Recovery Potential Metrics Summary Form

Indicator Name: CORRIDOR PERCENT URBAN

Type: Stressor Exposure

Rationale/Relevance to Recovery Potential: As the intensity of urbanization increases, biotic integrity tends to decrease. Developed land cover in riparian zones is associated with aquatic biota more tolerant of pollutants. Increasing substrate embeddedness and bank erosion have also been observed to increase in streams in developing areas. Significantly lower water quality is often found downstream of highly developed corridors where not attributable to treatment plant discharges. Human shoreline development may lead to loss of littoral habitats. Threshold responses to percentages of development found in corridors were not borne out also at the watershed scale, indicating potentially greater significance of corridor vs watershed effects from urbanization.

How Measured: Extracted from land cover mapping within a set corridor width, and summarized as % developed (e.g., residential, commercial, industrial, urban center, etc) by area within the corridor.

Data Source: Land cover sources include the National Land Cover Data from 1992 (See: http://www.epa.gov/mrlc/nlcd.html),2001 (See: http://www.epa.gov/mrlc/nlcd-2001.html), and 2006 (http://www.mrlc.gov/nlcd06_data.php), as well as various state sources at finer resolution. Temporal urban mapping is available from the USGS Land Cover Institute (See: http://landcover.usgs.gov/urban/umap/). Corridors can be generated from hydrographic data (See: http://www.horizon-systems.com/nhdplus/) using a set buffer width for delineation.

Indicator Status (check one or more)

______ Developmental concept.
______ Plausible relationship to recovery.
______ Single documentation in literature or practice.
______ Multiple documentation in literature or practice.
______ Quantification.

Comments: Operational, with wide applicability to flowing waters in all regions.

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

- (Potter et al 2004)The resulting vulnerability models indicate that North Carolina watersheds with less forest cover are at most risk for degraded water quality and stream habitat conditions. Studies have found strong positive relationships between diverse assemblages of stream benthic macroinvertebrates that are intolerant of water quality degradation and watershed-wide forested land cover (Lenat and Crawford 1994, Stewart and others 2001, Weigel and others 2003) or forested land cover within riparian zones (Basnyat and others 1999, Sponseller and others 2001, Stewart and others 2001, Weigel and others 2003). Meanwhile, research has shown less diverse and more intolerant macrobenthic communities to be correlated with agricultural land cover (Lenat and Crawford 1994, Richards and others 1996, Weigel and others 2000, Genito and others 2002) and urban land use (Lenat and Crawford 1994, Morley and Karr 2002, Morse and others 2003, Roy and others 2003, Volstad and others 2003, Wang and Kanehl 2003).
- (Potter et al 2004) Two of the three watershed land cover variables — percent agricultural and percent forested — exhibited somewhat strong relationships. The percent

of agriculture land cover at the watershed scale had a positive relationship with the indices, meaning that it was negatively correlated with aquatic ecological integrity. The percent of forest was correlated with better stream conditions. In our statewide analysis, the percent of forest cover at the watershed scale and in riparian zones were highly correlated enough (0.776) that the two have similar value as predictors of macroinvertebrate tolerance for water quality degradation. Forested land cover, at both the watershed and riparian scales, was a statistically significant predictor of benthic macroinvertebrate communities that are less tolerant of stream degradation, and that indicate a greater level of aquatic ecological integrity and better water quality. The opposite was the case for agricultural land cover at the watershed and riparian scales, and developed land cover in riparian zones.

- (wang 2001) The results shown in Table 5 indicate that the land-use components within the catchments could be major predictors for biotic integrity. The percentage of urban land was the second strongest predictor for both IBI and ICI. The negative signs of those coefficients indicate that as the intensity of human activities increase there is a tendency that the biological integrity of the rivers decreases. The percentage of wooded land was the third strongest predictor for IBI.
- (ourso and frenzel 2002) Increasing substrate embeddedness and bank erosion have been observed to increase in developing areas (Arnold et al., 1982; Furniss et al., 1991)
- (wang 2001) After statistically analyzing the spatial patterns of the water quality in receiving rivers and land uses and other point pollution sources in the watershed, the results showed that the water biotic quality did not degrade significantly below wastewater treatment plants. However, significantly lower water quality was found in areas downstream from high human impact areas where urban land was dominated or near point pollution sources
- Alberti *et al.* (2007) reported that the configuration or pattern, as well as the amount, of urbanization, was significantly related to macroinvertebrate IBI scores.
- (Sondergaard and Jeppesen 2007) Several recent papers have focused on the role of human shoreline development, which may lead to loss of littoral habitats for species such as submerged macrophytes and of littoral reed beds, both vital for the functioning of lakes (Elias & Meyer 2003), not least the shallow ones (Jeppesen *et al.* 1997; Scheffer 1998). Shoreline development may also affect other structures like plant roots (which serve as refuge for fish) and woody debris, as well as sediment composition (Marburg, Turner & Kratz 2006). Species richness, spatial distribution and production of fish may also be affected (Scheuerell & Schindler 2004), though not everywhere (Mehner *et al*. 2005).

