ONLINE SUPPLEMENT

A REVIEW OF CLIMATE CHANGE EFFECTS ON PRACTICES FOR MITIGATING WATER QUALITY IMPACTS

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1-Biofiltration		
General Characteristics		
	Geographic Applicability	Urban and semi-urban lands; nationally widespread, other than arid regions where irrigation costs can outweigh water quality benefits
	Functions	- Stormwater pollutant sedimentation, filtration, soil sorption, and/or plant uptake - Infiltration of runoff into underlying soils - Reduce flow velocity of stormwater runoff
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Performance of biofiltration practices can decrease with short runoff contact time, channelization, large storm events, frozen ground, short grass heights/sparse vegetative cover, and high runoff velocities and discharge rates; many of these factors can be affected by changes in temperature and precipitation - Increased temperature can also extend growing season. - Changes in precipitation intensity could lead to concentration of sheet flow via rill erosion, causing increased transport of sediment and other contaminants as well as reduced infiltration
	Relative Impact on Functional Processes (BMP Effectiveness)	- Design discharge capacity could change, decreasing retention time and increasing runoff velocities - Increased channelization could short circuit practice, decreasing runoff contact time and overall performance - (wetter growing season) Increased vegetative cover and soil OM, and consequently filtration, infiltration, and erosion cover; increased management needs to control vegetation - (drier growing season) Decreased soil moisture and soil OM could reduce vegetative cover, infiltration, and filtration functions - Change in seasonal timing of plant growth relative to pollutant loads could affect treatment performance
	Effects on carbon cycle, greenhouse gases	- Increased vegetation in the built environment can lead to increased carbon sequestration
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Can be affected in the shorter term by vegetation management and other maintenance activities - Redesign opportunities can be limited in urban applications where available land area is limited
	Management Adaptation Strategies	- Incorporate flow diversion structures to bypass intense events, and/or increase size of pretreatment/energy dissipation structures - Alter vegetation species composition for increased drought and/or moisture tolerances - Provide supplemental irrigation during extreme drought periods - Modify maintenance and media replacement frequencies based on changes in decay rates, humidity distribution, and media failure rates (increased clogging from more extreme sediment buildup/wash-off patterns)
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	California Stormwater Quality Association (CASQA) BMP Handbook; CWP, 2013; State of Washington Department of Ecology Stormwater Management Manual; Liu et al., 2016

2-Bioreactors		
General Characteristics		
	Geographic Applicability	Agricultural croplands with subsurface drainage systems; mostly concentrated in central plains and temperate prairies; less common in southeast coastal and mixed wood plains, Atlantic highlands, warm desert and Mediterranean CA regions
	Functions	- Filter out excessive nutrients (particularly nitrate via enhanced denitrification by denitrifying bacteria) from tile drainage water leaving crop fields before it reaches receiving waters
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature - Summer temperature
	Climate change sensitivity	- If precipitation increases in volume or intensity residence time could be reduced and bioreactors could more regularly be bypassed via overflow discharge infrastructure - Changes in chip bed microclimates could also affect denitrifying bacteria populations in the chip bed
	Relative Impact on Functional Processes (BMP Effectiveness)	- Under current design standards, residence time could be reduced and bioreactors could more regularly be bypassed via overflow discharge infrastructure - Changes in chip bed microclimates that support denitrifying bacteria populations could alter treatment capacity - Increased temperature and chip bed decomposition could shorten practice lifespan
	Effects on carbon cycle, greenhouse gases	- Denitrification of drain tile outflow could lead to increased emissions of nitrous oxide and/or ammonia gas - Nitrous oxide can also be indirectly produced via the volatilization and atmospheric oxidation or deposition of released ammonia gas
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Typically designed to last at least 10 years and up to 20 years - Can replace media on a shorter timescale
	Management Adaptation Strategies	- Modify inlet and outlet control structures to provide the required capacity and hydraulic retention time - Adjust frequency of media replacement based on change in humidity distribution and decay rates - Provide flow equalization storage at inlet to help mitigate increased storm intensities and volumes
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	MDA, 2017; Christianson et al., 2012; Adeuya et al., 2012; Iowa State University Cooperative Extension fact sheet; NRCS FOTGs; Jaynes and Isenhart, 2014

3-Bioretention		
General Characteristics		
	Geographic Applicability	Urban and semi-urban lands; nationally widespread; gaining popularity and becoming more common, particularly in highly urbanized areas
	Functions	- Stormwater pollutant removal via adsorption, filtration, plant uptake, soil microbial activity, decomposition, sedimentation, and volatilization - Possibly infiltration and groundwater recharge, some peak runoff rate and runoff volume reduction
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature - Summer temperature - PET/soil moisture
	Climate change sensitivity	- Changes in precipitation may affect retention time and design treatment volume, rendering the practice less effective - Changes in soil moisture could affect infiltration capacity and plant growth/uptake, while higher temperatures may amplify microbial activity in the soil media - Change in plant community dynamics among species adapted to bioretention conditions
	Relative Impact on Functional Processes (BMP Effectiveness)	- Design treatment volume could change, decreasing retention time and water quality volume treatment performance - Increased storm intensity will influence bypass control design; increase failure rates in in-line treatment systems - (wetter growing season) Increased vegetative cover, soil OM, and soil biological activity in the soil media could increase treatment performance; increase management requirements - (drier growing season)Decreased vegetative cover, soil OM, and soil biological activity in the soil media could reduce treatment performance; lower vegetation management requirements - Extended growing season will increase total annual treatment performance - Changes in soil moisture could affect infiltration rates, saturation points, soil cover, OM, and microbial activity
	Effects on carbon cycle, greenhouse gases	- Increased vegetation in the built environment can lead to increased carbon sequestration
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Redesign/expansion opportunities can be limited in urban applications where available land area is limited - Can be affected in the shorter term by vegetation management and other maintenance activities
	Management Adaptation Strategies	- Alter vegetation species composition for increased drought and/or moisture tolerances - Provide supplemental irrigation during extreme drought periods - Adjust OM content of soil media - Modify maintenance and media replacement frequencies based on changes in decay rates, humidity distribution, and media failure rates (increased clogging from more extreme sediment buildup/wash-off patterns)
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CASQA BMP Handbook; CWP, 2013; NCDWQ Stormwater BMP Manual; Jaynes and Isenhart, 2014; Barber et al., 2003; Gülbaz and Kazezyılmaz-Alhan, 2017; Wang et al., 2019; Hoss et al., 2016; Kristvik et al., 2018; Tirpac et al., 2021; District of Columbia Stormwater Management Guidebook

