# Recovery Potential Metrics Summary Form

**Indicator Name:** BANK STABILITY/WOODY VEGETATION

**Type:** Ecological Capacity

**Rationale/Relevance to Recovery Potential:** At the edge of rivers and streams as well as lakes, unstable banks are prone to continual erosion and greater likelihood of continuing to deliver excess sediment load. Destabilizing forces can include the absence of woody and/or herbaceous vegetation, steep slope, an unstable channel form (e.g. cut banks), or the soil type itself may be erosion-prone. Continual erosion and excess sediment are often linked to instream habitat degradation and diminished spawning success of lithophilic spawners, and may also sometimes add to other impairments such as elevated nutrients or water temperature. Research points to the importance of rooting depth and the stabilizing influence of both herbaceous and woody cover in combination; this indicator focuses on woody cover because it generally is combined with herbaceous cover. River and stream banks without woody vegetative cover may be particularly prone to erosional damage during extreme high flow events and slower to recover in the aftermath. The prevalence of streambank stabilization projects involving woody (as compared to herbaceous-only) plantings in restoration practice reflects the widespread opinion that the relative proportion of stable banks and woody vegetation needs to be high for the system to recover.

**How Measured:** Land cover datasets coarsely identify woody vegetation (e.g forest, shrub, forested wetland, shrub wetland) that can be assessed as % of bank length with woody cover along the reach being assessed, calculated for both banks:

Lwoody / 2 Ltotal X 100

Making this a linear metric (i.e. length of woody cover actually in contact with both stream/river banks, as mapped) discerns this metric from the "Riparian % woody cover" which is areal and relates to additional recovery relevant factors. GIS algorithms may set buffer = 0.

**Data Source:** Land cover datasets are available through the National Land Cover Pattern Database (See: http://www.mrlc.gov/index.php ). Land cover for coastal areas is available through NOAA's Coastal Change Analysis Program (See: http://www.csc.noaa.gov/digitalcoast/data/ccapregional/index.html) Orthophoto maps or remote imagery can be a good source for detailed local information. NHD Plus dataset contains flowline attributes on % for each land cover type from the National Land Cover Dataset (http://www.horizon-systems.com/nhdplus/index.php ).

**Indicator Status (check one or more)**
______ Developmental concept.
___x__ Plausible relationship to recovery.
____ _ Single documentation in literature or practice.
___x__ Multiple documentation in literature or practice.
______ Quantification.

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**Examples from Supporting Literature (abbrev. citations and points made):**

- (Collison and Simon 2001) The mechanical effects of vegetation can be summarized as increased soil strength due to root reinforcement (stabilizing) and increased surcharge due to tree weight (destabilizing).

