

## **Attachment E. Ecosystem Process Definition Tables**

Each ecosystem process is described in terms of delivery, movement and loss to an ecosystem in both unaltered and altered conditions. Each of these aspects of the process is further broken up into components. For example, overland flow, shallow subsurface flow, and discharge are all different components of movement within the hydrologic cycle.

The next sections of the tables describe the major natural controls of the process and the key areas where the process interacts with the landscape. For example, the key areas for large woody debris (LWD) delivery to aquatic areas are generally located adjacent to the aquatic area and become less important the further away from the shoreline one gets. So, while windthrow may be an important natural control of delivering trees to the ground over an entire watershed, it is only important for this analysis where it is close to an aquatic area, because this analysis is not concerned with how LWD interacts with upland areas for wildlife habitat, as it is outside of SMA jurisdiction.

The next section of the table describes the alterations to the process, the cause/s for that alteration, and indicators that can be used in a GIS analysis to represent those alterations. For example, an alteration to the delivery of LWD can be caused by a lack of trees adjacent to aquatic areas. Non-forested landcover data adjacent to aquatic areas can be used as the indicator to evaluate if that alteration has happened or not.

Some changes were made to Stanley et al (2005) in order to clarify the intent. For example, "straight-line hydrography" was changed to "channelized streams and rivers". Many references to a single shoreline type (stream) were removed and changed to shoreline, since the process is occurring along all shoreline types (marine, stream and lake). In some cases, additional causes of change and indicators were added to the table. Any such additions are explained with scientific references. The newly added processes of light energy, wave energy, and tidal influences are described in the same format with references.

### Attachment E1

Hydrologic							
Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change	
<i>Delivery</i>		Precipitation patterns	Recharge areas with higher amounts of precipitation	Altered runoff	Climate change		
		Timing of snowmelt	Rain-on-snow zones Snow dominated zones	Increase streamflow	Removal of forest vegetation in rain-on-snow zones	Non-forested vegetation in rain-on-snow zones	
<i>Movement</i>	<i>At the surface</i>	Overland flow	Precipitation patterns Soils	Saturated areas	Change timing, type and routing of flows to saturated areas	Land cover alteration,  Watershed imperviousness Stormwater discharge pipes Drainage ditches in seasonally saturated areas Loss of seasonally saturated areas	
		Surface storage	Topography Surficial geology Soils	Areas of low gradient floodplains	Increase streamflow  Decrease storage capacity  Increase water transport capacity	Drainage or filling of depressional wetlands	Loss of depressional wetland area
						Channelization of streams	Straight-line hydrography in depressional wetlands
						Disconnection of stream from floodplain	Straight-line hydrography of stream reaches with floodplains
					Dikes and levees on stream reaches with floodplains		

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					Increase water storage capacity Decrease downstream flow	Dam operation	<b>Dams</b>	
<i>Movement continued</i>	<i>Below surface</i>	Shallow sub-surface flow	Topography Surficial geology	Areas on geologic deposits with low permeability	Convert to surface runoff	Removal or compaction of soil	New construction	
				Areas on geologic deposits with high permeability		Impervious surfaces	<b>Land uses with impervious cover on geologic deposits of low permeability</b>	
				Entire watershed		Removal of forest cover	<b>Non-forested vegetation on geologic deposits of low permeability</b>	
		Recharge	Topography Surficial geology	Areas on geologic deposits with low permeability	Convert to surface runoff	Removal of forest cover	<b>Non-forested vegetation on geologic deposits of moderate to high permeability</b>	
					Reduce groundwater recharge	Impervious surfaces	<b>Land uses with impervious cover on areas of moderate to high permeability</b>	
				Entire watershed	Shift location of groundwater recharge Losses from supply pipes of sewer lines, or septic drainfields	Leaky pipes or irrigation canals Water supply and wastewater management	Utility lines Septic systems Unlined irrigation canals	
					Decrease quantity of groundwater available for	Groundwater pumping	Drawdown patterns Baseflow trends	
		Vertical and lateral sub-surface flow	Topography Surficial geology	Areas on geologic deposits with low permeability				