4-Blue Roofs		
General Characteristics		
	Geographic Applicability	Ultra-urban settings with space limitations; limited applicability to date; typically found in dense urban areas due to cost
	Functions	- Water storage on rooftops with controlled release - Sstorage can be in a permanent pool or modular containers
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Winter temperature
	Climate change sensitivity	- Limited ability to modify design to address changes in precipitation volume due to space and load capacity limitations
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in precipitation volume and distribution may limit the volume of runoff that can be captured
	Effects on carbon cycle, greenhouse gases	N/A
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Engineered designs have limited flexibility; modular designs are more flexible
	Management Adaptation Strategies	- Connect overflow to downstream infiltration or bioretention BMPs - For modular systems, increase number of trays within roof load capacity
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	Philadelphia Water, 2018; Philadelphia Stormwater Management Manual

5-Conservation Till/No-till		
General Characteristics		
	Geographic Applicability	Agricultural croplands; widespread; moderately less common in south central semi-arid prairies
	Functions	- Increase organic matter and soil tilth - Reduce sheet, rill, and wind erosion - Increase plant-available moisture - Reduce energy use and emissions - Provide food and escape cover for wildlife
Climate Sensitivities		
	Key climatic drivers	- Precipitation intensity - Summer temperature - PET/soil moisture
	Climate change sensitivity	- Climate changes could make crop residue more susceptible to movement (e.g., increased temperature and sun exposure could more quickly and thoroughly dry residue, making it more easily transportable by wind) - Increased precipitation could contribute to residue movement via surface flow - Higher temperatures will increase soil decomposition rates, overall biological activity, and nutrient cycling
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increase of rill/concentrated flow erosion and sediment transport - Increased risk of soil capping - Change in relative fractions of soil OM types, potentially increasing nutrient leaching and/or availability to crops - (Wetter growing season) Increased nutrient leaching; faster decay of surface residue and reduced soil cover - (Drier growing season) Slower decay of surface residue, temporarily increasing soil cover
	Effects on carbon cycle, greenhouse gases	- Reduced use of machinery can decrease emissions and increase soil carbon storage
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Seasonal
	Management Adaptation Strategies	- Adjust timing of planting and residue termination dates to adjust for shifts in humidity and temperature. - Increase crop stubble height to trap more snow - Produce more soil cover and OM via higher-residue crops and varieties, incorporating biomass-building cover crops into rotations, and/or adjusting plant populations through seeding rates and row spacing
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	MDA, 2017; Liu et al., 2016; Penn State University, 1996; Natural Resources Conservation Service (NRCS) Conservation Effects Assessment Project (CEAP); NRCS FOTGs; Garbrecht et al., 2014; Hatfield and Prueger, 2004; Schmidt et al., 2019; Wallace et al., 2017

6-Constructed Wetland	
General Characteristics	
Geographic Applicability	Treats wastewater and stormwater runoff in urban, agricultural, and industrial settings; geographically widespread; can be difficult and/or costly to maintain permanent pools in arid regions
Functions	- Biological treatment of water - Sedimentation - Denitrification - Stormwater volume reduction and flow attenuation
Climate Sensitivities	
Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature - Summer temperature - PET/soil moisture
Climate change sensitivity	- Constructed wetlands rely partly on hydrophytic vegetation for water treatment; wetland plants must be suitable for local climatic conditions, climatic changes could alter species composition and affect treatment capacity (invasive or non-native species should be avoided) - The design hydraulic retention time could be affected - Increased temperature and changes in soil moisture will affect soil biological activity (mineralization/denitrification) - Extension of growing season could increase performance of constructed wetlands
Relative Impact on Functional Processes (BMP Effectiveness)	- Increased storm intensity could reduce retention time and increase frequency/magnitude of "flushing" events (yielding increased pollutant export and decreased performance) - Changes in water table will affect site suitability - (wetter growing season) Increased vegetative cover, soil OM, and soil biological activity could increase nutrient uptake and removal - (drier growing season) Decreased soil moisture could decrease vegetative cover, soil OM, and soil biological activity, decreasing treatment performance - Extended growing season will increase nutrient uptake and reduce duration of plant die-back periods (when nutrients are re-mineralized and potentially exported) - Changes in plant community dynamics could alter species composition, treatment capacity, and management requirements (invasive species control) - Seasonal timing of plant growth relative to pollutant loads could affect treatment performance
Effects on carbon cycle, greenhouse gases	- Anaerobic conditions can promote the generation of methane - Conversely, the accumulation of organic matter and sediments can sequester carbon
Relative Climate Sensitivity	High
Adaptation Potential	
Flexibility/ Adaptability	- Long-term - Redesign/expansion opportunities can be limited in urban applications where available land area is limited - Can be affected in the shorter term by vegetation management and other maintenance activities
Management Adaptation Strategies	- Incorporate flow diversion structures to bypass intense events, and/or increase size of pretreatment/energy dissipation structures - Provide flow equalization storage at inlet to help mitigate increased storm intensities and volumes. - If needed, replant vegetation species according to humidity changes during growing season (although the vegetation will naturally adjust to the new flow/flooding regimes) - During extreme droughts, provide supplemental water to maintain permanent pools and hydrophytic vegetation
Relative Climate Adaptability	Low
Supporting Literature	
Supporting Literature	MDA, 2017; Kovacic et al., 2000; NRCS FOTGs; CWP, 2013; North Carolina Division of Water Quality (NCDWQ) Stormwater Best Management Practices (BMP) Manual; Liu et al., 2016

7-Contour Farming		
General Characteristics		
	Geographic Applicability	Sloping agricultural croplands; more common in south central semi-arid prairie and Ozark, Ouachita-Appalachian forest regions
	Functions	- Increase infiltration and moisture management on sloped terrain - Reduce erosion and transport of sediment and other contaminants
Climate Sensitivities		
	Key climatic drivers	- Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Increased precipitation intensity could exceed the ability of contours to control runoff and strengthen the potential for concentrated flow erosion
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increase the potential for rill and concentrated flow erosion and sediment transport - Increased risk of soil capping - Decrease infiltration and moisture availability
	Effects on carbon cycle, greenhouse gases	N/A
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Seasonal
	Management Adaptation Strategies	- (Wetter growing season) Increase min/max row grade - (Drier growing season) Decrease max row grade - Adjust ridge height, row spacing, and/or plant spacing within the row based on regional climate conditions - Incorporate Keyline patterning techniques to better distribute moisture across the landscape - Expand use of residue/tillage management and no-till practices to increase interception/infiltration - Shorten slope lengths through use of diversions, terraces, etc. - Modify stable outlets to accommodate larger design storms
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	MDA, 2017; NRCS CEAP; NRCS FOTGs; Liu et al., 2016

