to become smaller with time as illustrated in Table II. With this in mind, it can be stated that the longer the duration of a release in a perennial stream, the smaller will be the conveyance loss.

Table I
Summary of Conveyance Loss Results

Study Area	Average Increase of Inflow, c.f.s.	Average Increase in Stage, feet.	Loss % per mile	Upper 95% Confidence Limit, % per mile	Lower 95% Confidence Limit, % per mile
Piney Creek, 1st	41.8	0.18	0.76	1.49	0.00
Piney Creek, 2nd	84.6	0.47	1.66	1.99	1.31
Laramie River					
Lower Reach	114.6	1.02	0.34	1.0	*
Upper Reach	91.3	0.35	* *	*	
New Fork River	203.3	1.26	0.85	3.27	*

*Results showed an increase in gains

The water that was considered to be lost due to the releases in Piney Creek, the lower reach of the Laramie River, and the New Fork River was not actually lost to these systems, but was merely detained in the alluvial materials bordering these streams. In the case of Piney Creek, it was assumed that a majority of the detained water returned to the river following the recessions of the release hydrographs. However, since the hydrographs showed little evidence of this actually occurring, it was assumed that the stored water was released at a rate which was initially high (very small in comparison to total flow), but rapidly decreased with time. A similar observation was made by Livingston (1973).

The data collected in 1984 and illustrated in Table I at the three study areas resulted in loss values ranging from 0.34 to 1.66 percent per river mile. These results are rather high compared to those measured by studies indicated earlier in the paper, which ranged from zero to 0.35 percent per river mile in Colorado. Several factors could have accounted for the differences in the results.

In the first place, the durations of the releases in previous studies were generally longer than those report in this paper even with the longer time duration illustrated in Table II on Piney Creek. As stated earlier, the longer the duration of the release, the smaller the incremental conveyance loss in terms of percentages.

Secondly, a difference in geologic conditions between the Wyoming and previous study areas could have accounted for the contrast in the results. For example, the hydraulic characteristics of the material surrounding a study reach can have a large influence on the rate at which water from the stream will enter the banks during a release.

Another reason for the dissimilarity between the results could be the fact that the previous study

Table II
Time Duration Effect on Conveyance Losses

Study Area	Change in Inflow, c.f.s	Change in Outflow c.f.s	Change in Diversions c.f.s.	Average Conveyance Loss c.f.s.	Loss % per mile
Piney Creek (3 days)	41.8	34.8	0	7.0	0.76
Piney Creek (15 days)	119.2	89.6	19.6	10.0	0.38

reaches were several times longer than the Wyoming reaches. In general, a short reach will experience a smaller total loss of water than will a long reach. Since the accuracy of many gaging stations' records is in the neighborhood of ±5 percent, any small losses in this range will be difficult to detect. The larger losses in the longer reaches will be affected to a lesser degree by uncertainties in the gaging stations' records. As such, the data collected from studies of long reaches will possiby yield more reliable results. This makes it difficult to compare the results from studies of short reaches to those of long reaches. The effect that the uncertainties in the flow records has on the conveyance loss results from short study reaches can be large, as shown with the 95 percent confidence limits listed in Table I.

Acknowledgements

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DATA NEEDS, TIME AND ECONOMICS IN RIPARIAN MANAGEMENT DECISIONS

James J. Jacobs[1]

Abstract

Regardless of the resource management problem being addressed, there are some general procedural steps that can be followed in evaluating alternative management practices. These main aspects or procedural steps in management decisions are as follows:

1) Identification of problem and objectives
2) Identification of management techniques and their associated costs
3) Quantification of physical response from management techniques
4) Valuation of the physical response
5) Selection of the management techniques

While these procedural steps appear to be straight forward, riparian management decisions are generally quite complex. This complexity exists because of: (1) the multiple use aspects of riparian lands; (2) the potential impact on water quantity and quality; (3) interrelationships among climate, soils, uses, management and the productivity of riparian lands; (4) the possibility of alternative management strategies with associated cost and effectiveness; (5) the extended life of the response from riparian practices and (6) the difficulty in valuing all the effects of riparian management decisions. These complexities of water management decisions can only be addressed in the framework outlined above and if accurate technical information is available.

The relevance of these general procedural steps can be illustrated in the economic analysis of a proposed riparian management practice. The economic evaluation of a management practice is always based upon some stated objectives and assumptions. Furthermore, the economic analysis requires that accurate technical information is available on the management practice being considered and the physical response associated with that practice. At this point, the cost of the management technique and the value of the associated response must be determined. Since long periods of time are usually involved, these values are generally expressed in terms of present value. Finally, the alternative management techniques being considered must be compared. Thus, the economic analysis requires that the general procedural steps be completed. In completing these steps, any major weaknesses in the proposed practice should be pointed out to both the researcher and decision-maker for possible further consideration. Following this general procedure should help in providing the information needed to improve riparian management decisions.

Introduction

It is interesting to note that riparian lands and economics have a concept in common. The concept referred to in both disciplines is that of a "steady state." Webster's dictionary defines "steady" as being firm in position, fixed, stable. In both economics and riparian lands, the tendency is to regard a "steady state" as being a stable condition.

While the idea of stability is one of the goals strived for in management decisions, there is another aspect of the "steady state" concept in both riparian lands and economics. This was brought to my attention in a statement by Heede (1985): "Due to the dynamic nature of systems, change is the rule and steady state does not exist." This immediately reminded me of a statement I have made in introductory economics classes: "The only thing constant about economics is that it is constantly changing."

Since change is inevitable, a question which has received considerable attention is, "How are riparian lands changing?" The general consensus appears to be that the changes occurring on riparian lands are having negative impacts. Anderson (1985) concludes that less than 30% of the riparian lands in Idaho are properly managed. According to Platts and Wagstaff (1984), the management on more than 440,000 acres of the 500,000 acres of riparian land managed by the Bureau of Land Management (BLM) needs to be improved.

The improper management practice leading to degradation of riparian lands in the arid and semi-arid west most frequently mentioned is that of overgrazing (Marlow and Pogacnik, 1985). Typical changes in the riparian habitat associated with overgrazing are summarized by Behnke and Raleigh (1978). Realizing that the management of riparian land could be improved, the question becomes, "What management practices should be implemented?"

[1]Professor, Department of Agricultural Economics, University of Wyoming, Box 3354, Laramie, Wyoming 82071.

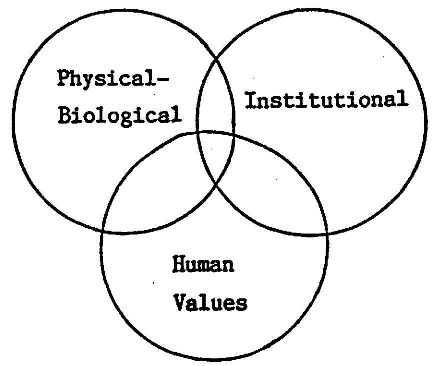
While the first question is important, the later question is the one researchers and managers should focus on. In reviewing the literature on riparian research, it appears that the majority of studies are centered around the question of changes in riparian lands. These studies tend to be of two types: (1) studies which attempt to document the change that has occurred, or (2) studies which attempt to show the change if a particular management practice were adopted. These types of studies form the basis for the scientific data that we are so proud of. Unfortunately, most of these studies only scratch the surface in terms of information needed to answer the question of: "What management practices should be implemented?" Why is this the case?

Rather than dwell on specific shortcomings of past studies in answering the above question, two general limitations of these studies will be discussed. The first limitation is what might be called the "isolated context of the studies." The main difficulty here is that researchers and managers recognize the complexity of riparian lands. This complexity can largely be attributed to the diversity of plant and wildlife inhabiting riparian lands and the variety of uses of riparian land. Even though this complexity is recognized, the majority of studies isolate a particular physical-biological aspect of the riparian habitat and/or use in analyzing the results of a particular management practice. Such an approach ignores the potential effects the management practice may have on other plants, wildlife and/or uses of the riparian land. As Buckhouse (1985) points out, this suggests that a more holistic look (systems approach) is needed when studying and managing riparian lands.

A second limitation is the lack of consideration given to socioeconomic issues in managing riparian lands. The significance of this component is eluded to by Crumpacker (1985): "The degree to which riparian ecosystems will eventually be conserved depends ultimately on the importance of their natural qualities to humans rather than to vegetation, wildlife and livestock." This suggests that any management decision needs to be related to its impact on human activities. Loeks (1985) makes this clear when he states, "The primary goal of environmental management is to maintain the capacity of the environment to meet human needs and aspirations." This human aspect of management includes both human values and institutions. "Institutions" refers to all the laws and regulations (rules of the game) which affect human behavior and management decisions.

Integration of these two general limitations of riparian studies helps focus on the complexity of management decisions on riparian lands. Combining these two limitations suggests that management is concerned with processes and their use to maintain or enhance a resource's ability to meet human needs and aspirations.

The complexity of such a concept of management can be illustrated through a Venn diagram.



The diagram suggests that there are at least three main components (aspects) in managing riparian lands. It also indicates that these components are interrelated. Thus management decisions at a minimum would revolve around three key questions:

1) What is physically-biologically feasible?
2) What is politically possible?
3) What is humanly acceptable?

These are indeed difficult and interrelated questions but all play a role in riparian management decisions. Using this concept of management, what role (if any) does economics have to play in this process?

Riparian Management Decisions

While it may not be possible to obtain a consensus on the primary concern in managing riparian lands, there may be general agreement that the overall goal is to allow for multiple use while sustaining yield. This does not imply a static situation, but rather would allow uses and productivity to change as human knowledge, needs and aspirations change.

The prevalent problem mentioned in the literature is that of overgrazing[2] riparian lands and its potential impact on other uses. The question of whether to change grazing practices is a major management decision. While the question appears simple, an

[2]The use of grazing is an example and is not intended to imply it is the only problem.

appropriate answer requires careful planning and a detailed analysis because of the interrelationships among the climate, soils, plants, animals, institutions and human wants. These interrelationships need to be considered by researchers and managers as they attempt to manipulate vegetation, wildlife and use of riparian lands. While management decisions on riparian lands will come at different times and locations and under different circumstances, the decision process can be broken into several procedural steps.

The main procedural steps in riparian management decisions, which generally involve long-term adjustments and impacts, are as follows:

1) Identification of problems and goals
2) Identification of management techniques
3) Quantification of the physical responses for each management technique
4) Valuation of the physical response
5) Selection of management techniques

While the paper focuses on riparian lands, the procedural steps outlined above apply to most resource management decisions. The procedural steps also present the main components of an economic analysis. Each of these steps or components will be discussed separately.

Problem Identification

Identification of the problem is frequently viewed as being straightforward and quite simple. For single use resources, this may be the case. For multiple use resources problem identification becomes more difficult due to interrelationships between uses. Even if a problem has been identified, it may be difficult to decide on specific goals or objectives. This is particularly true of riparian lands because of the multiple uses of those lands.

