WATER QUALITY RISK ASSESSMENT FOR GRAZING AREAS

Introduction

The purpose of this publication is to help livestock managers and landowners assess risk of water quality pollution in streams associated with grazing areas and design grazing management changes to improve riparian health. This publication is not an enforcement tool. It is not intended to ensure compliance with water quality regulations but to reduce noncompliance risk through reducing pollution risk. Use this publication to learn about riparian conditions and grazing practices that increase or decrease risk of water quality impairment and that increase the environmental, social, and economic sustainability of livestock operations. This is not a comprehensive self-diagnosis and treatment manual but an assessment. Depending on the risks identified, you may wish to discuss management options with a natural resources professional (for example, Extension, USDA Natural Resources Conservation Service, conservation district). Remember that land manager commitment and attention to riparian function is more important for success than the adoption of any particular management practice.

This publication will cover:

- Water quality regulations;
- Riparian health effects on water quality and effects of grazing on riparian health;
- Pollutants associated with livestock grazing;
- Improper versus sustainable grazing;
- Conditions that increase risk of water quality problems;
- Grazing practices that increase risk of water quality problems;
- Conditions that characterize healthy streams and create good water quality;
- Grazing practices that promote healthy streams and water quality;
- Exclusion fencing and riparian pasture management; and
- Reference materials for further study.

Water Quality Regulations

More than 15,000 households in Washington State own livestock. Many of those animals are occasionally in proximity to surface water—water which benefits others in the watershed. Because of the dual nature of surface water as a public and private good, federal and state laws regulate water users to protect other uses of the same water.

The federal Clean Water Act’s stated goal is "to restore and maintain the chemical, physical and biological integrity of the nation's waters." The Clean Water Act defines, and regulates, separately, two kinds of pollution: **point source**, which is contaminated water coming from a discrete "point," such as a pipe or ditch (think waste treatment plant), and **nonpoint source**, which is diffused contamination to surface waters or groundwater coming from a larger, geographically dispersed source (such as nutrient runoff from excess fertilizer application, etc.). According to the federal Environmental Protection Agency, “Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification.” Most livestock operations are potential nonpoint sources. In addition to the federal Clean Water Act, Washington State law regulates nonpoint source pollution. The Washington State Water Pollution Control Act (RCW 90.48) makes it unlawful to discharge pollutants into state waters. This includes discharges from livestock operations.

“It shall be unlawful for any person to throw, drain, run, or otherwise discharge into any of the waters of this state, or to cause, permit or suffer to be thrown, run, drained, allowed to seep or otherwise discharged into such waters any organic or inorganic matter that shall cause or tend to cause pollution of such waters according to the determination of the department” [of Ecology] (Revised Code of Washington, 90.48.080).

State law encompasses multiple water quality parameters that are influenced by livestock, including nutrients, bacteria, dissolved oxygen, pH, temperature, and sediment. The Department of Ecology (Ecology) is responsible for enforcement of the Washington State Pollution Control Act and has been delegated the authority to administer the federal Clean Water Act. Nonpoint source pollution is, by nature, difficult to track; multiple minor sources and contributions combine to produce a major problem. In addition, many organisms in the environment other than livestock contribute pollutants such as fecal bacteria. For these reasons, proactive efforts to stop pollution before it happens and promote healthy riparian vegetation and functioning riparian processes (which are what cause good water quality) are critical. Prevention, not dilution, is the solution to pollution. This document identifies general site conditions that represent pollution risk and identifies livestock management practices that increase risk of pollution. More importantly, it offers practices that promote riparian health and water quality. Landowners are obligated to avoid contributing to both nonpoint and point source pollution.

However, nonpoint source pollution cannot be adequately defined and managed through water quality testing (Kozlowski et al. 2016). Regulatory authorities and scientists agree that riparian health is the driver of water quality in a natural setting. Therefore, the federal Clean Water Act and management literature on water quality recommend using *assessments of biological function to evaluate relative risks of pollution* in riparian ecosystems (Aron et al. 2013; Hall et al. 2014). The EPA is directed to publish information on "establishing and measuring water quality criteria for toxic pollutants on other bases than pollutant-by-pollutant, including biological monitoring and assessment methods."