8-Controlled Drainage	
General Characteristics	
Geographic Applicability	Relatively flat agricultural croplands with high water tables; mostly concentrated in central plains and temperate prairies; present but less common in southeast coastal and mixed wood plains, Atlantic highlands, warm desert and Mediterranean CA regions
Functions	- More intensively manage and control water cycle and availability depending on crop needs and soil requirements - Higher water table promotes denitrification within soil profile (however, higher water tables may also promote dissolved phosphorus transport) - Reduce nutrient, pathogen, and pesticide loading from drainage systems into downstream receiving waters - Reduce oxidation of organic matter in soils
Climate Sensitivities	
Key climatic drivers	- Precipitation volume - Winter temperature - PET/soil moisture
Climate change sensitivity	- A major benefit of controlled drainage is less nitrogen export in the late winter and early spring - Higher winter temperatures could lead to more denitrification and better overall performance - This practice is most effective in areas where a high natural water table exists or has existed; changes in hydrology and groundwater levels could alter ideal geographic/ecoregion placement of this practice, as well as infrastructure sizing and design - Higher water tables may also increase the release of soluble phosphorus from mineral soils
Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in precipitation intensity and temporal distribution will alter effectiveness of existing drainage infrastructure - Temperature increases, extended growing season, and increased soil biological activity (i.e., denitrification) in the non-growing season could reduce nutrient loading - Decreased soil OM (from increased annual soil temperatures) could decrease denitrification rates
Effects on carbon cycle, greenhouse gases	- Promotes increased plant growth, leading to more carbon sequestration
Relative Climate Sensitivity	Low
Adaptation Potential	
Flexibility/ Adaptability	- Long-term infrastructure is required, but management strategies can be short-term and highly adaptive
Management Adaptation Strategies	- Adjust water control structure elevations and timing of elevation shifts - Place practice in areas that are expected to have high water tables
Relative Climate Adaptability	Medium
Supporting Literature	
Supporting Literature	Adeuya et al., 2012; Gilliam et al., 1997; Horsley Witten Group, 2015; NRCS FOTGs; Schmidt et al., 2019; NCSU

9-Cover crops		
General Characteristics		
	Geographic Applicability	Agricultural croplands; geographically widespread; marginally more prevalent in southeastern plains and coastal plains and Appalachian forest regions
	Functions	- Increase soil stability, organic matter, infiltration, aeration - Sustain/increase pollinator populations - Increase nutrient cycling and filtration
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature - Summer temperature - PET/soil moisture
	Climate change sensitivity	- Cover crops will take up excess water; the practice will also cause infiltration to increase, but if rainfall is reduced, cover crops could begin competing for moisture and decrease the main crop's moisture access - Increases in temperature could extend growing season for the main crop and reduce the effectiveness of cover crops - Increased decomposition rates could affect nutrient availability from cover crops
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased risk of rill/concentrated flow erosion and sediment transport - (Drier growing season) Increased soil moisture competition with cash crops - Extended cash crop growing season could shorten winter cover crop growing season - Faster mineralization of cover crop residue (increased leaching and/or availability for cash crops) - Change in cover crop species suitability, selection, and management needs - (Wetter growing season) Increased growth rates and vegetative cover of warm-season cover crops - (Drier growing season) Slower decay of surface residue, increasing soil cover but reducing mineralization and energy flows
	Effects on carbon cycle, greenhouse gases	- Although cover crops can increase equipment runtime and therefore emissions, the extra vegetative cover removes CO2 from the air and stores it in the form of carbon in the plants and soil
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Seasonal
	Management Adaptation Strategies	- Adjust cover crop species and varieties that are better adapted to the seasonal shifts in humidity and temperature (e.g., types with higher heat/drought tolerance for drier growing season areas) - Adjust method and timing of cover crop planting and termination - Incorporate more biomass yielding species to increase soil organic material and ground cover - Increase diversity of cover crop mixes - Incorporate more roll/crimp no-till termination methods to preserve soil moisture and increase ground cover
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	MDA, 2017; Penn State University, 2006; NRCS CEAP; NRCS FOTGs; Liu et al., 2016; Schmidt et al., 2019; Gautam et al., 2015; Lee et al., 2017; Alonso-Ayuso et al., 2018

10-Dry Detention Ponds		
General Characteristics		
	Geographic Applicability	Used throughout the U.S. for storm peak runoff and flood control
	Functions	- Temporary storage in a pond to control peak flows with controlled release over a short period
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Redesign of pond treatment volume and live storage in response to increased precipitation volume and intensity is likely to be difficult.
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased rainfall intensities could increase bypass flow relative to annual treatment volumes; lower retention times will lower treatment performance
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Redesign/expansion opportunities can be limited and costly in urban applications where available land area is limited - Can be affected in the shorter term by dredging and other maintenance activities
	Management Adaptation Strategies	- Retrofit outlet control structures and increase storage to accommodate larger design storms
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	Hoss et al., 2016; CWP, 2013; District of Columbia Stormwater Management Guidebook

11-Grassed Waterways		
General Characteristics		
	Geographic Applicability	Agricultural cropland; geographically widespread; more common in central and southeastern plains, temperate and semi-arid prairie regions other than Texas Gulf region
	Functions	- Increase concentrated runoff filtration, wildlife habitat, biodiversity, and pollinator populations - Reduce erosion and gully formation - Decrease runoff velocity and increase infiltration
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Increased precipitation could strengthen the possibility of concentrated flow erosion and cause the need to alter discharge capacity of grassed waterways - Extended growing seasons could benefit functional processes, while significantly warmer temperatures could reduce soil cover and thus the overall effectiveness of the practice - Changes in plant growth and vegetative cover depending on changes in moisture
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increase in frequency and peak of design discharges could reducing treatment performance (reduce detention time), and increase risk of rill/concentrated flow erosion (increased velocity and shear stress). - Increased channelization could short circuit practice, decreasing runoff contact time and overall performance - (Drier growing season) reduce plant vigor, vegetative cover, and soil OM, consequently reducing filtration and infiltration. - Seasonal timing of existing plant growth relative to pollutant loads could affect treatment performance
	Effects on carbon cycle, greenhouse gases	- Increased permanent vegetation in the agricultural landscape can remove more CO2 from the air and store it in the form of carbon in the plants and soil
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Relatively easily redesigned/rebuilt to suit changing needs - Can be affected in the shorter term by vegetation management and other maintenance activities
	Management Adaptation Strategies	- Retrofit existing practices to increase flow width and freeboard heights - Modify outlet design to accommodate larger storms - Alter vegetation species composition that is better adapted to regional climate conditions (more wet or drought tolerant species?) - Adjust mowing/grazing management as needed to manage larger storms, drier growing season, etc.
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	MDA, 2017; NRCS CEAP; NRCS FOTGs; Center for Watershed Protection (CWP) Stormwater Manager's Resource Center (SMRC); Liu et al., 2016; Barber et al., 2003