Using overgrazing of riparian lands as an example, the problem might be rather easy to identify and support through data collection. However, identifying and quantifying the impacts of overgrazing on other uses could be quite difficult and time-consuming. In addition, establishing acceptable goals for the various uses is also likely to be a difficult task. The point is that problem identification and establishment of goals is a difficult and time-consuming task. It requires sufficient data collection to recognize the problem and considerable knowledge about the interrelationships between the resource, management, productivity and uses to begin establishing goals and potential management practices.

Identification of Management Techniques:

Once the problems are identified and goals established, owners and managers can begin to consider alternative management techniques to maintain and/or enhance the productivity of riparian habitat. Decisions on investments in management techniques are largely a function of: (1) the existing condition of riparian land; (2) its future condition e.g. will production continue to decline and the rate of depletion; (3) potential recovery of the riparian habitat and the rate of recovery; (4) interrelationships between uses associated with the recovery and (5) time frame and cost of the improvement technique.

As with most decisions, the question of how to manage riparian habitat depends on a variety of factors. The decision as to which management technique is influenced by such factors as planned uses for the area, existing vegetation, soil type, topography, potential for recovery and management costs. These are some of the factors that should be considered in evaluating alternative management methods.

Quantification of Physical Response

A most difficult and time-consuming task in evaluating the management of riparian land is that of determining the physical response of riparian habitat to a particular management practice. It is difficult because of the diversity of and complex interrelationships between climate, soils, plants, animals, uses and productivity of the riparian habitat. Determining the physical response is further complicated by the time period needed to obtain the productivity response.

This physical response of riparian lands to a management practice over time can be broken into at least two periods: (1) the rate and level of the increase in physical response, and (2) life of the physical response. To quantify this relationship, studies of riparian improvements may need to occur over an extended time period. This requires the researcher and his administrators to make long-term commitments in time and funds to carry out such a research project. However, it should be made clear that the economic analyses of management practices is based on these long-term physical responses.

In addition to time, Rinne (1985) points out the complexity of the physical interrelationships that must be considered in studies of riparian habitats. This complexity is illustrated by studies of riparian habitat which show impacts on vegetation, fishery, wildlife, water quality and water quantity. Therefore, the multiple use of riparian areas for such uses needs to be considered or controlled in stuies designed to determine the response from management practices. The need for long-term studies and a more holistic approach to riparian habitats cannot be over-emphasized.

Valuation of the Physical Response

The need to evaluate the use of riparian lands is supported in Meyer's (1985) conclusion that the general public places a high value on riparian resources and wants to preserve them. Economics provides an approach to valuing the many uses man makes of riparian habitat. The basic premise of the economic approach is that value is based on human preferences and that the overall objective is to maximize these human values or well being (King, et al., 1978).

Conducting such an economic analysis forces the analyst to specify objectives, identify alternatives and provide values which can be used in weighing the merits of alternative management practices. A basic guiding concept in determining the net (additional) change in value associated with a management practice is the *with versus without principal*.. Under the *with versus without principal,* the guiding question the analyst must answer is: What is the difference between what would happen "with" the proposed improvement compared to what would happen "without" the proposed improvement? To answer this question requires knowledge of what the physical response is.

The next step is valuing the estimated net change in physical response. Valuation of the increased vegetation from riparian habitat improvement generally involves valuing such associated products as livestock grazing, fish and wildlife, recreation and water quantity and quality. In this economic process, the inability to measure the value of nonmarket goods is a frequent criticism of economic analyses as a decision-making tool for allocating natural resources among uses.

Of the products listed, the valuation of vegetation for livestock would generally be regarded as the easiest to do. This is because of existing markets for both forages and livestock. While several approaches could be used, the easiest and the approach currently suggested by the Bureau of Land Management is that of private grazing fees.

A major use which for all practical purposes a market does not exist, and which is often assigned substantial value, is recreation. However, methods for measuring the value of recreation have improved substantially and making use of them is better than merely indicating that recreation is *good* and/or that it is increasing. Two methods for measuring the value of recreation which are widely used and recognized are the contingent valuating method (CVM) and the travel cost method (TCM).

The contingent valuation method is also referred to as bidding games. This stems from the procedure of asking individuals if their use would change given a new hypothetical situation. Thus, instead of the individual changing consumption in response to price, bidding games asks how the individual would respond to a hypothetical change for a nonmarket good. A major difficulty with this approach is that of designing the questionnaire. If the bids are to be meaningful the participant needs to be presented with a well-defined good so they are aware of the proposed changes and its possible effects. Once the good being valued is defined the participant is asked: (1) how much would you be willing to pay for an improved situation, or (2) how much would you have to be compensated to accept a reduced situation. The resulting bids represent a measure of consumer surplus.

Another method which empirically estimates recreation benefits is the travel cost method. This method uses travel costs as a proxy for price in deriving a demand curve for a recreation site. The underlying assumption is that visits to the recreation site will decrease as time and travel costs increase. The first stage of the TCM analysis involves estimating the statistical relationship between travel cost and trips per individual or per 1,000 population if a zonal approach is used. Regression analysis can be used to estimate a function for visitation rates based on travel cost as a proxy for price and other socioeconomic data. The second stage of the TCM involves using the statistical relationship to determine the total number of visitations at a given fee; this represents one point on the demand curve. Additional points on the demand curve can be obtained by using alternative hypothetical fees and then estimating visits at each fee using the per capita functional form. The area under the demand curve estimated in the second stage represents an estimate of net willingness to pay or consumer surplus for that recreation site.

Both the CVM and TCM are generally regarded as appropriate techniques to estimate net willingness to pay for recreation at a particular site and can be used in determining the economic effects of proposed management practices. A more detailed review of CVM and TCM is presented by Sorg and Loomis (1985).

An additional area that has generally been overlooked is the physical response of water quantity, quality and timing associated with alternative riparian management practices. Attempts to value such changes would face the same difficulties as valuing recreational activities since both are nonmarket goods. Research in this area is needed to: (1) establish the physical relationships; (2) estimate appropriate values and (3) identify potential conflicts with existing institutions (e.g. water law).

Selection of Management Technique

Having completed the above procedural steps for each alternative being considered, the next step is to compare the alternatives. The specific criterion for choosing between alternative improvement practices with similar costs is to select that alternative with the greatest net present value (NPV) of future net returns.

Since costs and benefits occur over extended time periods and their magnitudes generally vary at different times, discounting is used to obtain the NPV of future net returns. The general formula for calculating NPV is:

$$NPV = \sum_{n=1}^{t} \frac{NR_n}{(1+r)^n} = 0$$

Where:

NPV = Net Present Value
NR_n = change in net returns in year n (e.g. additional returns less additional costs)
r = discount rate
n = year

Discounting is a procedure to allow for the fact that future income has less value than present income because of foregone interest earning and the uncertainty involved. It also opens the door for the continued debate over what the discount rate should be which is beyond the scope of this paper.

The economic feasibility of the investment in the improvement practice is determined by the sum of the discounted flow of net returns (NR_n). If the sum of discounted NR_n (NPV) equals or exceeds zero, the initial investment is recovered along with a rate of return equal to or greater than r and the project would be economically feasible.

Summary

Decisions on management practices to improve riparian habitat are complex because of: (1) the multiple use aspects of riparian lands; (2) interrelationships among climate, soils, management, livestock, fish and wildlife and the productivity of riparian lands; (3) alternative management practices and their associated costs and physical response; (4) the extended life of the physical response and (5) difficulties in valuing nonmarket goods of riparian lands. These complexities in riparian habitat improvement decisions were discussed in the suggested procedural steps for riparian management decisions:

1) Identification of problems and goals
2) Identification of management techniques
3) Quantification of the physical responses for each management technique
4) Valuation of the physical response
5) Selection of management technique

Regardless of the riparian habitat problem being addressed, these general procedural steps need to be followed if the physical and economic desirability of the proposed management practice is to be considered and evaluated. The alternative is merely stating that the management practice is an improvement without quantifying the amount of change.

In following these procedural steps, the economic approach is outlined and plays an important role by pointing out: (1) that several management techniques be considered; (2) the necessity and complexity of physical response data over time; (3) that valuation is based on the net change in products for the "with" vs. "without" situation; (4) the need for estimating the value of the change in products and discouting the determining economic feasibility and in selecting among management practices. For riparian habitat researchers, the ecnomic approach suggests the need for a much more holistic approach so that the relationships between uses as well as the physical responses for management practices can be quantified.

It also suggests that the consideration of institutions and economics be incorporated into their proposed research.

An example of this need is the numerous studies of fencing riparian areas and measuring changes in the riparian habitat. Such studies show improved production, yet if the economics and existing institutions are considered, this practice may not look nearly as appealing.

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RANCH MANAGEMENT OF STREAMSIDE ZONES

Kathleen R. Sun[1]

We were asked to talk about ranch management of streamside zones, which I will do. However, I think it very pertinent to the discussion to give some history of our particular area.

The "Sun Ranch", the Hub and Spoke, was started in 1872 where the Oregon Trail passes by Devil's Gate on the Sweetwater River. The Oregon Trail follows that river for almost its entire course, and that trail had an impact on the whole Sweetwater Valley.

During the mid-1800s, hundreds of thousands of immigrants traveled west on the Oregon Trail. These people brought with them livestock; some brought only the oxen and horses needed for transportation, and some brought herds of breeding stock also. Of necessity, these animals grazed the forage along the trail, sometimes having to go miles on either side to find sufficient grass.

Later, as the country became more settled, ranchers bought stock outside of the State. Away from the railroads, the only means of getting that stock home was to trail them. So, many trail herds also use the Oregon Trail. Thousands upon thousands of animals grazed wherever they could find grass. Tom Sun, Sr. bought cattle in Oregon several times and trailed them home in the late 1800s.

This heavy use continued for many years--almost exclusively in the summer when grass can be damaged. Obviously, the Sweetwater Valley was badly overgrazed many times during those years for as far as ten miles on either side of the river.

The soil in the valley is almost exclusively sand with a little clay. The bottomland is silty clay. Most of it is not what people usually think of in terms of "good top soil."

Precipitation ranges from 9 to 14 inches annually. The elevation at the foot of Devil's Gate is not quite 6,000 feet. A drying wind blows almost continuously.

Desert ecology is, however, an amazing thing. This seemingly fragile land recovers miraculously with just a little water. Those of us who have been here long can all tell of times when land as bare as this floor has sprung to life and produced lush growth when the rains came or when irrigation water was applied.

If we look even farther back in history we see this valley, as most of the West, heavily grazed before the "white man" came. Estimates put the number of buffalo roaming in the West as high as 80 million.

Captain Benjamin Bonneville, in July, 1832, reported seeing "immense herds" of buffalo in the Sweetwater Valley.