Riparian Proper Functioning Condition and Grazing Effects

Biological monitoring and assessment methods are based on indicators of stream health. In the risk assessment section, risky riparian conditions are described adjacent to livestock management factors that may contribute to risk conditions. Likewise, healthy riparian conditions are listed along with healthy grazing practices and strategies.

According to the interagency technical reference for riparian health (TR 1737-15), a stream is "functioning properly when adequate vegetation, landform, or woody material is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality;
- Capture sediment and aid floodplain development;
- Improve floodwater retention and groundwater recharge;
- Develop root masses that stabilize streambanks against erosion; and
- Maintain channel characteristics" (Dickard et al. 2015).

Livestock may be a dominant influence on vegetation. Vegetation, in most circumstances, controls these riparian functions. Riparian function maintains water quality. Grazing effects on riparian zones must be a primary consideration in grazing planning for land management units that include streams.

The effects of livestock grazing on streams are highly variable, depending on site factors such as stream type, substrate type, vegetation composition, hydrology, as well as grazing-related factors such as timing, duration, **intensity**, and frequency of grazing use (Swanson et al. 2015). Partial defoliation of herbaceous and woody plants is the dominant mechanism by which livestock grazing affects riparian zones. This has a much greater potential influence on streams with sediment-bed channels, which are stabilized by vegetation, than on those with rock and cobble channels whose stability is not dependent on vegetation (Wyman et al. 2006). Negative effects on vegetation and, therefore, on bank stability can usually be avoided by **proper grazing**. Proper grazing is defined by results, and proper grazing results in soil stability and vigorous, diverse, reproducing, site-adapted plant communities. In riparian plant communities, this means grazing allows the reproduction and vigor of wetland herbaceous species such as sedges and rushes as well as riparian trees and shrubs. Riparian plant species are qualitatively different than non-riparian species. They typically have greater root tensile strength, root length, and root mass per unit volume than upland species. These qualities allow riparian plant communities to hold soil against the energy of moving water (see Figure 1).

The greatest risk from improper livestock grazing is the possibility of long-term changes to the ability of riparian areas to filter and assimilate inputs of sediment, nutrients, and bacteria and by weakening processes that moderate stream temperature (Hall et al. 2014). Improper livestock grazing does not just affect

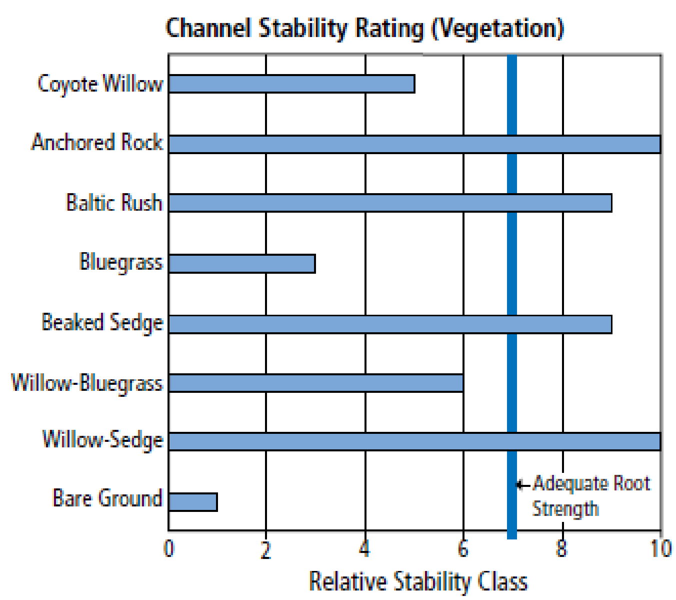

Figure 1. This graphic illustrates the relative ability of different species of common riparian vegetation to stabilize stream channels. Species with a rating less than seven have inadequate root strength to withstand the energy of moving water (Wyman et al. 2006).

What Is a "Riparian" Area?

