Riparian Management Guidelines for Agency of Natural Resources Lands

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I. Statement of Purpose

Riparian areas have long been recognized for their important contribution to ecological and physical processes which significantly influence water quality, stream channel equilibrium, aquatic and terrestrial habitats and the diversity of species and natural communities they support. It is for these reasons that the Agency of Natural Resources (ANR) has a long history of formally advocating for the protection, restoration and enhancement of riparian areas. In addition to working cooperatively with watershed organizations, angler groups, municipalities and state, federal and non-governmental natural resource organizations to proactively protect, restore and enhance riparian areas, ANR provides direction or recommendations for riparian area protection within the following regulatory processes:

- Act 250
- Public Service Board Section 248
- Shoreland Protection Act
- Vermont Wetland Rules
- Flood Hazard Area and River Corridor Protection Procedure
- Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont

ANR, through its three principal departments, manages nearly 350,000 acres of state owned land for various conservation and recreation purposes. Additionally, ANR holds conservation and public access easements on close to 150,000 acres of private lands. These diverse holdings encompass a multitude of water features including streams, rivers, lakes, ponds, wetlands and associated riparian areas. Collectively, these resources provide significant ecological, economic, and recreational benefits to the State.

The wide array of riparian area functions and values, particularly in light of ANR's emphasis on climate change and flood resiliency, highlights the need for focused attention to the management of these important areas on ANR lands. While ANR, through its regional and interdisciplinary Stewardship Teams has always considered riparian areas in its management of ANR lands, a consistent and targeted management approach has not been available. The purpose of these guidelines is to:

- Provide ANR land managers with a full understanding of the functions and values of riparian areas.
- Provide ANR land managers with strategies and considerations for the identification and management of riparian areas to protect, restore or enhance riparian area functions and values.
- Ensure consistent management of riparian areas by ANR lands managers across the state.

II. Riparian Area Definition and Overview

Riparian areas can be defined as a zone of interaction and influence between aquatic and terrestrial ecosystems along streams, rivers, lakes, wetlands and other waterbodies (RSTC 2007). These areas perform important ecological functions which link aquatic and terrestrial ecosystems and thereby support unique habitats, natural communities and high biological diversity (RSTC 2007, ANR 2005).

Verry (2000) further offers the following functional definition for riparian areas:

> *"Riparian areas are three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width."*

Riparian areas provide a host of physical, hydrological and ecological functions including water temperature moderation, sediment and nutrient filtration and retention, large wood and organic material recruitment and retention, streambank, shoreland and floodplain stability as well as habitat and travelways for a wide variety of species. The many functions of riparian areas will ultimately determine their dimension and position on the landscape.

These guidelines consider riparian functions associated with streams, rivers, lakes, and wetlands, and vernal pools. Although these can be diverse features, they share common riparian functions. When interpreting and assessing these functions at specific sites, it can be helpful to consider them in the context of the associated natural communities. For example, riparian areas along a stream flowing through a northern hardwood forest will function somewhat differently than those along a stream flowing through an alder swamp.

A brief overview of riparian functions is provided on the following pages. ANR land managers are encouraged to refer to the 2005ANR *Riparian Buffers and Corridors Technical Papers* in Appendix A which provide a comprehensive overview of scientific research on riparian functions. Information provided in the ANR "technical papers" on riparian function has also been summarized and supplemented in the R*esearch Notes* provided in Appendix B of this document.

A. Riparian Functions:

Temperature Moderation

Riparian vegetation has a profound effect on moderating temperatures in both surface and ground waters. Forest canopies limit the input of solar radiation and insulate waterbodies from extreme temperature changes during the summer and winter months. Aquatic species such as brook trout, slimy sculpin, spring salamander and many invertebrates are dependent upon cold, well oxygenated waters for their long term viability. Maximizing cold water in tributary streams is also extremely important for moderating temperatures and providing thermal refuges in the larger streams, rivers and lakes which they feed.

Sediment and Nutrient Retention and Control

The impact of sediment discharges to aquatic habitats and the populations they support has been well documented. Sediment can have direct detrimental effects on populations or result in degraded habitats which impact reproduction and abundance. As nutrients are attached to soil particles, processes that control sediment transport to surface waters also affect nutrient inputs. Riparian vegetation influences the discharge of suspended sediments by reducing soil erosion; filtering and trapping sediment transports from upland sources prior to entering surface waters; binding and fortifying streambanks and shorelands; creating pools and debris jams which store sediments; and moderating stream flows and bed scour during high water events. The effectiveness of riparian areas for controlling sediment and associated nutrients will be influenced by slope, vegetative cover, ground complexity and roughness, soil type, permeability and stability, and adjacent land uses.

Large Wood Recruitment and Retention

Large wood features, such as individual logs, rootwads and more complex log jams are recruited from riparian areas into nearby waterbodies by means of natural aging and falling, wind throw, flood, and landslide. Large wood plays an important role in the development and maintenance of aquatic habitat structure and complexity. Larger wood provides more stable habitat features and sources of organic material as they are less prone to movement than smaller individual pieces. The interaction of stream flow with large wood causes scour, captures and retains smaller wood and creates complex pool and near-bank habitats with hiding and isolation cover, thereby increasing the number of fish that can occupy a given area. Large wood features also moderate sediment transport rates thereby reducing sedimentation of spawning habitats and rapid filling of pools.

Energy & Food Supply

Allochthonous (produced outside of the aquatic system) organic material, in the form of leaves, needles and woody debris from riparian vegetation, represent the dominant energy source supporting biological processes in small streams. Once recruited to the stream, this material is conditioned by microbes before becoming available to aquatic invertebrates which, in turn, can be consumed by fish. Large wood is very important in capturing and retaining leaves, organic litter and smaller wood, both within the stream channel and its floodplain, allowing for this energy source to be utilized within the stream reach before being transported downstream.

Shoreland Stability and Stream Channel Equilibrium
Trees and their root systems, individual stems or complexes of wood act as hard borders and protect shorelands, streambanks and beds from erosion. The presence of large wood, including log jams, influences flow velocity, channel shape and sediment storage and is important in dissipating energy of high flow events. Standing and downed wood in floodplains also serve to trap sediment and organic material and reduce velocities during flood flows.

Terrestrial Habitat and Travel Corridors
Streamside and shoreland riparian areas provide a distinct habitat that is used by many wildlife species. While many generalist species may use riparian areas, there are some species for which riparian habitat is essential. Activities that degrade riparian area habitat quality will have a disproportionate negative impact on these riparian obligates. In addition, streams, shorelands, and wetland edges are important travel and dispersal routes for many wildlife species.

Many of the same functions of a streamside or lakeside riparian zones also apply to wetlands and their adjacent uplands. Wetlands play an important role in the connection between terrestrial and aquatic systems, and provide critical riparian functions that directly impact the quality of Vermont's surface waters and aquatic habitat. These can include:

- Water storage for flood water and storm runoff, moderating extreme flows in rivers and streams
- Surface and ground water protection, through the removal of excess nutrients and retention of sediment
- Reducing erosion by binding and stabilizing soil
- Providing fish and wildlife habitat for numerous species that depend on aquatic habitat for all or part of their lifecycle, such as northern pike, stream salamanders, and waterfowl

While wetland natural communities are quite varied in their vegetation, soils, and hydrology, in all cases the zone around them is important for sediment retention and nutrient control, habitat structure (such as large wood features), and terrestrial wildlife travel corridors. Shade and temperature moderation is important for many small wetlands. Shade can also limit the spread of invasive species into both the riparian zone and the wetland itself. For forested wetlands, the zone around a wetland is important for wind protection, as the upland forest can stabilize and protect shallowly-rooted wetland trees. Finally, the zone around a wetland is important for mediating the inflow and outflow of surface and ground water to a wetland – particularly in basin wetlands and many peatlands, which are characterized by very specific hydrologic regimes.

Vernal pools are a distinct wetland type that provides a very specific habitat function. Vermont has four amphibian species that are considered pool-specialist breeders: spotted salamander, Jefferson salamander, blue-spotted salamander, and wood frog. Although all four species require breeding pools with specific conditions to produce offspring, these amphibians spend the vast majority of their time in adjacent or nearby upland habitat. These species are typically associated with vernal pools, but may also use other areas of ponded water. Protecting this habitat function requires particular considerations based on the life history of the amphibian species.

III. Process

In 2013 the ANR Secretary tasked the ANR Lands Stewardship Team with developing guidelines for managing riparian areas on ANR lands. The aftermath of tropical storm Irene in Vermont and the Agency's subsequent focus of flood resiliency reinforced the need to develop some clear guidelines for managing riparian areas on ANR lands. Additionally, this initiative was intended as a complementary effort to the Agency's process of revising its Act 250/Section 248 Riparian Buffer Guidance document which was undergoing a thorough review at this time.

The process of developing "riparian guidelines" for ANR lands actually began more than a decade ago. This earlier effort was spearheaded by district stewardship teams and produced some good information along with preliminary draft guidelines, though no consensus was reached regarding final guidelines. This renewed effort used the draft recommendations and related information from the Agency's initial attempt to develop such guidelines as a starting point in developing riparian area management guidelines for ANR land.

The ANR Lands Stewardship Team established an "ANR riparian lands" work group composed of representatives from the three ANR departments and ANR's Office of Planning and Legal Affairs. Work group members included Mike Fraysier (chair), Gary Sabourin, and Jim Horton from FPR; Rich Kirn and Bob Zaino from FWD; Shannon Pytlik from DEC; and Billy Coster from ANR/OPLA.

The work group was charged with developing draft riparian land policy and guidelines for ANR lands for the review and approval by the ANR Lands Stewardship Team and ultimately, the ANR Leadership Team. As stated in the work group's official "Charge", the policy and guidelines … *"should be based on the best available science, practical to implement, and reflective of the diversity of ANR lands and the full range of uses and management objectives for these lands"*. A copy of the full charge to the work group is provided in Appendix E.

The work group met on almost a monthly basis over a two year period beginning in March of 2013. Members devoted a considerable amount of time up front reviewing available research on the various functions and values of riparian areas. Much of this information is summarized within the "research notes" provided in Appendix B and the 2005 ANR Riparian Buffers and Corridors Technical Papers provided in Appendix A. This information provides a solid foundation upon which to develop specific guidelines for riparian area management on ANR lands.

The work group took special care to ensure that these guidelines complement, are consistent with, and where appropriate, reference and reinforce other related ANR regulations or initiatives.

IV. Riparian Management Zones

ANR recognizes the importance of riparian areas for their significant influence on ecological systems and physical processes and therefore seeks to manage these areas for their inherent values. To this end, the concept of the *Riparian Management Zone* (RMZ) is introduced as a planning and management tool for ANR land managers. As described in the following sections, the RMZ is delineated based upon a variety of factors including the adjacent water resource and land use, topography and soils, species occurrences and riparian functions of interest. Management within these zones will be based upon current RMZ condition relative to defined riparian objectives and desired conditions.

The accompanying policy for riparian management on ANR lands states that "*management of riparian areas on ANR lands will: 1) Maximize riparian function and values by maintaining or enhancing desired riparian conditions. 2) Provide for public access infrastructure and other water and land-based recreation facilities (e.g., fish culture stations, boating access areas, swimming areas, trails, etc.) that are designed and operated to maximize retention of riparian functions and values and minimize negative impacts*"

This policy recognizes that the vast majority of ANR lands are comprised of undeveloped holdings which can provide a full range of riparian functions and values, while also acknowledging that the limited development of certain water-based facilities within the riparian zone is of public value.

As guidance for ANR land managers, riparian management objectives and desired riparian conditions, along with general management guidelines for both undeveloped and developed areas are provided in the sections below. It should be noted that these objectives and desired conditions are not prioritized and may, in some cases, conflict.

A. Riparian Management Zone - Objectives:

- Maintain native vegetation appropriate for the natural community of the site.
- Maximize shading of stream channel and incoming water sources to moderate water temperatures in adjacent and downstream receiving waters.
- Provide for natural recruitment woody material, including large wood features, to stream and riparian areas to develop and maintain stable and complex aquatic and riparian habitats.
- Provide natural rates of production, recruitment and retention of organic materials.
- Provide for the effective retention and infiltration of sediments and nutrients prior to entering adjacent surface waters.
- Maintain stable streambanks, channel dimensions, profile, planform and migration rates consistent with natural equilibrium conditions.
- Maintain stable shorelands consistent with natural conditions.
- Maintain natural hydrology and geomorphic processes.
- Provide habitat for riparian obligate species, or rare, threatened or endangered (RTE) species which may use riparian habitat, and species using riparian areas as travel corridors.

B. Riparian Management Zone - Desired Conditions:

- Natural vegetation with species and structure appropriate to the natural community of the site. For sites that would be expected to have a forested natural community: community-appropriate species diversity, a range of tree ages and stem diameters (including large, old, young, small), vertical and horizontal structural complexity, and naturally abundant standing and downed dead trees of a range of species and diameters.
- Complete, continuous and diverse forest canopy, appropriate to the natural community of the site, to maximize temperature moderation function.
- Natural topography.
- Forest floor comprised of natural duff layer providing for infiltration and diffuse overland treatment of surface runoff.
- Complex instream, riparian and floodplain habitats comprised of large wood features which provide stable channel boundaries, including adequate roughness elements to moderate velocities and promote natural rates of sediment/organic material transport and retention.
- Forest conditions characterized by native species, natural disturbance processes, unaltered soils and natural hydrology.
- Connectivity to suitable upland habitats; streamside connectivity; hydrologic connectivity with other waterbodies.
- Low risk of widespread windthrow.

C. Riparian Management Zone - Management Strategies:

Management of riparian zones will be based upon an evaluation of current conditions and the extent to which they achieve the desired conditions listed above. In most cases an undisturbed forested RMZ, comprised of native species and with natural hydrology, would be expected to provide riparian functions and values; however, when riparian function is compromised or threatened, active management may be the best way to achieve desired conditions and restore riparian function. Some examples and likely management strategies include:

- Encouraging re-vegetation including the planting of native vegetation appropriate to the natural community, in cases where riparian forest cover is lacking or natural regeneration is inadequate.
- Restoration of natural hydrology in altered landscapes, such as the restoration of channelized streams, ditched wetlands, rip-rapped shores, etc.
- Controlling and eliminating non-native invasive species.
- Enhancing aquatic or riparian complexity through active addition of large wood features.
- Relocation of roads and other infrastructure that can be sited outside the riparian zone.

Silvicultural techniques designed to mitigate threats to riparian forest functions, or to enhance riparian forest structure and complexity, can offer an opportunity to improve certain riparian functions. The benefits of the improved functions should be carefully weighed against the risk of possible negative impacts to other riparian functions of the site. Scenarios where silvicultural treatments might improve overall riparian functions include, but are not limited to:

- Disturbed riparian forests vulnerable to widespread windthrow or other natural disturbances.
- Riparian stands with species at significant risk of insect or disease outbreak (e.g. eastern hemlock, ash species, balsam fir) where mortality would result in a sudden and significant loss of canopy cover. In such cases, enhancing species diversity would help to mitigate potential threats.
- Aquatic and riparian habitats lacking structural complexity, large wood features, or other components where the addition of those components is necessary for a species of conservation concern. (Note that in-stream habitat projects have additional design and permitting considerations beyond the scope of these guidelines.)

These restorative silviculture prescriptions should be based on specific site conditions and goals, but a few considerations apply to all RMZ silvicultural practices. In most cases, strategies that retain forest biomass within the riparian management zone (either as standing or downed wood) will be preferable unless in conflict with riparian function or achievement of riparian management objectives and desired conditions. Retaining dead and downed wood of all sizes promotes retention of soil, sediment, and nutrients, slows storm runoff, and promotes fish and wildlife habitat. Biomass retention by felling or girdling also limits the need for heavy equipment and skidding in the RMZ, reducing the potential for negative impacts. Biomass removal may be appropriate when long term forest health is jeopardized such as from disease outbreak or insect infestation.