The Mungers, a couple who were missionaries, wrote in June, 1839, in the Sweetwater Valley, they "saw a large number of buffalo, in sight of perhaps 1500."

In 1846, William E. Taylor, a member of an immigrant party, wrote that they saw "thousands of buffalo" in what is now the Sweetwater Station area.

The western grasses evolved in response to this grazing. Most grasses actually need the cropping effect to prosper, just as your new lawn fills in better if you keep it mowed. These grasses also evolved to respond to the unpredictable moisture patterns, producing the quick recovery rates that I refered to.

Now lets look at some pictures of the Sweetwater Valley. Figure 1 was taken in 1870 by the pioneer photographer, Jackson, on the Hayden survey expedition. You will note that the river is wide and shallow with many cut banks and sand bars. There is little brush for stabilization and wildlife habitat.

Figure 2: (Jackson, 1870) looks west from the top of Devil's Gate. Note the width of the stream, the sand bars and braiding in the river bends in the center of the picture.

Figure 3: (Tedford, 1895) shows the same river bends filled in and grown over with vegetation. The river is now narrower with stable banks. The light dusting of snow gives this picture a rather barren look.

Figure 4: A view of Devil's Gate, taken in 1916, compares unfavorably with Figure 5 which shows a great deal more vegetative growth in 1985.

Figure 6: A view of Split Rock showing the condition of the river bank (Jackson, 1870).

Figure 7: The Sweetwater River above Split Rock (Jackson, 1870). The narrow riparian zone is significant. Note the ancient river banks above the present course of the river. In many of these pictures the old river meanders are evident. The cut banks that often draw criticism are merely where the river meanders into a hillside. It is a natural process of level-

[1]Rancher and Water Development Commission member-at-large, 1611 Park Drive, Rawlins, Wyoming 82301.

improving the riparian zone over a long period of time. While we work to stabilize cut banks, how far should we go in fighting nature?

There were no trees on the ranch when my mother-in-law came as a bride in 1913. She told of many failures with the trees she planted until they planted one in an old buffalo wallow and it grew. Then they knew they had to dig through the hard pan to get them to root.

More trees are planted every year. Figure 8 shows plantings in the last few years below the ranch buildings.

Figure 9 shows trees planted three years ago on the right. Also, this area was newly seeded to meadow grass two years ago. On the extreme left, ruts of the Oregon Trail still show. This pasture is heavily used all fall and winter because our main set of corrals is just below here and most of our weaning, vaccinating, shipping, etc., takes place here. These pastures are all winter pastures, not used during the growing season, so they remain in excellent condition.

Figure 10 shows the good condition of the river banks.

Figure 11: To the left are the ruts of the Oregon Trail as it ran along this bluff above the river. Note the sandy soil and the good condition of the river banks. In the background can be seen juniper trees that have come in along the river just in the last 30 years.

Figure 12: One of nine wells drilled along the river to provide water when the river freezes to the bottom. An added advantage is the distribution of grazing.

Figure 13: One of two man-made lakes at the 66 Ranch, just east of Muddy Gap, filled from Whiskey Creek and Muddy Creek. This south lake is particularly popular with all types of waterfowl. The usual sand hill cranes, geese and ducks are joined by pelicans, swans, herons and all types of waterfowl in the spring and fall. The nesting sites for geese shown here have not been used.

Figure 14: This marsh land in the Turkey Track meadow is fed from irrigation return flow. It remains wet all summer and is popular with waterfowl.

Figure 15: The YZ meadow, west of the Sun Ranch headquarters about 13 miles, shows the excellent condition of the river, even where barrels of mineral supplement attract heavy use. A small diversion dam through a gap on the left provides water for irrigation, which is in itself a means of preserving and expanding riparian zones.

Although there is no record of moose in this area previously, 8-10 moose have located here the last few years.

Figure 16: Heavy runoff in 1983 caused flooding on the Sweetwater. There have been only three floods since 1870. In 1924 an ice jam in Devil's Gate caused water to back up. Floods in 1978 and 1983 did no damage to the river channel or meadows.

All of the pastures we have viewed so far have been on private land along the Sweetwater, where most of the grazing is done in the winter. The next pictures are of Pete Creek, which is a tributary to the Sweetwater heading in the Ferris Mountains to the south.

Figure 17: Upper Pete Creek is in a BLM allotment used in the summer. The season of use makes a great deal of difference. Because of heavy use during the early part of the growth cycle, we see some degradation of the riparian zone. Sagebrush is encroaching. Cut banks are caving and willows are not showing new growth. Measures are being taken to restore this reach of the stream.

Figure 18: The BLM has constructed 9 trash collectors here and are planning more. In addition, we have changed the pattern of grazing. For the last two years we have used a modified intensive grazing program. As you know, intensive grazing involves turning a large number of cattle into a pasture for a short period of time. The goal is to have each blade of grass grazed once. The second bite on the same grass is considered overgrazing. In this way the grass can be used in the spring without damaging it. It takes more management but is beneficial to both the land and the cattle. Also, hoof action helps the precipitation penetrate the soil.

To avoid additional expense, we used existing pastures, i.e., the lower Bar 11 meadows, upper Bar 11 meadow, and the "horse pasture," all on private land. Cattle were not turned into the allotment until the end of July, giving the forage a good start.

Additionally, we propose to build a fence from the corner of the horse pasture paralleling the creek to the mountain. We can then rest the stream bank when needed.

Last we go back to the Oregon Trail, just opposite Devil's Gate, to Rush Creek (Figure 19). This was a campsite on the Oregon Trail, used every night and still in use when Tom Sun, Jr. was a boy in the late 1800's. Imagine, if you can, how it must have looked with the constant trampling and heavy grazing every night all summer for over half a century.

Now we see an ideal little stream; narrow, deep, with grassy, overhanging banks. An excellent riparian zone, in spite of continuous winter grazing.

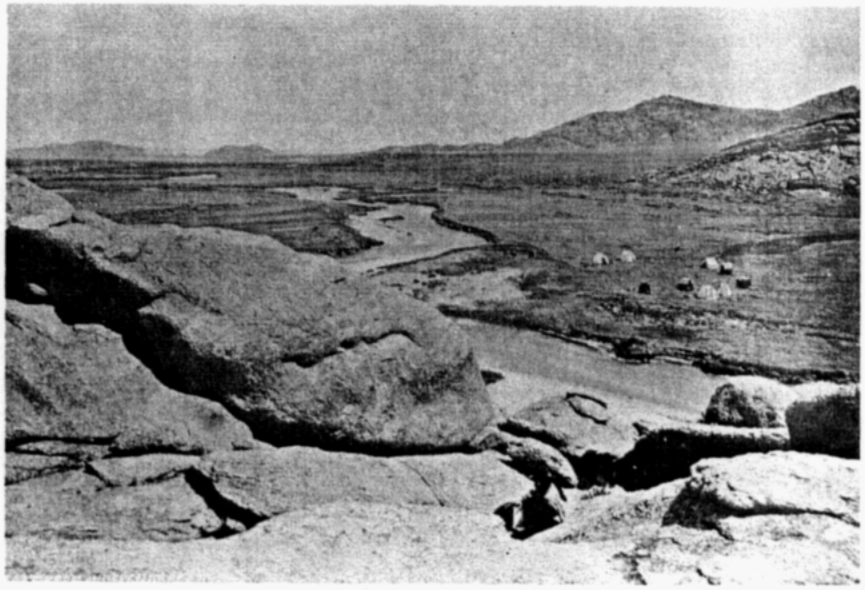

Figure 1. Looking east from Independence Rock.

Figure 2. Sweetwater River, 1870. Looking west from the top of Devil's Gate.

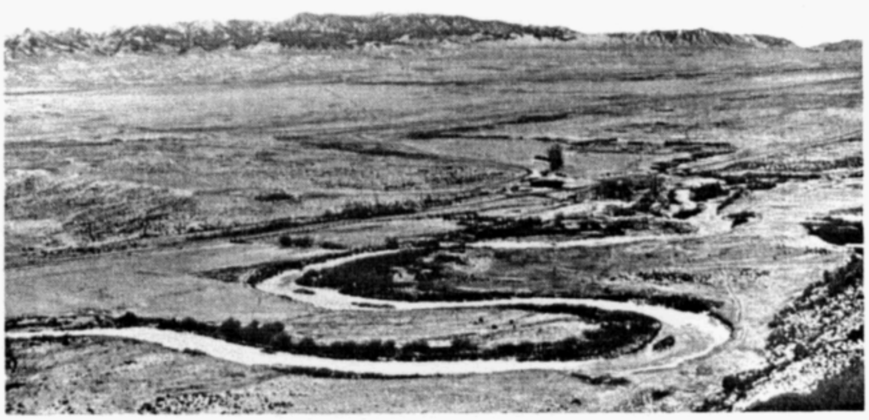

Figure 3. Sweetwater River, 1985. Looking west from Devil's Gate.

Figure 4. Devil's Gate, 1916.

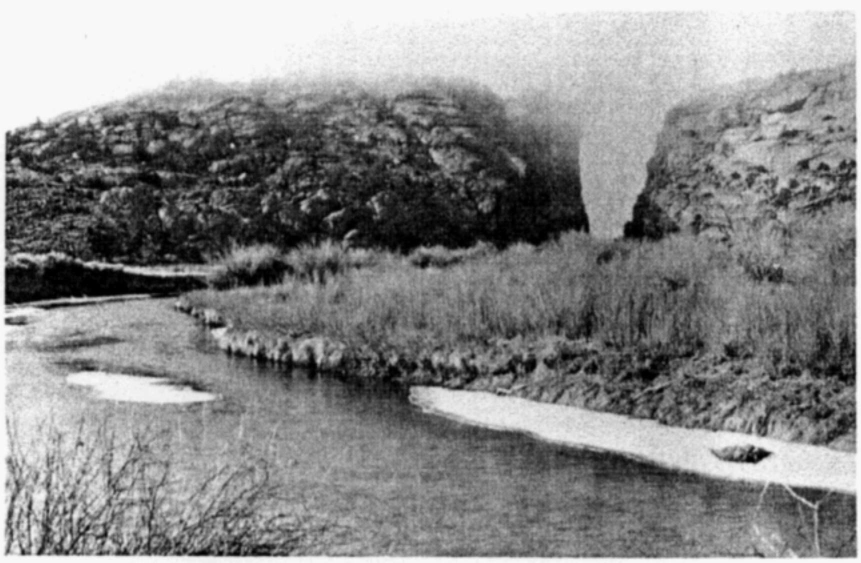

Figure 5. Devil's Gate, 1985.

Figure 6. Split Rock, 1870.