"*Riparius*" is Latin for river, which comes from "*ripa*" for bank. The term "riparian" refers to the areas alongside a river and the plants, soils, and animals which are associated with rivers and streams. A technical definition for riparian ecosystem is "those assemblages of plants, animals, and aquatic communities whose presences can be either directly or indirectly attributed to factors that are water-influenced or related" (Bedell 1998).

the quantity of standing vegetation in a stream zone—over a period of years, excessive grazing pressure can shift the kind of vegetation, that is, the species composition of the plant community, away from stabilizer species that are adapted to the stream zone and toward upland species which may tolerate higher grazing pressure but which do not have the root strength and mass necessary to hold streambanks together. This can result in a shallowing and widening of the channel and decreased contact with colder, deeper soil, warming the stream.

Numerous studies have documented the adverse effects of improper or poorly managed grazing on riparian, aquatic, and upland ecosystems. Platts (1986) summarized these deleterious effects: "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."

Proper grazing provides for animal distribution across space and time such that this ecological dysfunction is avoided. Proper grazing that avoids this dysfunction also avoids significant pollution because it creates positive environmental conditions which attenuate pollutants and does not accumulate manure in sensitive areas. Figure 2 shows juvenile willows trees re-occupying a site that had been grazed too frequently during the summer to permit willows to grow.

Proper grazing is adaptive by definition. Adaptive management involves deciding on a desired future condition, creating a plan based on reliable information to move from the current condition toward the desired future condition, implementing the plan (which should be different management than what existed before if prior management was partly responsible for undesirable conditions), and evaluating the results to determine whether riparian (or upland) health under new management is improving (Steffens et al. 2013; Provenza et al. 2013). Finally, if riparian health is not improving, a manager must adjust the plan and repeat the process! With or without the robust planning described here identifying a desired future condition, grazing management must adjust on the fly, in real time, to respond to ever-changing environmental variables.

Pollutants Related to Livestock

As stated earlier, while any single contributor (landowner) of nonpoint source pollution may not be significant, the cumulative effects of multiple sources in a watershed can be a major problem. The contaminants and impairments of natural water bodies which are associated with livestock include bacteria, sediment, nutrients (especially nitrogen and phosphorus), and water temperature. Figure 3 shows a horse drylot devoid of vegetation. If this were the only area vulnerable to soil loss in a watershed, it would represent relatively little ecological risk. However, when multiple properties exhibit these characteristics, the cumulative effect can be significant pollution.

Figure 2 Willows beginning to re-occupy a historically degraded riparian site. Photo by Tip Hudson.

Figure 3. Denuded upland pasture adjacent to a stream. These conditions promote pollution both by accumulating manure and by eliminating protective vegetation. Photo by Tip Hudson.

Pollutant Focus: Microbial Pathogens

Fecal coliform (FC) bacteria are a necessary inhabitant of the digestive tracts of all warm-blooded animals. A healthy riparian zone attracts a tremendous diversity and abundance of wild animals, all of whom discharge waste in some manner (Bohn and Buckhouse 1985). Most fecal coliform bacteria do not cause disease. However, since they are an indicator of the presence of animal fecal material, scientists and regulators have historically used fecal coliforms (and, more recently, *E. coli*) as an indicator for the possible presence of other pathogenic (disease-causing) microorganisms, such as *Cryptosporidium*, *Giardia*, or *Salmonella*, for example. Excessive levels of fecal-source pathogens are a human health risk and are often associated with excess sediment and nutrients, which are more significant ecological problems than elevated fecal coliform alone.

The pollutants listed above are pollutants by degree. These substances or conditions occur naturally in a healthy environment; they are only a problem when they are at unnatural levels for a given site. When unnatural levels of sediment, fecal bacteria, nitrogen, phosphorus, or (high) temperature are present and persistent, they may be very ecologically destructive.

Discharge of livestock-related pollutants can occur in three related ways:

1. Defecation directly into a water body;
2. Overland movement of fecal material deposited adjacent to water carried in runoff into a water body; and
3. Excessive grazing pressure which destabilizes riparian and upland soils, making them vulnerable to severe erosion and stream degradation.