  To date, few studies have elucidated the effects of physical degradation on invertebrates. However, in a study of seven German lowland lakes, Brauns *et al*. (2007) demonstrated how alteration of shorelines by retaining walls to control erosion caused significantly lower species richness and diminished the abundance of several littoral macroinvertebrate groups compared to reference sites. Recreational beaches had a similar impact, while the use of techniques causing less severe damage of the structural complexity; for instance, ripraps did not significantly affect littoral macroinvertebrates (1092).
- (Andersen et al., 2007) However, agriculture and other human developments on floodplains can constrain or eliminate the benefits of maintaining or restoring natural hydrologic processes (465).
- (DeLuca et al., 2004) Our IMBCI identified thresholds with 95% probability for the amount of development that can occur within 500-m (14%) and 1000-m (25%) buffers of an estuarine wetland before ecological integrity is significantly compromised (Figure 3). Moreover, we found a 60% probability that a changepoint occurred in IMBCI scores with relatively low levels of disturbance (6% development at the 500-m scale and 8.5% development at the 1000-m scale). The thresholds identified in our study indicate levels of local disturbance, beyond which, marsh bird community integrity is unattainable. This does not imply that marshes with local percent development levels below thresholds necessarily have high integrity. It does imply, however, that marshes with local

development below threshold levels have the capacity for high integrity, whereas marshes with local development above threshold levels do not (843).

- (DeLuca et al., 2004) Our research demonstrates that anthropogenic disturbance surrounding a wetland can have negative effects on marsh bird community integrity. Furthermore, we identified a specific land-use disturbance threshold at approximately 14%, similar to thresholds identified in other studies (844).
- (Gage et al., 2004) Changing land use patterns, including increases in impervious surfaces and construction near riparian zones, affect deposition of sediment, flow patterns (Oberlin et al. 1999), and stream communities (Décamps 1993, Thornton et al. 2000). Land use practices can strongly impact aquatic diversity well into the future; e.g., Harding et al. (1998) found that land use in the 1950s was the best predictor of present day diversity in streams (345).
- (DeLuca et al., 2004) We did not detect changepoints in IMBCI scores for percent development, agriculture, or forest at the watershed scale (*P* 5 0.22, *P* 5 0.22, and *P* 5 0.26, respectively) (842-843).
- (DeLuca et al., 2004) In our study, the threshold response to development decayed when we moved from local buffers to the watershed scale. This finding implies that there is a scale-dependent effect of development on estuarine wetlands (844).
- (Walsh et al., 2005) Deforestation, particularly in the riparian zone, is often identified as an important driver of urban impacts to streams (e.g., Stephens et al. 2002, Booth 2005). Urban land use and riparian degradation usually covary (e.g., Morley and Karr 2002, Burton et al. 2005, King et al. 2005), with lowland urban development often resulting in restructuring or loss of riparian vegetation (714).
- (Dodds and Oakes 2008) Riparian land use may be particularly influential and, in some cases, a better predictor of in-stream water quality than land cover in the entire catchment (Johnson and others 1997; Osborne and Wiley 1988). Intact riparian zones provide water quality benefits and help preserve the biological integrity of watersheds (Gregory and others 1991) (368).
- (Dodds and Oakes 2008) Across all studied watersheds, riparian land cover was a significant predictor of among-site variation in water chemistry concentrations at the watershed and first-order streams scales, particularly for nutrients (Table 1) (371).
- (Ekness and Randhir 2007) Species richness has been shown to increase as vegetative density increases and with distance from developed areas (1470).
- (Groffman et al., 2003) Alteration of riparian soil profiles can have dramatic effects on processes that produce and consume NO3-. We have observed high levels of NO3- and nitrification (a microbial process that produces NO3-) and low rates of denitrification (an anaerobic process that consumes NO3-) in aerobic, urban riparian soil profiles with water tables that are deep in comparison to forested reference watershed riparian soils with shallow water tables (Groffman *et al*. 2002; Figures 5 and 7). These results suggest that soil and hydrologic changes associated with urbanization can cause riparian zones to be sources rather than sinks for NO3- in urban watersheds, but these results need to be verified in other watersheds (318).
- (Groffman et al., 2003) Comparisons of vegetation between the rural/suburban (upper) and urban (lower) sections of the watershed show distinct patterns across an urban to rural gradient (Brush and Zipperer unpublished). In the lower, more urbanized section of the watershed, wetland tree species are either absent or occur as small stems, while upland species are abundant and occur in mixed sizes. A comparison of the number of wetland and upland species in the mostly urbanized Gwynns Falls riparian zone versus the non-urbanized Piedmont floodplains throughout Maryland (Brush *et al*. 1980) shows approximately twice as many upland species in the urban floodplains than in the non-urbanized floodplains (319).
- (Groffman et al., 2003) Our vegetation analysis clearly shows the effect of riparian hydrologic drought induced by urbanization. The riparian zone is becoming drier throughout the Gwynns Falls watershed, with the lower urbanized watershed providing