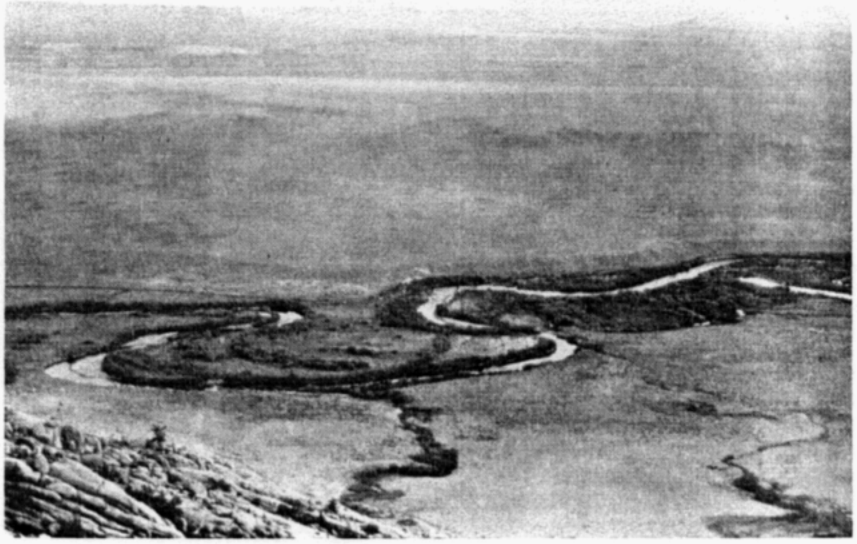

Figure 7. Sweetwater River at Split Rock, 1870.

Figure 8. Newly planted trees.

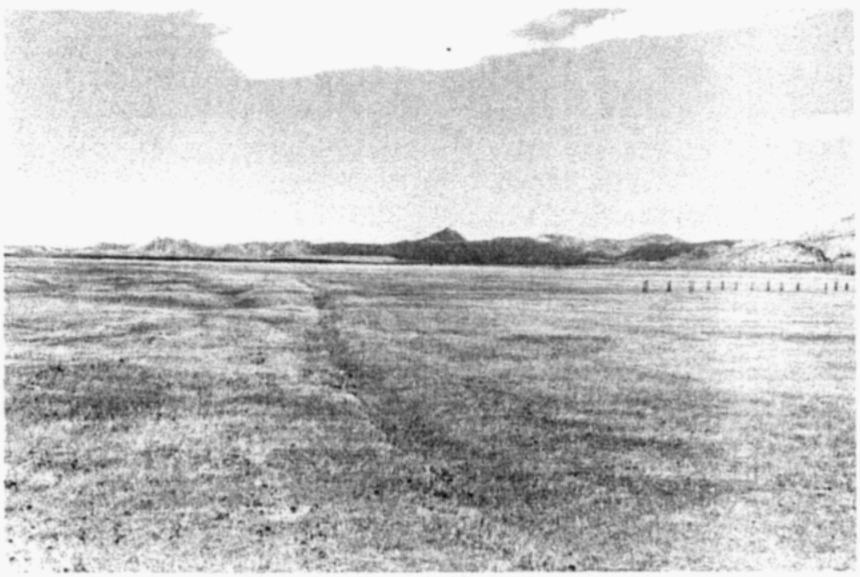

Figure 9. Newly seeded pasture. New trees on the right. Ruts of the Oregon Trail on the extreme left

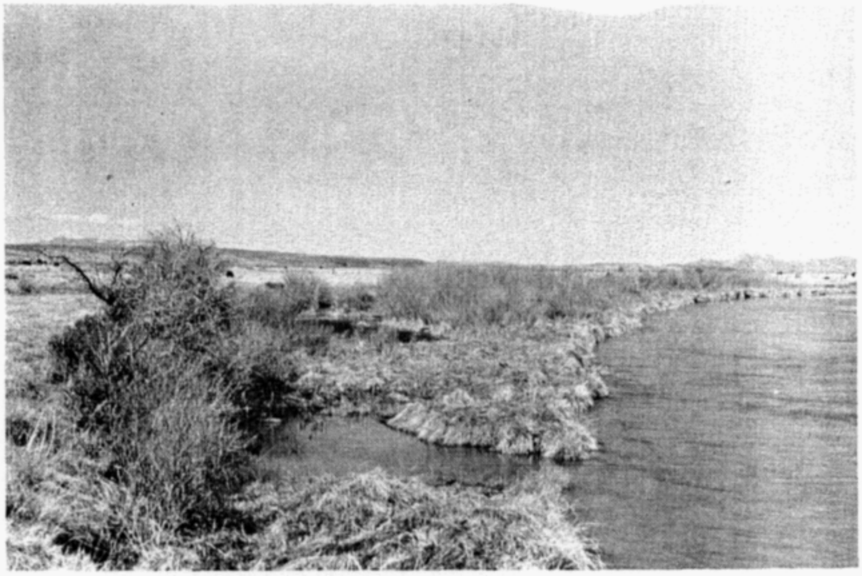

Figure 10. Vegetation along Sweetwater River today.

Figure 11. Oregon Trail as it is today.

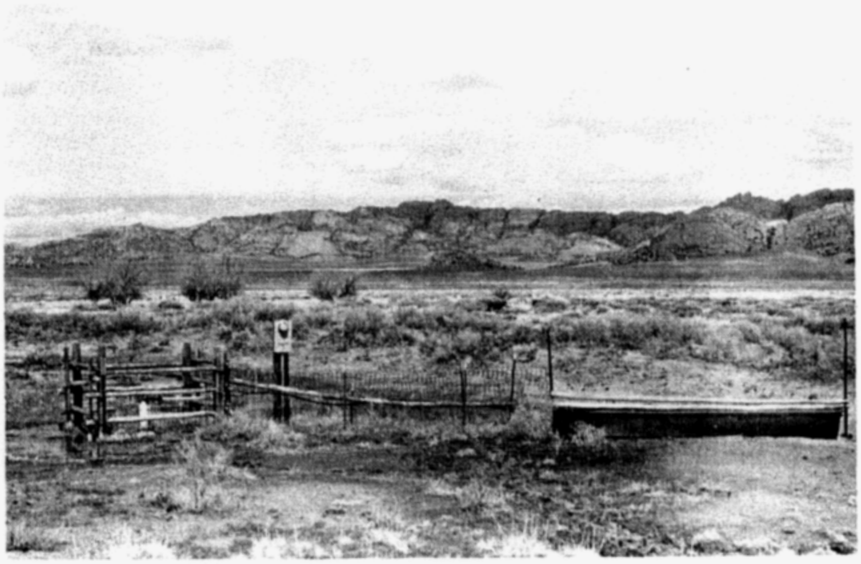

Figure 12. A well in one of the pastures.

Figure 13. 66 Lakes.

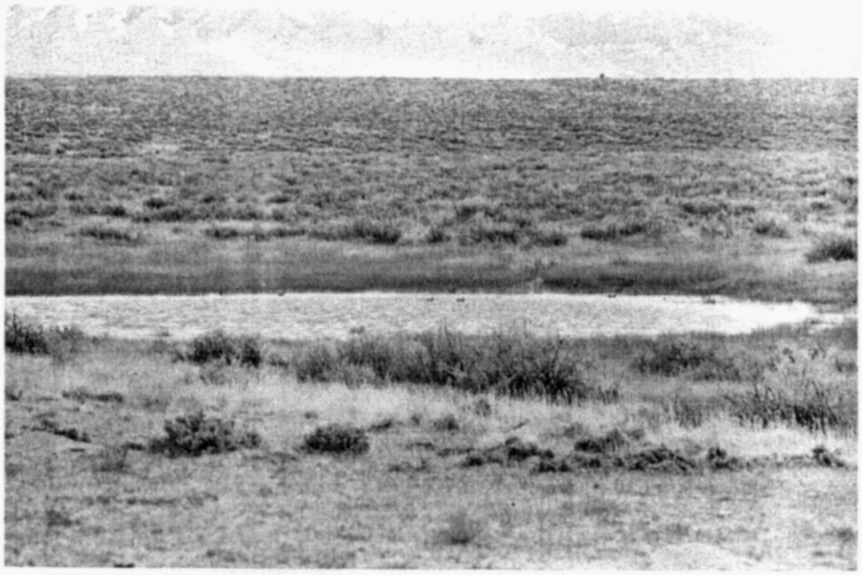

Figure 14. Turkey Track Meadow.

Figure 15. YZ Pasture.

Figure 16. Sweetwater River in flood stage, 1983.

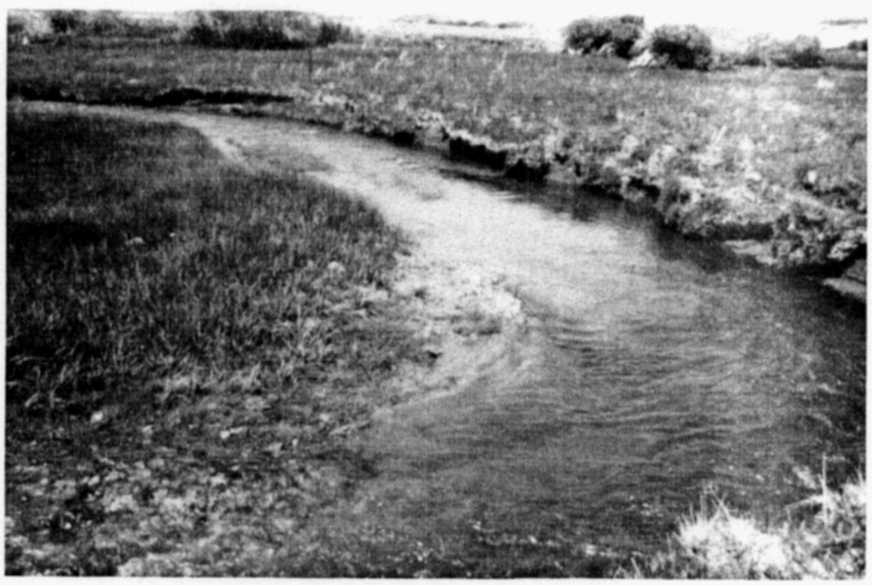

Figure 17. Pete Creek in Bar 11 allotment.

Figure 18. Pete Creek trash collector.

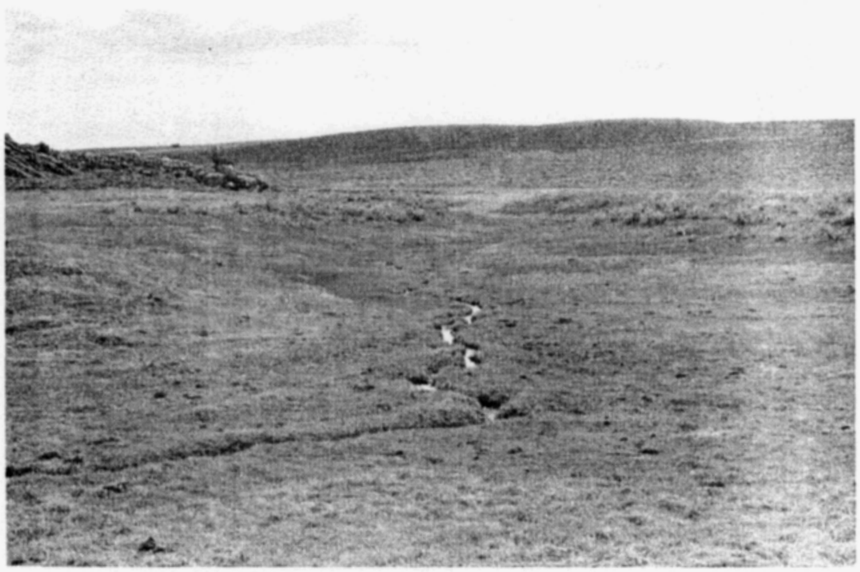

Figure 19. Rush Creek.