Livestock management efforts must address all three pathways to potential pollution by limiting the amount of time animals spend in the stream corridor and riparian zone and by maintaining or improving the health of the plant communities and soils which capture and store incoming precipitation. It is impossible to prohibit all livestock waste from contacting surface water; whether potential pollution is significant pollution depends on whether actual pollutants exceed the ability of the riparian and aquatic ecosystems to capture and neutralize them (George et al. 2011).

Mitigating livestock-related water quality problems from the pollution pathways discussed above requires both manure management and maintaining healthy upland and riparian vegetation. Healthy, stable upland and riparian zones stabilize soil, hold water, and sequester natural pollutants, making maintenance of these zones the less obvious but most important key to protecting water quality and ensuring lasting watershed function (Swanson et al. 2017).

Wetland plant species, like sedges, rushes, and riparian shrubs and trees, are uniquely adapted to withstand the high energy of moving water at the transition zone between the aquatic and the upland environments. Sedges and willows will hold soil together during times of saturated soil or high flow events; Kentucky bluegrass and clover will not. Similarly, on uplands, a diversity of perennial plant species native or adapted to the site will provide significantly greater soil protection and ecological function of all kinds than a narrow suite of species selected by excessive grazing pressure.

As stated earlier, vegetation is the ecological “driver” of water quality because it provides direct physical filtration of pollutants in the water column, it creates and maintains healthy soil in the riparian zone, and it anchors sediment and smaller rock which

Pollutant Focus: Sediment

Flowing stream systems naturally pick up and carry sediment downstream. They are constantly scouring outside bends, picking up fine sediments embedded in stream bottom gravels, and sometimes downcutting parts of stream channels, only to deposit these materials somewhere the kinetic energy of the water has dissipated, forming new banks and bars which will be colonized by new plants if the riparian area is healthy. These new plants stabilize the new banks and catch more sediment (see Figure 4). The process of sediment deposition downstream is called aggradation. In riparian zones that have experienced excessive erosion and downcutting, aggradation is important for raising the elevation of the stream channel and restoring stream access to its floodplain. Excess sediment loss from uplands or stream banks or stream bed is a very serious ecological problem, because topsoil is critical and hard to replace; further, sediment is a carrier of pollutants and nutrients. Problems from sedimentation include:

- Reduced oxygen levels in water;
- Siltation of stream gravels crucial for spawning areas and aquatic insects; and
- Pesticides carried into surface water.

Figure 4. Degraded stream recovering sinuosity (increasing length) and elevation of water table through sediment collection, sediment stabilization by colonizer vegetation, and channel formation. Photo by Tip Hudson.

Pollutant Focus: Nutrients

Excess manure concentrated near a stream can elevate nitrogen and phosphorus levels in surface water. High levels of nitrates and phosphates in aquatic ecosystems can cause a flush of algae growth and subsequent high inputs of organic matter from rapid decomposition, depleting the water of oxygen and causing fish kills. Nitrogen and phosphorus are macronutrients critical for plant growth and development, and it is in the best interest of a land manager to keep them on upland soils where they can benefit upland plants. Nutrient loading commonly occurs in non-grazed ecosystems; other sources of nutrients, including natural decomposition of heavy vegetation, may impact surface waters. Wildland riparian ecosystems in the semi-arid West rarely exhibit excessive nitrogen or phosphorus (Jackson et al. 2006).

creates and maintains stream channel shape. Preventing excess removal of this vegetation and the conversion to a non-riparian-type plant community more tolerant of heavy grazing pressure is essential to protecting stream function and water quality. **Excessive grazing**, what is sometimes called **overgrazing**, will be defined below.

What Is "Improper" Grazing?

Consider this photograph (Figure 5) of a typical sagebrush-steppe wildland stream. Both sides of the fence are grazed.

Persistent grazing pressure (occurring for too long) in the foreground in Figure 5 has led to the removal of riparian-type vegetation, loss of soil, dramatic change in **channel dimension** and **stream pattern**, and decrease in water-holding capacity of this portion of the stream's floodplain. The water is dissipating into the surrounding substrate instead of being held in a channel and adjacent soil.