- (Pollen-Bankhead and Simon 2010) Although positive and negative effects of riparian vegetation occur on streambank stability, positive effects usually dominate, resulting in a link between increased vegetation density and decreased bank erosion.
- (Simon and Collison 2002) There is a general consensus in the literature that the main effects of vegetation on bank stability are mechanical rather than hydrological.
- (Collison and Simon 2001) Hydrologic effects are as important as the mechanical effects, and can be either beneficial or detrimental, depending on antecedent rainfall.
- (Collison and Simon 2001) A question raised is whether the detrimental hydrologic processes, combined with surcharge, can ever outweigh the beneficial effects of root reinforcement and antecedent moisture reduction.
- (Shields and Hoover 1991) Woody vegetation becomes established on the berms, which promotes more rapid sediment accretion and bank stability.
- (Simon et al. 2006) The addition of vegetation has the same effect as reducing the angle of the bank face, with this effect becoming more significant as the bank angle becomes flatter. Therefore, a vegetated bank with an angle of 90 degrees has similar critical conditions to an unvegetated bank with an angle of 80 degrees. The addition of vegetation is equivalent to physically reducing the angle of the bank.
- (Simon and Collison 2002) Vegetation increases soil strength due to the tensile strength and spatial density of its roots. The roots, therefore, provide reinforcement by transferring shear stress in the soil to tensile resistance in the roots.
- (Easson and Yarbrough 2002) The modes of failure observed along stream banks in the study area were tension dominated.
- (Simon and Collison 2002) Soil is generally strong in compression, but weak in tension. The fibrous roots of trees and herbaceous species are strong in tension but weak in compression. Root-permeated soil, therefore, makes up a composite material that has enhanced strength.
- (Simon and Collison 2002) Considering roots of the same size (2 – 3 mm diameter class) to eliminate the effects of diameter on tensile strength, sycamore roots are stronger (mean tensile strength of 45 MPa), followed by river birch and sweet gum (22 and 18 MPa respectively), gamma grass (17 MPa), black willow (13 MPa) and switch grass (8MPa). This shows that the high median strength of gamma and switch grass roots is due to the preponderance of small, strong roots rather than inherently superior strength properties. Of all the species studied switch grass has by far the greatest number of roots per unit area.
- (Simon and Collison 2002) Most of the strength for woody species comes from larger (>5 mm diameter) roots. This finding goes against the widely held view that more reinforcement can be obtained from a large number of small roots with a greater tensile strength per unit area, rather than large, weaker roots. In general, root area is more important than root strength for woody species. Among the grasses this is also the case: switch grass has the greatest cohesion due to roots because of its extremely high root area, rather than having stronger roots.
- (Simon et al. 2006) The strength of individual roots of comparable size from the Lemmon’s willow and lodgepole pine were similar. Lemmon’s willow had much greater root density, especially in the smaller root diameter size classes.
- (Simon and Collison 2002) River birch and sycamore had the greater benefit, with an increase in safety factor due to root reinforcement of 42 per cent and 41 per cent respectively.
- (Simon and Collison 2002) Switch grass had the greatest root reinforcement effect of any species tested, with an increase in safety factor of 104 per cent.
- (Pollen-Bankhead and Simon 2010) The presence of small volumes of roots may rapidly decrease soil erodibility from that of a bare soil.
- (Easson and Yarbrough 2002) When no root reinforcement existed, the slope was marginally stable. When simulated root reinforcement was applied, the slope was shown to be completely stable.

- (Simon et al. 2006) The maximum willow root area ratio at any depth was more than double the maximum root area ratio for lodgepole pine.
- (Simon et al. 2006) Adding 5.5 kPa of root reinforcement to the bank, therefore, has the equivalent effect of reducing the bank angle from 10 degrees to more than 15 degrees depending on the initial angle of the bank.
- (Simon and Collison 2002) For all species most of the increase in strength is concentrated in the upper 50 cm of soil, with little below this. At the time of minimum bank stability in April 2000, cohesion due to roots increased bank factor of safety by an average of 39 per cent for woody species, with 70 per cent for grasses.
- (Pollen-Bankhead and Simon 2010) In the case of the switch grass root networks tested, the roots at the soil surface initially protected the soil from erosion. Once the jet of water scoured underneath the roots, the roots then protected the sides of the scour hole and the base of the scour hole at different depths where roots were concentrated.
- (Easson and Yarbrough 2002) A majority of the root reinforcement was near the surface.
- (Simon and Collison 2002) Vegetation can affect streambanks by increasing surcharge. Surcharge has both a beneficial and detrimental effect; it increases the mass acting on a potential failure surface and increases normal stress and, therefore, shear strength due to friction. Whether the net effect is stabilizing or destabilizing depends on the slope of the shear surface and the effective friction angle of the soil, but in most cases it will be destabilizing due to the steep shear-surface slopes of streambank failures.
- (Pollen-Bankhead and Simon 2010) Vegetation growing in the bank toe region generally obstructs the flow of the channel and reduces mean flow velocities in vegetated zones when compared to non-vegetated zones.
- (Pollen-Bankhead and Simon 2010) For vegetation with flexible canopies, higher flows can cause stems to become prone, thereby resulting in additional protection of the substrate.
- (Simon and Collison 2002) Vegetation increases bank stability by intercepting rainfall that would otherwise have infiltrated into the bank, and by extracting soil moisture for transpiration. Both processes enhance shear strength by reducing positive pore-water pressure and encouraging the development of matric suction.
- (Simon et al. 2006) Vegetation removes water from the root zone for use in the processes occurring in the above ground biomass.
- (Simon et al. 2006) At 100 cm, the vegetated sites were drier than the control throughout the summer due to the removal of soil moisture by evapotranspiration.
- (Simon and Collison 2002) Riparian zone managers seeking to use vegetation to increase streambank stability need to select species as much for their hydrologic properties as for their mechanical attributes.
- (Simon and Collison 2002) Coniferous species may have an important role to play in bank stabilization.
- (Simon and Collison 2002) The greatest benefits will almost certainly result from mixed stands of riparian woody and grass species.
- (Pollen-Bankhead and Simon 2010) Prolonged rainfall can transform a stable bank into an unstable bank through four mechanisms. First, the infiltration of rainfall into the bank increases the soil bulk unit weight, thereby increasing the driving force acting on the bank. Second, infiltration of rainfall causes a loss of matric suction and, therefore, apparent cohesion, weakening the bank material and reducing the resisting force of the bank. Third, generation of positive pore-water pressures within the bank, primarily from lateral seepage at times of high flow in the channel, acts to decrease frictional strength of the bank material, increasing instability. Fourth, the drawdown of the channel during the receding limb of the storm hydrograph removes the confining pressure of the water in the channel that was acting to increase the resisting force of the bank during high flow.
- (Pollen-Bankhead and Simon 2010) (Collison and Simon 2001) (Simon and Collison 2002) Canopy interception and stem flow tend to concentrate rainfall locally around the stems of plants and create higher local pore-water pressures.