Other recommendations for protecting riparian functions during silviculutral activities include:

- Minimize ground disturbance.
- Favor silvicultural techniques that minimize the size of canopy openings, with the possible exception of cases where catastrophic stand loss (e.g. due to insect, disease, fire or windthrow) is imminent, to minimize impacts to canopy shade and forest structure.
- Consider riparian plantings to establish native vegetation if other techniques are not suitable to regenerate appropriate native species.
- Manage upland areas adjacent to RMZs to minimize the risk of widespread windthrow within the RMZ.

D. Water-Based Facilities and Development on ANR Lands:

While the primary goal for riparian management on ANR lands is to maintain and enhance riparian function, the Agency of Natural Resources also recognizes the value and necessity of public water-based facilities, such as swimming areas, boat access areas and fishing platforms on ANR lands. Without their development, access to important water-based recreational opportunities for the public would be extremely limited. These public facilities can also help reduce the need for the development of similar amenities by private shoreland owners. Nevertheless, because these facilities must by their nature be located on the shorelines of lakes, ponds, rivers and streams, they result in unavoidable impacts to riparian areas. Therefore, these facilities should be designed and operated so that they achieve their intended purpose while maximizing riparian functions and minimizing potential negative impacts.

Where infrastructure currently exists, riparian area functions and values should be considered and restored to the greatest extent practical. When new facilities or developments are proposed within riparian areas on ANR lands, they should be carefully considered to ensure that there is a clear and unavoidable need for the project to be located within a riparian area. In many cases, an expansion or modification of existing facilities is preferable to new development in riparian zones. All potential impacts to riparian functions should be fully considered and avoided where possible, or otherwise minimized and mitigated

For both existing and new facilities, evaluation criteria should include:

- The scale and scope of negative impacts to riparian function
- The overall ecological sensitivity of the site (presence of RTE species, significant natural communities, etc.)
- The extent of riparian function in adjacent shoreland areas
- The extent of riparian function within the watershed

V. Delineating Riparian Management Zones:

There have been many studies focused on the determination of effective dimensions for various riparian functions. The *ANR Riparian Buffers and Corridors Technical Papers* (Appendix A) and research notes compiled during the development of this document (Appendix B) provide an extensive list of scientific studies. While study results may vary due to differences in waterbody characteristics, topography, climate, vegetation and adjacent land uses, there is general support for the influence of many important riparian functions extending 100' or more from waterbodies. These inferences are supported by comprehensive works including a recent literature review by Sweeny and Newbold (2014) who conclude *"Overall, buffers ≥ 30m wide are needed to protect the physical, chemical, and biological integrity of small streams."* In *Riparian Management in Forests of the Continental Eastern United States*, Verry et al. (2000) also indicate that many riparian functions approach 60 to 80% of their maximum within 100 feet.

Riparian Management Zones will vary based upon the adjacent water resource, topography, species occurrences and the specific riparian functions and values of concern. To assist land managers in the delineation of riparian areas, the following broad categories and riparian area management zone definitions are provided:

A. Streams:

Streams encountered on ANR lands will fall under several categories including ephemeral, intermittent, and perennial with varying floodplain configurations. Physical features, such as *top of bank* or *top of slope* are often used in the delineation of the stream RMZ and are further described in Appendix C.

Ephemeral streams are defined by Levick et al. (2008) as *"a stream or portion of a stream which flows briefly in direct response to precipitation in the immediate vicinity, and whose channel is at all times above the groundwater reservoir."* Unlike intermittent and perennial streams, these streams are not characterized by clearly defined channels formed by scour. While ephemeral streams do not support aquatic populations, these streams influence aquatic ecosystems and larger stream channel processes by storing and transporting water, sediment, nutrients and organic material. Their prevalence on the landscape underscores their collective influence on water quality, aquatic habitat and stream processes.

Intermittent streams are those with well-defined channels, evidence of sediment transport and which regularly experience periodic interruption of surface flow throughout its length. Like ephemeral streams, these streams influence water quality, aquatic habitat and stream processes by transporting water, sediments, nutrients and organic material to larger waterbodies. These streams may also support aquatic populations on a seasonal basis, including spawning and incubation habitat for spring spawning fishes. As surface flow may occur for many months of the year, or year-round in wet years, the riparian function of water temperature moderation is also relevant for these streams.

Perennial streams flow year round and with very few exceptions will support aquatic populations including fish. The determination of an intermittent stream versus a small perennial stream may be difficult to identify in the field at a single point in time. The Vermont Department of Environmental Conservation provides the following technical guidance for identification of perennial streams for the purpose of regulatory jurisdictional determinations (VDEC 2011):

"A perennial stream is a watercourse, or portion, segment or reach of a watercourse that, in the absence of abnormal, extended or severe drought, continuously conveys surface water flow....
A perennial stream may be characterized by any of the following:

> *1. Direct observation or compelling evidence obtained that surface flow is uninterrupted.*
>
> *2. Presence of one or more geomorphic characteristics typically associated with perennial streams including:*
>
> > *a. Bed forms; i.e. riffles, pools, runs, gravel bars, other depositional features, bed armor layer*
> >
> > *b. Bank erosion and/or bed scour*
> >
> > *c. Indications of waterborne debris and sediment transport*
> >
> > *d. Defined bed and banks*
>
> *3. Watershed size greater than 0.5 square miles*
>
> *4. VHD data layer-derived application of USGS regression for intermittent stream flow probability*
>
> *5. Presence of aquatic organisms requiring uninterrupted flow for survival*
>
> *6. Base flows are primarily supported by groundwater recharge as indicated by bank seeps, springs or other indicators*
>
> *7. Absence of highly permeable channel (particularly streambed) boundary conditions which, in conjunction with decline of the groundwater table below the streambed elevation may be anticipated to interrupt flow occasionally to frequently.*
>
> *8. Surrounding topography exhibits characteristics of being formed by fluvial processes."*

The scientific evidence does not clearly distinguish the relative benefits of specific riparian zone widths for small vs. moderate and large perennial streams. Small stream channels are more effectively shaded, receive a greater relative contribution of organic materials from a given riparian area width and experience lower erosive forces of flows from smaller drainage areas. In those instances ***where stream channels are stable and adjacent land use development and activities do not result in increased flow or sediment inputs or otherwise negatively impact riparian functions***, ephemeral, intermittent and small perennial stream channels may achieve full riparian function with RMZs less than 100 feet. However, it should be noted that water quality and aquatic populations supported within small stream channels are more vulnerable to degradation as they are less able to assimilate increased flows, sediments and other pollutants. On a watershed scale, these small channels are numerous and significantly influence water quality, aquatic habitat and physical processes of larger streams.

From a practical standpoint, it is desirable to provide ANR land managers with waterbody designations that can be easily mapped with available GIS based data in advance of field verification. To this end, stream categories will be partially based upon drainage area thresholds. It should be understood that this approach will not necessarily provide an accurate representation of streamflow permanence or the presence of aquatic life and may need field verification.

1. Ephemeral Streams and Small, Stable Intermittent Streams (< 0.1 mi^2):

Due to their small size and abundance, general considerations are provided for the protection of riparian areas associated with ephemeral and small, stable intermittent streams (< 0.1mi^2). These channels will generally have bankfull channel widths less than 5 feet. While it is generally expected that drainages of this size will be dry through most of the year, Vermont Fish and Wildlife Department stream sampling has documented fish populations in watersheds substantially less than 0.1 mi^2. Where aquatic life is documented within this stream category, ANR land managers should apply RMZ strategies appropriate for small perennial streams (V.A.2).

Riparian Management Zone:

- Maintain complex ground cover features including standing and downed wood within and adjacent to ephemeral and small stable intermittent streams.
- Avoid activities that disturb soil and duff layers which could lead to increased flows and sediment entering ephemeral and small stable intermittent streams.
- Avoid activities that will lead to the concentration of flows (e.g. gullying, rutting, ditching).
- Adhere to Vermont AMP's for practices regarding stream protective strip distances and practices.
- Avoid ground disturbance in areas where high densities of small stream channels exist.

2. Intermittent and Small Perennial Streams (0.1 – 0.5 mi^2):

Streams in this category will be more likely to support aquatic populations, yet are small enough where full riparian functions may be achieved with RMZs less than 100 feet. This equates to streams with bankfull widths of up to approximately 10 feet and is consistent with the small stream threshold and RMZ recommendation of Ilhardt et al. (2000).

Riparian Management Zone:

- A minimum of 50 feet, measured horizontally and inland from the top of the streambank or slope and extending to the water's edge.
- The designated top of bank or slope should include all active overflow channels (flood chutes) or potential channels.

3. Perennial Streams and Rivers with Narrow Floodplains:

The physical features associated with perennial streams and rivers will vary with channel slope, valley setting, local geology, adjacent land use and geomorphic stage. Streambanks, streambank slopes and active floodplains should be the primary features used to delineate RMZ's for perennial streams and rivers. Most perennial streams on ANR lands will be relatively steep, have narrow floodplains and easily recognized top of bank or top of slope features.

Riparian Management Zone:

- A minimum of 100 feet, measured horizontally and inland from the top of the streambank or slope and extending to the water's edge.
- The designated top of bank or slope should include the active floodplain and all active overflow channels (flood chutes) or potential channels.
- River corridors should be identified and managed for their potential as future riparian areas (Section VI B).

4. Perennial Streams and Rivers with Broad Floodplains:

Streams and rivers in broader valleys will have larger floodplain features which will need to be carefully evaluated as they directly influence water quality, aquatic and terrestrial habitats and river processes and may support unique natural communities and species assemblages. These floodplains are characterized as flat, adjoining lands which are inundated during high flows, created by active river processes (Leopold 1997) and in some cases may extend hundreds of feet from the stream or river (e.g. Otter Creek, Winooski River). Current management practices, including agricultural leasing and licensing and traditional habitat manipulation should be re-evaluated for conformance with riparian zone management goals and desired conditions. Where past management practices have degraded riparian functions or prevent the development of expected riparian vegetation and natural communities, opportunities for active or passive restoration should be explored.

Riparian Management Zone:

- A minimum of 100 feet, measured horizontally and inland from the top of the streambank or slope and extending to the water's edge.
- The designated top of bank or slope should include all active overflow channels (flood chutes) or potential channels.
- The active floodplain as determined by its current or potential riparian function and natural communities.
- River corridors should be identified and managed for their potential as future riparian areas (Section VI B).

B. Lakes and Ponds:

A study of 40 Vermont lakes showed significant differences in 9 of 10 biotic metrics between sites with undeveloped, naturally vegetated shorelines vs. developed shorelines (Merrell et al.

2009). Decreases associated with tree cover, shading, woody structure, leaf litter and biological production were noted adjacent to developed shorelines while sediment embeddedness and percentage of sand substrate increased. This study further confirmed the importance of protecting riparian functions along Vermont's lakes and ponds and lead to the passage of the Shoreland Protection Act in 2014, which developed regulatory standards for shoreland development. The following link provides additional background on the basis and details of the legislation and regulations (http://www.watershedmanagement.vt.gov/permits/htm/pm_shoreland-about.htm). These concepts are reflected in the following RMZ delineation for lakes and ponds.

Riparian Management Zone:

- A minimum of 100 feet measured horizontally from the lake's mean water level inland onto shore.
- The creation of cleared or impervious surfaces adjacent to the RMZ should ensure that riparian functions are not compromised.

C. Wetlands:

For the purposes of these guidelines, "Class I" and "Class II" wetlands are any wetlands so identified under the Vermont Wetland Rules (Vt. Code R. 12 004 056). "Wetland natural communities" include those wetland natural community type recognized by the Vermont Fish and Wildlife Department's Natural Heritage Inventory. These include, but are not limited to, floodplain forests, swamps, open peatlands, marshes, and wet shores. State-significant (a.k.a. exemplary) natural community examples are those that, because of their overall ecological quality, meet objective criteria thresholds established by the Vermont Fish and Wildlife Department's Natural Heritage Inventory. In all cases, land managers shall use reasonable professional judgment in identifying wetland-upland boundaries for the purposes of establishing these RMZs.

Riparian Management Zone:

- State-significant wetland natural communities (excluding seeps and vernal pools), and Class I wetlands: the wetland and a minimum of 100 feet, measured horizontally and inland from the top of the wetland edge.
- Other wetland natural communities (excluding seeps and vernal pools), and any Class II wetland: the wetland and a minimum of 50 feet, measured horizontally and inland from the top of the wetland edge.
- All Seeps greater than 0.02 acres (approx. 900 sq ft) in size: the seep and a minimum of 50 feet, measured horizontally and inland from the seep edge.

D. Vernal Pools (and other amphibian breeding pool habitat):

A vernal pool is usually contained within a small basin, has no permanent inlet or outlet, and does not support predaceous fish. It forms from snowmelt, rainwater, or groundwater. Vernal pools generally last only a few months and then disappear by the end of summer, although some may persist in wet years. Generally, water deep enough to cover egg masses and larvae must remain for at least two to three months for successful amphibian breeding. For the purposes of these guidelines, only pools with known breeding populations of any pool-specialist amphibian species, or a reasonable likelihood of such populations, shall be considered here.

In addition, pool-specialist amphibian species can use breeding habitat other than a vernal pool, such as beaver ponds, wetland edges, oxbows, permanent fishless ponds, flooded or ponded gravel pits, etc. For the purposes of these guidelines, "other amphibian breeding pool habitat" includes those habitats with known breeding populations of at least one of the following species: spotted salamander, Jefferson salamander, blue-spotted salamander.

The functions, and therefore the riparian zones around vernal pools and other amphibian pool habitat are based on the particular needs of pool-specialist species. Because of the large upland areas used by these species, there is more flexibility for management in some portions of the riparian zone. Management that sustains viable populations of pool-breeding amphibians must recognize the importance of the pool depression and the immediate riparian zone, as well as the surrounding upland forest that is critical terrestrial habitat for pool-breeding species during most of the year. For detailed information on vernal pool functions and management guidelines, refer to Appendix F.

Riparian Management Zone:

- The pool area and a minimum of 100 feet, measured horizontally and inland from the top of the wetland edge.
- Upland amphibian habitat will be considered in a secondary zone measured horizontally and inland at least an additional 550 feet from the edge of the RMZ. (Therefore, this zone ends a minimum of 650 feet from the pool edge.) This zone allows for flexibility with management. Default guidelines for this secondary zone shall be those outlined by the Vermont Fish and Wildlife Department in "Conserving Pool-specialist Amphibian Habitat" (Appendix F). Below is a summary of some important considerations:
    - *Clearing of land and construction should be limited to less than 25% of this zone. The remaining terrestrial habitat should then be managed to maximize amphibian habitat function, to prevent additional negative impacts*
    - *Whenever possible, avoid locating permanent roads, log landings, and truck roads within this zone.*
    - *Avoid activities that create barriers to amphibian movement, including rutting, silt fencing, curbing, etc.*
    - *During timber harvest, maintain at least 60% canopy cover (either dispersed or clumped) with trees at least 25 feet tall, to protect terrestrial habitat and prevent drying of the forest floor*
    - *Retain or enhance dead and downed wood in this zone; avoid whole-tree harvests, salvage harvests, or other actions that reduce these features*

- *Studies show that many amphibians will travel further than 650 feet from the pool; therefore, managing forests beyond this 650-foot zone for amphibian conservation is strongly recommended in areas with exceptional vernal pools or clusters of pools.*

VI. Additional Considerations

RMZ delineations described in Section V provide minimum dimensions based upon stable conditions, typical landforms and common habitats and species assemblages. There are several additional considerations that should be evaluated which may require further adjustment to RMZ boundaries in specific locations:

A. Terrain and Soil Texture:

Slope and soil texture are major factors to consider for determining width of riparian area. Terrain can vary considerably within a riparian area. Steep terrain will increase the potential for soil erosion, sedimentation and mass movement of a hillside. Slope and natural surface roughness are the main factors determining how far sediment and other pollutants are transported to a waterbody. As slope increases, the speed at which water flows over and through the RMZ increases. Therefore, the steeper the land within the RMZ, the wider it needs to be to have time to slow the flow of water and absorb the pollutants and sediments within it. If the runoff water does not spread over the RMZ, it will move through the RMZ in channels thereby making it ineffective at pollutant removal. Many researchers suggest that especially steep slopes serve little value for retaining and filtering pollutants and recommend excluding areas of steep slope when calculating RMZ width.