A RANCH DEPENDENT ON STREAMSIDE ZONE GRAZING

Michael W. Healy[1]

The LU Sheep Company was established in 1899 near Grass Creek, Wyoming, and is located on both sides of Highway 120 between Thermopolis and Meeteetse. In recent years the ranch sold the last of the sheep and is now primarily a cattle ranch--in spite of the ranch name.

Most of the ranch's grazing resource useable from June through December is located in a series of long east-west valleys between steep, dry ridges in the 10-12 inch precipitation zone. Good grass is found along the tops of the ridges but it is far from water. There is little accessible forage along the slopes of the ridges. The north exposures are heavily covered with juniper and pine while the south exposures are steep and rocky with little soil or vegetation. Thus only the valley floors, the meander belt of small streams support good forage accessible to our cattle. These valley floors vary in width from only a few yards to about a half mile. But they are long, 15 miles along Grass Creek, 8 miles along Enos Creek, 7 miles along Left Hand Creek and 5 miles along Little Grass Creek. Elevation ranges from 5800 feet at the lower end of Left Hand Creek to 8400 feet above the headwaters of Grass Creek. None of these creeks carry much water though our ranch; they do not reach to the forested snow catch areas to the west which are drained by the Wood River and Gooseberry Creek. Springs in the headwaters areas are too low for development of gravity flow pipeline to water the grassy ridge tops. Thus our ranch is heavily dependent on grazing the valley floors within the streamside zones.

Complicating management of these pastures is the ownership pattern. Almost all the valley floors are state or private land. The steep slopes and grassy ridge tops are mostly federal land administered by the Bureau of Land Management.

Only Grass Creek maintains a perennial stream flow. In some stream reaches the channel is downcut and no longer subirrigates the valley floor. In other reaches the stream is near the valley floor soil surface and these areas support heavy stands of willows. Our cattle prefer these valley floors and concentrate their grazing here, especially in late summer and fall. Of course our cowboys do not like to work cattle in these same willow bottoms. Most of our other streams are ephemeral--or perennial only in short sections. The Left Hand Creek pasture, particularly, is sandier and a drier allotment with very little stream flow.

We have developed several reservoirs for livestock use and wildlife habitat. Left Hand Reservoir is a critical water supply for that dry pasture. Of course livestock concentrate around the edges of the reservoir--another riparian area--and there is very little riparian vegetation. We need to fence this reservoir and pipe the water to troughs below. The next reservoir below maintains more riparian and aquatic vegetation and has more use by waterfowl.

Our ranch also has some erosion problems in our winter and spring grazing allotments. Gillies Draw in a pasture east of Highway 120 begins with a huge head cut into a large gulch. Here there is no cut down gully above. Apparently underground water dissolves the salts and creates soil slumping where it emerges at the head of the gulch. The valley above is well covered with good vegetation. Is this a case of natural erosion? In either case, how can we stop this process and preserve our limited soil resource?

We also have a downcutting gully or gulch in Little Buffalo Basin, a pasture north of Gooseberry Creek. This gully begins in the adjacent hills and reaches across much of the basin pasture. This gulch contains at least two generations or periods of erosion. The older gulch contains a smaller gully in its bottom. This cut gulch is so huge and its sides near vertical that our cattle cannot reach a large portion of the pasture. How can we, or is there any feasible method, solve this serious erosion problem and impediment to proper use of the pasture.

Through the slides shown in the oral presentation and these written comments I meant to show you some of the problems and limiting situations of our ranch. The productivity of our ranching operation clearly depends on wise use of our valley floors and streamside zones. The physical constraints of topography and the availability of water severely limit our management approach and economic solution. Some problems have neither an obvious cause nor a clear solution. We are aware of many of the problems. We invite your help in finding feasible methods of solving some of them.

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[1]President, LU Sheep Company, P.O. Box 699, Worland, Wyoming 82401.

STATE FINANCING ALTERNATIVES FOR WYOMING WATER DEVELOPMENT : OUTLINE OF PRESENTATION

Stan Smith[1]

I. Background of water development in Wyoming

II. Funding in recent past
   A. Total budgeting
      1. Prior to 1983, $199 million with $42.7 million expended
      2. In 1986, added $86 million for total of $280 million
   B. Projects approved
      1. Buffalo Bill; $47 million
      2. Deer Creek; $45 million
      3. Sulphur Creek; $25 million
      4. Cheyenne Water Project; $107 million, including $40 million loan
   C. Middle Fork Project put on hold

III. We are now at a stage where we need to re-examine funding sources
   A. Decline in value of oil, natural gas, and other minerals with reduced revenues. ($1.00 decline in oil price = $190,00 loss to the Water Development Account II.)
   B. Long start-up time requires advance planning
   C. Discussion of present system

IV. Repayment of loans to local governments
   A. Water revenue bonds
   B. General obligation bonds
   C. Optional sales tax (two-year option--the fourth one cent)
   D. Capital facilities optional sales tax (the fifth one cent)
   E. Combinations of these options mixed with appropriations from the general fund

V. Other approaches to funding
   A. Arizona
   B. Montana
   C. Industrial companies--Little Horn Group
   D. Intermediation option
      1. Bring capital from other sources to entities that cannot borrow on their own
      2. WCDA as possible intermediary
   E. Secondary repayment sources
      1. State loan with take-out later
      2. Substituting tax revenues which are not pledgeable under the Witzenburger decision with federal mineral royalties; permissible under the Herschler decision

VI. Summary & conclusions

[1]State Treasurer, State of Wyoming, Capitol Building, Cheyenne, Wyoming 82002.

WHERE DO WE GO FROM HERE: A SUMMARY OF THE WYOMING WATER AND STREAMSIDE ZONE CONFERENCE

Rod S. Miller[1]

After listening to the information that has been presented over the past two and a half days, and addressing the question "Where do we go from here", I think that I ought to preface my summary with a quote from Tom Watson, former chief executive officer at IBM. When Mr. Watson assumed the mantle of authority at IBM, he assembled his top staff and imparted to them his philosophy of corporate leadership. He told his staff, "From now on, our philosophy will be to do the right thing in the right way." It would seem to me that this would be valuable advice for us to heed as we determine how to manage riparian zones in Wyoming.

It has been clear from what we've heard here that we have a good idea of the right thing to do. Riparian zones have emerged as extremely important ecological resources that deserve our attention and the best management possible. This, however, is only half of Mr. Watson's formula. We still need to determine the right way to carry out this management. Based on what I have heard presented at this symposium, I would submit that we still do not know with certainty what is the right way to manage riparian zones.

Much research into the best methods to manage this resource is ongoing, and let me stress the term ongoing. We have heard reports on many of these research projects, and few, if any, have been concluded. How many times have you heard a researcher say during his presentation that "we don't know yet" or "we don't have enough information to make a firm decision" or "the science is still to young to tell us." Mike Parker told us that we must carefully distinguish between fact and hypothesis--this is doubly important when attempting to make policy decisions. The study of riparin zones and how they respond to man's influence is still embryonic, so in my opinion, it would be premature to attempt to institutionalize a rigid management scheme until the data base matures.

However, it is clear that pressure upon public land managers to "do something" about riaprian zones will not abate. The challenge then is to do the right thing in the right way. Several of the speakers have touched upon the necessity of approaching riparian management from an interdisciplinary standpoint. Hillary Oden told us that "riparian management is a cross-cutting activity, affecting all disciplines." Paul Hansen related to us the steps that Montana is taking to address riparian zone management on a interdisciplinary basis with a strong grass roots orientation. This would appear to be a prudent direction to take, once it becomes feasible to develop a riparian policy.

Given the many and divergent constituencies who have an interest in the issue, a cooperative effort to develop a policy is a must. I think that it is equally important that policy development and decision making be as localized as possible. The Symposium has brought out that the best management practices for riparian zones in intermountain basins are quite different from those for the desert southwest. This fact argues strongly for a policy that is sensitive to differing conditions in different locations.

Stewardship programs, coordinated resource management programs and cooperative management agreements are all resource management models that have been discussed. Each holds promise as a tool for addressing riparian area issues at the grass roots level and achieving the consensus necessary for sound management decisions. This approach is especially important when considering that riparian zones are so important to such a large and diverse cross section of interested parties.

In summary, I would suggest that another conference such as this one be held a year or so from now, when more of the research projects discussed here have been completed. At that point, we should have a much more definitive data base from which to answer the question, "WHERE DO WE GO FROM HERE."

In the meantime, it is not too early to begin to build the communications and partnerships that will be necessary to translate good information into good management. All of the stakeholders in the issue need to link up now to openly discuss what their concerns and expectations are. Once the science has matured to a point that we know what we want to do about the resource, then we will have some assurance that we are doing the right thing in the right way.

[1]Range Resource Analyst, State Planning Coordinator's Office, Herschler Building, Second Floor East, Cheyenne, Wyoming 82002.

APPENDIX

TRANSCRIPT OF QUESTIONS POSED TO CONFERENCE SPEAKERS

Transcribed by Rod Miller[1]

Questions to Clayton Marlow

1. Where did riparian zone building material come from?

ANSWER: It came out of upland areas through natural erosion processes. Geologic parent material and erosion rates will determine how quickly a riparian zone develops.

2. How long does it take for a riparian zone to develop?

ANSWER: In areas of granite parent material, several thousand years. The slide showing the well developed riparian zone in the midwest indicated a zone that has taken 30 - 40 thousand years to develop.

3. How long did it take for some of the degraded riparian zones in the slides to degrad to the extent shown?

ANSWER: In that particular area, abusive agronomic or cropping practices led to degradation with a span of 80 years.

4. How would you classify cottonwood lined ephemeral channels?

ANSWER: That may be the early stage of development of a riparian zone. However, we don't have the information base to definitely state that such a channel would fully develop into a riaprian zone.