- (Pollen-Bankhead and Simon 2010) Roots often contract as they become drier, and this combined with shrinkage of drying soil, creates a gap between the roots and the soil. It has been suggested that this gap may act to concentrate water flowing through the soil around the roots, hence, channeling water at higher speeds and to greater depths in the soil profile via these macropores.
- (Easson and Yarbrough 2002) Knowledge of the plant's ecology and physiology is crucial to the understanding of the plant's effects on the stability of channel banks.
- (Simon and Collison 2002) The tree cover experiences brief periods of 'negative suction' (positive pore water pressure) after rainfall events in the spring, indicating increased infiltration capacity and the development of a perched water table in the root zone. The steep decline in suction under this cover indicates enhanced infiltration rates via macropores, probably along root pathways. This represents one of the potential detrimental effects of woody vegetation.
- (Collison and Simon 2001) Decreases in shear strength due to a loss of matric suction are a leading cause of bank failures in incised channels.
- (Simon and Collison 2002) (Collison and Simon 2001) A point that tends to be overlooked when discussing vegetation effects on bank stability is that most bank failures occur during the winter or early spring, when deciduous vegetation is dormant and canopies have been shed.
- (Simon et al. 2006) Bank failures occur during winter and spring months, brought on by repeated basal melting of snowpacks and rain-on-snow events that maintain saturated conditions for extended periods.
- (Simon and Collison 2002) The most striking feature is the reduction in overall stability due to wetter ground conditions and reduced hydrologic benefits in the tree species, and increased detrimental hydrologic effects in the grasses.
- (Simon and Collison 2002) Vegetation can have detrimental hydrologic effects on bank stability, when increased infiltration capacity is able to overcome the soil moisture deficit built up over the antecedent period.
- (Langendoen et al. 2009) Riparian vegetation and the degree of saturation of riparian soils greatly affect erosion rates of streambank materials.
- (Pollen-Bankhead and Simon 2010) At certain times of the year above-ground biomass may be limited, and during these times the predominant protective effect of vegetation on toe erodibility comes from the root networks of the plants.
- (Pollen-Bankhead and Simon 2010) The relative importance of the three root effects (hydraulic scour, matric suction and mechanical root-reinforcement) will change seasonally over time.
- (Collison and Simon 2001) During summer and fall very high suctions are developed. Matric suction under the tree plot is 40 to 60 kPa higher than under the other treatments.
- (Simon et al. 2006) The effect of the higher matric-suction values resulted in levels of cohesion 8 to 10 kPa greater than the control until December, when these values decreased rapidly due to periodic melting of snow.
- (Simon et al. 2006) Soil at 100 cm at the Lemmon's willow site stayed drier longer than the corresponding depth at the pine site, not reaching minimum matric-suction values until mid-January, compared to late December in the case of lodgepole pine.
- (Simon et al. 2006) The cohesion added by the root network of Lemmon's willow (5.5 kPa) had a considerable effect on the factor of safety, most importantly during the critical wet period during February and March.