Soil texture affects how quickly water can be absorbed. Fine texture soils, such as silt and clay are less permeable than coarser textured soils and may have greater runoff. On the other hand, soils that are largely made up of sand may drain water so rapidly into the groundwater that roots are not able to effectively absorb pollutants. Also, the presence of silt, very fine sand and clays will be more prone to erosion than soil types that are predominantly sand, sandy loam or loam textured soils. Furthermore, soils that are moister and more acidic have a better capacity to take up nitrogen from the soil and release it to the atmosphere through denitrification.

Considerations:

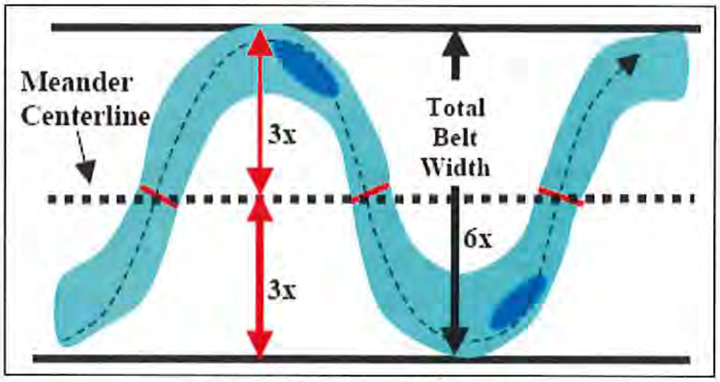
- The forest floor is an important hydrologic attribute of forestland. The presence of an intact forest floor on the soil surface protects soil from being eroded. The forest floor is composed of the litter layer, underlying organic layer (humus), and fibrous roots.
- Steeper slopes may require wider RMZs and/or additional measures to slow down and capture fast-moving runoff.
- Fine texture soils such as silt and clay are more prone to erosion than coarser textured sandy/gravelly soils.

Be aware of equipment limitations and difficulty of operating on steep slopes that may cause excessive soil disturbance and increase the potential for erosion and sedimentation.

B. River Corridors:

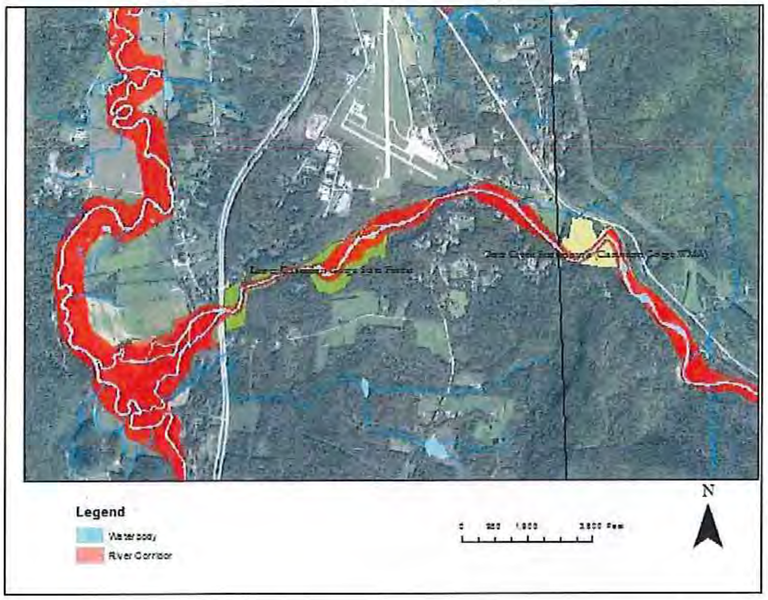
Rivers are not static features in the landscape. Over time, river channels migrate naturally or adjust as a result of natural or human influences. Common causes for channel adjustments include floods, debris jams, ice dams, and changes in watershed sediment loads and flow regimes. Anthropogenic river adjustments often result from watershed developments as well as activities or infrastructure that alter natural river processes, such as gravel mining and channelization or the construction of undersized culverts and bridges.

To account for these channel adjustments, the concept of "river corridors" is utilized in land use planning and river management (Kline and Dolan 2008). A river corridor is the area within which a stream channel is predicted to occur over time. The width of a river corridor is based on what the stream needs to be "stable", i.e. in its least damaging / erosive form. By considering the entire river corridor, rather than the current stream channel, ANR land managers can reduce conflicts with infrastructure investments and maintain channel stability over time. Stable channels maintain water quality, create and maintain complex and diverse aquatic habitat conditions and provide flood resiliency. Stable channels, while not static, are less prone to erosion and serve to dissipate energy and water during flooding events, resulting in less infrastructure damage within the river corridor as well as downstream.



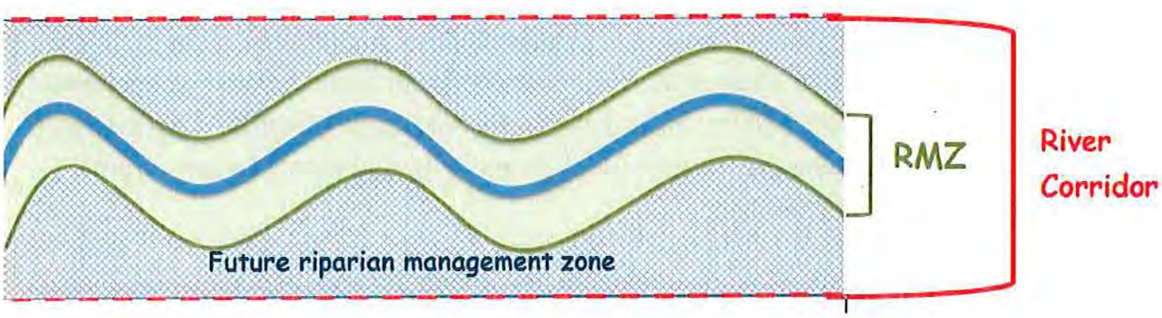
River Corridor Diagram

Calculating the dimensions of a river corridor takes into account the width of the channel (a.k.a. bankfull width), the valley type, and the stream condition. Accounting for these three factors, river corridors range from 1 channel width for very stable stream channels (such as in a bedrock gorge) to 8+ channel widths for low gradient streams in wide alluvial valleys (for example, Otter Creek). River corridor delineations are available on the ANR Natural Resources Atlas http://anrmaps.vermont.gov/websites/anra/



River Corridor Map 1: River Corridor along the Otter Creek and Mill River in Clarendon, VT. Note the varying width of the river corridor depending on the valley and channel dynamics.

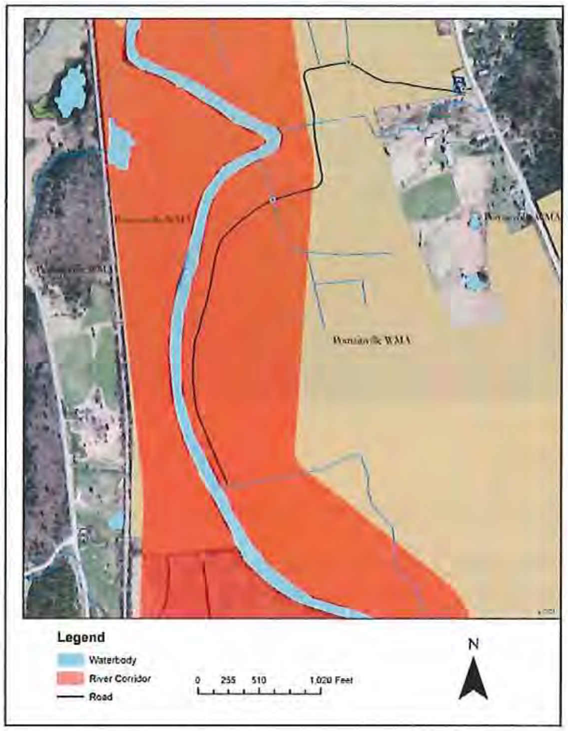
ANR land managers should incorporate the concept of river corridors into their long-term riparian management strategy. It is important to recognize that as stream and river channels naturally migrate over time, so will the associated RMZ. Therefore it will be important to account for this potential by managing lands ***adjacent*** to current RMZ's and ***within*** the river corridor for their potential as future RMZ's as depicted below:



The following practices should be followed with defined river corridors:

- Apply management practices which are compatible with the development of desired riparian conditions as described in section IVB.
- Avoid practices that result in the development or maintenance of large clearings (e.g. forest conversion, agricultural leases, etc.).
- Avoid development of new infrastructure within the river corridor which will require protection from future channel migration.
- Avoid or limit further investments in existing infrastructure within river corridors.

- Identify opportunities to relocate existing investments out of river corridors.



River Corridor Map 2. Pomainville WMA. Due to the risk of erosion within the river corridor, the road should be maintained with minimal investment in case the river relocates.

C. Rare, Threatened, and Endangered Species:

Many of Vermont's RTE species use aquatic or riparian habitat for some or all of their life cycle. These include fish (e.g. stonecat, channel darter), mussels (giant floater, dwarf wedgemussel), invertebrates (cobblestone tiger beetle), birds (black tern, bald eagle), reptiles (spotted turtle, wood turtle), mammals (Indiana bat, eastern small-footed bat), and plants (satiny willow, tubercled orchid, Jesup's milk vetch).

When an RTE species is known to occur in Riparian Management Zones or adjacent aquatic habitat, priority should be given to management strategies that emphasize protection and restoration of those functions critical to the persistence of the species. As needed, RMZs should be expanded to accommodate these critical functions. These should be considered on a site-by-site basis, given the condition of the RMZ and the RTE species (or suite of species) present. A few general considerations apply:

- For aquatic species, which are especially sensitive to changes in water quality, emphasize sediment and nutrient filtering, consider using expanded RMZs as appropriate.
- For plant species which are dependent on natural disturbances such as flooding, scouring, or deposition of materials, maintain or restore these processes.

- For wide-ranging (e.g. wood turtle) or disturbance-sensitive (e.g. bald eagle) wildlife species, manage both the RMZ and the adjacent upland for RTE protection.

D. Natural Communities:

A wide variety of Vermont's natural community types occur along the shores of streams, rivers and lakes. These natural community types include open shores, marshes, shrub swamps, forested swamps, and floodplain forests, as well as the typical upland forests that are found along many small streams. The diversity of shoreland community types reflects the dynamic and stressful nature of this environment – floods, ice scour, wave action, and deposition and erosion of sediments are all natural processes that affect shoreland communities. Many shoreland natural communities are rare in Vermont. Some, such as Calcareous Riverside Seeps, are rare because the environmental conditions that create them are rare on the landscape. Others, such as floodplain forests, are uncommon because of extensive land use and development in floodplains. Thus, these communities need special considerations both for their riparian functions and also for their other ecological values.

Intact, functioning shoreland natural community occurrences—those that have the species composition and structure, and natural disturbance processes appropriate to their setting—will provide riparian functions and values. Thus, understanding and managing for high-quality shoreland natural communities is an important tool in implementing RMZ guidelines. Likewise, managing for riparian functions and values will usually entail managing for high quality natural communities in the RMZ. Finally, while shoreland natural communities provide riparian functions, in many cases the shoreland communities themselves need an appropriately-sized upland buffer in order to ensure their own functions and values are not compromised. Management actions include:

- Map and assess shoreland natural communities during management planning.
- Promote vegetation composition and structure appropriate to the natural community.
- Maintain or restore normal natural disturbance processes.
- For sensitive natural communities, consider an expanded RMZ to include a larger upland zone around the community.

E. Adjacent Land Use:

The character and extent of land uses and development adjacent to RMZ's may significantly impact RMZ function and must be carefully considered. The creation of substantial cleared, impervious or disturbed surfaces may compromise RMZ function by increasing surface runoff and sediment transport or by increasing the risk of widespread windthrow. In these situations, RMZ dimensions may need to be expanded, or the scale and character of adjacent activities modified. Likewise, if adjacent land conditions have been stabilized and restored, RMZ dimensions should be re-evaluated and reduced to base levels if appropriate.

VII. Managing Encroachments within Riparian Management Zones

In some cases ANR land management projects may require temporary or permanent intrusions into RMZs and potentially compromise the riparian protection provided in this document. Common situations include linear projects such as trails and roads for recreation, facility access or silvicultural activities and utilities (communications, water, electric, etc.) which often need to cross waterbodies and thereby encroach within riparian areas. When planning these projects, the following practices are recommended:

- Avoid encroachments into the RMZ where possible. When required, limit the number of stream crossings and RMZ encroachments to the minimum necessary.
- Design project crossings perpendicular through RMZs and streams to limit the footprint of disturbance.
- Minimize the removal of mature vegetation and strictly limit the surface area of exposed and disturbed soils within the project corridor.
- Ensure roads, trails, utility corridors and stream crossing approaches are stable and will not result in concentrated runoff and erosion.

VIII. Developing Riparian Management Zone Recommendations

The preceding riparian management guidelines provide land managers with the necessary information regarding riparian functions and values, riparian management goals, desired conditions and strategies for delineating and managing RMZs on ANR lands. This information should assure that riparian functions and values are fully considered and riparian management strategies are consistently applied throughout the state.

When evaluating a parcel for long term management planning, timber sales, habitat enhancement, project development or maintenance, riparian functions and values must be considered. This document should be used to guide ANR land managers to:

1. Identify water resources and delineate associated RMZ.
2. Evaluate the current condition of the RMZ regarding riparian functions and desired conditions.
3. Identify threats or constraints to achieving desired conditions.
4. Identify strategies to first avoid, then minimize and lastly mitigate impacts to riparian functions and values.
5. Identify opportunities to enhance and restore riparian functions.