Periodic grazing in the background has allowed vegetation to persist, promoting healthy riparian attributes. The problem with the foreground pasture is not that it is grazed—both sides are grazed; rather, the problem is the duration (all growing season, at least) and frequency of grazing (individual plants repeatedly defoliated with no opportunity for significant regrowth).

Figure 5. Properly and improperly grazed riparian zones in Nevada. Photo courtesy of the National Riparian Service Team.

The pattern of defoliation and regrowth on herbaceous riparian vegetation during the growing season in the overgrazed foreground of the photo looks something like Figure 6:

Figure 6. Frequent or continuous grazing does not permit sufficient growing season recovery to support herbaceous plants in the riparian area.

The pattern of defoliation and regrowth in the properly grazed background of the photo, characterized by healthy riparian function, looks something like the pattern illustrated in Figure 7:

Figure 7. Grazing of limited duration allows significant growing season recovery.

Plants are overgrazed when the recovery period following a grazing event is not long enough for the primary **forage species** to fully recover. In the overgrazed pasture (foreground of Figure 5), the riparian grasses and grass-like plants are being grazed severely for an extended period, causing multiple defoliations of the same plants, and they are never given an opportunity to regrow or store energy during the growing season. Late summer use has also led to the near elimination of any woody species on this overgrazed segment of the stream. In the properly grazed pasture, the riparian plants are grazed for a short period of time and allowed to grow unimpeded for the remainder of the growing season.

There are several worthy rules of thumb that can guide proper grazing. One collection promoted by retired USFS range supervisor Floyd Reed (Wyman et al. 2006) includes these guidelines:

- Defoliate the primary (most preferred) forage species moderately;
- Do not graze at the same time in the same place every year; and
- Allow plants to regrow before grazing them again.

The section on healthy grazing practices describes in more detail specific ways to accomplish these goals. Figure 8 illustrates moderate defoliation during the active growing season.

Risk Assessment

Risky Conditions

Multiple-season grazing in a riparian area will often cause vegetation to shift away from the types of plants that are effective at maintaining streambank stability and toward plants that will tolerate more frequent defoliation, usually non-riparian species that have lower root strength (see Figure 9). In addition, loss of riparian vegetation can lead to streambed erosion during peak flows which downcuts the stream, effectively lowering the water table, and disconnecting the water table from floodplain vegetation (drying the floodplain out) resulting in long-term reductions in the riparian area's forage-production capacity and stream-stabilization ability. Excessive manure may enter a stream when livestock graze for long periods on streams with insufficient quantity and quality of vegetation. Manure can get into the stream through animals defecating directly into the water body as well as through surface runoff during rainfall or precipitation events that exceed the soil's infiltration capacity.

This multi-season grazing, because of the heavy defoliation, lack of regrowth opportunity, and more frequent hoof activity, also tends to cause soil compaction, exacerbating the problem of

Figure 8. Properly grazed bluebunch wheatgrass in eastern Washington. Photo by Tip Hudson.

Figure 9. Heavily grazed ephemeral stream segment. Photo by Tip Hudson.

overland flow and decreasing root development. *Grazing management strategies designed only for uplands may allow damage to riparian areas unless riparian-focused management is applied. Riparian-focused management is needed when off-stream water is not available, when grazing occurs during hot and dry conditions, and when the grazing period is long* (Swanson et al. 2015). A conscientious livestock owner must manage to prevent or reduce direct deposition and prevent or reduce the likelihood and severity of overland flow that could carry nutrients and bacteria into the water. The following lists will help to illustrate this continuum of risk and the principle of cumulative risk or risk reduction.

Conditions within the stream zone which increase risk of a water quality problem include:

- Bare soil;
- Visibly eroding streambanks; streambanks are more prone to erode when soils are saturated (note: this is sometimes a hydrologic feature rather than livestock damage);
- Erosional features in livestock trails; and
- Replacement of riparian-type vegetation with upland-type vegetation or invasive plants.