12-Green Roofs		
General Characteristics		
	Geographic Applicability	Flat to moderately sloping roofs in urban environments; geographically widespread
	Functions	- Stormwater volume reduction and flow attenuation - Increase evapotranspiration, wildlife habitat, and biodiversity - Potentially increase urban food production
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Changes in temperature and precipitation may alter the species composition best suited for green roofs in a particular ecoregion - Greater precipitation volume and intensity may increase export of sediment/growth media and limit flow attenuation benefits - Extended growing season; changes in plant community dynamics among species adapted to green roofs
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in annual precipitation volumes will influence levels of leaching from soil media increase export of sediment/growth media - Increased storm intensities will increase risk of sediment export, overflow bypass, and green roof failure rates - (wetter growing season) Increased vegetative cover and soil OM may increase runoff volume reduction and flow attenuation - (drier growing season) Increased risk for plant dieback during hot/dry months, reducing vegetative cover, soil OM, and green roof benefits
	Effects on carbon cycle, greenhouse gases	- Increased vegetation in the built environment can lead to increased carbon sequestration
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term but can be planted/replanted as necessary - Roof footprint and load capacity may limit ability to expand - Can be affected in the shorter term by vegetation management and other maintenance activities
	Management Adaptation Strategies	- Replant and adjust species composition that is better adapted to regional climate conditions - Incorporate downstream storage practices (e.g., cisterns) that help mitigate extreme event overflows and provide supplemental irrigation of green roof - Where feasible, increase soil OM content of media to increase moisture retention to drier growing season regions
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	NCDWQ Stormwater BMP Manual; Washington State University (WSU) Extension and Puget Sound Partnership LID Technical Guidance Manual for Puget Sound; Sohn et al. 2018; Alfredo et al., 2010; Culligan, 2018

13-Infiltration systems		
General Characteristics		
	Geographic Applicability	Urban and semi-urban lands; can be utilized in most regions of the country, but not suitable for karst topography; some concern of groundwater contamination in areas with high water tables
	Functions	- Stormwater pollutant attenuation via sedimentation, precipitation, filtration, sorption, bacterial degradation, and/or plant uptake - Stormwater runoff infiltration and ground water recharge
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Changes in the seasonal high water table could affect the general infiltration capacity of the practice as well as the level of groundwater contamination resulting from infiltration - Rainfall fluctuations could affect design standards and make some existing facilities obsolete
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased storm intensities will increase bypass flow volumes relative to treatment volumes; increases chances of system failure for in-line systems - (drier growing season) Reduced soil moisture and vegetative cover could increase levels of soil capping and lower infiltration rates - Where annual rainfall increase, higher groundwater levels could increase the possibility of groundwater contamination from infiltration
	Effects on carbon cycle, greenhouse gases	N/A
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Redesign/expansion opportunities can be limited in urban applications where available land area is limited
	Management Adaptation Strategies	- Incorporate flow diversion structures to bypass intense events, and/or increase size of pretreatment/energy dissipation structures - Where feasible, excavate bottom area to increase treatment volumes - Provide flow equalization storage at inlet - If a vegetated system, replant with species better adapted to regional climate conditions
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	CASQA BMP Handbook; CWP, 2013; Horsley Witten Group, 2015; State of Washington Department of Ecology Stormwater Management Manual; Barber et al., 2003

14-Nutrient Management Plans		
General Characteristics		
	Geographic Applicability	Crop and pasture lands; widespread; moderately more common in cold desert and semi-arid and temperate prairie regions
	Functions	- Encourage efficient nutrient cycling while minimizing entry of nutrients into surface or groundwater supplies - Maintain or improve the physical, chemical, and biological condition of soil
Climate Sensitivities		
	Key climatic drivers	- Precipitation intensity
	Climate change sensitivity	- Unpredictable weather patterns could disrupt nutrient application schedules, and increased rainfall intensity would strengthen the likelihood of nutrient runoff
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased risk of erosion and nutrient export in runoff - (Wetter non-growing season) Increased risk of nutrient leaching - (Drier growing season) Slower decay of surface residue - Erratic weather patterns reduce effectiveness of nutrient application schedules - Changes in average temperature and humidly distribution will alter nutrient release rates, affecting nutrient availability and/or plant uptake
	Effects on carbon cycle, greenhouse gases	- Management of nutrients optimizes the storage of soil carbon - Proper application of nitrogen can reduce emissions of nitrous oxide
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Seasonal - Highly adaptable depending on weather patterns and soil and plant needs
	Management Adaptation Strategies	- Adjust application rates, sources, timing, and placement (both for application and storage) to match specific climate changes -Avoid manure application during periods when intense rainfall is likely - Increase frequency of soil and crop testing to improve efficiency of nutrient applications - Incorporate conservation techniques (subsurface injection, no-till and residue management, etc.) that improve nutrient use efficiency and minimize surface or groundwater losses
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	MDA, 2017; Tilman et al., 2000; NRCS CEAP; NRCS FOTGs; Hatfield and Prueger, 2004