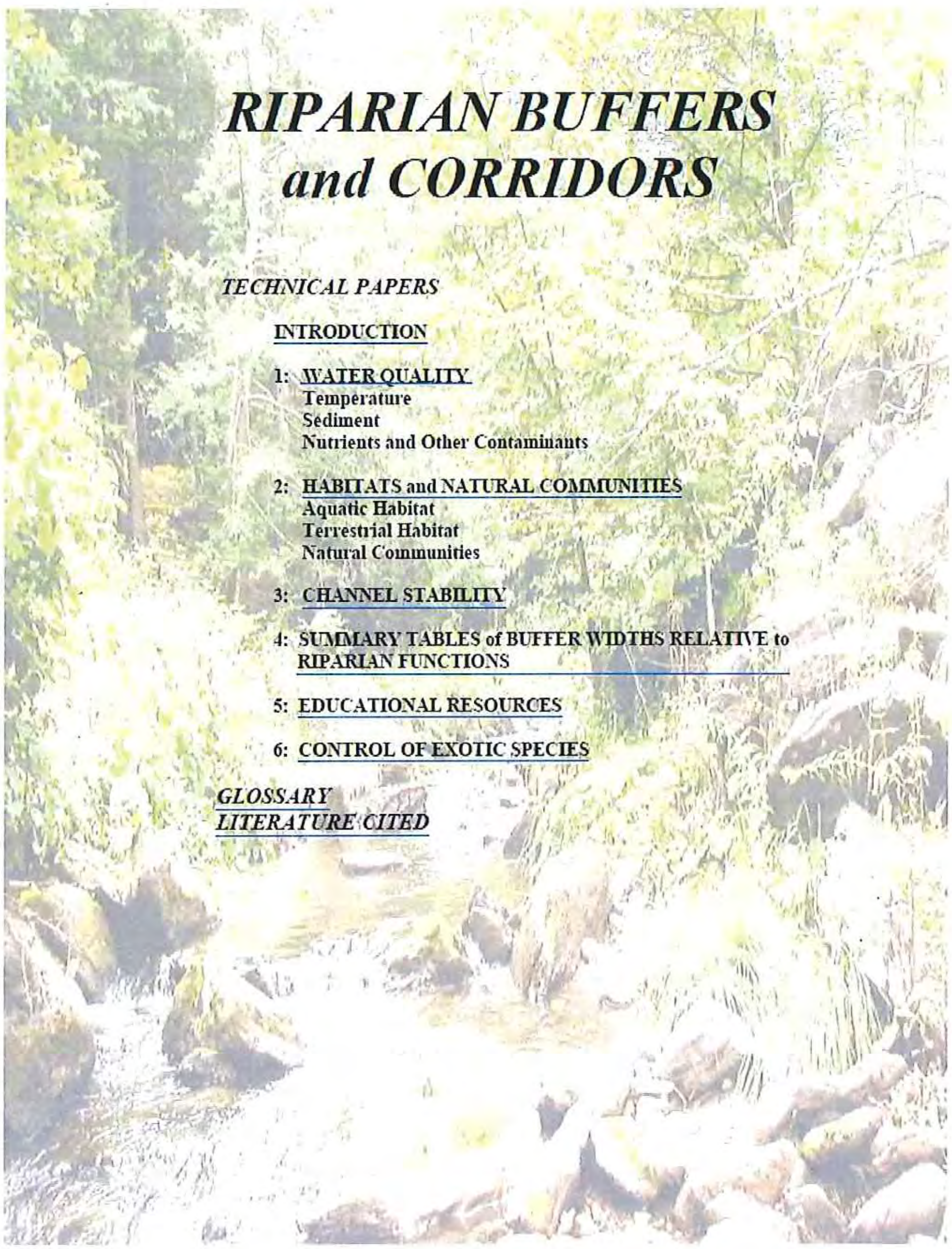
It is recognized that due to the diversity of ANR land holdings and varied management objectives, the professional judgment of interdisciplinary Stewardship Teams will be necessary at times to address conflicting management goals and develop alternative strategies which are consistent with the intent of this guidance and policy. Where riparian management goals and desired conditions cannot be fully achieved due to inherent differences in project purpose or other constraints, land managers should explore strategies which minimize impacts and identify opportunities for mitigation, enhancement or restoration of riparian functions.

IX. Riparian Management Research and Demonstration Projects

ANR lands provide an excellent opportunity to collaborate with other state, federal and non-governmental natural resource agencies and universities to research, develop and demonstrate new techniques for riparian area assessment, protection, enhancement and restoration. ANR land managers are encouraged to use an interdisciplinary approach for developing riparian management research and demonstration projects to ensure the range of riparian functions described in this document are addressed.

APPENDIX A: Riparian Buffers and Corridors Technical Papers

This document was developed by ANR staff in 2005 and provides a detailed discussion of riparian area functions and values used in the development of this guidance: http://www.watershedmanagement.vt.gov/rivers/docs/Educational%20Resources/rv_RiparianBuffers&CorridorsTechnicalPapers.pdf



RIPARIAN BUFFERS and CORRIDORS

TECHNICAL PAPERS

INTRODUCTION

1: WATER QUALITY
Temperature
Sediment
Nutrients and Other Contaminants

2: HABITATS and NATURAL COMMUNITIES
Aquatic Habitat
Terrestrial Habitat
Natural Communities

3: CHANNEL STABILITY

4: SUMMARY TABLES of BUFFER WIDTHS RELATIVE to RIPARIAN FUNCTIONS

5: EDUCATIONAL RESOURCES

6: CONTROL OF EXOTIC SPECIES

GLOSSARY
LITERATURE CITED

APPENDIX B. Research Notes

Riparian Function: *Temperature Moderation*

Overview: Aquatic species such as brook trout, slimy sculpin, spring salamander and many invertebrates are dependent upon cold, well oxygenated waters for their long term viability. Riparian canopies play an important role in moderating stream temperature extremes throughout the year. During the summer, stream canopies shade direct solar radiation thereby maintaining water temperatures, and insulate stream channels in the winter, reducing heat loss. Forested riparian areas also reduce the temperature of groundwater entering surface waters, providing stable inputs of cool water which provide critical spawning and refuge habitats. Climate change predictions suggest the habitats for coldwater species and communities will be significantly reduced where land use practices compromise forested riparian habitats.

The primary mechanism by which riparian vegetation controls stream temperature is through insulation, by shading the stream and trapping air next to the stream surface (Poole and Berman, 2001). As the principal source of energy for heating small streams is direct solar radiation, the more canopy that is removed, the greater the impact. Once stream temperatures are warmed, they will generally not be cooled unless a source of colder water, such as a spring or tributary, enters the stream or ambient temperature is reduced below stream temperature (Beschta et. al 1986; Poole and Berman, 2001).

Riparian forest canopy is more effective at shading narrower streams than wide rivers because the canopy shades a greater portion of the water surface. However, shading smaller streams is not only important in maintaining its cool water temperatures, but also in moderating water temperatures in the larger streams and rivers which they feed (Poole and Berman, 2001).

Research Highlights:

- When compared with stream segments having 30-m wide buffers, analysis indicated that individual stream segments with 15-m wide buffers have: 1) higher peak temperatures (average peak stream temperatures during the warmest week of the year increase by ~2.0 ± 0.3°C, depending on summertime climate conditions); and 2) more fine sediments (fines in riffle habitats increase by approximately 25% of the observed inter-study-site range). (Jones, K. L., G. C. Poole, J. L. Meyer, W. Bumback, and E. A. Kramer. 2006.)
- For streams <6m wide, stream shade modeling suggests that 80% shade can be achieved by managing for a 12m wide riparian buffer with 30m tall dense vegetation in mid-

latitude areas such as central Wisconsin. Study modeled potential temperature reduction with riparian shading. (Cross et. al. 2013)

- A west coast study projects that native cutthroat trout already excluded from much of its potential range by nonnative species, will lose a further 58% of habitat due to an increase in temperatures beyond the species' physiological optima and continued negative biotic interactions. Habitat for brook trout and brown trout is predicted to decline by 77% and 48%, respectively, driven by increases in temperature and winter flood frequency caused by warmer, rainier winters. Habitat for rainbow trout is projected to decline the least (35%) because negative temperature effects are partly offset by flow regime shifts that benefit the species. Stream temperature is often influenced by anthropogenic activity and future increases can be offset by restoration measures such as maintenance of stream flows and reforestation. (Wenger et. al. 2011)
- USACE (1991) review of several studies indicated buffers generally ranging from 10-30 m were effective in maintaining water temperatures in small streams.
- In a review of riparian buffer studies for the Minnesota Forest Resources Council, RSTC (2007) concluded that most shade functions are protected with moderate Riparian Management Zone widths of 50-100 ft if shade is dense (comparable to undisturbed control streams).
- Stream reaches in Western Oregon with complex old-growth riparian forests had frequent canopy gaps which lead to greater stream light availability compared to adjacent reaches with simpler second-growth riparian forests. (Warren et. al. 2013)
- In an extensive literature review, Sweeny and Newbold (2014) suggested that buffer widths $\geq$ 30m are required to provide full protection from measurable temperature increases.
- In the development of a stream temperature prediction model for the eastern US throughout the native range of the brook trout, DeWeber and Wagner (2014) found that riparian forest cover had a negative effect on stream temperature. This relationship was strongest at the extremes (0-10% and 90-100%) indicating substantial cooling benefits of full riparian forest cover.

<u>Management Considerations:</u>

- Climate change studies recognize the importance of forested riparian habitats in mitigating temperature impacts to cold water ecosystems.
- The effects of solar radiation will be dependent upon stream size, stream orientation, riparian slope, vegetation height and density, solar angle and direction.
- Continuous canopy is important as stream temperatures do not readily cool down unless additional coldwater inputs from springs or tributaries occur.
- Maximizing cold water conditions in headwater and upland areas will extend temperature benefits to downstream reaches.
- Need to recognize the effect of riparian vegetation on groundwater temperature inputs.
- Need to recognize the risk of riparian zone blowdown from upslope harvest.

- Old growth forests result in more frequent canopy gaps than second growth forests. Therefore managing for maximum large wood contributions may conflict with temperature moderation goals.

<u>Riparian Function:</u> ***Large Wood Recruitment and Retention***

<u>Overview:</u> In addition to providing a source of coarse particulate matter, large wood plays an important role in the development and maintenance of instream habitat structure and complexity. The interaction of stream flow with large wood causes scour and creates complex pool and near-bank habitats with hiding and isolation cover, thereby increasing the number of fish that can occupy a given area. Retention of sediment and organic material by woody debris and jams influence stream nutrient cycling and aquatic invertebrate populations dependent on detritus. Large wood or complexes of large wood act as hard channel borders and protect streambanks and beds from erosion. Large wood provides more stable habitat features and sources of organic material as they are less prone to movement than smaller individual pieces.

Large wood features, such as snags, logs, and rootwads, are recruited from riparian areas into nearby waterbodies by means of natural aging and falling, wind throw, flood, and landslide. During high flows, forested floodplains next to large rivers are a primary source of large wood, as are trees falling directly from the bank and riparian area are recruited into the channel. Standing and downed wood in floodplains also serve to trap sediment and organic material and reduce velocities during flood flows.

A recent study in the Northeast Kingdom found large wood to be highly correlated with brook trout abundance. Studies in the Adirondacks indicate that old growth riparian forests provide for greater in stream complexity and pool habitats that earlier successional forest types, suggesting forest management include development of late successional habitats within riparian areas.

<u>Research Highlights:</u>

- Old-growth riparian forest structure is more complex than that found in mature forests and exhibits significantly greater accumulations of aboveground tree biomass, both living and dead. In-stream LWD volumes were significantly greater at old-growth sites (200 m3/ha) compared to mature sites (34 m3/ha) and were strongly related to the basal area of adjacent forests. In-stream large-log densities correlated strongly with debris-dam densities. AIC models that included large-log density, debris-dam density, boulder density, and bankfull width had the most support for predicting pool density.

There were higher proportions of LWD-formed pools relative to boulder-formed pools at old-growth sites as compared to mature sites. Old-growth riparian forests provide in-stream habitat features that have not been widely recognized in eastern North America, representing a potential benefit from late successional riparian forest management and conservation. Riparian management practices (including buffer delineation and restorative silvicultural approaches) that emphasize development and maintenance of late-successional characteristics are recommended where the associated in-stream effects are desired. (Keeton et. al. 2007).

- In a study of stream in the Northeast Kingdom, VT, the top-ranked model included the duration of water temperatures exceeding 20°C, total wood density, and maximum riffle depth, and predicted that brook trout biomass could be expected to increase with increasing woody habitat where water temperature do not exceed 20°C for 200 h per summer. (Kratzer and Warren 2013).
- In a study of natural rates of input of large woody debris in southeastern Alaska, reported that nearly all of the LWD was derived within 30m of the stream and that a 30m unlogged buffer should maintain LWD (Murphy and Koski 1989).
- Andrus et al (1988) suggest that trees must grow beyond 50 years (coastal Oregon) before riparian stand yield large debris in quantities similar to old growth forests and is essential for maintaining pool formation.
- Palik et al. 2000 suggested using maximum tree height or greater to define recruitment distance, recognizing that floodwaters may transport large wood beyond a single tree length. They also suggest managing riparian areas for LWD by: a) leaving an undisturbed buffer of old growth timber, b) manage timber harvests on longer rotations (100-150 years) or c) manage riparian areas for even delivery of large wood.
- Of all the ecological functions of riparian areas, the process of woody debris loading into channels, lakes and floodplains requires the longest time for recovery after harvest (Wenger 1991).
- Research conducted on a small third-order stream in the Green Mountains of Vermont suggests that large organic debris has an important influence on sorting and storage of sediment, spacing of pool-riffle sequences, and channel geometry. Large organic debris appeared to cause a negative feedback mechanism where channel degradation leads to increased standing timber recruitment and large organic debris sediment-storage sites. The study suggests that constant rates of standing timber recruitment lead to predictable volumes of sediment stored upstream of LOD and that accumulations remain stable for at least 8 years. The maintenance of these stream-side conditions may be crucial in maintaining the present sediment storage conditions within the stream (Thompson 1995).

- Low residual BA (<25ft2/ac) and narrow riparian zones (<100') results in aquatic habitat indicators below reference conditions (RSTC 2007). In reviewing available scientific evidence, this study suggests that with the exception of stream wood, aquatic habitat functions may recover within 10 years, in RMZs of 30 m (100 ft) or wider. Wood volume has been found to increase for a period after harvest, generally due to inputs of slash and blowdown; however, after a period of about 10-120 years, wood decay results in decreased wood abundance relative to a reference range, with full recovery taking as long as 100 to 150 years.
- In a study of a high gradient stream in the Adirondack Mountains, Warren and Kraft (2008) found large wood length strongly influences its potential to move in high gradient streams. Nearly all mobile wood was smaller than the bankfull width of the stream. Debris dams resulted in reduced large wood movement rates and movement distances for wood of all sizes.
- Both Sweeny and Newbold (2014) and Veery et al. (2000) recommend suggest riparian buffer widths for coarse wood recruitment based upon 1-2 mature tree heights. Distances greater than one mature tree height recognizes the fact that significant amounts of wood is recruited to streams during extreme floods and bank failures. Veery et al. (2000) suggest managing for big trees to speed accrual of wood to streams, including intermittent and ephemeral channels, and lake basins.

Management Considerations:

- Large wood provides benefits to aquatic habitats (habitat diversity and complexity), stream processes (sediment sorting and storage, pool-riffle spacing and channel geometry) and reduces the erosive force of water by contributing to channel roughness.
- Larger stems are less mobile and decay slower, therefore have greater long term influence on stream habitat and processes.
- Management for large wood may conflict with management for temperature moderation as old growth forests provide greater frequency of canopy openings.
- Width of riparian buffer to promote LWD will be larger in broader valley streams where floodplains may contribute to large wood production.

Riparian Function: *Sediment Control*

Overview: The impact of sediment discharges to aquatic habitats and the populations they support has been well documented. A good summary of this research can be found in the 1995 American Fisheries Society publication *Sediment in Streams: Sources, Biological Effects and*

Control by Thomas F. Waters. Sediment can have direct detrimental effects on populations or result in degraded habitats which impact reproduction and abundance:

Suspended sediments & turbidity:

- May result in respiratory impairment and gill abrasion and lead to direct mortality or increased susceptibility from disease.
- May create degraded water quality conditions which result in avoidance of stream reaches and important habitats.
- May reduce photosynthesis and associated primary productivity.
- May increase invertebrate drift.
- May result in reduced feeding and growth.
- Carry nutrients (phosphorous, nitrogen) which can lead to degradation of water quality in downstream receiving waters, particularly lakes and ponds.

Deposited sediments:

- May degrade spawning habitat conditions by creating embedded substrates which cannot be excavated for egg deposition.
- May reduce interstitial flow (oxygen, waste removal) to developing eggs and fry.
- Post spawning sediment deposition may entrap fry and make them unable to emerge from gravels.
- May degrade available habitat for aquatic invertebrates and amphibians.
- May degrade or eliminate pool habitats.

Excessive inputs can also significantly affect the stream channel ability to process its sediment load. This can lead to channel aggradation and widening, resulting in impact to aquatic habitats and infrastructure. High sediment loads may reduce stream crossing hydraulic capacity while resultant channel widening may increase lateral migration of the stream channel.

Riparian vegetation influences the discharge of suspended sediments by reducing soil erosion; filtering and trapping sediment transports from upland sources; binding and fortifying streambanks; creating pools and debris jams which store sediments; and moderating stream flows and bed scour during high water events.

Waters (1995) suggests that the elimination of agricultural, silvicultural and development within riparian areas as the best practice to eliminate severe sedimentation.