Questions to Burchard Heede

1. How do you evaluate whether a degraded stream is able to recover naturally or whether intervention is warranted?

ANSWER: If, for example, a fire destroys streambank vegetation, the erosion rate increases by two orders of magnitude. The channel is not accustomed to this sediment load and immediate aggradation can be expected. If precipitation and growing conditions are adequate. Revegetation could begin naturally within two or three years. However, variable conditions may require 20 or 30 years before dynamic equilibrium is reestablished. If landscape conditions such as landslides are present, perhaps two to three hundred years will be required. It is difficult to predict the time frame with certainty though, because riparian zone research is such a young science. We need to be very careful to differentiate between what is fact and what is conjecture. We are not yet at the point where we can quantitatively forecast what will happen.

2. How did riparian zones look two hundred years ago, as compared to today?

ANSWER: We can speculate that, with the opening up of the West, the influences upon riparian zones has been extensive. In the short term that we are discussing, man has caused more change than nature itself has, and things have become worse.

Questions to Quentin Skinner

1. Who has the four wheel drive vehicles now?

ANSWER: Everybody has them. Its not limited to ranchers or land managers.

2. Who benefits from deep drilling?

ANSWER: We all do. It is only one of the multiple-use activities that impact riparian zones.

Question to Fee Busby

1. Where did proposals originate that would place the burden of riparian zone fencing and rehabilitation on the rancher?

ANSWER: Those types of proposals come from fellow citizens who have an intense interest in seeing improved streams and fish habitat. It raises the very important question of who benefits from those activities and who should pay for them. There is a lot of information suggesting that fish are worth a lot of money from a recreational standpoint, as well as a food source. The question before us is "how do we collect that money?" We have to have that money to pay for the management and the accompanying tradeoffs.

Questions to Larry Wolfe

1. When a reservoir is built mainly for impoundment but not actual use, is Wyoming really protecting that water supply for future use?

ANSWER: The key words in the Colorado River Compact are "beneficial consumptive use", you are

[1]State Planning Coordinator's Office, Herschler Building, Cheyenne, Wyoming 82002.

not using your compact allocation unless you are consumptively using it. Hence, Wyoming is not protecting its consumptive use by that strategy. However, the compact contains a provision that states that the failure of a state to use its allocated supply does not constitute a relinquishment or abandonment of its right to use water in the future. I believe that the compact protects Wyoming's ability to develop water as uses arise and a forced development program probably isn't necessary.

2. Are you saying that the "use it or lose it" theory isn't correct, at least as far as the Colorado River Compact is concerned?

ANSWER: I don't think that theory is entirely correct and it shouldn't be used as a justification for construction of water projects. The compacts protect our right to use water in the future.

Question to Hillary Oden

1. Where will the money come from for planning, implementation and monitoring associated with various activities that receive benefits?

ANSWER: If, for example, wildlife is the primary beneficiary of an activity, the funds would come from our wildlife subactivity fund. Similar funds exist for water and air and other activities. The Range Improvement Fund, derived from 50 percent of the grazing fees on public lands also is a source.

Questions to Glen Hetzel

1. How do you reconcile consideration of multiple use prescriptions with the comparison of present stream condition with the potential for producing catchable fish?

ANSWER: Both prescriptions are articulated in the Forest Plan. The plan provides broad direction but specific guidelines are still in the development stage. Although information in still being developed, if it can be shown that a stream has an opportunity for increased fisheries production and it can still be done within the matrix of Forest Plan objectives, that is the direction that we will take.

2. Will the Forest Service rate the condition of riparian areas?

ANSWER: Yes. The intent is to use the scorecards to rate the condition of a woody draw or a riparian area against its potential. This leads to the question, "for what condition will we manage the zone?" The riaprian guidelines in each Forest Plan will make that determination. In most of the plans that I've read, we will manage for a mid- to high-seral stage condition.

3. What are your management plans for private land intermingled with public land?

ANSWER: The Forest Plans include prescriptions for public lands only. The treatment of intermingled private lands is a valid one, and we cannot deal with it unilaterally. I think that those kinds of issues will need a coordinated approach involving all the parties concerned.

Question to Dave Engels

1. Has damming activity impacted streamside development?

ANSWER: Some existing developments are impacted and in some cases, flooded during periods of large scale release for downstream users.

Question to George Christopulos

1. Are waters taken out of alluvial wells along rivers counted against compact or decree allocations?

ANSWER: If those waters are used after Januaary 1, 1976, they are counted as part of the depletion under the Bear River Compact. Different situations exist along different drainages.

Questions to David T. (Tex) Taylor

1. How will improvement in riparian zones that benefit recreational activities be funded?

ANSWER: I think that recreational user fees would be a source of funds for mitigation activities that benefit recreation.

2. How can we determine what the market value of recreation on private land would be?

ANSWER: Some preliminary work has been done and information is being developed to quantify those values.

3. What are the negative economic considerations of recreational activity, particularly liability?

ANSWER: This has not yet been addressed. However, if the state is serious about promoting recreation, these institutional barriers must be addressed.

Questions to William Platts

1. What utilization level would you recommend in riparian systems in a 5-12 inch precipitation zone?

ANSWER: Utilization is one of seven criteria in determining a grazing strategy in riparian zones. Other considerations include distribution, season of use, class of livestock, land type, community type and fishing habitat type. In the Great Basin, riparian zone forage production can be increased threefold by a good grazing strategy. Deferred rest systems with a utilization level of 40-60 percent would be suggested.

2. Does your research indicate that most of the damage in riparian areas is due to trampling and hoof action, or is it more related to vegetation removal, due to ice shear?

ANSWER: This depends upon the land type involved, and the community type. It is indicated that ice shear can initiate the problem, but I think more damage is done by removing the vegetative matter and exposing the soil to erosion.

3. Have you identified any areas where stream channels have been degraded by big game?

ANSWER: I have identified no areas where elk have caused riparian damage. In Yellowstone Park and in the Gallatin National Forest I have seen some areas where concentrations of elk have caused some damage. However, this did not occur in any of our study areas.

Questions to Steve Mizell

1. What is your definition of a riparian zone?

ANSWER: As a hydrologist, I stress the availability of accessible water as a determining factor in the definition of a riparian zone.

2. Is the University studying geology and basic soil types related to geology as a factor in erosion?

ANSWER: Not yet.

Questions to Tom Wesche

1. Has the siltation embeddedness associated with construction of the North Fork of the Little Snake River been remedied?

ANSWER: If we get the three flushes that have been requested, we feel that it will go a long way toward a remedy to the situation, but this has not yet occurred. The three flushes are scheduled for this spring.

2. Would normal spring runoff independent of the three planned flushes take care of the problem?

ANSWER: I don't think that we have enough watershed available to produce sufficient runoff to do the job.

Questions to Don Brosz

1. Are you suggesting that the irrigation effficiency in the Salt River System is returning that system to preirrigation conditions?

ANSWER: Absolutely.

2. Is this a favorable development?

ANSWER: We can't yet make that determination. In fact, effects will differ between wide and narrow drainages. By not diverting as much water, we are getting better crop production, however, the increased early spring runoff may have some negative effects. We do not yet know.

Question to Mike Healy

1. As you have changed from sheep to more cattle, have you noticed any difference in erosion patterns?

ANSWER: We have noticed very little change, almost negligible.

Question to Stan Smith

1. Can riparian rehabilitation costs be borne by the state if analysis shows that it is uneconomical for private individuals to pay?

ANSWER: I have attempted to get the Legislature to fund an improvement program for state lands, but have not yet been successful.

Question to Rod Miller

1. Has the State Planning Coordinator's Office received any recommendations for a riparian zone program?

ANSWER: No entity has yet proposed a Wyoming riparian area policy or program. We are aware of the federal agency programs and have commented upon the draft BLM riparian policy, but no specific state policy has been proposed.

WYOMING WATER 1986 AND STREAMSIDE ZONES

Monday April 28
MORNING PROGRAM SESSION
Natrona Room

Registration Booth
8:00 a.m. (Registration Continues Throughout the Day)

Presiding: Dave Nicholas, State Senator, Albany County, Laramie

Riparian (Streamside) Systems
9:00 a.m. *Characterizing Riparian Zones:* Clayton Marlow, Assistant Professor, Animal and Range Science Department, Montana State University, Bozeman, Montana

Balance and Adjustment Process in Stream and Riparian Systems. Burchard Heede, Research Hydrologist, Rocky Mountain Forest & Range Experiment Station, Forest Service, Tempe, Arizona

Break
10:15 a.m. Refreshments in the Display Area (Mardi Gras Room)

Riparian Systems (continued)
10:45 a.m. *Riparian Zones - Then and Now:* Quentin Skinner, Associate Professor, Range Management Department, University of Wyoming, Laramie

Wyoming's Challenge in Riparian Management: Fee Busby, Associate Dean and Director of Agricultural Extension Service, College of Agriculture, University of Wyoming, Laramie

Lunch
12.00 p.m.

AFTERNOON PROGRAM SESSION
Natrona Room

Presiding: Gerald Geis, State Senator, Hot Springs - Washakie Counties, President of the Senate, Worland

Legislation and Laws
1:15 p.m. *Environmental Conservation Legislation - Current and Future:* Malcolm Wallop, U.S. Senator from Wyoming, Washington, D.C.

Federal/State Water Laws: Larry Wolfe, Attorney, Holland and Hart, Cheyenne

Federal Land Management Responsibilities
2:30 p.m. *Forest Service:* Glen Hetzel, Director, Range, Wildlife, Fisheries and Ecology, U.S.D.A., Forest Service, Rocky Mountain Region, Lakewood, Colorado.

U.S. Bureau of Land Management: Hillary Oden, Wyoming State Director, U.S. Bureau of Land Management, Cheyenne

Break
3:10 p.m. Refreshments in the Display Area (Mardi Gras Room)

Wyoming's Use and Needs of Riparian Areas
3:40 p.m. *Municipalities:* Dave Engels, Chairman, North Platte Powers Board, Casper

Agriculture: Don Meike, Rancher - Irrigator, Sussex

Industry: Pat O'Brien, Coordinator, Ecological Programs, Chevron Corporation, San Francisco, California

Recreation: David "Tex" Taylor, Community Development Specialist, Agricultural Economics Department, University of Wyoming, Laramie

4:40 p.m. *Wyoming's Water Resources:* George Christopulos, State Engineer, State Engineer's Office, Cheyenne

EVENING PROGRAM SESSION
Mardi Gras Room

Hospitality
5:00 - 7:30 p.m. Visit Educational Displays and Discussion with Speakers

Tuesday, April 29
MORNING PROGRAM SESSION
Natrona Room

Registration Booth

8:00 a.m. (Registration continues throughout the day)

Presiding: Marlene Simons, State Representative, Crook County, Sundance

8:30 a.m. *Hydrologic Impacts from Riparian Zone Management:* Steve Mizell, Assistant Professor, Wyoming Water Research Center/Geology Department, University of Wyoming, Laramie.

9:10 a.m. *Riparian Zone User Impacts and Mitigation:* William Platts, Fisheries Research Specialist, U.S.D.A. Forest Service, Boise, Idaho.