the driest habitats, which are more favorable for germination and growth of upland species. Such a shift could have dramatic effects on ecosystem services provided by vegetation in the riparian system (319).

- (Groffman et al., 2003) Alterations in riparian vegetation induced by urban hydrologic drought are a particularly important type of wetland vegetation effect, because of the functional importance of riparian zones in watersheds. For example, such change has been identified as a key factor in stream degradation in the Puget Sound/Seattle metropolitan area of Washington State. In a survey of 45 sites along second- and third-order streams, measures of stream biotic integrity declined strongly with the percentage of urban land cover in the riparian zone (Booth *et al*. 2001) (319).
- (Gage et al., 2004) Streambed characteristics and hydrology of small streams may change as development decreases riparian forests and increases sedimentation (Beschta 1996, Décamps 1993, Gore 1996, Swank et al. 1988). This may decrease flow, which can cause a drop in dissolved oxygen and an increase in temperature, eliminating taxa sensitive to those changes (Boulton and Suter 1986). Increased disturbance thus leads to decreased diversity in streams (Hogg and Norris 1991, Karr 1991, Lamberti and Berg 1995, Lemly 1982, Lenat and Crawford 1994, Schleiger 2000), and tolerant species may come to dominate the macroinvertebrates (Closs and Lake 1994) (346).
- (Gage et al., 2004) Sedimentation and turbidity also increase as headwater forests are cleared (Lamberti and Berg 1995), and this decreases species richness, the proportion of pollution-sensitive species, overall insect biomass, and abundance (Beschta 1996, Kemp and Spotila 1997, Lamberti and Berg 1995, Lemly 1982, Oberlin et al. 1999, Schleiger 2000).
- (Andersen et al., 2007) Floodplain development was largely uncoupled from hydrologic alteration in UCRB rivers. Although 64% of the total floodplain area examined remained undeveloped; one out of four subbasins had half or less of the original area of natural vegetation remaining. These results underscore the potentially large and independent role of land conversion in reducing the extent of natural vegetation, including riparian cottonwood forest, on floodplains in semiarid and arid regions (462).
- (Andersen et al., 2007) Agricultural and urban development typically results in habitat fragmentation and a reduction in mean patch size, which, in turn, can lead to a decline in the diversity of native species (465).
- (Ekness and Randhir 2007) Land use practices within a riparian zone are known to impact species richness and the diversity of amphibians, reptiles, birds and small mammals (Barclay, 1980; Mensing et al., 1998). Disturbance of the natural riparian riverine system may result in long-term modification to and reduction in natural biodiversity (Harding et al., 1998). Some of those impacts include changes in wildlife behavior, migration patterns, dispersal patterns, and distribution of species within a watershed (1470).
- (Morgan and Cushman 2005) We examined correspondence between urbanization and fish assemblages at a broad (ecoregional) spatial scale; however, it may be more accurate to address such relationships at the smaller reach scale because assemblages may be more influenced by reach-scale conditions or processes (Wang et al. 2003). For example, changes in riparian conditions attributable to urbanization may alter channel complexity, which, in turn, may alter fish assemblages (Booth 2005) (652).
- (Ekness and Randhir 2007) All habitat potentials showed a strong influence along spatial dimensions and disturbance. The habitat potential for all vertebrate groups studied decreased as the distance from the riparian zone increased. Headwaters and lower order subwatersheds had higher levels of species diversity compared to higher order subwatersheds. It was observed that locations with the least disturbance also had higher habitat potential (1468).
- (Ekness and Randhir 2007) A spatially variable policy that is based on stream order, riparian distance, and land use can be used to maximize watershed ecological benefits. Wider riparian zones with variable widths, protection of headwaters and lower order subwatersheds, and minimizing disturbance in riparian and headwater areas can be used