<u>Research Highlights:</u>

Effective riparian buffer widths for controlling overland sediment discharge will be dependent upon slope, vegetative cover and complexity, soil permeability and erodibility, adjacent land use or activities (Waters 1995).

The variability of riparian conditions and adjacent land use is reflected in studies which have generally shown 10m - 30m riparian buffers to be adequate in most situations, although most studies recognize the need to increase buffer size with increasing slopes (USACE 1991, RSTC 2007).

Buffers are less effective if flow is concentrated; buffers become submerged or filled with sediments and during the winter when infiltration is compromised (USACE 1991).

Sweeny and Newbold (2014) summarized "studies of the ability of streamside buffers to trap sediment, when limited to streamside studies or comparable field conditions, show that buffers 10 m wide can be expected to trap about 65% of sediments delivered by overland flow, while 30-m buffers can be expected to trap about 85% of sediments. The increased removal attained by wider buffers represents a small fraction of the total sediments (by mass), but probably a large fraction of the finer silts and clays, which are typically released from narrow buffers in concentrations high enough to impair water quality."

Management Considerations:
Slope and adjacent land use or activities should be key considerations for buffer width, assuming vegetative cover is consistent.

Channelized flow and reduced permeability compromises filtration & absorption.

Riparian floor roughness and complexity will influence sediment retention.

Riparian Function: *Energy Production*

Overview: Allochthonous (produced outside of the aquatic system) organic material, in the form of leaves, needles and woody debris from riparian vegetation, represent the dominant energy source for headwater streams and is more fully described in Murphy and Meehan (1991). Plant species, deciduous leaves and coniferous needles vary widely in decay rates and nutrient composition which will affect the total nutrient content provided to the aquatic system. Large wood has been found to be very important in retaining leaf and organic litter, both within the stream channel and its floodplain, allowing for this energy source to be utilized within the stream reach before being transported downstream.

All leaves and needles must be "conditioned" by microbes for ~30 days before invertebrates will consume them. Invertebrate "shredders" will consume these conditioned materials and convert them to fine particles available to "collector" invertebrates. The organic materials are repeatedly transported, stored, metabolized and exported downstream and provide an important energy source for larger streams. In addition, the macroinvertebrates which process these materials collectively provide a very important food source for fish.

Canopy removal may result in localized increases in periphyton production by increasing sunlight exposure and spur increased abundance of macroinvertebrates and fishes. However, elevated stream temperatures resulting from increased solar radiation may have cumulative negative impacts to downstream reaches, reducing overall coldwater fish production in the watershed.

Research Highlights:
Palik et. al. (2000) suggests that little research is available to define the width of riparian vegetation which influences the contribution of particulate organic matter. While guidelines often call for relatively narrow distances from the stream channel, a Minnesota study showed that one-third of the leaf litter biomass originated beyond 100-feet of the stream.

Management Considerations:
Riparian management may profoundly influence the source and magnitude of allochthanous inputs which will directly affect the density and diversity of species dependent upon. Tree and plant species vary in the nutrient content, quality and decay rates which will drive the effective energy inputs to the stream.

While localized improvements in energy production can be obtained through canopy removal, increased water temperatures can result in a net loss of coldwater populations on a watershed basis.

Riparian Function: *Riparian Wildlife Habitat*

Overview: Riparian areas provide a distinct habitat that is used by many wildlife species. While many generalist species may use riparian areas, there are some species for which streamside riparian habitat is essential. These species, called riparian obligates, include stream salamanders (spring, dusky, and two-lined), wood turtle, belted kingfisher, water shrew, river otter, and beaver. The riparian zone around wetlands provides similar important habitat for many wildlife species, including many species of amphibians, water shrew, spotted turtle, ribbon snake, and many species of birds. There are also rare, threatened and endangered (RTE) species, such as the little brown bat, which are not riparian obligates, but which frequent riparian habitat and are of special management concern. Activities the lower the habitat quality of the riparian zone will have a disproportionate negative impact on these riparian obligates.

Wildlife species vary in their habitat needs and sensitivity to disturbance, but typically riparian-obligates prefer a forest with a complex size and age structure, dead and downed wood, and snags and cavity trees. Some species, especially amphibians, may need moist soils in order to use habitat away from the stream. Loss of tree cover, and the resulting increase in sunlight and temperature, can have negative impacts to these habitat features.

Overall there is no single "wildlife" riparian zone – different species require different habitat sizes and conditions. Furthermore, since many species of wildlife are wide-ranging or disperse long distances, it is unlikely that any buffer that can be practically implemented will meet the needs of all riparian-obligate wildlife and riparian-associated RTE species. Thus, due consideration to wildlife habitat in upland areas is essential for protecting riparian species.

<u>Research Highlights:</u>

- A review of riparian obligate wildlife habitat requirements found that a 50m buffer would meet the needs of most species of invertebrates, mammals, and riparian-obligate birds, but would not meet the needs of some species of Odonates, amphibians, turtles, or the denning needs of mink and otter. It would also not meet the dispersal needs of large mammals, or provide suitable core-forest habitat for forest interior bird species. (Stoffyn-Egli and Willison 2011)
- Multiple studies (Semlitsch and Bodie 2003, Petranka and Smith 2005) suggest that 20-30 meter zones from stream will include the majority of core habitat for stream salamanders, including dusky salamander, two-lined salamander, and spring salamander, though this will not include dispersal habitat. Of note, Willson and Dorcas (2003) found that habitat disturbance at the watershed scale was a predictor of salamander abundance while habitat disturbance in a riparian buffer did not correlate with salamander abundance.
- deMaynadier and Hunter (1998) found edge effects from intensive harvests in Maine extend 25-35 meters for amphibians.
- Semlitsch et al. (2009) found that most timber harvesting activity had negative impacts on the abundance of most (but not all) amphibians. However, partial cutting had less impact than clear cutting. The authors suggest leaving >50% canopy cover.
- In the Alleghany Mountains, "bat activity levels in nonriparian upland forest and harvested forest were low relative to forested riparian areas." The researchers noted that some harvesting may improve foraging opportunities for some bat species, but it

also removes the snags, cavity trees, and old trees with loose bark used for roosting. (Owen et al. 2004)

- A study of Vermont streams found that a zone 150m from a stream included 90% of the birds species found within 200m of streams (Spackman and Hughes 1995).
- Parren (2013) studied Vermont wood turtles, an uncommon species in the state, and found the average maximum distance from the stream for adult females was 276 +/- 86.4 meters. Wood turtles have been reported to range as far 600 meters from streams in New Hampshire (Kaufman 1992 cited in Semlitsch and Bodie 2003), and Chase (1995) reports even further distances up to 1 mile (cited in VT ANR 2005)
- Spotted turtles can travel >400 meters from wetland edge during summer (Milliam and Melvin 2001). Ribbon snakes stay within 5m of water (Bell et al. 2007). In general, reptiles appear more resilient to timber harvesting, so long as individuals and nests are not directly harmed (Moorman et al. 2011).

Management Considerations:

- Riparian management should be designed to protect riparian-obligate wildlife species, and to protect important (even if not essential) habitat for rare, threatened, or endangered wildlife species.
- Because many wildlife species can have large dispersal distances, it is impractical to expect that riparian management alone will meet all life needs of riparian wildlife. Thus, it is important to consider landscape connectivity, particularly the connections between streams, wetlands, and other riparian features which can serve as "stepping-stones" for dispersal.
- The ideal width of streamside riparian habitat may vary depending on conditions at the watershed. A smaller zone may function to protect many species, if adequate habitat is available in the watershed and there are opportunities for dispersal. Conversely, in a highly disturbed watershed, larger areas may be needed to protect the full life-cycle of riparian wildlife species.

Riparian Function: *Hydrologic Integrity*

Overview: Wetlands are inherently defined by their hydrology. Inputs from precipitation, surface water, and ground water are balanced against evaporation and surface and groundwater outflow. The specific hydrologic pattern and balance of each wetland creates soil and other conditions that favor a certain suite of plants and animals (Smith et al. 2009; Goslee et al. 1997; Carter 1986) and which overall result in particular natural community types. Changes in hydrological inputs or outputs can cause dramatic changes to the wetland system

(Carter 1986; Mitsch and Gosselink 1986), and therefore the associated natural community and its functions (such as carbon storage).

Certain wetlands types are especially sensitive to changes in hydrology, and even small disturbances can have a disproportionate negative impact. Basin wetlands, such as Red Maple-Black Gum Swamps or Vernal Pools typically have small watersheds and only limited input and output of water. For these wetlands, activities that cause even minor alterations to the rate or volume of input/output can have negative impacts on the natural community and associated species.

Many Vermont wetlands receive significant nutrient inputs via surface or groundwater flow. These enriched wetlands, such as Intermediate Fen and Rich Fen, and Calcareous Red Maple-Tamarack Swamp, typically host a unique suite of plants, including many rare and uncommon species. Other wetlands, such as Poor Fens, Dwarf Shrub Bogs, and Black Spruce Swamps, receive little or no nutrient input and are characterized by strongly acidic conditions. In both cases, alterations to the rate or source of water input and output has the potential to change the nutrient balance, with negative impacts to the natural community and associated species.

Floodplains and other wetlands associated with large river or lake systems are characterized by seasonal flooding and drying, and many species may be dependent on the regular influx of nutrients carried by floodwaters. Changes to river flow regimes or to lake levels would negatively impact these natural communities.

While permanent development probably has the greatest potential to impact wetland hydrology (Faulkner 2004), other activities can also cause hydrological changes. Timber harvesting infrastructure can alter water surface flow patterns, particularly by capturing and channelizing naturally diffuse sheet flow. (Many recreation trails have the potential for the same impact.) In addition, changes in forest composition and structure from harvesting can alter rates of evapotranspiration on the landscape.

Research Highlights:

- Small changes in recharge/discharge in bog wetlands can result in dramatic changes in water chemistry in the bog and alter the vegetation present in the wetland (Siegel 1988).
- Jansson et al (2007) found that groundwater discharge increased riparian plant species diversity by 36-209%: "These results demonstrate that riparian zones are controlled by water and nutrient input from upland parts of catchments in ways that have been overlooked."

- Kemmers and Jansen (1988) report that rich fens are threatened by changes to regional water management that alters groundwater seepage, while poor fens are at risk to alteration of their immediate catchment area.
- Heavy timber harvesting (clearcutting 100% of catchment area) results in a short term increase in water yield before vegetation regrowth, due to decreased evapotranspiration (Hornbeck et al. 1993). Stednick (1996) indicates that the threshold for this response is clearing 20% of the catchment vegetation. Wang et al. (2006) found increased nutrient runoff but no change in water yield after a partial (33% basal area removal) harvest in a Catskill Mountain watershed.
- A review of catchment harvesting studies (Brown et al. 2005) found that after a catchment is harvested, it can take up to several decades for water yield to return to pre-treatment levels.
- Experimental harvesting within Black Ash (*Fraxinus nigra*) wetlands resulted in altered evapotranspiration that was evident in an increased water table height (Slesak et al. 2014). The results were more dramatic in wetlands with a shallow water table.
- Barksdale et al. (2013) studied the effects of land use and land cover on headwater wetlands in Alabama and came to these conclusions: "Changes to wetland hydrology showed effects on the cycling and storage of forest floor carbon. In more forested watersheds, wetland water levels increased more slowly in response to rain events. In more altered landscapes, water increasingly entered wetlands as surface flow from specific locations (ditches and storm water outlets) with higher energy and greater potential for export of detrital material. Such export reduced the ability for headwater wetlands to retain carbon and reduced leaf litter stock on the forest floor that may influence nutrient cycling and soil organic matter."

Management Considerations:

- Successful protection of the full range of wetland functions and values requires a consideration not just of the wetland itself, but the surrounding watershed and hydrological processes
- Activities that alter the volume, rate, or chemical composition of water inflow or outflow to and from wetlands may result in negative impacts. These impacts are likely to be more pronounced in small wetlands with correspondingly small watersheds, or wetlands that are strongly characterized by nutrient levels.
- Changes in wetland hydrology can affect biogeochemical processes such as carbon storage and nutrient cycling.
- For many wetlands, especially small ones, the risk of soil damage—compaction, rutting, and channelization—from machines may pose the greatest local threat to wetland hydrology.

- Timber harvesting can be expected to temporarily alter evapotranspiration and the nutrient movement rates, but there is little science quantifying the effects of these changes in small-scale, partial harvests that are likely to affect wetlands on ANR-managed lands.
- It is usually not possible to readily determine the extent of the groundwater inputs to a wetland. In cases where groundwater protection is critical (i.e. Rich Fens) it may be necessary to use the surface watershed as an imperfect approximation of the ground watershed.

Riparian Function: *"Coarse Filter" Conservation*

Overview: Because many groups of organisms are cryptic or poorly understood (for example, fungi and soil invertebrates), it is not practical to make lists of all of them (Anderson et al. 1999; Willis and Whittaker 2002). Even if we could assemble such lists of species, it would be impossible to manage the land with all of them in mind. Instead, natural communities are treated as a proxy for the biological organisms of which they are composed. It is thought that if examples of all of Vermont's natural communities are conserved at the scale at which they naturally occur, most of the species they contain, from the largest trees and mammals to the smallest insects, will also be conserved (NCASI 2004). Natural communities are thus a coarse filter for "catching" the majority of an area's native organisms.

Riparian areas may be distinct natural community types, such as floodplain forests, or wetlands. They can also be "mesofilter" elements within large, landscape-scale natural community types such as Northern Hardwood Forest or Lowland Spruce-Fir Forest (Hunter 2005). In these latter cases, even though the riparian zone may not appear distinct, it may harbor native species such as fungi or invertebrates with particular riparian requirements. Because these species are cryptic and cannot easily be identified, they are unlikely to be singled out for specific protection. Protection of the riparian zone is important if natural communities are to be expected to serve as a conservation proxy for biological organisms.

Research Highlights:

- Hagan et al. (2006) found that small headwater streams in spruce-fir northern hardwood forest ecosystems in Maine had a distinct vegetation community that was found within 5-13m of the stream. This shows that even when small streams are bordered by common and widespread natural community types, there are specific habitats found only in the riparian zone.

- A meta-analysis by Sabo et al (2005) found that worldwide, across taxa, riparian zones increase regional species richness not by having more species, but by having different species than the surrounding uplands.

Management Considerations:

- Small-stream riparian zones are not distinct on natural community maps, and may be overlooked as a "coarse filter" conservation consideration.
- Protection of even small-stream riparian zones may be necessary for the conservation of some species.
- Because much is unknown about species like fungi and invertebrates, their role in the riparian and aquatic ecosystem is not understood.

Riparian Function: *Wildlife Movement Corridors*

Overview: Riparian zones are frequently recognized as functional corridors for terrestrial wildlife and plant species movement and dispersal (Naiman and Décamps 1997). The Vermont Wildlife Action Plan recognizes riparian movement corridors as an important element of landscape-level, community-level, and species-level conservation. These corridors can function for a variety of purposes, which span a wide range of spatial and temporal scales. In particular, functional corridors can facilitate (adapted from Bennett 1998):

- Localized movement of wildlife species that have specific habitat requirements (e.g. amphibians, wood turtle, otter) or are at higher risk of predation or mortality in unsuitable habitat (e.g. some songbirds and small mammals).
- Dispersal and movement of wide-ranging species that regularly travel between habitats.
- Migrations of wildlife that use different habitats or regions at different times of year or during particular stages of their life-cycle.
- Genetic connectivity between habitat blocks, reducing the likelihood for inbreeding depression and localized extinction.
- Recolonization of habitat blocks if local extirpations do occur.
- Shifting plant and animal ranges across the landscape in response to a changing climate.