**Attachment E1**

				Areas on geologic deposits with high permeability			
				Entire watershed	Change location of groundwater discharge	Interception of sub-surface flow by ditches and roads	Constantly wet road ditches
		Sub-surface storage	Surficial geology	Deep permeable geologic deposits	Decrease quantity of groundwater available for discharge	Groundwater pumping	Well locations and volumes
	<i>Return to surface</i>	Discharge	Topography Surficial geology	Slope breaks (steep above gentle below) Stratigraphic pinchouts Contact area between geologic deposits of different permeabilities	Decrease groundwater inputs to aquatic resources	Drainage of discharge wetlands	<b>Loss of area of groundwater discharge wetlands</b> <b>Straight-line hydrography in groundwater discharge wetlands</b>
<i>Loss</i>		Evaporation	Climate	Entire watershed	Alter evaporation rates	Change temperature and precipitation patterns	
		Transpiration	Vegetation Climate	Entire watershed	Alter evapotranspiration rates	Clearing vegetation Shifting vegetation composition	Land cover
		Streamflow out of basin	Topography	Entire watershed	Change streamflow direction	Diversions Interbasin transfers	Diversion structures
		Groundwater flow out of basin	Topography Geology	Entire watershed	Altering quantity and pattern of groundwater flow	Interbasin transfers Groundwater pumping Impervious surfaces Interception of sub-surface flows	Baseflow trends Well locations, pumping rates and volumes

# Wave Energy

## Attachment E2

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
Delivery		Beach slope Fetch	Shoreline areas with water bodies large enough to have wind generated waves.	Increase in number of waves reaching the shoreline	Boat wakes	Shorelines adjacent to major shipping/transit lanes  Shorelines experiencing high recreational boat traffic. (i.e. near marinas)
				Increase in wave energy reaching the shoreline	Loss of eelgrass	Areas where eelgrass is known to have been previously present (note data doesn't exist)
				Reduction in wave energy reaching the shoreline.	Anthropogenic structures in deeper water	Breakwaters  Docks and piers
Movement				Wave energy unable to dissipate naturally on the beach.	Armoring causes energy to be reflected back onto beach, causing scour, and change in sediments.	Armored shorelines, especially at or below OHWM

## Attachment E3

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>	Streambank/ shoreline erosion	Water energy Riparian vegetation Erodibility of soils Tidal Height (marine only)	Unconfined channels Non-accretion shoreform beaches (marine only)	Reduce bank undercutting	Channelization of streams Reduction of flow (diversions/dams)	Dikes and levees Straightline hydrography on unconfined channels
					Armoring of shoreline	Shoreline armoring
				Reduce LWD available to reach shoreline	Remove riparian vegetation	Non-native land cover adjacent to stream (impervious surface, agriculture practices,
	Mass wasting	Topography	Mass wasting areas that are likely to deliver debris to shoreline	Reduce LWD available to reach shoreline	Remove forest vegetation on high mass wasting hazard areas	Non-forested land cover on high mass wasting hazard areas
	Windthrow	Riparian vegetation Weather patterns	100 ft from aquatic resource	Reduce LWD available to reach shoreline	Removal of vegetation adjacent to shoreline	Non-forested land cover within 100' of shoreline
<i>Movement</i>	Storage	Transport capacity of water	Channels with <4% slope Accretion shoreforms (marine only)	Reduce capacity of shoreline to store wood	Channelization of streams Armoring of shoreline (especially below OHW)	Dikes and levees (armoring) Straightline hydrography on unconfined channels
					Increased streamflow <sup>1</sup>	
<i>Loss</i>	Breakage/ Decomposition	Biotic interactions			People pulling it out	Streamside housing Docks and boat ramps Public access?

<sup>1</sup> Addressed in delivery, movement, and loss of hydrologic cycle.