in watershed policy. These management objectives could be achieved using targeted economic incentives, best management practices, zoning laws, and educational programs using a watershed perspective (1468).

- (Nelson and Booth 2002) Sources of fine sediment, nearly two-thirds of the sediment production, are dominated by landslides (49%), followed by forested gravel roads (10%) and urban sediment production from residential and commercial areas (9%). Other sources that contribute significant percentages of fine sediment to the budget are channel-bank erosion (8%) and gravel-residential and paved roads (7%) (Fig. 5). Only three processes evaluated for this sediment budget contribute coarse sediment to the overall budget: landslides, soil creep, and channel-bank erosion. Again, the dominant coarse sediment-producing process is landsliding activity (54%). Channelbank erosion supplies 43% of the coarse sediment, with the remainder attributed to soil creep (62).
- (Andersen et al., 2007) Our failure to detect a relationship between CF extent and either total annual discharge or peak discharge even when these differences in peak flow timing were taken into account (Fig. 4) suggests other factors, such as land use, are strongly influencing CF extent (464).
- (Palmer et al., 2005) We propose that the first step in river restoration should be articulation of a guiding image that describes the dynamic, ecologically healthy river that could exist at a given site. This image may be influenced by irrevocable changes to catchment hydrology and geomorphology, by permanent infrastructure on the floodplain and banks, or by introduced non-native species that cannot be removed. Rather than attempt to recreate unachievable or even unknown historical conditions, we argue for a more pragmatic approach in which the restoration goal should be to move the river towards the least degraded and most ecologically dynamic state possible, given the regional context (Middleton 1999; Choi 2004; Palmer *et al*. 2004; Suding, Gross & Housman 2004) (210).
- (Ekness and Randhir 2007) Spatial variations created by different riparian distance, stream order, and land use affect the type and quality of habitat potential at a particular position within a watershed. The buffer is often critical in the flow of mass and energy into and out of water bodies. The longitudinal dimension reflects upstream-downstream linkages, which is a key factor in watershed ecology. Various land uses contribute to the type and level of disturbances in a watershed. The intensity and the extent of land disturbance affect the habitat potential of a watershed (1471-1472).
- (Ekness and Randhir 2007) In general, habitat potential decreases with respect to land disturbance for most vertebrates. It is highest for birds, mammals, and amphibians in undisturbed forested, nonforested wetland, woody perennial, or open water areas. Reptiles are exposed to higher disturbance in cropland and pastures, possibly because of a higher availability of prey. There was an increase in habitat potential for birds, mammals, and amphibians between disturbance values of 1 and 2. The transition between the forested and urban areas could explain this increase. This is consistent with the intermediate disturbance hypothesis, which proposes that disturbance at intermediate levels can contribute to moderate increase in species diversity at particular levels (Dial and Roughgarden, 1998). Habitat potential for all four vertebrate species declines with increases in disturbance except for the transition between disturbance Levels 1 and 2 mentioned before (1475-1476).
- (Ekness and Randhir 2007) Maintaining land use in the riparian corridor within the lower disturbance categories along the whole longitudinal dimension of the watershed can benefit habitat potentials for multiple species. Policies can target lower order subwatersheds to achieve maximum benefits for habitat potential (1479).