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Reducing Ecological Impacts of Shale Development: RECOMMENDED PRACTICES FOR THE APPALACHIANS

ECOLOGICAL BUFFERS

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Ecological buffers are protected zones established around sensitive or critical areas — such as wildlife breeding or hibernation habitats, streams, and wetlands — to lessen the impacts of human activity and land disturbance. Well pads, roads and pipelines developed for shale oil and gas development reduce and fragment native forests, rivers and natural grasslands, reducing the quality of migration, foraging and nesting habitats for fish and wildlife. Changes in land cover can also have a negative impact on water quality and watershed health. Ecological buffers may be used to reduce or minimize the risks of land use disturbance and proximity of infrastructure specifically associated with shale energy development.

STATE OF THE RESEARCH

Significant research exists documenting the importance and effectiveness of maintaining riparian buffers around streams, lakes and wetlands to minimize impacts to water quality.[1–3] Most of this research is derived from monitoring responses to forestry and agricultural practices. In addition to reducing development impacts to water quality, riparian buffers have also been shown to provide habitat and movement corridors for many species of birds, mammals, reptiles, fish and invertebrates.[4–6]

Upland and interior buffers help lessen impacts to species that rely on other habitat types, such as caves or interior forest habitat, and protect areas important to breeding, rearing and hibernation.[2,4–11] Although these buffers fill an important role, studies specific to buffer widths needed to protect these species are relatively limited.

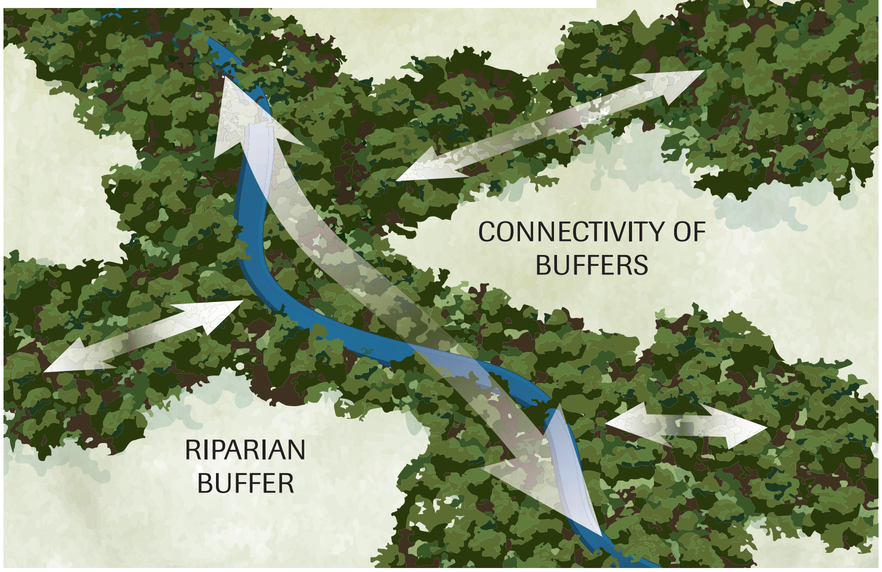
Many factors influence the determination of a buffer width that is effective, including the targeted function of the buffer (e.g., to reduce erosion or protect raptor nesting habitat) and landscape characteristics, like slope, geology and vegetation.[6,12–16] Riparian buffers that are effective in maintaining species diversity are often wider than those required to reduce sedimentation.

Width is not the only factor that determines buffer effectiveness; buffers that are continuous around the perimeter or along the length of a sensitive habitat area can be more effective than fragmented buffers in providing fish and wildlife habitat and preserving ecosystem health.[2,3,6,17] Conservation strategies that target landscape-scale planning, including the configuration and connectivity of buffers and cumulative watershed development are most effective at supporting regional biodiversity.[2,5,11,18–22]

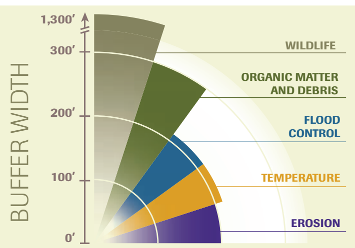
Studies specific to habitats and species in the Appalachian region and to shale energy infrastructure could improve the effectiveness of conservation strategies as development expands. This document does not address buffers necessary to minimize ecological risks associated with the transport, use, storage or disposal of fracturing chemicals, nor does it address buffers to minimize for air-quality impacts associated with shale development.

Ecological Buffers

Interior forest and upland buffers can protect interior forest areas, provide connectivity between different habitat types, and reduce disturbances to critical breeding and nesting areas.



Riparian buffers along streams, lakes and wetlands can help to lessen the impacts of nearby development. Riparian areas also provide habitat for a variety of plant and animal species and protect water quality and aquatic habitats.