Any one of the above factors is not necessarily evidence of substantial pollution but represents increased potential to pollute and increased risk; multiple risk factors increase the likelihood of a water quality violation. The language “potential to pollute” is controversial. This concept has value, though, understood the right way. Many ecological interactions exhibit non-linear threshold behavior. For example, wind may not move soil until the wind velocity reaches 25 mph. It is not that half the soil moves at 12 mph; rather, nothing moves until 25 mph and then lots of soil is lifted. Streambank erosion occurs in similar fashion—no erosion occurs until soils are saturated and large volumes of soil move all at once. A threshold event, for example, a rain-on-snow event, may cause significant pollution where no pollution was previously present in water. This can occur both in the water and on the bank. At very high flows, stream-bottom sediments and larger rock and cobble can be suspended in the water column and transported.

Certain visual indicators or conditions are direct evidence of discharge; whether this discharge is a significant contributor of pollutants requires further consideration of the amount, frequency, and duration of the discharge:

- A "plume" of sediment in the water where a streambank is being actively eroded by heavy livestock activity;
- A “plume” of manure continually being washed into a stream; and
- Significant manure accumulation in or immediately adjacent to water, above levels that the soil-plant interface can effectively stabilize or prevent from being transported to water.

Water quality degradation risk increases with these grazing management variables:

- Increasing length of grazing period or cumulative length of grazing events in a year;
- Decreasing length of rest and recovery period between grazing events; and
- Severity of defoliation in grazing event, sometimes called intensity—intensity may be confused with animal density, which does not necessarily result in severe defoliation.

Absence of woody vegetation may be an indicator of impaired riparian vegetation; however, not every riparian area naturally has woody species, so absence of trees may not be an indicator. Trees and shrubs are important for building banks; their roots function like rebar in concrete, maintaining a healthy stream shape, pattern, and profile—all of these factors are drivers of stream temperature. Where woody vegetation is a natural component of the riparian zone, its absence may be an indicator of dysfunction. In floodplains with anaerobic soils, tree species will not grow and planting efforts will fail.

Similarly, stock trails may erode. Whether a particular trail is a water quality problem depends on whether it serves as a conduit for sediment and manure into surface water. Where trails are actively eroding, landowners or managers should use erosion control measures, similar to what would be done for a road that is eroding during heavy rainfall events.

Risky Grazing Practices

The following grazing practices are often associated with declining trends in riparian condition and declining or impaired water quality. Any one practice does not represent evidence of discharge.

- Long grazing periods or season-long grazing;
- Short recovery and rest periods (recovery time is variable depending on seasonality and severity of defoliation);
- Grazing during the hot season every year in pastures with a riparian area;
- Grazing on steep slopes adjacent to a stream;
- No off-stream stockwater options;
- No opportunity for vegetation regrowth before winter in riparian areas;
- Any heavy grazing use that occurs too often (high defoliation frequency, short stubble);
- Placing salt or other supplements on or near creeks;
- Leaving a small number of animals behind in a pasture with a riparian zone;
- Feeding livestock (hay, etc.) near surface water;
- Late summer, early fall grazing without practices to discourage riparian loafing that results in unacceptable browsing levels on woody species; and
- Grazing on saturated soils near a stream—this increases the likelihood of manure on the soil surface washing into a water body.

Healthy Conditions

Conditions which are indicative of a healthy plant community that maintains water quality and riparian function include:

- Diversity and vigor of riparian vegetation, including the expected woody species of a particular riparian system;
- Majority of the **greenline** (the soil on the bank at the water's edge) is occupied by desirable riparian-wetland plants;
- Livestock have offsite water or a hardened access point such that animal time in the water is prevented or minimized; and
- Healthy upland vegetation.

Uplands are tied to their drainages, and what happens in the uplands does not stay in the uplands. In grazing areas, there must be sufficient residual at the end of the grazing and growing season to facilitate plant regrowth in spring and provide for soil stability. Figure 10 shows adequate herbaceous vegetation on the greenline to support streambank stabilization and new sediment capture. Proper livestock grazing may enhance these attributes by discouraging undesirable species and promoting reproductive success of desirable species.