15-Perennial Cropping	
General Characteristics	
Geographic Applicability	Moderately sloping croplands; Mediterranean CA, cold desert and warm desert regions, along with south central prairie and Appalachian forest regions
Functions	- Reduce erosion and transport of contaminants - Improve water use efficiency and infiltration
Climate Sensitivities	
Key climatic drivers	- Precipitation intensity - PET/soil moisture
Climate change sensitivity	- Optimal species/variety for particular ecoregion could change over long-term timeframe - Extended growing season - Changes in precipitation intensity could lead to concentration of sheet flow via rill erosion, causing increased transport of sediment and other contaminants as well as reduced infiltration
Relative Impact on Functional Processes (BMP Effectiveness)	- (Wetter growing season) Increased plant growth rates and vegetative cover - Species suitability and selection will change with shifts in annual precip., seasonal temperatures, growing day degrees (GDD), frost days, temporal humidity distribution, etc. - (Drier growing season) decrease in plant growth rates and vegetative cover; more brittle areas may no longer be able to support woody species without considerable irrigation requirements - Shifts in community dynamics could increase pest and disease issues that are longer-lasting impacts in perennial systems
Effects on carbon cycle, greenhouse gases	- Perennials will sequester carbon on land that may otherwise not be cultivated
Relative Climate Sensitivity	Medium
Adaptation Potential	
Flexibility/ Adaptability	- Long-term - Depends on lifespan of particular crop grown
Management Adaptation Strategies	- Replant with different species/varieties better adapted to regional climate changes - Shorten slope lengths through use of terraces, Keyline patterning techniques, etc. - (Drier growing season) Install or expand irrigation as needed; or convert to more efficient irrigation practices to help offset increased demand - Change ground cover management to increase interception, infiltration, and retention of rainfall/humidity (e.g., mulching, perennial cover) - Expand on-farm biodiversity to help mitigate pest/disease pressures - Adjust pesticide/fertilizer types and application schedules accordingly - Incorporate appropriate agroforestry practices that help increase effectiveness of water and mineral cycles
Relative Climate Adaptability	Medium
Supporting Literature	
Supporting Literature	MDA, 2017; NRCS CEAP; NRCS FOTGs; Ha and Wu, 2017

16-Permeable Pavement		
General Characteristics		
	Geographic Applicability	Primarily moderate to low traffic areas; widespread; less prevalent in heavy snow areas
	Functions	- Pavement system that allows water to infiltrate to subsurface layer with gradual release
Climate Sensitivities		
	Key climatic drivers	- Precipitation intensity - Winter temperature
	Climate change sensitivity	- Treatment is controlled by infiltration rate; higher intensity storms may limit effectiveness
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in precipitation intensity may limit the volume of water that can be infiltrated
	Effects on carbon cycle, greenhouse gases	N/A
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term; fixed installation with high cost and moderate life span - Redesign/expansion opportunities can be limited in urban applications where available land area is limited
	Management Adaptation Strategies	- If solids load increases, provide pretreatment or divert flows from high load areas - Increase frequency of maintenance to reduce clogging
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	Hoss et al., 2016; CWP, 2013; District of Columbia Stormwater Management Guidebook

17-Prescribed Grazing		
General Characteristics		
	Geographic Applicability	Pasture and grazing lands; Great Plains, temperate and semi-arid prairies; southwest warm deserts; central, SE, and coastal plains; mixed wood plains and Appalachian forests
	Functions	- Improve or maintain desired species composition and vigor of plant communities, and thus quantity and quality of forage for grazing; improve or maintain water availability and quality along with riparian and watershed functions - Increase soil stability, organic matter, biological activity, and nutrient cycling - Manage fuel loads
Climate Sensitivities		
	Key climatic drivers	- Winter temperature - Summer temperature - PET/soil moisture
	Climate change sensitivity	- Extended growing seasons could increase grazing productivity and biological processes - Climate changes could affect species composition by making invasives and other undesirables more competitive, and if newly dominant species are less palatable, could reduce browsing efficiency and stocking density
	Relative Impact on Functional Processes (BMP Effectiveness)	- Change in plant community composition will alter grazing management strategies - Increased cold and heat stress on livestock and forages - (Drier growing season) Reduced soil moisture and plant vigor; slower plant recovery times following disturbance; slower decay of surface residue - (Wetter growing season) Increased soil compaction, nutrient leaching, and soil disturbance; decreased infiltration (potential temporary impacts); faster decay of surface residue
	Effects on carbon cycle, greenhouse gases	- Healthy, dense, and diverse vegetative cover can store more carbon
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Monthly to annual - Depends on management strategies and plant needs
	Management Adaptation Strategies	- Adjust paddock density, length of duration, frequency, and grazing plans to adjust for changes in native forages - Interseed cool or warm season annual forages into perennial pastures to supplement for changes in both growing and non-growing seasons - Utilize portable shade structures to help alleviate heat stress during growing season - Select breeds and internal genetics of livestock that are better adapted to regional climate conditions
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	MDA, 2017; NRCS CEAP; NRCS FOTGs; Liu et al., 2016; Garbrecht et al., 2014

18-Rainwater Harvesting		
General Characteristics		
	Geographic Applicability	Potentially applicable in all regions, but more popular in areas of water scarcity
	Functions	- Capture of rainwater, typically from roofs, for non potable reuse
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume
	Climate change sensitivity	- Harvesting systems typically have a pre-set size; changes in precipitation patterns may make the installed size sub-optimal
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in precipitation intensity and distribution may limit the volume of runoff that can be captured.
	Effects on carbon cycle, greenhouse gases	N/A
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term, especially for cisterns in large building applications; residential rain barrels are more easily modified - Systems incorporated into structures may be difficult to resize
	Management Adaptation Strategies	- Connect overflow to downstream infiltration or bioretention BMPs
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CWP, 2013; District of Columbia Stormwater Management Guidebook

19-Riparian Buffers		
General Characteristics		
	Geographic Applicability	Applicable to agricultural and urban lands; geographically widespread; slightly more prevalent in eastern temperate forest regions
	Functions	- Provide/improve aquatic and terrestrial habitats and biodiversity - Sheet flow runoff interception and filtration for water bodies and shallow groundwater tables
Climate Sensitivities		
	Key climatic drivers	- Precipitation intensity - Summer temperature - PET/soil moisture
	Climate change sensitivity	- Extended growing seasons could improve filtration, while significantly higher temperatures could alter species composition and/or reduce soil cover/OM, diminishing the benefits of the practice - Increased precipitation could cause excessive sheet-rill and concentrated flow erosion along with associated streambank erosion, scour, and headcuts
	Relative Impact on Functional Processes (BMP Effectiveness)	- More intense storm events will increase potential for rill and concentrated flow erosion and associated streambank erosion, scour, and headcuts. Increase in tree collapse is also a concern that causes considerable impact to the riparian buffer/stream stability - (wetter growing season) Increased vegetative cover and soil OM could increase filtration, interception, and energy dissipation - (drier growing season) Decreased soil moisture and rainfall will decrease vegetative cover, soil OM, and plant vigor, potentially reducing riparian area stability and treatment effectiveness - Seasonal timing of plant growth relative to pollutant loads could affect treatment performance - Change in plant community dynamics will affect riparian ecological stability
	Effects on carbon cycle, greenhouse gases	- Increased permanent vegetation in the agricultural landscape can remove more CO2 from the air and store it in the form of carbon in the plants and soil - Forested buffers have the potential to sequester more carbon than buffers with mainly herbaceous cover
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Ideally includes mature woody species
	Management Adaptation Strategies	- Increase sheet-rill and concentrated flow erosion control up-gradient of the buffer site - Extend buffer widths, where feasible - Adjust species composition, selecting plants that have higher rates of carbon sequestration in soils and plant biomass and are adapted to site conditions to assure strong health and vigor
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	MDA, 2017; Dorioz et al., 2006; Lee et al., 2000; NRCS CEAP; NRCS FOTGs; Liu et al., 2016; Garbrecht et al., 2014