**Light**

**Attachment E4**

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>		Riparian vegetation Topography Climate patterns		Additional natural light reaching the shoreline	Clearing of shoreline vegetation	No overhanging vegetation  No shoreline vegetation
				Light reaching the shoreline when it should be dark.	Night time lighting for human use OR human development along the shoreline	Streets within 100 feet of shoreline  Houses within 100 feet of shoreline  Docks and piers
<i>Movement</i>						
<i>Loss</i>		Water Topography Climate patterns		Reduced water depth at which light can penetrate	Human structures causing shade	Docks and piers over the water  Buildings within 50 feet of shoreline
					Decrease in water clarity	Increase in nutrients (which increase other plant growth)

# Phosphorus

## Attachment E5

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>	Phosphorus sources	Climate patterns Surficial geology		Additional sources	Application of fertilizer	Urban land use/ impervious surface Agricultural land use
					Application of manure	Agricultural land use adjacent to dairies
					Septic systems	Rural residential landuse
	Surface erosion	Hydrologic regime Soil erodibility	Steep slopes with highly erodible fine soils			
<i>Movement</i>	Biotic uptake and decomposition	Biotic cover and composition Hydrologic regime				
	Adsorption (P)	Soil characteristics	Depressional wetlands with mineral soils Upland areas, with clay soils adjacent to aquatic ecosystems	Reduced phosphorus adsorption	Draining or filling of depressional wetlands with mineral soils	Straight-line hydrography in depressional wetlands with mineral soils Loss of area of depressional wetlands with mineral soils
					Loss of upland areas with clay soils	Urban land cover in areas of clay soils adjacent to aquatic ecosystems
	Sedimentation <sup>1</sup>	Water transport capacity (velocity)	Depressional wetlands, lakes, floodplains, depositional channels	Reduced storage of phosphorous & toxins	See Sediment table	See sediment table.
<i>Loss</i>	Export out of the basin	Hydrologic regime				



# Nitrogen

## Attachment E6

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>	Nitrogen sources	Weather patterns Biotic composition		Additional sources	Application of fertilizer	Agricultural landuse Residential landuse
					Application of manure	Agricultural landuse
					Sewer discharge	Sewer outfalls
					Septic systems	Rural residential landuse
<i>Movement</i>	Biotic uptake and decomposition	Biotic cover and composition Hydrologic regime	Headwater streams	Increase stream discharge and depth	Channelization of headwater streams	Straight-line hydrography in headwater streams
	Nitrification	Hydrologic regime	All depressional wetlands (excluding bogs and fens)	Reduced area with seasonal flooding	Draining or filling of depressional wetlands	Straight-line hydrography in depressional wetlands
						Loss of area of depressional wetlands
Adsorption	Hydrologic regime	Headwater Streams	Increase stream discharge and depth	Channelization of headwater streams	Straight-line hydrography in headwater streams	
<i>Loss</i>	Denitrification	Hydrologic regime	All depressional wetlands (excluding acidic wetlands)	reduced area for denitrification	Draining or filling of depressional wetlands	Straight-line hydrography in depressional wetlands
						Loss of area of depressional wetlands
		Surficial geology	Riparian areas with a consistent supply of shallow groundwater	Loss of hydrologic connectivity between upland and riparian area	Interception of shallow groundwater flow into riparian areas	
	Volatilization	Bacterial activity Quantity of organic matter				

# Pathogens

## Attachment E7

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change	
<i>Delivery</i>	Fecal inputs	Wildlife	Aquatic resources Upland areas with hydrologic connectivity to aquatic resources	Additional fecal inputs	Failed septic systems	Rural residential land use	
					Discharge of untreated human and animal waste		
<i>Movement</i>	Transport	Overland flow	Precipitation patterns Soils	Seasonally saturated soils	Channelized flow	Ditching & draining of saturated areas	
		Surface flows	Topography Surficial geology Soils	Streams, rivers and connected wetlands	Increased velocity and erosion of streambed	Channelization of streams	Straight-line hydrography
		Subsurface flows & Recharge	Topography Surficial geology	Low permeability geologic deposits High permeability geologic deposits	Conversion to surface flows	Impervious cover Ditching in areas of low permeability	Urban land cover and/or impervious cover Ditching on geologic deposits of low permeability
	Adsorption		Mineral and organic soils Surface water velocity	All depressional wetlands.	Reduce storage of pathogens	Ditching, draining or filling depression wetlands with mineral and organic soils	Loss of area of depressional wetlands Straight-line hydrography in all depressional wetlands
	Sedimentation <sup>2</sup>						
<i>Loss</i>	Death	UV radiation Starvation Predation	All depressional wetlands	Reduce residence time	Draining or filling of depressional wetlands with mineral and/or organic soils	Loss of area of depressional wetlands.	