Effective buffer width depends upon a variety of factors, such as slope, vegetation and function.

Connectivity of buffers is essential in reducing impacts of development and allowing species to move across the landscape and access vital resources.

Graphic adapted from Figure 2.38 of "Stream Corridor Restoration: Principles, Processes, and Practices" by the Federal Interagency Restoration Working Group

EVIDENCE OF IMPACT
Disturbance to Fish and Wildlife Habitat

Fish and wildlife need stream, riparian and upland habitat for breeding, nesting and hibernation, as well as the ability to move through the landscape.[4–6] Effects of energy development – including fragmentation, noise and light pollution, human activity, and the spread of invasive species – can result in disturbance to and loss of these valuable habitat areas, which can lead to reduced reproductive rates and changes in behavior.[23,24] For example, disturbance around raptor nests (i.e. hawks and eagles) during the breeding season can result in avoidance behavior that interferes with feeding and rearing behavior or an abandonment of eggs or young.[10,25,26] Development can also accelerate the spread of invasive species that compete with native species and alter Appalachian ecosystems.[27,28]

While buffers can lessen disturbances to wildlife and important habitat areas, many forest-dependent species still require protection of larger, high-quality upland or interior habitat areas to survive and reproduce.[4–6]

Mammals can lose valuable habitat and the ability to move through the landscape as a result of habitat loss and fragmentation.[4–6] Riparian buffers can protect foraging habitat for small and semi-aquatic mammals, such as river otter and water shrew, and act as movement corridors for larger mammals like bobcat, red fox, deer and black bear.[4–6] Upland and interior buffers around caves and bat hibernacula can help lessen the disturbances to bats and other cave-dwelling species.[7]

Songbirds can be exposed to higher rates of nest predation and lose valuable habitat from the effects of energy development.[29-32] Riparian buffers of a sufficient width are able to support many riparian and woodland birds and have been associated with lower nest predation rates, however they are unlikely to maintain most forest-interior bird species that rely on large areas of intact forest habitat.[4,5]

Reptiles and amphibians can lose critical aquatic, riparian and upland habitats used for foraging, overwintering, breeding and nesting as a result of energy development.[11,18–20] The benefits and effectiveness of buffers around these habitats vary widely between species.[2,4,33] Generally, conservation strategies that extend beyond riparian buffers and also maintain a connected landscape with relatively large areas of natural forest and wetlands are more effective.[34-41] Maintaining healthy stream and wetland habitats is also important to reptiles and amphibians during their aquatic life stage. For example, increased sediment has been shown to reduce tadpole densities and smother eastern hellbender salamander larvae.[21,42]

Fish and aquatic invertebrates can be impacted by the effects of energy development near streams, wetlands and vernal pools, including changes to stream characteristics such as temperature, light and sediment that can cause changes in community structure.[5,43-45] Freshwater mussels, which play an important part in stream and lake ecosystems by providing habitat and influencing food availability, are one example of a species that could be

Reptiles, like the eastern box turtle, need a variety of habitats for foraging, breeding and nesting activities. Maintaining riparian buffers and connectivity between habitat areas is important. © Kent Mason

negatively impacted by inadequate buffers. They are particularly sensitive to changes in water quality.[46] The Appalachian region hosts dozens of freshwater mussel species, several of which are federally endangered.

Disturbance to Aquatic Ecosystem Processes

Stream, lake and wetland ecosystems work to retain floods, regulate stream temperatures, and filter sediment and nutrients. Hundreds of studies document impacts, and in some cases loss, of these functions if adequate buffers are not maintained.[1,5]

Watershed Scale Functions

Studies show a watershed scale planning strategy that considers the function, configuration and connectivity of protected areas is necessary to prioritize and establish buffers and to protect watershed quality and critical habitat areas.[2,3,5,6,21,22,47-49] Contiguous riparian buffers, when connected with upland buffers, have most effectively reduced impacts of development on these functions.[50-53]

Headwater streams, although small, make up the majority of stream systems in a watershed network and are vital in protecting stream health and biodiversity.[6,33,47,54-56] Impacts to headwaters cascade into other parts of the ecosystem at a large scale, resulting in declines in aquatic and terrestrial species, water quality and supply, and the resilience of the stream ecosystem.[47,54-56] Consequently, large buffers downstream will not significantly improve water quality if headwater networks lack adequate buffers.[6]

Wetland, vernal and floodplain complexes provide essential ecological functions, such as water storage, groundwater replenishment, and sediment and nutrient retention that can be impacted by development.[57,58] These systems also contribute significantly to local biodiversity, providing critical habitat for diverse, and in many cases rare, groups of species.[59]