20-Sand Filters		
General Characteristics		
	Geographic Applicability	Suitable only for application to highly impervious, stabilzed areas; typically found in dense urban areas due to cost
	Functions	- Subsurface filtration system
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature
	Climate change sensitivity	- Changes in precipitation may increase flow bypass and increase likelihood of cloggin, requiring more frequent cleanout
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in precipitation intensity and distribution may limit the volume of runoff that can be treated
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term, high-cost engineered BMP with fixed size
	Management Adaptation Strategies	- Combine with upstream flow control to adapt to increased runoff - Increase cleanout frequency as needed
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	CWP, 2013; District of Columbia Stormwater Management Guidebook

21-Saturated Buffers		
General Characteristics		
	Geographic Applicability	Agricultural croplands with subsurface drainage systems; mostly concentrated in central plains and temperate prairies; less common in southeast coastal and mixed wood plains, Atlantic highlands, warm desert and Mediterranean CA regions
	Functions	- Filter out excessive nutrients (particularly nitrate via enhanced denitrification by soil organisms) from tile drainage water leaving crop fields before it reaches receiving waters - Enhance or restore saturated soil conditions for certain landscape classes
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Summer temperature - PET/soil moisture
	Climate change sensitivity	- If precipitation increases in volume or intensity under current designs, buffers could more regularly be bypassed via overflow discharge and/or be subject to excessive surface flow due to buffer oversaturation - Change in plant community dynamics among species adapted to the saturated buffer conditions - Changes in soil microclimates could also affect denitrifying bacteria populations in the soil
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increase in surface flows relative to subsurface flows reducing levels of treatment; due to increased dry conditions (soil capping) or extreme wet conditions (buffer oversaturation) - Increased storm intensities could create additional stream incision, reducing suitable areas where this practice is applicable - Changes in soil moisture and lower natural water tables that support denitrifying conditions could reduce treatment performance - Decreased soil OM as a result of temperature increases could also lower denitrification rates
	Effects on carbon cycle, greenhouse gases	- Denitrification of drain tile outflow could lead to increased emissions of nitrous oxide and/or ammonia gas - Nitrous oxide can also be indirectly produced via the volatilization and atmospheric oxidation or deposition of released ammonia gas
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Requires subsurface piping and establishment of plant communities in buffer
	Management Adaptation Strategies	- Extend buffer widths, where feasible - Adjust target water table elevations - Add additional water control structures to manage surface and groundwater flow uniformity - Replant and alter species composition as necessary to ensure healthy soil cover, maintain soil microclimates, and increase OM to support denitrification - (Drier growing season) Manage upland areas for increased soil cover to promote infiltration and subsurface flow
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	MDA, 2017; Adeuya et al., 2012; NRCS FOTGs; Jaynes and Isenhart, 2014

22-Two-stage Ditches	
General Characteristics	
Geographic Applicability	Relatively flat agricultural croplands; most commonly found in plains and prairie regions
Functions	- Decrease flooding, erosion, and scour; improve habitat and biodiversity - Reduce sediment and nutrient transport - Encourage nutrient assimilation
Climate Sensitivities	
Key climatic drivers	- Precipitation intensity - Winter temperature - Summer temperature - PET/soil moisture
Climate change sensitivity	- Changes in hydrology could affect design and sizing of new two-stage ditches and existing ditches could become less effective - Extended growing seasons could increase nutrient assimilation and bank stability, while substantially warmer temperatures could adversely affect stage-2 vegetation, decreasing nutrient assimilation and bank stability
Relative Impact on Functional Processes (BMP Effectiveness)	- Increase in peak discharge can reduce effectiveness of existing ditches - (Wetter growing season) Increase in plant vigor and vegetative cover could increase sediment/nutrient removal and bank stability - (Drier growing season) Reduce plant vigor and vegetative cover, thus decreasing BMP effectiveness. - Extreme weather events (heat wave, drought, flash flood. etc.) could reduce vegetative cover and impair channel stability - Seasonal timing of plant growth relative to pollutant loads could affect treatment performance
Effects on carbon cycle, greenhouse gases	- Increased permanent vegetation in the agricultural landscape can remove more CO_2 from the air and store it in the form of carbon in the plants and soil - Wetland microcells may release small amounts of methane
Relative Climate Sensitivity	Low
Adaptation Potential	
Flexibility/ Adaptability	- Typically long-term - Relatively easily redesigned/rebuilt to suit changing needs
Management Adaptation Strategies	- Retrofit existing channel geometries to accommodate larger design storms - Adjust channel vegetation accordingly to regional climate conditions - Add armoring (e.g., riprap, turf reinforcement matting) to channel to accommodate higher shear stresses
Relative Climate Adaptability	Medium
Supporting Literature	
Supporting Literature	Mahl et al., 2015; Roley et al., 2006; D'Ambrosio et al., 2013; Hodaj et al, 2016; Liu et al., 2016; NRCS FOTG

23-Wet Detention Ponds		
General Characteristics		
	Geographic Applicability	Relatively popular in urban and semi-urban settings; geographically widespread; less applicable in arid regions where it can be difficult to justify supplementing water to maintain a permanent pool
	Functions	- Pollutant removal via sedimentation and biological uptake - Can integrate some degree of peak flow attenuation - Provide wildlife habitat, biodiversity, and possibly aesthetic/recreational value
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Increased precipitation volume and intensity require changes in wet pond treatment volume and/or live storage - Temperature increases will affect biological activity and nutrient uptake rates; extend growing season
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in annual rainfall volumes and humidity distribution will affect minimum drainage area requirements to sustain wet ponds - Increased rainfall intensities could increase bypass flow relative to annual treatment volumes; lower retention times will lower treatment performance - Increased evaporation rates will lower permanent pool volumes, affecting plant and aquatic species survival
	Effects on carbon cycle, greenhouse gases	- Anaerobic conditions can promote the generation of methane - Conversely, the accumulation of organic matter and sediments can sequester carbon
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term, especially in highly developed locations where space may be limited - Redesign/expansion opportunities can be limited and costly where available land area is limited - Can be affected in the shorter term by dredging and other maintenance activities
	Management Adaptation Strategies	- Retrofit outlet control structures and increase storage to accommodate larger design storms and - Provide supplemental water during extreme drought periods to help maintain permanent pools
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	CASQA BMP Handbook; CWP, 2013; NCDWQ Stormwater BMP Manual; Liu et al., 2016; District of Columbia Stormwater Management Guidebook; Hoss et al., 2016; Sharma et al., 2011