An extended treatment of attributes of healthy riparian ecosystems can be found in the publications listed in the Further Reading section at the end of this document.

Figure 10. Sedges and rushes occupying stream edge and anchoring new sediments on a grazed site. Photo by Tip Hudson.

Healthy Grazing Practices

The following practices and principles tend to maintain riparian health and decrease risk of pollution:

- Off-stream water, which dramatically reduces animal time in the riparian zone (Miner et al. 1992; Larsen et al. 1994);
- Salt and supplements placed well away from water sources;
- Short grazing periods, which reduce the risk of severe defoliation;
- Long recovery periods (time between grazing events);
- Conservative stocking rates that plan to take less than half of the standing forage biomass (Holechek et al. 2006);
- Changing the season of grazing use on range and forest each year;
- Moderate defoliation of most preferred plants in the riparian zone;
- Riparian fencing, temporary or permanent, which controls livestock impacts to the stream (permanent exclusion fence prevents most livestock impacts; establishing a riparian pasture allows the manager complete control over timing, duration, and intensity of riparian grazing);
- Using utilization of preferred forage species or woody species as a “trigger” for moving animals out of a grazing unit with a riparian system;
- Grazing during late spring or early summer only every other year;
- Early spring grazing: in early spring animals spend less time in the riparian zone because it is colder and upland forage has higher water content and is abundant; this practice provides a long recovery period and plenty of standing biomass going into winter. Exceptions to this include regions with heavy spring rainfall and saturated soils where intensively grazed pastures are likely to discharge manure into their adjacent drainages or streams;
- Herding animals: herding is different from mere chasing—proper herding settles animals into a safe area where they have sufficient forage;
- Hardened access points or crossing points on streams, especially where banks are steep or soft; and
- Annual grazing use monitoring and trend monitoring as part of an adaptive management strategy.

Exclusion Fence vs. Riparian Pasture Management

Exclusion Fence

If one chooses to use permanent fence to manage stream impacts, there are two possible kinds of fence: drift fence prevents animals from accessing the stream at a preferred access or crossing point or perimeter fence may be used around an entire riparian area (which will necessarily cross the stream at two points).

Total perimeter exclusion fence is often required by cost-share programs; this option usually provides the most regulatory certainty. Perimeter fence works well in locations where animals are more intensively managed or are otherwise supervised, such as tame pasture near a homestead or headquarters. These locations are also where animals usually spend more time or spend the winter and stream protection is critical. Perimeter fence is less advisable in remote forest or range pastures where less frequent observation occurs and where other management practices to reduce riparian grazing pressure should be tried first.

In theory, exclusion fence removes the possibility of grazing impacts in the riparian area. However, exclusion fence in the absence of other management effort may cause several well-known problems:

- Hard fence is hard on wildlife;
- Livestock may still get in and then be trapped inside;
- Fence requires constant maintenance;
- T-post fences often sink during winter in riparian areas, necessitating more frequent fence maintenance; and
- Thatch accumulation from invasive riparian grasses, such as reed canarygrass, may serve as a source for excess nutrients after five to ten years and function as refugia for rodents, which often have more dangerous fecal pathogens than domestic livestock.

Riparian Pasture

Fencing the entire riparian zone as a single, viable grazing unit or paddock allows the manager to control the timing, duration, and intensity of livestock grazing toward any number of riparian management objectives. A riparian fence usually also serves as a cross fence on the larger landscape, expanding management options on the adjacent upland pasture or range, not just inside the riparian pasture. This can avoid riparian damage during periods when upland soils are dry and firm but riparian soils are saturated and subject to hoof damage.

In addition to the legal risk management benefits of carefully controlling riparian grazing, there may be production benefits of establishing a riparian fence and providing off-stream water. Animals have been shown to experience improved health through reduced exposure to waterborne pathogens, maintaining a drier hair coat in cold weather, and increased water consumption due to a warmer water supply (Willms et al. 2002). Degraded ecosystems are typically less productive, and controlling livestock access to a degraded riparian zone often improves forage yield. Riparian zones may be ten times more productive than the adjacent uplands if the vegetation is fully expressed.