Stream Flow and Temperature

Loss of vegetated riparian buffers along streams, lakes and wetlands can result in a loss of flood retention and base flow regulation. Without adequate vegetated buffers, the ability of floodplains to store flood flows associated with major storm events and wet seasons might be significantly reduced, resulting in increased flooding and scour.[5] Buffers that fail to extend along an entire stream length, regardless of size, might result in a loss of these functions.[3,12,60]

Forested riparian buffers provide shade, which can help maintain stream temperatures, as well as food and cover for many aquatic species.[5,6,56,61] For headwaters, creeks and small rivers, a riparian buffer that does not extend shade to at least half of the stream or wetland might increase risk to the temperature regime, impacting fish and invertebrate communities.[2,5,21,61] This risk is greater for cold-cool water habitats and species, such as brook trout, that require cooler waters to survive and are less tolerant of large temperature fluctuations and therefore might require wider buffers.[5,34,56,62]

Regulate Sediment, Nutrients and Organic Matter

A major function of riparian buffers is to control erosion and sedimentation by stabilizing banks and filtering sediments and nutrients.[6,60,63] Sedimentation can negatively affect water quality and aquatic species, as well as alter stream and wetland characteristics.[64] In addition, sedimentation reduces the amount of light in the water column which can decrease primary production (i.e. submerged vegetation or zooplankton). This can cause cascading effects throughout the ecosystem and significantly reduce populations of aquatic organisms through mortality, reduced physiological condition and habitat avoidance.[3,65] Riparian buffers capture and slowly filter the overland runoff of stormwater and nutrients, which can otherwise stress aquatic ecosystems.[66-68]

Streams create important fish and wildlife habitat and provide essential aquatic ecosystem processes. © Jack Mills

Riparian habitats provide many ecological functions, including stabilizing soil along stream banks and regulating stream temperature. © Cathy Kerkam, TNC

Preservation of riparian vegetation to control erosion is also important in protecting fish populations because fine sediments can fill in spawning gravels and adversely affect egg development and/or larval fish emergence.[43,62] Failure to maintain riparian buffers might also result in reduced organic matter inputs, including coarse woody debris in streams and wetlands.[6,69] These inputs are critical in regulating energy dynamics and providing habitat structure.

CONSERVATION PRACTICES AND SCIENTIFIC SUPPORT

Scientific literature supports practices that establish and maintain ecological buffers to reduce the effects of human activity and disturbance from energy development on fish, wildlife and aquatic habitats. Moreover, to adequately protect fish and wildlife and aquatic ecosystem processes, buffers need to be established in the context of landscape-scale planning and supplemented with other conservation practices. The following practices are derived from management and guidance documents developed by state agencies, scientific/conservation organizations and industry groups.

Establish Buffers to Minimize Impacts to Fish and Wildlife Habitat

Scientific literature suggests maintaining a buffer around many wildlife and aquatic habitats. While most research is conducted on single species, it is important that a broad multi-species or landscape approach be considered when determining buffer widths. Research supports buffer widths up to 1,300 feet to support a variety of birds, mammals, reptiles, amphibians, fish and invertebrates and should include areas important for time-sensitive periods, including breeding and hibernation. Generally, wider riparian buffers can support higher species abundance and diversity.[3,5] Suggested buffer widths found in the literature for different taxa include:

- *Songbirds:* Suggested buffer widths start at 150 feet, with 330 feet being a common recommendation.[6,9,21,30-32,70] Riparian buffers of more than 660 feet may retain some forest-interior songbirds.[4,5]
- *Mammals:* Riparian corridors equal to or greater than 330 feet.[6,71] Den sites should be buffered, though recommended buffer widths vary widely. Buffers around bat hibernacula range from 500 feet to more than 1,000 feet and should be based on wind direction patterns, adjacent land use and surrounding vegetation.[7,72,73]
- *Amphibians and reptiles:* Riparian buffers vary widely, though buffers of 300 to 540 feet are most commonly recommended.[2,11,69,74,75] Most of these recommendations are based on salamander studies.
- *Fish and aquatic invertebrates:* Suggested riparian buffer widths range from 33 to 330 feet.[3,6,76-78] In general, the number of fish species and fish abundance is significantly greater in buffered streams, and length can be as important or more important than width.[60,65,79,80]

Existing conservation practices involve establishing buffers along and around aquatic habitats (e.g., streams, lakes, ponds, wetlands, vernal pools, spring seeps), interior forest, and other sensitive wildlife habitats to minimize impacts to fish and wildlife. Prior to development, identify wildlife and habitat areas that might benefit from buffers by completing a survey of biological and physical components. Take into account the sensitivity of species, their habitat and landscape characteristics to determine the most appropriate width and configuration of buffers.