While the ecological benefits of habitat connectivity are irrefutable (Beier and Noss 1998; Bennett 1998), and studies have demonstrated the functions of riparian corridors (see below), there are few studies identifying corridor requirements for the local movements of particular species, and little if any information on requirements for successful long-term range shifts of plant species. For long-term, multi-generational range shifts of plants, movement corridors are identical to suitable habitat. For some bird and mammal species, however, the minimum conditions necessary to facilitate movement across the landscape may be quite different from those needed in core habitat. Implementation of riparian connectivity for terrestrial species will like require an adaptive management approach, based on site and species-specific conditions, to be effective.

Research Highlights:

- 100-meter uncut lakeside riparian buffer strips in the boreal forest of Alberta enhanced movement rates of juvenile songbirds and maintained movement rates of adult songbirds when adjacent land was harvested (Machtans et al. 1996)
- Vignieri (2005) found that Pacific jumping mice used riparian corridors for cross-drainage migrations, and that "connecting habitat plays a considerably larger role in limiting or facilitating dispersal and migration than does the presence of large topographic barriers."
- Riparian corridors 50-150 meters wide enhanced movement of a translocated forest specialist bird in fragmented tropical forest, when compared to forest gaps and 15-30 meter wide fencerows (Gillies and Clair 2008).
- In a study of salamander movements along stream corridors, Cecala et al. (2014) found evidence suggesting "that riparian disturbance can reduce permeability to salamanders, even in the absence of additional land-use change. Because anthropogenic features, such as roads and powerlines, frequently cross small streams, the accumulation of apparently small land-cover changes has the potential to reduce continuous populations to small fragments with limited connectivity."

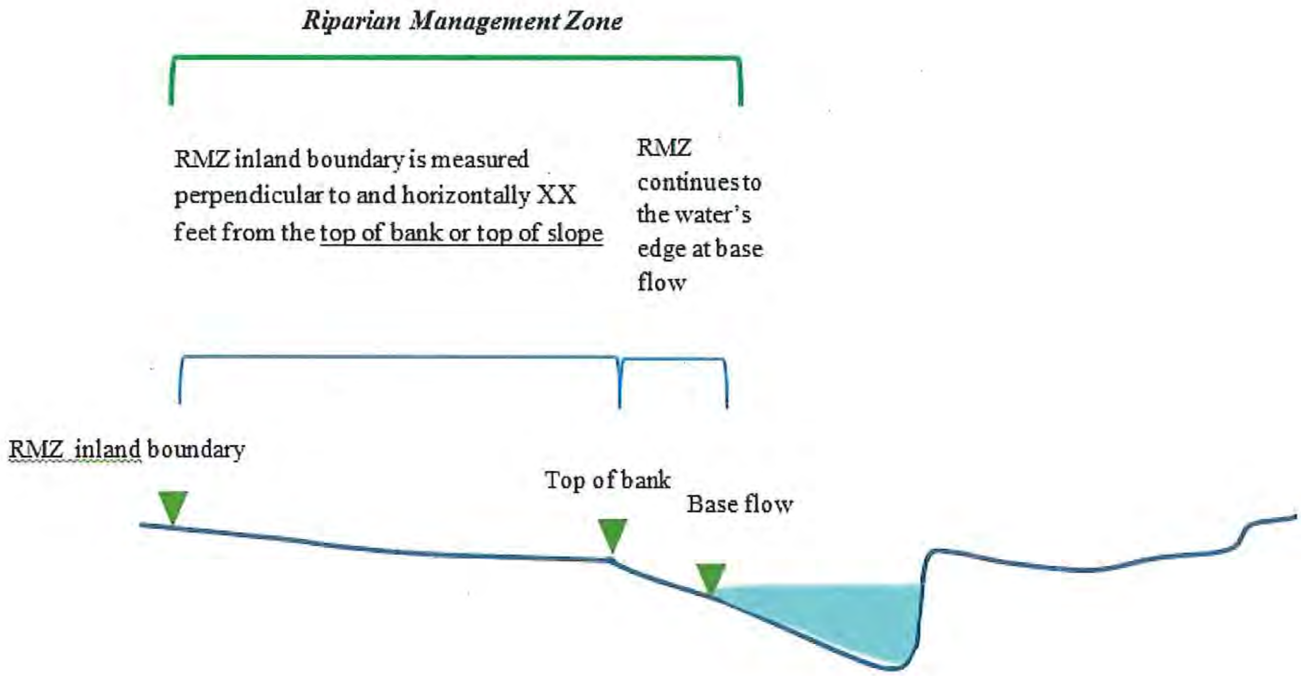
Management Considerations:

- Wildlife movement corridor widths and conditions may be different than preferred or core habitat sizes and conditions.
  The widths needed to provide functional riparian corridors are still largely unknown, but limited research indicates that corridors >50 meters wide provide this function.
- While effective riparian corridors might be achieved with RMZs designed to protect water quality and aquatic habitat, these narrow corridors may not provide the full range of spatial and temporal scale functions listed above.
- Land managers should identify target species or processes for particular riparian corridors, and establish widths and criteria based on those targets. A summary of wildlife use of different riparian zone widths can be found in the ANR Riparian Buffers and Corridors Technical Papers.

- Monitoring and adaptive management will likely be necessary to ensure successful functioning of riparian connectivity.

APPENDIX C. Measuring Stream Riparian Management Zones

When establishing riparian management zones on streams it is important to consider which feature should be used to measure – from the **top of bank** or **top of slope,** depending on the physical channel characteristics. In all cases, the RMZ is measured a specific distance inland, perpendicular to and horizontally from the top of bank or top of slope and continues to the water's edge at base flow conditions as depicted below:



<u>Measuring from top of bank:</u> Figure C.1 represents a stream channel with a relatively flat and wide floodplain, which the stream accesses during flows at or exceeding the average annual high water stage. When these channel characteristics are present RMZ's can be measured from the top of bank, perpendicular to the channel. When contiguous wetlands are present in the floodplain, however, the Agency recommends that buffer measurement begin at the upland edge of the wetland.

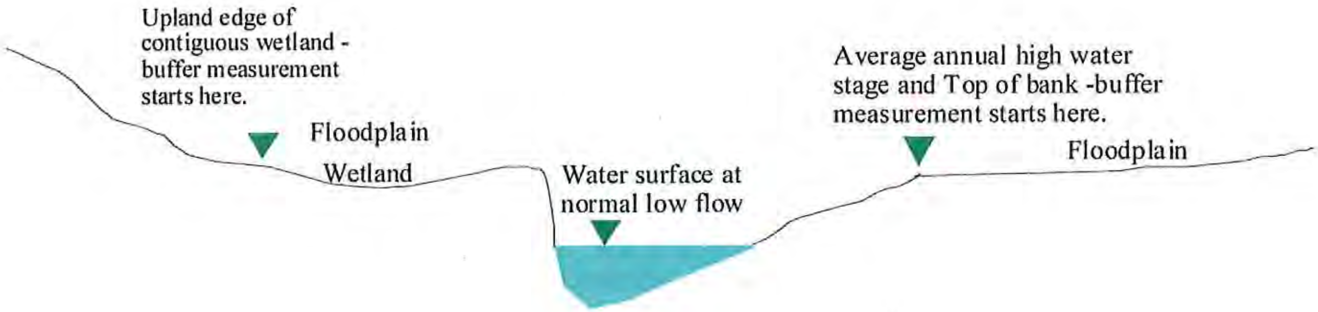


Figure C.1. Top of bank typical of streams with flat, wide floodplains that the stream accesses during flows exceeding average annual high water. Upland edge of wetland typical of continguous wetlands sometimes present in the floodplain.

<u>Measuring from top of slope:</u> There are at least three scenarios when RMZ's should be measured from the top of slope.

Scenario 1: When a channel is contained in a narrow V-shaped valley that has steep side slopes RMZ measurement should begin at the top of slope (Figure C.2). There is often little or no floodplain in this scenario, which increases the threat of slope toe erosion and slope failure, especially during storm and flood events.

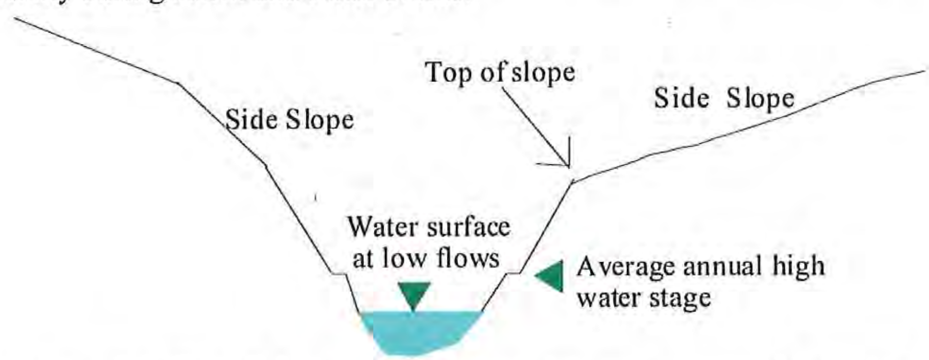


Figure C.2. Top of slope typical of steep streams in narrow V-shaped valleys with little or no floodplain.

Scenario 2: When a channel has adequate floodplain on one side but borders a steep valley side slope or high terrace on the other, RMZ measurement should begin at the top of slope on the valley wall or terrace side and the top of bank on the floodplain side (Figure C.3). The absence of a floodplain in areas where the channel runs adjacent to the steep valley side slope or high terrace increases the threat of slope toe erosion and slope failure.

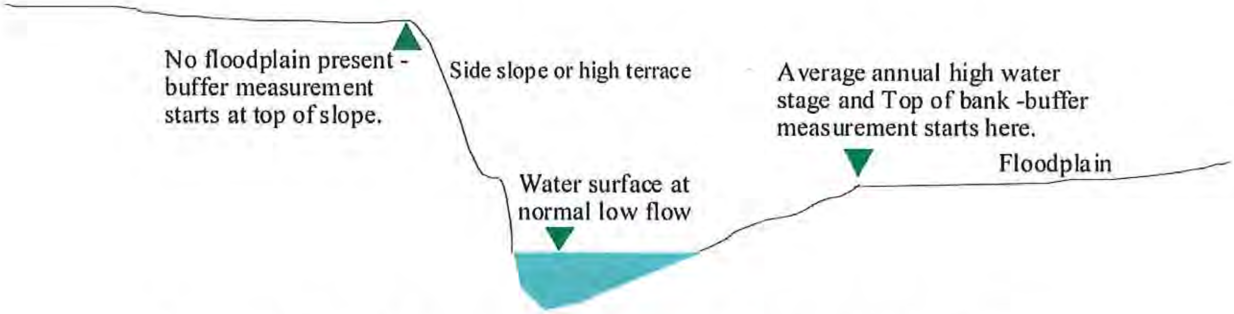


Figure C.3. Top of slope typical of streams that run adjacent to steep slopes or high terraces on one side of the valley but have adequate floodplain on the opposite side of the valley.

Scenario 3: Where streams that once had access to floodplains have since steepened and incised, the top of slope is found at the edge of the floodplain undergoing abandonment (Figure C.4). These streams are undergoing a channel evolution process, often taking decades to erode their banks and reestablish meanders, creating new floodplains at lower elevations. This often involves the cutting away of the toe of the steep slope, leading to slope failure. To ensure that streamside slopes are not compromised during this channel evolution process RMZ's should be established from the top of slope.

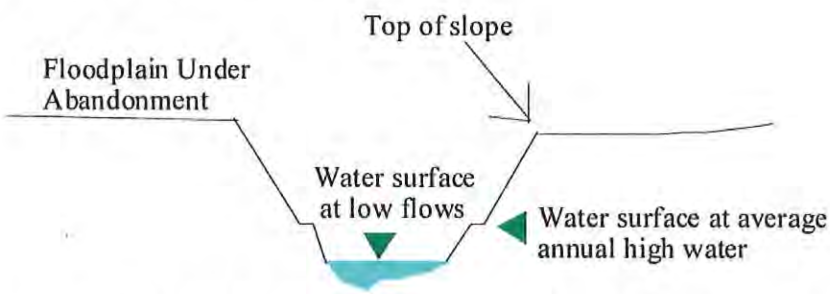


Figure C.4. Top of slope typical of incised streams that have little or no access to their floodplains and have yet to establish a new floodplain.

After a stream has incised and widened, it develops a new floodplain at a lower elevation. Often these floodplains are contained in narrow valleys and are flanked by steep slopes. In the case of narrow floodplains, where the slope and depth of the stream is maintained by the stream's ability to meander across the full width of the floodplain, RMZ's should be established from top of slope to protect the stability of the stream as well as the stability of the adjacent slopes (Figure C.6).

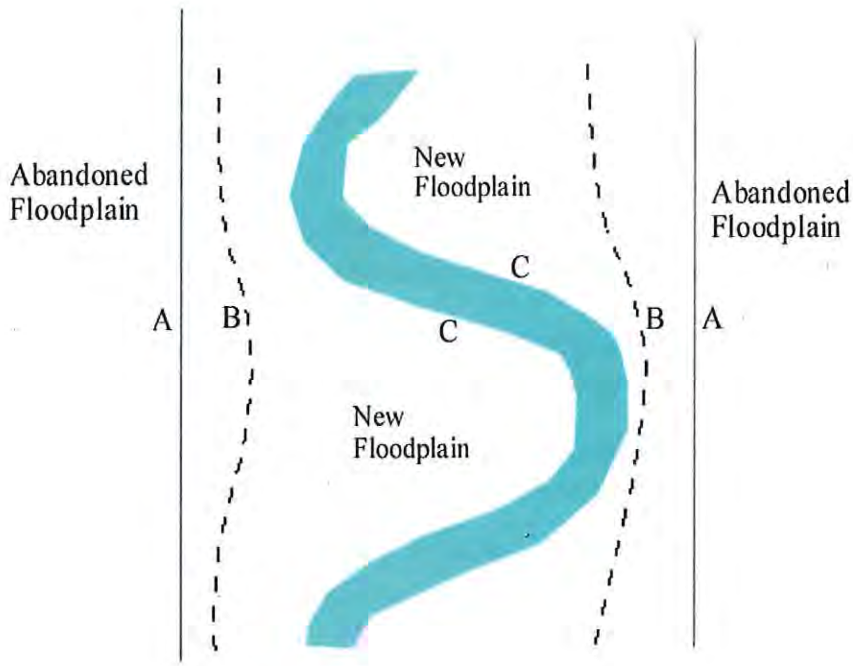


Figure C.6. Bird's eye view of stream in Figure C.5. A=top of slope, B=outer edge of floodplain, C=top of bank.

APPENDIX D. Literature Cited & Bibliography

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APPENDIX E. ANR Lands Riparian Management Workgroup Charge

Background: In the wake of tropical storm Irene and other extreme weather events, the need to enhance and improve flood resiliency across the State has emerged as a top priority of the Agency of Natural Resources. As a part of this broad effort, the ANR Secretary has asked the ANR Lands Stewardship Team to develop clear policy and guidelines regarding the establishment, management, and restoration of riparian buffers on ANR lands. In response to the Secretary's request, the ANR Lands Stewardship Team has established a Work Group on Riparian Buffer Guidelines for ANR Lands. The ANR Lands Stewardship Team initiated a similar effort to develop riparian buffer guidelines for ANR lands several years ago. This effort generated a considerable amount of useful information and ideas but stopped short of establishing clear ANR lands policy and guidelines regarding riparian buffers. This information should provide a useful starting point for the Work Group. (A parallel effort is currently underway by the Agency to revise the Act 250/Section 248 riparian buffer guidelines for development projects. This effort should also help inform this Work Group).