Proper grazing inside a riparian pasture (enclosure) is critical. Extra care should be taken to avoid grazing on saturated soils and to avoid repeated defoliation of herbaceous species on streambanks.

These practices do not guarantee compliance with water quality laws; however, when applied as part of an adaptive management strategy for managing riparian vegetation for optimum riparian function, they reduce the risk of water quality pollution and risk of noncompliance. These practices are explained in more detail in *Riparian Area Management: Grazing Management Processes and Strategies for Riparian-Wetland Areas* (Wyman et al. 2006) found in the References section.

To Exclude or Not to Exclude

It may be either ecologically necessary or logistically easiest for the manager or landowner under certain circumstances to exclude domestic livestock for several years to allow riparian vegetation to grow, become established, and begin to facilitate riparian processes, eventually improving water quality. Here are a few scenarios where exclusion is likely the best approach:

- When excess grazing pressure or improperly timed grazing has resulted in loss of riparian-type herbaceous species or naturally-occurring woody species important for streambank stabilization, exclusion has been effective in allowing riparian species to re-establish. This sometimes requires management efforts to suppress competitive species, such as reed canarygrass or weedy forbs, which may interfere with restoration goals.
- Where animals are necessarily present for a long period on a small area, such as on small farms, multiple-season access or year-long access to a stream will not protect water quality and exclusion fence is likely necessary to avoid the high-risk site conditions described above. A riparian pasture may be a successful option, but the riparian vegetation must not be constantly, tightly grazed. Extended periods without grazing pressure are necessary.
- Research has shown that in larger landscapes historically overgrazed, anywhere from three to ten years of rest from livestock grazing pressure improves riparian and aquatic habitat, woody species abundance, and water quality. It is critical to remember that when grazing is resumed on these recovered riparian sites the timing, duration, and frequency of use does not mimic the grazing which caused degradation in the first place.
- Additionally, feeding on pasture in the winter adjacent to a stream may cause significant discharge if the area is near the stream and soil conditions or slope cause contaminated

surface runoff. If animals will not stay away from or out of the stream, fence may be necessary to prevent riparian damage. Factors to consider when evaluating risk of damage and water quality degradation include the amount of manure, slope, late winter precipitation, ability of soils to infiltrate precipitation, frequency of rain-on-snow events, and, most importantly, distance to water.

Finally, exclusion to allow prolonged vegetation recovery should always be used in conjunction with a plan for upland range or pasture management that maintains or improves upland health. Remember, riparian management starts at the ridgeline, not the greenline.

Glossary

channel dimension: The cross-sectional view of a stream, whether narrow and deep, wide and shallow, braided, etc.

forage species: Plant species most readily consumed by large herbivores, both wild and domesticated.

grazing intensity: Grazing intensity generally refers to the density of animals in a given grazing unit, like a pasture, and is usually accompanied by greater management attention; it should not be confused with grazing severity, which refers to very low plant residual after a grazing event.

greenline: The elevation where vegetation begins on the streambank, usually at the "line" above which water does not stay long, the ordinary high water mark. A biological definition is "the first perennial vegetation that forms a lineal grouping of community types on or near the water's edge. Most often it occurs at or slightly below the bankful stage" (Winward 2000). Greenline is more a biological feature than a geophysical or hydrological feature.

nonpoint source (NPS): "Any source of water pollution that does not meet the legal definition of 'point source' in section 502(14) of the Clean Water Act;" "NPS pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. NPS pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters" (EPA 2018).

overgrazing/excessive grazing: "Continued heavy grazing which exceeds the recovery capacity of the community and creates a deteriorated range. cf. overuse" (Bedell 1998).

point source: "Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture" (EPA 2018).

proper grazing: Any combination of timing, duration, frequency, and severity of grazing use over time that maintains or improves soil stability, hydrologic function, and the health of natural plant communities.

stream pattern: The aerial view of a stream, most notably its sinuosity, defined as the length of the stream over the valley length for a given stream segment.

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