Section 1.1: References - Urban and Agricultural

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Section 2: Forestry Practices

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1-Chemical use planning		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Minimize impacts of chemical applications on waterways and forest ecosystems - Reduce populations of pests, weeds, invasive species, and fungi - Fertilize to increase forest production - Reduce mortality of native or desired species - Manage vegetation during reforestation or habitat and watershed management
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Increased precipitation increases runoff by which chemicals enter and degrade water quality in waterways - Pathogens, infestation, wildfires, competition with invasive species and higher rates of thinning result in increased tree mortality, further increasing runoff - Increased frequency and severity of drought will call for higher fertilizer use, which may damage forest health and increase vulnerability to drought conditions
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased risk of chemical runoff into waterways - Fertilizer applied in drought conditions increase drought vulnerability - Fertilizer entering waterways via runoff disrupts nutrient cycling - Tree mortality and thinning due to increased pests/diseases causes increased runoff
	Effects on carbon cycle, greenhouse gases	- Chemical application can cause increased vulnerability to drought and therefore tree mortality, which puts C stores at risk
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Depends on management strategies
	Management Adaptation Strategies	- Avoid use of chemical treatments in aquatic management zones - Apply other BMPs that limit erosion and runoff effects - Consider precipitation and weather patterns in sites before using chemical applications
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; USDA 2012; Adams et al. 2012; Bartkowiak et al. 2015; Grace et al, 2006; Newton and Norgren 1977; Ogden and Innes 2008; USEPA 2005; Ward et al. 2015

2-Wildland fire management planning		
General Characteristics		
	Geographic applicability	Northern Forests; Eastern Temperate Forests; Western Forested Mountains; Mediterranean California; Southern Semi-Arid Highlands
	Functions	- Minimize negative impacts from fire management activities - Maintain soil and slope stability - Maintain water quality
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Increased frequency and severity of drought may complicate strategies to mitigate fire management effects as droughts and intense storm events decrease soil stability - Fire control measures might become increasingly important and applicable due to drought, winds, and tree mortality which increase fire severity and likelihood - Change in community dynamics among trees and pests/diseases
	Relative Impact on Functional Processes (BMP Effectiveness)	- Droughts, especially when paired with extreme weather, decrease soil stability and complicate fire management activities - Forest fires release C from C stores - Increased tree mortality creates higher fuel loads, necessitating fire management planning
	Effects on carbon cycle, greenhouse gases	Planning for fire management can help reduce C losses
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term
	Management Adaptation Strategies	- Develop plans on a site-by-site basis - Maintain natural fire regimes - Engage in fuels management activities, such as thinning or prescribed fires
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; NASF 2017b; Ogden and Innes 2008; USDA 2012; Bessie and Johnson 1995; Ogden and Innes 2008; Parker et al. 2006; Schowalter 1986; Stocks 1987; Swetnam and Betancourt 1997; USDA 2012; Vose et al. 2012b

3-Wildland fire control and suppression	
General Characteristics	
Geographic applicability	All forested ecoregions
Functions	- Suppress and stop the spread of wildfires - Reduce impacts to water quality from suppression activities
Climate Sensitivities	
Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature
Climate change sensitivity	- Increased frequency and severity of drought will necessitate more severe suppression techniques, making it more difficult to minimize adverse effects of these techniques - Drier conditions and unstable soil from extreme precipitation and storm events will increase the amount of soil disturbed and ground cover lost, further increasing erosion and runoff from suppression activities
Relative Impact on Functional Processes (BMP Effectiveness)	- Soils are disturbed, erosion and runoff increase with increased precipitation volume and intensity - Forest fires release C from C stores - Runoff of chemical retardants and nutrients disturb the nutrient cycle in waterways - Runoff disrupts nutrient cycles
Effects on carbon cycle, greenhouse gases	Fire suppression can help reduce C losses
Relative Climate Sensitivity	Medium
Adaptation Potential	
Flexibility/ Adaptability	- Long-term
Management Adaptation Strategies	- Increase public awareness about how wildfires may change with climate change as fire suppression efforts become more costly with warming climate - Remove active fuels from sites to control fires before they occur - Maintain natural fire regimes to reduce long-term intensities of wildfires
Relative Climate Adaptability	Medium
Supporting Literature	
Supporting Literature	CEC n.d.; NASF 2017b; Ogden and Innes 2008; USDA 2012; Vose et al. 2012b

4-Wildland fire suppression damage rehabilitation		
General Characteristics		
	Geographic applicability	Northern Forests; Eastern Temperate Forests; Western Forested Mountains; Mediterranean California; Southern Semi-Arid Highlands
	Functions	- Rehabilitate watershed features and functions damaged by wildfire control and suppression activities -Minimize adverse effects to soil, water quality, and riparian resources
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- More rehabilitation will be necessary as wildfires increase in frequency and severity - Increased soil instability from extreme precipitation and storm events will also make it more difficult to control erosion caused by suppression activities
	Relative Impact on Functional Processes (BMP Effectiveness)	- Soils are disturbed and erosion and runoff increase with increased precipitation amounts and intensity - Increased erosion and runoff elevates amount of damage rehabilitation needed - Runoff disrupts nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Immediate after fire
	Management Adaptation Strategies	- Increase efforts to rehabilitate ecosystems after damage caused by fire suppression techniques - Treatments to protect watershed resources after fires may be needed more frequently
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; NASF 2017b; Ogden and Innes 2008; USDA 2012