Goals for Riparian Buffer Guidelines for ANR Lands: Riparian buffer guidelines for ANR lands should be guided by the following general goals:

- Protect/enhance water quality
- Maintain/enhance flood resiliency
- Protect/enhance natural communities
- Protect/enhance wildlife and aquatic habitats
- Provide for sustainable outdoor recreation opportunities
- Provide for sustainable timber management
- Maintain/restore stream equilibrium

Work Group Charge: The Work Group is charged with developing draft riparian buffer policy and guidelines for ANR lands for the review and approval of the ANR Lands Stewardship Team and ultimately, the ANR Leadership Team. The draft policy and guidelines should be based on the best available science, practical to implement, and reflective of the diversity of ANR lands and the full range of uses and management objectives for these lands. Further, the policy and guidelines must strike a balance between the need for providing a consistent approach across management districts with the need to provide flexibility in applying these guidelines that reflects site specific needs and demands and makes the best use of the professional judgment of ANR lands and natural resource managers. Specific Work Group tasks include:

- Review/assess proposed draft buffer guidelines and related information from ANR staff and other public agencies and private organizations.
- Solicit input on riparian buffer guidelines and management from ANR staff and experts.

- Coordinate closely with and help inform the Act 250/Section 248 riparian buffer work group regarding riparian buffers for development projects on ANR lands and incorporate these guidelines and recommendations as appropriate.
- Develop draft Policy Regarding Establishment, Management, and Restoration of Riparian Buffers on ANR Lands.
- Develop draft set of Riparian Buffer Management Guidelines for ANR lands
- Identify resources and information for use by ANR land managers as reference material for riparian buffers management.
- Develop recommendations for incorporating riparian buffers assessments and associated management recommendations within long range management plans for ANR lands.

Other Considerations: In developing the draft riparian buffer policy, guidelines, and recommendations, the Work Group should consider these additional suggestions:

- Acknowledge that limited management is sometimes necessary or appropriate within buffer areas under specific and defined circumstances (e.g., develop uneven-aged stands, conduct instream habitat improvements, trail development).
- Provide a formal process for addressing and accommodating deviations to buffer guidelines.
- Provide criteria and guidance for deciding whether to re-establish or re-route existing roads or develop new roads within riparian areas and river corridors.
- Riparian buffer policy and guidelines should distinguish between developed ANR lands (e.g., developed state parks) and managed forest land.
- Acknowledge and address buffer management constraints associated with water-based developments (swimming beaches, access areas, and road/trail stream crossings).
- Consider establishment of primary and secondary buffers with associated guidelines.
- Riparian buffer guidelines should address wetlands (including seeps and vernal pools), lakes and ponds as well as riparian areas associated with streams and river corridors.
- Consider desired condition and management goals for river corridors as well as for riparian buffers.

Work Group Members: The Work Group will include the following individuals: Mike Fraysier (Chair, FPR), Rich Kirn (FWD), Bob Zaino (FWD), Jim Horton (FPR), Gary Sabourin (FPR), Billy Coster (OPLA), Shannon Pytlik (DEC).

Time Frame: The Work Group should make every effort to complete its work and submit recommended draft Riparian Buffer Guidelines for ANR Lands and a proposed ANR Lands Riparian Buffer Policy to the ANR Lands Stewardship Team by September, 2013.

APPENDIX F. Conserving Pool-specialist Amphibian Habitat

Conserving Pool-specialist Amphibian Habitat

Mark Ferguson
Vermont Department of Fish and Wildlife

Purpose

The objective of this document is to summarize and provide information about pool-specialist amphibians and their habitats in Vermont. These animals represent a unique assemblage within Vermont's fauna, being specialized to take advantage of ephemeral breeding habitat on the landscape. To help readers better understand these animals and their needs, this document includes information about natural history and habitats, characteristics that make these species particularly vulnerable, and activities that can pose threats to local populations. Conservation practices that can be used to conserve and maintain critical habitat are also provided. This information will help landowners, planners, developers, educators, biologists, and the general public safeguard pool-specialist amphibian populations for this and future generations.

What makes pool-specialist species unique?

Although small and inconspicuous, amphibians are the harbingers of spring in Vermont, leaving their winter hideouts long before the neotropical migrant birds arrive. Vermonters may not be as familiar with the sight of a wood frog as they are the sound of a "quacking" chorus of males congregated at their breeding pool. Meanwhile, the spotted salamander with its bright yellow spots makes its springtime trek to breeding sites. Some local groups and individual citizens have become active throughout the state, "adopting" local populations by helping these salamanders traverse roads, where traffic can kill many migrating amphibians.

Amphibians make up a major part of Vermont's vertebrate fauna and utilize a wide variety of habitats. Twenty-one species occur here, occupying lakes, streams, wetlands, forests, and other habitats. Some are entirely aquatic, while others may spend the great majority of their lives in uplands. Almost all require a mixture of aquatic and terrestrial habitats to complete their life cycles. Certain species, however, are adapted to use unique habitats to complete their lifecycles. One such group of amphibians can be described as "pool specialists", mating and laying eggs primarily in temporary or semi-permanent pools such as vernal pools, beaver ponds, flooded or ponded gravel pits, and farm ponds. These pools are usually formed by rainfall, snowmelt, beaver activity, stream flooding, or wetland flooding and are largely without predatory fish. A temporary pool must generally hold water for at least three consecutive months after eggs are laid, depending on the species using it, to support successful amphibian reproduction. Ponds and pools that do not dry each year can also provide excellent breeding habitat if they are without predatory fish or if there are sufficient hiding places for protection. Although these amphibians do share specific requirements, habitats used for breeding and during other times of year are varied.

Pool-specialist amphibians

Species in Vermont that are considered pool-specialist breeders are the **spotted salamander, Jefferson salamander, blue-spotted salamander, wood frog,** and **western chorus frog.** The first three species belong to a group known as the mole salamanders. Although all five species require breeding pools with specific conditions to produce offspring, these amphibians spend the vast majority of their time in adjacent or nearby upland habitat. These salamanders and the wood frog are typically found in woods or forests that provide sufficient canopy to keep the forest floor moist and cool, and have breeding habitat nearby. Dry soil conditions and temperature extremes are not favorable for these species. The western chorus frog's habitat tends to be more open, with few trees compared to that of other pool-specialists. For details on breeding and nonbreeding habitat use by each species, see section titled "Amphibians on the landscape".

These guidelines will focus on the five pool-specialist species listed above. Several other Vermont amphibians, such as spring peepers and American toads, also breed in pools used by these five species. Those, however, are not dependent on the habitat features described here for pool-specialist breeders and are able to produce offspring in other, more generalized types of habitat, such as lakes, wetlands, or streams. Other important priorities of amphibian conservation not covered here are protection of *rare, threatened, and endangered species*, and prevention of *large-scale impacts to common species*. Although these topics will not be specifically addressed here, many of the same concepts for conservation of pool breeding species can be applied. See Appeudix B for habitat descriptions for each of Vermont's amphibians species.

Is breeding pool habitat the same as vernal pool habitat?

Temporary upland pools are often referred to as "vernal pools", indicating their general characteristic of appearing in late fall/early spring and drying out before summer's end. Some printed information sources have recently mistakenly referred to mole salamanders and the wood frog as "obligate" vernal pool breeders, a term meaning they only breed successfully in vernal pools. Although vernal pools often support amphibian breeding and are very important to several of these species, other similar waters can also provide successful breeding habitat for pool-specialists. Below are some important distinctions between vernal pools and amphibian breeding pool habitat.

Vernal Pool - These ephemeral, natural pools are scattered across Vermont and often host a unique diversity of wildlife. A vernal pool, also called a temporary upland pool, is usually contained within a small basin, has no permanent inlet or outlet, and does not support predaceous fish. It forms from snowmelt, rainwater, or groundwater. This temporary pool generally lasts only a few months and then disappears by the end of summer, although some may persist in wet years. Years of filling and drying result in a unique type of **natural community** composed of a variety of wildlife specialized to take advantage of these conditions. A natural community is an interacting assemblage of plants and animals, their physical environment, and the natural processes that affect them. A vernal pool is often rich in specialized insects, molluscs, and other invertebrates, as well as amphibians. When conditions are favorable, vernal pools are often used by mole salamanders and wood frogs for breeding. Generally, water deep enough to cover egg masses must remain for at least two to three months for the young to survive. Vernal pools that are too shallow or dry too quickly to support successful amphibian breeding may still host many other species of plants and animals and serve as unique natural communities. Some unique invertebrates found in vernal pools include fairy shrimp and certain species of fingernail clams, snails, and insects.

Amphibian Breeding Pool Habitat – Classifying a pool as amphibian breeding habitat is based on its use by particular species. This habitat is not defined as a single natural community type, as is vernal pool. Use of a pool by any of the pool-specialist amphibians can indicate a breeding pool. While many vernal pools serve as breeding habitat, mole salamanders and wood frogs may successfully use several other types of habitat that do not fit the definition of vernal pool, such as beaver ponds, wetland edges, oxbows, permanent fishless ponds, flooded or ponded gravel pits, etc. For example, some spotted salamander populations may depend upon permanent or semi-permanent waters, snch as beaver ponds, that have favorable conditions to support breeding. In contrast, a vernal pool could contain a specialized invertebrate community while drying too quickly to support successful amphibian breeding.

Why protect pool-specialist amphibian habitat?

Important breeding pools represent critical habitat for amphibians, as well as other specialized wildlife, and are crucial for the annual completion of the life cycle for many species. The distribution, rarity, and condition of breeding pools in an area need to be considered when gauging the value of a specific pool, as well as the pool's quality and potential to serve the needs of local amphibian populations. Impacts to a breeding pool or its surrounding summer/winter habitat, for example, can have a multitude of detrimental effects, including loss of a local population over time, isolation of surrounding populations, and, consequently, loss of genetic exchange. An isolated pool, meaning that there is no exchange of migrating amphibians with other pools, is more likely to lose its populations permanently, since the potential for recolonization from surrounding habitat is greatly reduced. While abundant species with generalized requirements may persevere when their habitat has been compromised, pool breeders are more strongly tied to specialized habitats during portions of their life cycles, making them more vulnerable when these areas are impacted. Mole salamanders tend not to move to better sites when their habitat becomes impacted (Petranka et al 1994). Even a common species, such as the spotted salamander, is likely to experience population declines when habitat impacts result in lowered reproductive success or continuous loss of individuals. The result can be loss of local populations. It is important to note that breeding occurs for only a brief period each spring. The rest of the year, adults and juveniles live in the surrounding forests, meadows, or wetlands, depending on the species. **These amphibians cannot survive unless, in addition to the breeding areas, the habitat used the rest of the year is also present and safely accessible.** Usually camouflaged or concealed below the soil surface, these animals are at their most vulnerable state when migrating from the upland habitat to their breeding sites in the spring and, later, back again. These overland routes used for migration must be unobstructed and able to support safe passage of adults and juveniles for local populations to survive (e.g., no roads that carry more than light traffic).

Two aspects of breeding pool habitat occurrence that are important to consider are:

1. **Clustered habitat supporting metapopulations.** Large areas that support the greatest populations of pool-specialist amphibians often contain several different breeding sites. These pools may appear to be independent of each other on first inspection, being separated by several hundred feet or more and often having no hydrologic connection. However, populations using these separate pools are often closely associated with, and dependent on, one another. As an example, consider a large area containing a patchwork of wetlands, each of which may contain one or more temporary pools. Each individual breeding site is used by a different group of adult amphibians. Exchange of dispersing juveniles and some adults among the breeding sites, however, is crucial to ensure long-term survival of these individual groups of amphibians. These separate groups are collectively called a **metapopulation**. Migration can occur between neighboring pools that are generally < 0.5 km (1625 feet) apart (Semlitsch and Bodie 1998). If migration among pools is obstructed by a barrier such as a road or residential development, each site becomes more vulnerable to such threats as reproductive failure and loss of adults. Loss of critical breeding pools may also create barriers by leaving the remaining pools too far apart for amphibians to migrate between. This can lead to greatly reduced amphibian numbers and loss of local or even larger-scale populations. The splitting of large expanses of habitat by development or other human activities results in smaller, isolated patches of remaining habitat, where small populations must make it on their own or be lost. This isolation of habitat has been shown to be linked with reduced fitness in amphibians inhabiting these remaining areas (Blaustein et al 1994). Thus, loss of a confined breeding pool not only impacts the amphibians that regularly use it, but also compromises the condition of neighboring breeding populations over time by increasing the distance between remaining pools, and can lead to indirect population losses. It is critical to conserve the functions of pool-breeding amphibian metapopulations by preventing detrimental habitat fragmentation and loss. Therefore, it is necessary to consider not only the size of a particular habitat when evaluating its importance, but also the number of similar habitats in an area and the distances between them (Semlitsch and Bodie 1998; Gibbs 1993). Maintaining connectivity among breeding pools is critically important to the long-term stability of amphibian metapopulations.

2. **Locally important habitats.** While clustered habitats help to ensure long-term stability in large populations, local populations are not always part of a larger metapopulation and can sometimes endure on their own. This may be due to the existence of one large, optimal breeding pool or a group of closely-associated pools. In such situations, isolated breeding pool habitat can be extremely critical to survival, as there may be insufficient alternate sites to lay eggs if a pool is lost. Therefore, while metapopulations can often persevere after minor breeding habitat losses, isolated local populations cannot survive such impacts.

Amphibians on the landscape

Mole salamanders

Spotted, blue-spotted, and Jefferson salamanders belong to a group known as the mole salamanders. Adults and juveniles spend almost their entire lives out of sight beneath the forest floor, in leaf litter, in shrew and mouse burrows, or under cover objects such as logs, tree stumps, or flat rocks. In early spring, adults move, sometimes in mass migrations during warm rains, to specific breeding pools. There, after an elaborate courtship, they leave their eggs before returning to the forest floor. Time spent in the breeding pool may be as brief as four days. An adult tends to use the same breeding pool throughout its life. Mole salamanders can sometimes breed successfully in pools with small populations of fish, as long as predation is limited by the presence of sufficient cover for hiding or a low abundance of predaceous fish. Survival of young in these waters is probably much less than in fishless breeding pools, as the larvae are vulnerable to predation (Petranka 1998). After larvae transform into juveniles in the summer they leave the pools, which may be nearly dry at this point, and move to the forest floor. Juveniles generally migrate lesser distances than adults, based on information for Jefferson salamanders (Semlitsch 1998). The distance that salamanders travel between habitats is highly variable, even within one species. A review of migration distances found that adult mole salamanders traveled an average of 125.3 m (407 feet) from breeding pools, with distances reaching up to 625 m (2031 feet) (Semlitsch 1998). Semlitsch (1998) estimated that 95% of mole salamanders stayed within 164.3 m (534 feet) of the breeding pool. He termed this terrestrial habitat supporting 95% of the population around the pool a "life zone". A recent Vermont study found that adult spotted and Jefferson salamanders moved a combined average of 112.8 m (366 feet) from breeding pools, with spotted salamanders (136.8 m; 445 feet) averaging farther than Jefferson salamanders (92.8 m; 302 feet) (Faccio 2001). Both species could migrate over 200 m (650 feet) from breeding pools. Faccio (2001) estimated that 95% of these salamanders stayed within 157.1 m (516 feet) of breeding pools. Females were found to travel significantly farther from pools than males, indicating that "life zones" would need to be larger for females. Combining his data with those for these two species from the Semlitsch (1998) study, Faccio (2001) estimated a "regional salamander life zone" of 175 m (575 feet).

Frogs

The wood frog has a life cycle and habitat requirements similar to mole salamanders, but is more active above ground during the warm months after spring breeding. They are also able to successfully use shorter-lived breeding pools than those favored by mole salamanders. Wood frog eggs lack the gelatinous outer covering found in mole salamander egg masses, which may make young wood frogs more vulnerable to fish predation at the egg stage. After leaving the breeding pool, juveniles disperse an average distance of about 1550 feet (Calhoun and Klemens 2002). Average home range size has been reported as 45 (Windmiller 1996) to 64 m^2 (Bellis 1965). In Rhode Island, wood frog populations were noted as being absent in habitat patches of less than 100 acres, and consistently robust only in patches of greater than 1000 acres (Raithel, unpublished document). Thus, as development pressure further fragments Vermont's forested landscape, it can be expected that wood frog populations will disappear from even moderate-sized habitat patches that become isolated. In a Massachusetts study, the wood frog population associated with a vernal pool was extirpated within two years following clearing of nearby forested upland, despite the presence of a 150-foot forested buffer left intact surrounding the pool (Calhoun and Klemens 2002).