9:50 a.m. *Point and Non-Point Source Pollution:* E.J. Fanning, Water Quality-Soil Specialist, State Department of Environmental Quality, Water Quality Division, Cheyenne

Break

10:10 a.m. Refreshments in the Display Area (Mardi Gras Room)

10:45 a.m. *The 404 Permit Program in Wyoming:* Mike Carnevale, Planning Supervisor, State Department of Environmental Quality, Water Quality Division, Cheyenne

11:05 a.m. *Fishery Habitat Improvement:* Robert Pistono, Assistant Aquatic Habitat Biologist, Wyoming Game and Fish Department, Lander.

Lunch

11:30 a.m.

AFTERNOON PROGRAM SESSION
Natrona Room

Presiding: Bob Baker, State Representative, Fremont County, Dubois

Research Highlights

1:00 p.m. *Wyoming Water Research Center:* Victor Hasfurther, Acting Director, Wyoming Water Research Center, University of Wyoming, Laramie.

Grazing Exclosures and Natural Stabilization of Stream Channels: Bruce Smith, District Wildlife Management and Biologist Program Leader, U.S. Bureau of Land Management, Rock Springs

Water Nutrient Fluctuations from Beaver Damming Activities: Mike Parker, Associate Professor, Zoology and Physiology Department, University of Wyoming, Laramie.

Ephemeral and Perennial Stream Studies: Quentin Skinner, Associate Professor, Range Management Department, University of Wyoming, Laramie.

Wildlife Association with Streamside Zones: Stan Anderson, Unit Leader, Wyoming Cooperative Fishery and Wildlife Research Unit, U.S.D.I., Fish and Wildlife Service, Laramie

Fish Association with Streamside Zones: Wayne Hubert, Assistant Unit Leader, Wyoming Cooperative Fishery and Wildlife Research Unit, U.S.D.I., Fish and Wildlife Service, Laramie.

Patterns of Bird Distribution and Abundance in Riaprian Zones of Southeastern Wyoming: Deborah Finch, Research Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, U.S.D.A. Forest Service, Laramie.

Crop Water Use Studies: Larry Pochop, Professor, Agricultural Engineering Department, University of Wyoming, Laramie.

Break

3:05 p.m. Refreshments in the Display Area (Mardi Gras Room)

Research Highlights (continued)

3:35 p.m. *Effect of Upland Forest and Riparian Woodlands on Water Yield:* Dennis Knight, Professor, Botany Department, University of Wyoming, Laramie

Flushing Flow Investigations:
Tom Wesche, Research Associate, Wyoming Water Research Center, University of Wyoming, Laramie.

Increasing Irrigation Water Use Efficiencies and Resulting Return Flows:
Don Brosz, Associate Director, Wyoming Water Research Center, University of Wyoming, Laramie

Stream Channel Conveyance Losses:
Victor Hasfurther, Acting Director, Wyoming Water Research Center, University of Wyoming, Laramie

EVENING PROGRAM SESSION
Mardi Gras Room

Hospitality
5:00 - 7:30 p.m. Visit Educational Displays and Discussions with Speakers

Wednesday, April 30
MORNING PROGRAM SESSION
Natrona Room

Registration Booth
8:00 a.m. (Registration continues Throughout the Day)

Presiding: George Salisbury, State Representative, Carbon County, Savery.

8:30 a.m. *Data Needs, Time and Economics Evaluating Riparian Zones:* Jim Jacobs, Professor, Agricultural Economics Department, University of Wyoming, Laramie.

9:00 a.m. *Ranch Riparian Management:*
Kathleen Sun, Rawlins;

Mike Healy, Grass Creek;

Steve Adams, Baggs

Break
10:00 a.m. Refreshments in the Display Area (Mardi Gras Room)

10:30 a.m. *State Financing Alternatives for Wyoming Water Development:*
Stan Smith, State Treasurer, Cheyenne

11:00 a.m. *Where to From Here?* Rod Miller, Rangeland Resource Analyst, Governor's State Planning Coordinator's Office, Cheyenne

Adjourn
11:20 a.m.

PARTICIPATING ORGANIZATIONS:

Wyoming Wool Growers Association
Wyoming Department of Environmental Quality
Governor's State Planning Coordinator's Office
Wyoming State Grazing Board
Wyoming Section - Society for Range Management
Wyoming Stockgrowers Association
Wyoming Farm Bureau Federation
Wyoming Conservation Commission
U.S. Bureau of Land Management
Forest Service, USDA
Wyoming Game and Fish Department
Wyoming Association of Municipalities
Chevron Corporation - Petroleum Association of Wyoming
Wyoming State Treasurer
Jackson Hole Alliance
Wyoming Water Development Association
U.S. Army Corps of Engineers
University of Wyoming Departments of:
- Range Mangement
- Agricultural Economics
- Geology
- Zoology and Physiology
- Agricultural Engineering
- Botany

Montana State University
Wyoming Department of Agriculture
Association of Conservation Districts
Wyoming Chapter - Soil Conservation Society of America
Wyoming Public Lands Council
Fish and Wildlife Service, USDI
National Park Service, USDI
Soil Conservation Service, USDA
Wyoming Heritage Center
Rocky Mountain Forest and Range Experiment Station
Wyoming Cooperative Fishery and Wildlife Research Unit

WYOMING WATER '86 AND STREAMSIDE ZONES CONFERENCE

LIST OF PARTICIPANTS

Steve Adams
Box 117
Baggs, WY 82321

Eric M. Alden
P.O. Drawer 189
Wheatland, WY 82201

Arthur Anderson
U.S. Fish and Wildlife Service
5110 Bowie
Cheyenne, WY 82009

Stan Anderson
Wyoming Cooperative Fishery and Wildlife Research Unit
Box 3166, University Station
Laramie, WY 82071

Everett Bainter
Soil Conservation Service
100 East B St., Rm. 3124
Casper, WY 82601

Bob Baker
Fremont County - Representative
Dubois, WY 82513

Thomas Ball
1801 Bower
Worland, WY 82401

George Bartholomew
Basin Electric
905 20th
Wheatland, WY 82201

Eddie Bateson
Bureau of Land Management
Box 518
Cody, WY 82414

Ron Beiswenger
University of Wyoming
Geography Department
Box 3371, Unviersity Station
Laramie, WY 82071

Janet Bell
Soil Conservation Service
100 East B. St., Rm 3124
Casper, WY 82601

Michael Bell
Hydrologist
259 S. Center, Suite 306
Casper, WY 82601

Gregory Bevenger
U.S. Forest Service
Box 388
Encampment, WY 82325

Matthew Bilodeau
U.S. Army Corps of Engineers
2120 Capitol Ave., Rm. 7009
Cheyenne, WY 82001

Chuch Birkemeyer
U.S. Forest Service
Bridger Teton National Forest
Box 1888
Jackson, WY 83001

Larry Bourret
Wyoming Farm Bureau
Box 1348
Laramie, WY 82070

Donald Brosz
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Pearl Brosz
2304 Hillside
Laramie, WY 82070

Bobbi Brown
Wyoming Heritage Foundation
139 W. 2nd
Casper, WY 82601

F.E. Busby
University of Wyoming
Agricultural Extension Service
Box 3354, University Station
Laramie, WY 82071

Tim Byer
U.S. Forest Ervice
P.O. Box 2176
Mills, WY 82644

Cliff Byrd
Soil Conservation Service
100 East B St., Rm. 3124
Casper, WY 82601

Jacky Cahill
Powder River Basin
Resource Council
48 N. Main
Sheridan, WY 82801

Mike Carnevale
Wyoming Department of
Environmental Quality
Herschler Building
Cheyenne, WY 82002

Bryant Christensen
Targhee National Forest
Box 208
St. Anthony, ID 83445

George Christopulos
Wyoming State Engineer
Herschler Building
Cheyenne, WY 82002

Bill Claxton
Natrona County Planning Office
Box 610
Mills, WY 82644

Jay Cobb
Soil Conservation Service
Box 36
Pinedale, WY 82941

Robert Cobb
State Conservation Commission
3940 Washakie
Casper, WY 82609

James Collins
Bureau of Land Management
2301 Breck Ave.
Casper, WY 82601

Gene Dahlem
Bureau of Land Mangement
951 N. Poplar
Casper, WY 82601

Bruce Daughton
111 S. Wolcott
Casper, WY 82601

Roger Dean
Environmental Protection Agency
1390 Ithara Drive
Boulder, CO 80303

Marlene Depietro
U.S. Forest Service
809 S. 9th
Douglas, WY 82633

Jack Doyle
Soil Conservation Service
Box 36
Pinedale, WY 82941

Thomas Elson
U.S. Forest Service
11177 W. 8th Ave.
Box 25127
Lakewood, CO 80225

Dave Engels
Casper Board of Public Utilities
200 N. David
Casper, WY 62609

Alicia Espinoza
University of Wyoming
Range Mangement Department
Box 3354, University Station
Laramie, WY 82071

Collin Fallat
Director Agriculture Planning and Development, Wyoming Department of Agriculture
2219 Carey Ave.
Cheyenne, WY 82002

E.J. Fanning
Department of Environmental Quality
Herschler Building
Cheyenne, WY 82002

James Farrell
Bureau of Land Management
413 East Hugus, Apt. B
Rawlins, WY 82301

Deborah Finch
U.S. Forest Service
2275 North 15th St.
Laramie, WY 82070

Willie Fitzgerald
Bureau of Land Management
951 N. Poplar
Casper, WY 82601

Cliff Franklin
Bureau of Land Management
5051 King Arthur Way
Cheyenne, WY 82009

Carma Franz
University of Wyoming
Range Management Department
1207 Custer
Laramie, WY 82070

Ladd Frary
U.S. Forest Service
605 Skyline Drive
Laramie, WY 82070

Tom Frolli
809 S. 9th
Douglas, WY 82633

Alvin Gale
University of Wyoming
Agricultural Extension Service
Box 3354, University Station
Laramie, WY 82071

Charleen Garofalo
State Conservation Commission
2219 Carey Ave.
Cheyenne, WY 82002

Gerald Geis
Hot Springs - Washakie Co. - Senator
Worland, WY 82401

William Gentle
State Conservation Commission
2219 Carey Ave.
Cheyenne, WY 82002

Michele Girard
U.S. Forest Service
3924 Canyon Lake Dr.
Rapid City, SD 57702

Don Glenn
Bureau of Land Management
1716 Glasgow
Rawlins, WY 82301

Grant Godbolt
U.S. Forest Service
261 Sherman
Sheridan, WY 82801

Edwin Gooley
U.S. Army Corps of Engineers
Box 809
Riverton, WY 82501

Bob Gosman
Boettcher and Company
120 E. 15th
Casper, WY 82601

Ken Hamilton
Wyoming Farm Bureau
406 S. 21st. St.
Laramie, WY 82070

Terri Hammer
U.S. Forest Service
809 S. 9th
Douglas, WY 82633

Paul Hansen
University of Montana
1105 Haaglund Drive #23
Missoula, MT 59802

Victor Hasfurther
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Mike Healy
Box 699
Worland, WY 82401