Sedimentation can fill spawning gravels and adversely affect egg development and/or larval emergence. © Charles DeCurtis, TNC

Buffers can minimize impacts to cave species and habitats. Reducing impacts to bat populations by minimizing disturbances has become increasingly important as Myotis populations in the Appalachian region have recently been decimated by white-nose syndrome. © George C. Gress, TNC

Establish Buffers to Minimize Impacts to Aquatic Ecosystem Processes

Scientific literature shows that riparian buffers with a minimum width of 65 to 330 feet have supported the functions of flood retention, sediment retention, thermal regimes, and import and recruitment of organic matter and large woody debris.[15,33] Also important in preserving aquatic ecosystem processes and overall watershed health is maintaining buffers along headwater streams.[6,17,81] Suggested riparian buffer widths found in the literature for different functions include:

- *Flood retention and stream flow regulation:* Suggested widths range from 65 to 225 feet in areas with low slope.[6]
- *Erosion and sedimentation control:* Buffer widths of 50 to 160 feet have been shown to be effective.[3,6,13,49,82] However, soil type and slope are key factors in determining adequate buffer widths.[6] Wider buffers should be established in areas with steep slopes (more than 10 percent), larger water bodies, presence of rare species or communities, and less permeable soils.[12–14]
- *Stream temperature regulation:* Recommended buffer widths range up to 230 feet because of variations in stream size, type and position in the watershed. For headwaters, creeks and small streams, a general rule is to keep at least half of the stream in partial shade.[3,6,13,33,76,78,81] One study found that 75-foot buffers maintain water temperature at levels sufficient for brook trout.[76]
- *Organic matter and large woody debris recruitment:* Suggested buffer widths range from 33 to 330 feet.[3,6,83]

Existing conservation practices include maintaining riparian buffers around aquatic habitats, taking into account landscape characteristics and the desired function of the buffer in order to establish an appropriate width and configuration.

Maintain Contiguous Buffers across the Landscape

Scientific literature suggests that a landscape-scale planning strategy that considers the function, configuration and connectivity of protected areas can be effective in prioritizing and establishing buffers. This broader approach has been more effective in protecting watershed health and critical habitat than a smaller scale or single-species approach.[2,3,5,6,21,22,47-49] Connectivity of buffered features is important in maintaining aquatic ecosystem processes, overall watershed health, and the ability of wildlife to move throughout the landscape.[15,53,56,64] Contiguous riparian buffers, when connected with upland buffers, have most effectively reduced the impacts of development on these functions.[50–53] Buffers that mimic natural communities (e.g., native plant species and composition) and that contain a mix of trees, shrubs and grasses generally provide more functions than those that do not.[6]

Existing conservation practices include adopting a landscape perspective to assure continuous riparian buffers and connectivity to forest interior and upland buffers. Annually monitor and treat buffers for occurrences of invasive plant species.

Human activity can potentially disturb bald eagles, interfering with feeding, nesting and breeding activities. © Hal Korber, Pennsylvania Game Commission

TNC Recommended Conservation Practices

Based on scientific literature and existing practices, The Nature Conservancy recommends the following practices:

- ☑ **Preserve a buffer of at least of 330 feet around freshwater habitats** (i.e. streams, rivers, wetlands, ponds and lakes) to support fish and aquatic wildlife and to reduce sediment runoff, provide flood retention, moderate stream flow, maintain water temperatures, and provide vegetation inputs that form habitat in aquatic systems (including roots, branches, limbs and leaves). For larger streams, a buffer greater than 330 feet might be necessary to assure infrastructure is not sited in the floodplain.
- ☑ **Preserve canopy cover over headwater and cold water streams** to maintain water temperatures and physical habitat.
- ☑ **Avoid disturbance to sensitive species and habitats,** including those with special protection status by working with fish and wildlife management agencies to identify occurrences and develop site specific management plans. For example, larger buffers might be necessary around cave habitats to avoid extra stress on bat populations already significantly reduced as a result of white-nose syndrome.
- ☑ **Maintain vegetated buffers** that (1) are continuous along and around sensitive features; (2) connect lowland and upland areas; and (3) are composed of (or mimic the function of) natural vegetation.
- ☑ **Monitor buffers** during and after construction to ensure they are maintained throughout all phases of development, including identification and treatment of invasive plant species.

These recommendations are part of a suite of recommended practices intended to avoid and reduce impacts of shale development on Appalachian habitats and wildlife. These practices might need to be adapted to incorporate new information, consider operational feasibility and comply with more stringent regulatory requirements that might exist.

Visit nature.org/shale-practices-refs for a list of references used in this document

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The Nature Conservancy is a science-based organization working globally to protect ecologically important lands and waters for nature and people. The Conservancy has assessed the ecological impacts of energy development in the Appalachians and advanced strategies and tools that reduce those impacts. This collection of documents stems from research by The Nature Conservancy that evaluated the scientific support for existing management practices related to surface impacts of shale development. The Nature Conservancy gratefully acknowledges generous financial support from the Colcom Foundation and the Richard King Mellon Foundation.