<sup>1</sup> Addressed in delivery, movement, and loss of water; conversion of sub-surface flow to surface runoff.

<sup>2</sup> Addressed in delivery, movement, and loss of sediment

# Toxins

## Attachment E8

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>	Toxin sources	Climate patterns Surficial geology		Additional sources New toxins	Use of pesticides, herbicides, and other chemicals	Urban land use/ impervious surface Row crop land use Roads Marinas, docks, piers, creosote Bulkheading, Sewer discharges
	Surface erosion	Hydrologic regime Soil erodibility	Steep slopes with highly erodible fine soils			
<i>Movement</i>	Biotic uptake and decomposition	Biotic cover and composition Hydrologic regime				
	Adsorption (T)	Soil cation exchange capacity	Depressional wetlands with organic or clay soils	Reduced toxin adsorption	Draining or filling of wetlands with organic and clay soils	Straight-line hydrography in wetlands with organic or clay soils
						Loss of area of wetlands with organic or clay soils
Sedimentation <sup>1</sup> Export out of the basin	Water transport capacity (velocity) Hydrologic regime	Depressional wetlands, lakes, floodplains, depositional channels	Reduced storage of toxins	See Sediment table	See sediment table.	
<i>Loss</i>	Export out of the basin	Hydrologic regime				

# Tidal influences

## Attachment E9

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>		Climate patterns Season Phase of the moon. slope		Decrease in tidal range	Diversion of streams/rivers	Modified drainage networks
				Increase in tidal range or upland shift in tidal height	El Nino events Sea Level Rise	Shorelines adjacent to major shipping lanes  Shorelines at beaches that experience substantial small boat traffic.
<i>Loss</i>		Slope of shoreline	Shorelines exposed to tidal forces	Reduction in tidal range	Filling of the intertidal zone (below OHWM)	Armored shoreline below OHWM

# Sediment

## Attachment E10

Component of process		Major natural controls	Key Areas	Change to process	Cause of change	Indicators of change
<i>Delivery</i>	Surface erosion	Topography Soil erodibility Vegetative cover Wave energy	Steep slopes with erodible soils  Feeder Bluffs, Feeder bluff exceptional, potential Feeder Bluffs (marine only)	Increase delivery of fine sediment to aquatic resources	Removal of vegetation	Non-forested land cover on highly erodible slopes adjacent to aquatic resources
					Soil disturbance and clearing	New construction draining to aquatic resources  Row crop agriculture draining directly to aquatic resources
					Roads increasing stream network	Roads within 200' of aquatic resources
				Decrease delivery of sediment to shoreline	Armored shoreline	Bulkheads, levees, dikes, etc.
	Mass wasting	Topography	Hazard areas for shallow rapid landslides	Increase delivery of sediment to aquatic resources	Roads triggering landslides	Roads in high mass wasting hazard areas
					Removal of vegetation	Non-forested land cover on high mass wasting hazard areas
	Shoreline erosion (lakes/ marine)	Wave energy Tidal regime Riparian vegetation	All marine/ lake shorelines	Sediment along shore is impounded by	Bulkheading/armoring	Armored shorelines
In-channel erosion (streams only)	Transport capacity (velocity) Riparian vegetation	Unconfined channels	Alter fine sediment delivery to streams	Channelization of streams	Straight-line hydrography in unconfined channels	

### Attachment E10

					Increase in stream discharge	Urban land cover
<i>Movement</i>	Sedimentation	Transport capacity (velocity)	Depressional wetlands Floodplains and depositional channels Lakes Marine shorelines	Decrease sediment storage	Drainage or filling of depressional wetlands	Loss of area of depressional wetlands
						Straight-line hydrography in depressional wetlands
					Channelization of stream reaches with floodplains or that are depositional zones	Straight-line hydrography on stream reaches with floodplains or depositional channels
					Disconnection of streams from floodplains	Dikes and levees on stream reaches with floodplains
					Increase streamflow <sup>1</sup>	
				Increase sediment storage	Dams	Dams
				Modify sediment transport (increase updrift and a decrease downdrift) (marine only)	Structures in the intertidal zone	Groins Bulkheads below OHWM Docks/piers
<i>Loss</i>		Transport capacity (velocity)	Use local data	Decrease or increase in sediment storage	Same causes for movement	Use local data