Buchard Heede
Rocky Mtn. Forest & Range Experiment Station
ASU Campus
Tempe, AZ 85282

Rhonda Helzner
U.S. Forest Service
1222 Custer
Laramie, WY 82070

Frank Henderson
Agricultural Extension Service
107 N. 5th
Douglas, WY 82633

Charles Hendricks
U.S. Forest Service
11177 W. 8th Ave.
Box 25127
Lakewood, CO 80225

Garie Henry
Box 711
Robertson, WY 82944

Robert Henszey
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Glen Hetzel
U.S. Forest Service
P.O. Box 25127
Lakewood, CO 80225

Paul Hoffman
4003 Federal Building
Casper, WY 82601

Martha Horn
Hydrogeologist
Box 2133
Casper, WY 82601

Leslie Horsch
Casper-Alcova Irrigation District
Box 849
Mills, WY 82644

Wayne Hubert
Wyoming Cooperative Fishery &
Wildlife Research Unit
Box 3166, University Station
Laramie, WY 82071

Peter Jackson
Society for Range Management
2760 W. 5th Ave.
Denver, CO 80204

Jim Jacobs
University of Wyoming
Agricultural Economics Department
Box 3354, University Station
Laramie, WY 82071

Gerald Jech
Bureau of Land Management
1300 N. 3rd St.
Rawlins, WY 82301

Deanna Jefferis
863 S. Lincoln
Casper, WY 82601

Elmer N. Johnston
Johnston, Inc.
234 W. 1st St.
Casper, WY 82601

Wm. R. Jones
1355 Cottonwood
Wheatland, WY 82201

Harold Josendal
Box 892
Casper, WY 82602

Greg Kerr
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Ray Kiewit
Thunder Basin National Grassland
809 S. 9th St.
Douglas, WY 82633

William King
Wyoming State Highway
Department
929 Creighton
Cheyenne, WY 82009

Ngugi Kinuthia
University of Wyoming
Range Management Department
Box 3569, University Station
Laramie, WY 82071

Pid Kinyua
University of Wyoming
Range Management Department
Box 3569, University Station
Laramie, WY 82071

Duane Klamm
Soil Conservation Service
100 East B St., Rm. 3124
Casper, WY 82601

Dennis Knight
University of Wyoming
Botany Department
Box 3165, University Station
Laramie, WY 82071

James Kor
Bureau of Land Management
1602 Oxford Drive
Cheyenne, WY 82001

Richard Kroger
Bureau of Land Management
Box 119
Worland, WY 82401

Roy Kuehner
Box 504
Wheatland, WY 82201

Hanover Irrigation District
Box 965
Worland, WY 82401

Lynne Lanning
Wyoming State Highway
Department
Box 1708
Cheyenne, WY 82002

Bill Laycock
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Robert Leffert
U.S. Forest Service
Black Hills National Forest
RR 2 Box 200
Custer, SD 57730

Steve Libby
U.S. Forest Service
Black Hills National Forest
RR 2 Box 200
Custer, SD 57730

Dick Loper
Wyoming State Grazing Board
Box 1202
Lander, WY 82520

Jim Lowrie
U.S. Forest Service
Box 680
Sundance, WYU 82729

Sue Lowry
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Anne MacKinnon
Casper Star Tribune
P.O. Box 80
Casper, WY 82602

Clayton Marlow
Montana State University
College of Agriculture
Bozeman, MT 59715

Rebecca Mathisen
Wyoming Industrial Siting Admin.
7014 Bomar Drive
Cheyenne, WY 82009

Don Meike
Sussex Route
Kaycee, WY 82639

Earl Michael
3160 Monte Vista
Torrington, WY 82240

Gerard Mick
U.S. Army Corps of Engineers
215 N. 17th St.
Omaha, NE 68102

Rod Miller
Planning Coordinators Office
Herschler Building
Cheyenne, WY 82002

J.R. Mitchell
Box 11, Ucross Route
Clearmont, WY 82835

Stan Mitchem
Soil Conservation Service
100 East B St., Rm 3124
Casper, WY 82601

Steve Mizell
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Keith Mussallem
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Clarke McClung
Bureau of Land Management
110 S. Wolcott, Rm. 111
Casper, WY 82601

Dave Nicholas
Albany County-Senator
1051 Duna Dr.
Laramie, WY 82070

John Niland
State Conservation Commission
Herschler Building
Cheyenne, WY 82001

Mike O'Grady
5021 Hickory Pl.
Cheyenne, WY 82001

Sonny O'Neal
U.S. Forest Service
605 Skyline Dr.
Laramie, WY 82070

Pat O'Brien
Ecological Programs
Chevron Corp.
Box 7929
San Francisco, CA 94120

Hillary Oden
Bureau of Land Management
2515 Warren Ave.
Cheyenne, WY 82001

Linda Osterman
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Toney Ott
Environmental Protection Agency
One Denver Place, Suite 1300
999 18th St.
Denver, CO 80026

Don Park
1198 Mile High Dr.
Casper, WY 82604

Mike Parker
University of Wyoming
Zoology Department
Box 3166, University Station
Laramie, WY 82071

Barry Parrish
South Dakota Dept. of Game, Fish,and Parks
3305 W. S. St.
Rapid City, SD 57745

Carolyn Paseneaux
Box 115
Casper, WY 82602

Robert Pistono
Wyoming Game and Fish Dept.
260 Buena Vista Dr.
Lander, WY 82520

William Platts
U.S. Forest Service
1603 Sunrise Rim
Boise, ID 83705

Larry Pochop
University of Wyoming
Ag. Engineering Department
Box 3295, University Station
Laramie, WY 82071

Lloyd Porter
Bureau of Reclamation
Box 167
Cheyenne, WY 82009

Jeff Powell
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Roy E. Prior
Howard Neddles Tammen & Bergendoff
907 N. Poplar, Suite 250
Casper, WY 82601

Kenneth Radek
Targhee National Forest
Box 208
St. Anthony, ID 83445

John Rankine
Star Route
Worland, WY 82401

Roy Reichenbach
Converse County Weed & Pest District
Box 728
Douglas, WY 82633

Richard Rintamaki
Soil Conversation Service
2141 Sunflower
Casper, WY 82604

Merl Rissler
5256 Alcova Rt.
Casper, WY 82604

David Roberts
Bureau of Land Management
7126 Cordova Drive
Cheyenne, WY 82009

Dan Rodgers
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

W.L. Rohrer
Chevron USA, Inc.
P.O. Box 2619
Casper, WY 82602

Terry Rooney
Soltio Petroleum
P.O. Box 30
Casper, WY 82602

Phyllis Roseberry
Box 1724
Worland, WY 82401

Gary Rosenlieb
Bureau of Land Management
1204 Cove Way
Worland, WY 82901

George Salisbury
Carbon County-Representative
Savery, WY 82332

Robert Schmal
Medicine Bow National Forest
605 Skyline Drive
Laramie, WY 82070

Gerald Schuman
U.S. Department of Agriculture
8408 Hildreth Rd.
Cheyenne, WY 82009

Don Seibert
1013 Maple Way
Rock Springs, WY 82901

Carolyn Sieg
U.S. Forest Service
School of Mines
Rapid City, SD 57785

Ronald Siekert
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Frank Simons
Box 20
Beulah, WY 82712

Marlene Simons
Crook County-Representative
Sundance, WY 82729

Don Sims
Hydrographer-Commissioner
Box 818
McFadden, WY 82080

Quentin Skinner
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Bruce Smith
Bureau of Land Management
Box 1869
Rock Springs, WY 82901

Harriet Smith
5120 Ogden Rd.
Cheyenne, WY 82009

Jack Smith
Department of Environmental Quality
3313 Frontier
Cheyenne, WY 82001

Michael Smith
University of Wyoming
Range Management Department
Box 3354, University Station
Laramie, WY 82071

Stan Smith
State Treasurer
Capitol Bldg.
Cheyenne, WY 82002

Everett Spackman
University of Wyoming
Agricultural Extension Service
Box 3354, University Staiton
Laramie, WY 82071

Elbert Spencer
Bureau of Land Management
811 Creighton
Cheyenne, WY 82009

Fred Stabler
Bureau of Land Management
1212 Weaver St.
Rawlins, WY 82301

Ken Stinson
Bureau of Land Management
318 Sagebrush
Worland, WY 82401

Bo Stuart
U.S. Forest Service
Box 1888
Jackson, WY 83001

Dennis Sun
Sun Ranch
Alcova, WY 82620

Kathleen Sun
Sun Land and Cattle Company
1611 Park Dr.
Rawlins, WY 82301

David Tex Taylor
University of Wyoming
Ag. Economics Department
Box 3354, University Station
Laramie, WY 82071

Mbii Thigunku
University of Wyoming
Range Management Department
Box 3569, University Station
Laramie, WY 82071

Mike Titemeyer
Bureau of Land Management
Box 1455
Lander, WY 82520

Joy Trowbridge
U.S. Forest Service
5711 S. View Rd.
Laramie, WY 82070

Bob Turner
Audubon Society
4150 Darley #5
Boulder, CO 80303

Colin Voigt
Bureau of Land Management
3601 A. Cleveland
Rock Springs, WY 82901

Paige Waldvogel
Department of Environmental Quality
Herschler Building
Cheyenne, WY 82001

Jim Walsh
University of Wyoming
Geology Library
Box 3006, University Station
Laramie, WY 82071

Andy Warren
Bureau of Land Management
1300 N. 3rd St.
Rawlins, WY 82301

Jamie Watts
U.S. Forest Service
Medicine Bow National Forest
P.O. Box 187
Encampment, WY 82325

Tom Wesche
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Joe Wichman
Bureau of Land Management
P.O. Box 1175
Worland, WY 82401

Gerald Widhalm
1017 Laredo Dr.
Douglas, WY 82633

David Wilde
Bureau of Reclamation
4731 S. Center
Casper, WY 82601

Robert Wiley
Game and Fish Department
528 S. Adams
Laramie, WY 82070

Bill Wilson
Bureau of Land Management
408 N. Lane
Worland, WY 82401

Larry Wolfe
Holland & Hart
Suite 500
2020 Carey Avenue
Cheyenne, WY 82001

Steven Wolff
Wyoming Water Research Center
Box 3067, University Station
Laramie, WY 82071

Thomas Woodward
Evergreen Enterprises
110 W. 2nd St., Rm 230
Casper, WY 82601

H. Doug Yoder
Tennessee Valley Authority
P.O. Box 1892
Glenrock, WY 82637

Larry Young
Tennessee Valley Authority
P.O. Box 2482
Casper, WY 82602

Gail Zimmerman
Casper College
Biology Department
2361 Trojan Dr.
Casper, WY 82609