The western chorus frog may be the first frog to become active each spring. It is found only in the extreme northwestern corner of the state, where it spends the year in meadows, sedge wetlands, and similar open habitat with few or no trees. This species typically breeds in open temporary pools and shallow wetlands, and will often remain in wetter habitat after breeding than the wood frog and mole salamanders.

Critical habitat zones for pool-specialist amphibians

Management planning that sustains viable populations of these species must recognize critical habitat areas. The area used by a pool-specialist population year round can be represented by three management zones: the breeding pool, a 100-foot zone around the pool, and a third zone that extends 550 feet farther (650 feet from the pool edge).

Breeding pool – This area includes the pool depression measured at the spring high water. It is important to note that the pool may not be entirely full or may even be completely dry during part of the year. At such times, the high water mark must be determined using such evidence as water marks on trees within the depression, water-stained or silted leaves, or an obvious change in topography at the pool edge.

100-foot zone – Within this zone, pool-breeding adults and juveniles emerging from the pool can occur at high densities at critical times of the year. This zone also protects water quality and habitat by providing shade to the forest floor and pool, filtering runoff, providing root tunnels, and supplying leaf litter and woody debris to the pool.

650-foot zone – This zone represents the majority of the critical terrestrial habitat needed by these species during most of the year, based on studies by Semlitsch (1998) and Faccio (2001). These studies indicated that at least this much area around the pool is needed to protect 95% of adults in mole salamander populations. Faccio (2001) found that females moved farther than males, indicating that an even wider zone may be needed for females. Other studies indicate that *average* distances of movement for mole salamanders and juvenile wood frogs can go well beyond 650 feet from the pool at some sites. For these reasons, managing forests beyond this 650-foot zone for amphibian conservation should be strongly encouraged.

Potential threats and conservation actions

Road constructiou and traffic - Roads located between breeding and non-breeding habitats can cause high mortality for amphibians. Loss of significant numbers of adults can result when springtime migrations must cross roads to get to breeding pools. Juveniles emerging from the pools in summer must face this same peril. As traffic increases on such a road, greater numbers of amphibians are killed. Traffic volume is increasing steadily and rapidly in Vermont. As more people move into rural areas, small highways and town roads are carrying more and more vehicles. The resulting consequence to amphibian populations is that those located along these roadways that were once able to endure a light amount of traffic mortality are experiencing ever-increasing losses of breeding adults and juveniles. Where a road intersects amphibian habitat, this increasing mortality rate can eventually exceed a population's capacity to sustain itself and the population will either exist in a greatly reduced state or be lost. Roads also impact populations by direct loss of breeding or non-breeding habitat. In addition to the road surface and embankments, a right-of-way is often maintained as tree-less, making it uninhabitable for mole salamanders and wood frogs. Vertical curbing along roads can create a barrier to amphibians. Frogs and salamanders that make their way onto the road surface can find themselves trapped there by the curb, unable to climb over. An option where curbing is necessary is to use sloped curbs, or Cape Cod berms, which small animals can scale. Storm drains can also be death traps to migrating amphibians; alternative methods of moving stormwater should be employed near sensitive breeding populations. Other potential impacts to pool-specialist amphibian populations due to roads include salt runoff and increased predator access.

Wildlife underpasses are starting to be used in this and other countries. These passageways run below the road surface and, when properly designed, placed, and constructed, allow some animals to pass through the transportation right-of-way without encountering traffic. While wildlife underpasses can help move some animals across roads safely, this is still a new and developing technology. Few such structures have been designed and used specifically for amphibians in North America to date, and these have been only marginally successful. The best way to prevent impacts to pool-specialist amphibians is to avoid placing roads within their habitats.

Conservation strategies:

- Avoid using curbs or use sloping curbs (often called Cape Cod style curbing) when possible to avoid trapping amphibians on the road.
- Exclude all roads and driveways from within 100 feet of breeding habitat.
- Exclude roads and driveways that will carry more than very light traffic (5-10 vehicles per hour) from within 650 feet of the breeding habitat.
- Where existing roads are known to bisect pool-specialist amphibian habitat and cause mortality, explore methods that can help reduce this impact (e.g., wildlife passage structures).
- Reduce the width of the cleared area on each side of roads or driveways to avoid eliminating amphibians from these areas.

Land development - Land development within pool-specialist amphibian habitat can have severe impacts upon these populations. Construction, paving, and creation of unforested openings results in the permanent loss of habitat, as well as the loss of animals that occupy it. When amphibians must cross developed areas to move between breeding and non-breeding habitat, they experience increased mortality pressures due to predation, desiccation, chemical usage and waste, barriers, and vehicle traffic. Detrimental land development also includes creation of lawns, golf courses, and other turfed areas, which present a barrier to amphibians attempting to move below the ground surface. The rural landscape of Vermont is rapidly changing as residential development increases and erodes the quality of wildlife habitat in previously unimpacted areas. Called sprawl, people moving into undeveloped areas results in the loss of habitat and fragmentation of what remains, as houses, roads, and driveways are constructed.

Conservation strategies:

- Development and associated land clearing should not take place within 100 feet of breeding habitat.
- Clearing of land and construction should be limited to less than 25% of the habitat within 650 feet of a breeding pool. The remaining terrestrial habitat, along with the pool(s), should be

permanently protected through deed restriction, easement, or other methods, to prevent cumulative habitat loss over time.

- ❖ Avoid clearing steep slopes that filter runoff into breeding habitat.
- ❖ Avoid creating ruts and other artificial depressions that hold water, as these may attract breeding amphibians but do not provide suitable habitat for developing larvae.
- ❖ Employ erosion control methods to prevent sediment and pollutants from entering breeding habitat during and after clearing and construction. However, minimize use of silt-fencing within 650 feet of a breeding pool, as these can interfere with amphibian migration to and from breeding habitat. Do not leave silt fences in place any longer than necessary. Reseed disturbed soil as soon as possible to promote early germination and vegetative erosion control, as this will enable earlier removal of silt fencing.
- ❖ Designing development to maximize use of space (clustering) will help to reduce the overall footprint, the amount of impermeable surface, the need for additional roads, and the loss of forest and other important habitat.
- ❖ Limit the amount of forest clearing to that necessary for construction. Encourage maintenance of woodlands instead of lawns on business and house properties, as well as on public lands.
- ❖ Avoid draining pool habitat or altering the hydrology of the pool's watershed.

Forestry - When timber harvesting occurs near or in amphibian habitat, several effects can negatively impact the habitat and these animals if precautionary steps are not taken. Clear-cutting within non-breeding habitat results in drying of the forest floor. Mole salamanders and wood frogs, as well as other woodland amphibians, require moist conditions to survive, and may perish under clear-cutting conditions. When forestry activities occur near breeding habitat, impacts can include sedimentation of the pool, inadequate filling from runoff, and increased evaporation. In addition, heavy machinery can cause ruts that fill with water and mimic breeding habitat. These puddles often intercept some adults during spring migrations and cause them to deposit their eggs in this unsuitable habitat. These ruts usually dry up too quickly to support successful breeding. Running heavy machinery over wet ground can also result in death of amphibians hiding beneath. Avoidance of the pool and the immediate surrounding habitat, selective cutting within the upland habitat, and running heavy machinery when the ground is frozen can help prevent impacts to these amphibian populations.

Conservation strategies:

- ❖ Leave breeding pools undisturbed, with no cutting, heavy equipment, skidding, storage of slash or other woody debris, or sedimentation within these depressions during any season.
- ❖ Within 100 feet of the edge of a breeding pool, consider only light cutting or no cutting, such that at least an 80% canopy cover remains within this zone. Harvesting within this area should only occur on frozen ground and end prior to March 1 throughout the majority of the state, before March 15 in Orleans, Essex, and northern Caledonia counties.
- ❖ Between 100 and 650 feet from a pool's edge, adequate shading should be left to protect terrestrial habitat and prevent drying of the forest floor. At least 60% of the canopy cover should remain intact within this zone, composed of trees at least 25 feet tall.
- ❖ Practice uneven-aged management when possible to provide adequate amphibian habitat and canopy cover. Leaving some large, mature hardwoods is especially helpful for protecting and enhancing habitat.
- ❖ Where even-aged management is required, maintain suitable canopy cover and forest floor conditions in a majority of the area within 650 feet of a pool. Delay future harvesting in the area until the cut-over areas have regenerated enough to provide shade, with tree foliage at least 10 feet above ground.
- ❖ Avoid use of plantations, as these do not promote natural litter composition and provide little woody debris to the forest floor.

- Leave limbs and tree tops on site after harvesting operations to provide amphibian cover. Leave dead trees (snags) and stumps in place when possible, as many amphibians will use them for cover.
- Whenever possible, locate log landings and roads outside of the 650 foot zone. This will reduce sedimentation and forest floor disturbance.
- Avoid creating artificial ruts and depressions, as these may fill with water and intercept migrating adults on their way to natural breeding pools that support successful reproduction. Ruts may also alter natural drainage patterns, shortening the hydroperiod of some pools.
- Avoid use of herbicides, as amphibians are particularly susceptible to such toxins that can be absorbed through their skin.

Agricultural clearing - The effects of agricultural clearing are similar to those of forestry clear-cutting when it occurs within pool-specialist amphibian habitat, although agriculture may represent a more long-term impact. Complete loss of amphibians and their habitat within the clearing will result. If the clearing is located between the breeding habitat and the remaining non-breeding habitat, the effect can be additional loss of adults and juveniles during movement between these areas, due to increased predation, desiccation, and pesticide use.

Conservation strategies:

- Avoid clearing of land within 100 feet of a breeding pool.
- Limit the clearing of land within 650 feet of a breeding pool to no more than 25% of the available amphibian habitat.
- Avoid use of pesticides within 100 feet of a breeding pool or on land which carries runoff to breeding habitat. Consider not using pesticides within 650 feet of a breeding pool to avoid exposing migrating amphibians to these toxins.
- Leave land forested where it is not being used for crops.

Stream channelizing - In addition to the enormous impacts to aquatic habitats, channelization can alter the natural flooding regime in pools and oxbows within the floodplain of large creeks and rivers. This can result in the loss of breeding habitat for some species of pool-specialist amphibians.

Conservation strategies:

- Avoid channelizing streams. Natural meanders serve to slow the water current and provide aquatic habitat.
- Explore alternative methods to reduce flooding, such as protecting adjacent floodplains and wetlands.
- Avoid use of riprap along streams. This merely moves the erosion problem downstream and eliminates streamside and aquatic wildlife habitat.
- Explore alternative methods to reduce streambank erosion and loss of land, such as vegetative streambank restoration and instream habitat improvement.
- Protect floodplain pools, oxbows, and riverside marshes, as well as the surrounding terrestrial habitat. These serve as important habitat for some pool-specialist species. (see "Critical habitats for pool-specialist amphibians" for habitat management zones)

Hydrologic manipulation - Activities that alter either precipitation runoff patterns or groundwater flow can impact amphibian breeding habitat if located nearby. This can result in loss of habitat due to premature pool drying or lack of water recharge. Directing stormwater runoff or other water into the pool from outside the natural pool basin can cause egg and larvae mortality.

Conservation strategies:

- ❖ Avoid any activities that redirect water away from a breeding pool, as this reduces the amount of water held in the depression and increases the chance that the pool will dry before amphibian larvae complete their development.
- ❖ Avoid directing additional runoff into a breeding pool from outside its natural basin. This can introduce pollutants and increase sediments, both of which can kill eggs and developing larvae.

Wetland manipulation and filling - Many wetlands contain habitat that is used by pool-breeding amphibians (see Appendix A). Activities that result in alteration of a wetland can destroy breeding habitat of these animals, when present. Non-breeding habitat within the wetland can also be impacted by such actions.

Conservation actions:

- ❖ Avoid impacting wetlands and amphibian breeding pools due to construction, dredging, draining, filling, or similar activities. Recognize the importance of leaving adjacent terrestrial habitat intact as well (see "Critical habitats for pool-specialist amphibians" for habitat management zones).

Pesticides - Amphibians have been shown through research to be sensitive to a wide array of pesticides. When pesticides make their way to breeding pools in runoff or groundwater, the result can be death of adults, juveniles, and/or eggs, and effectively causes either short-term or long-term loss of habitat. Some pesticides and their metabolic products are known to be fairly persistent and may not leave an aquatic system for several years. In addition, exposure of adults or juveniles to certain pesticides in the non-breeding habitat can also result in the loss of these animals. Pesticide products regularly contain additives, called surfactants, which themselves may be toxic to amphibians or may cause synergistic effects (the products acting together are even more toxic).

Conservation strategies:

- ❖ Encourage homeowners not to use pesticides outdoors where houses are located within 650 feet of a breeding pool.
- ❖ Do not store pesticides or other toxins in areas that provide runoff to or pose a potential threat to breeding habitat.
- ❖ On golf courses, designate a "no pesticide zone" within 650 feet of any pool-specialist breeding habitat.
- ❖ Do not use amphibian breeding pools for stormwater detention.

Commercial collection - Several species of salamanders and frogs are collected in the United States for biological supply houses, fish bait, the pet trade, and possibly other uses. The adults are normally targeted in such collecting. Heavy or extended collection pressure can result in the loss of local populations, especially for such species as mole-salamanders, which depend on the long-lived adults to survive during years of poor reproductive success.

Conservation strategies:

- ❖ Discourage commercial collection of pool-specialist species through education and landowner contact.

Pets and Predators - Increasing residential development near amphibian habitat also means an increase in the number of pets and human-tolerant predators that roam the area. Cats and dogs can be predators of local wildlife, including amphibians. Amphibian eggs can be destroyed when dogs wade in breeding pools.

Conservation strategies:

- Avoid pools and adjacent amphibian habitats when establishing recreational trails, and consider redirecting existing trails away from these areas. This will reduce impacts to breeding pools from people and pets, as well as from wildlife predators (skunks, raccoons) that are attracted by human activity.
- Encourage homeowners to keep dogs confined or on leashes. Keeping cats indoors at all times will prevent them from entering critical habitats and killing amphibians and other small animals.

Types of Potential Impacts Posed by Different Human Activities

	Potential Impacts			
Human Use	**Breeding Habitat**	**Non-breeding Habitat**	**Migration Barriers**	**Direct Mortality**
Road construction	☐	☐	☐	☐
Traffic			☐	☐
Land development	☐	☐	☐	☐
Forestry - clearcutting, heavy machinery	☐	☐	☐	☐
Agricultural clearing	☐	☐	☐	☐
Stream channelization	☐			
Hydrologic manipulation	☐			
Wetland manipulation and filling	☐	☐		☐
Pesticides	☐	☐		☐
Commercial collection				☐
Pets and predators				☐

Conservation Planning

Amphibian habitat conservation and protection can be conducted on a site-by-site basis, as development projects are proposed. However, this can sometimes result in a type of crisis management, ending in compromise with all parties feeling frustrated. State regulations that protect wetlands and wildlife habitat often fall short of adequately protecting critical amphibian habitat. A much more effective, proactive, and long-term strategy for protecting these habitats is through local and regional planning initiatives. This allows communities to include pool-specialist amphibian habitat conservation in long-range planning processes. Breeding site inventories can be a good method to identify important habitat. Conducting egg mass counts in the spring, if done for several years, can be a good indicator of the size of a local amphibian population for some species. Through this planning process, habitat that is considered locally significant would be identified and mapped, and conservation strategies developed. In this way, developers, landowners, foresters, public decision-makers, and other citizens would be aware of where the critical habitats are and what restrictions would apply to each site. Examples of conservation strategies are easements, acquisition, and overlay zones.

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