5-Thinning	
General Characteristics	
Geographic applicability	All forested ecoregions
Functions	- Reduce fuel loads in areas at risk of natural fires - Improve resilience to drought in dry forests - Selectively influence species composition - Decrease risk of insect infestation and pathogen-related mortality - Lower competitive stress - Ensure prolonged productivity and protection of C stocks in remaining trees
Climate Sensitivities	
Key climatic drivers	- Precipitation volume - Summer temperature - PET/soil moisture
Climate change sensitivity	- Increased prevalence and severity of forest fires, drought, disease, and infestations may increase the need for thinning, especially in forests at risk of losing large C stores - Change in community dynamics among trees and pests/diseases - Extended growing season
Relative Impact on Functional Processes (BMP Effectiveness)	- Increased prevalence and severity of forest fires - Higher fire risk may increase need for thinning - Increased risk of thinning in some areas because of short-term conversion from C sink to source - Increased need for thinning in some areas because of risk of losing C stores to fires - Increased risk of disease and infection may increase need for thinning - Increased growth may lead to more frequent need for thinning
Effects on carbon cycle, greenhouse gases	- Thinning reduces C stores and converts sites from sink to source, but also increases productivity and thus long-term C storage of remaining trees
Relative Climate Sensitivity	Medium
Adaptation Potential	
Flexibility/ Adaptability	- Monthly to annual
Management Adaptation Strategies	- Modify timing and intensity of thinning operations to allow growth and C turnover - Careful implementation to avoid damaging forest functionality - Increased use of selective thinning to reduce infected/damaged stands - Coordinate thinning with planting to promote diversity and regrowth - Promote landscape level thinning over stand level thinning with caution - Avoid thinning in mature, old-growth forests with wet soil
Relative Climate Adaptability	Medium
Supporting Literature	
Supporting Literature	Black 2004; CEC n.d.; Chizinski et al., 2010; Cristan et al. 2016; Doppelt et al. 2009; NASF 2017b; Ogden and Innes 2008; Paashaus et al. 2004; Chan et al. 2006; Doppelt et al. 2009; Dore et al. 2010; Ferrell 1996; Grace et al. 2006; Marion et al. 2013; Ogden and Innes 2008; Schönau and Coetzee 1989; SFC 2010; Swanston et al. 2016; Vose et al. 2012b

6-Use of prescribed fire	
General Characteristics	
Geographic applicability	All forested ecoregions
Functions	- Reduce active fuel loads - Reduce prevalence of invasive species - Mitigate understory competition - Promote restoration of native species - Increase fire resilience
Climate Sensitivities	
Key climatic drivers	- Precipitation volume - Winter temperature - Summer temperature - PET/soil moisture
Climate change sensitivity	- Increased frequency and prevalence of drought may limit the applicability of controlled burns as forests become drier; a controlled burn may be less easily controlled in forests with high fuel loads, especially with increasing intensity and unpredictability of winds - Prevalence of invasive species and pest infestations may increase difficulty in selectively administering controlled burns - Less understory competition
Relative Impact on Functional Processes (BMP Effectiveness)	- Controlled burns become inadvisable in forests with high fuel loads - More invasive species may call for more controlled burns - Difficulty for young tree establishment may decrease need for controlled burns - Increased risk of controlled burn in some areas because of short-term C loss - Increase need for controlled burn in some areas because of risk of losing C stores to wildfires
Effects on carbon cycle, greenhouse gases	- Burning releases C from C from stores, but may increase C storage in the long term through increased productivity of larger, healthier, more resilient trees
Relative Climate Sensitivity	Medium
Adaptation Potential	
Flexibility/ Adaptability	- Depends on management strategies and plant needs
Management Adaptation Strategies	- Promote use of controlled fires in areas where severe wildfires are expected - Consider use of mechanical thinning in forests with very high fuel loads and extreme drought
Relative Climate Adaptability	Low
Supporting Literature	
Supporting Literature	CEC n.d.; Ferrell 1996; NASF 2017b; Swanston et al. 2016; Bessie and Johnson 1995; Ferrell 1996; Meixner 2004; Swanston et al. 2016

7-Road location and design		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Reduce likelihood of landslides and slope failure - Minimize soil disturbance and potential for erosion
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Increased risk of landslides and soil erosion due to severe and frequent precipitation, storm events
	Relative Impact on Functional Processes (BMP Effectiveness)	- Risk of slope failure and soil erosion is increased with increasing precipitation, impacting potential construction sites - Increased runoff from roads is amplified by increased precipitation - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies
	Management Adaptation Strategies	- Increase culvert size below roads to reduce risk of flood damage to roads and downstream resources - Design roads to minimize fragmentation and road density - Avoid construction of roads near unstable soils to minimize risks of slope failure from precipitation and snowmelt
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; Ogden and Innes 2008; Vose et al. 2012b; Dale et al. 2001; Swift 1985

8-Stream crossings **General Characteristics**		
	Geographic applicability	All forested ecoregions
	Functions	- Minimize erosion due to harvest activities - Maintain streamflow; - Stabilize soil and stream banks; - Minimize effects of logging activities on waterways - Minimize runoff from roadways into streams
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Changes in timing and volume of peak flows may damage infrastructure, pose threats to aquatic life, and impact potable water where stream crossings occur if they are not designed appropriately - Stream crossings established previously for logging operations may not be adequate as future hydrological events and streamflow extremes are expected to increase in severity
	Relative Impact on Functional Processes (BMP Effectiveness)	- Changes in timing and volume of peak flows affect stream crossings implementation by flooding and infrastructure damage - Previously established stream crossings damaged or unusable due to hydrological extremes - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies
	Management Adaptation Strategies	- Increase culvert size below roads to reduce risk of flood damage to existing stream crossings and downstream resources - Evaluate established crossings from previous harvest operations to assess present suitability - Design stream crossings to be compatible with geomorphology of streams
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; UNH 2009; Vose et al. 2012b; Ogden and Innes 2008; Ochterski 2004b; Swift 1985

9-Road storm-damage surveys		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Maintain roads to stabilize slopes and soil - Reduce sediment transport
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Severe storms and precipitation events are expected to increase with climate change, further necessitating more storm-damage surveys - Increased rainfall and erosion may overwhelm inadequate drainage systems, and interfere with maintenance, reducing efficiency of forest road BMPs (e.g., maintenance of roads is an invasive procedure that may no longer be desirable in forests sensitive to climate change disturbance) - Performing surveys and necessary maintenance may become more disruptive to ecosystem health - Change in community dynamics among trees and pests/diseases
	Relative Impact on Functional Processes (BMP Effectiveness)	- Erosion and runoff into waterways - Severe storms and precipitation overwhelm management systems, increasing need for surveys - Runoff velocity reduces efficiency of road maintenance and restoration - Runoff into waterways disrupts aquatic nutrient cycles - Surveying and maintenance may not be desirable in susceptible or sensitive forests
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies and plant needs
	Management Adaptation Strategies	- Conduct more frequent damage surveys - Improve drainage systems to manage flooding and runoff - Keep up with maintenance needs before storms occur
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; Mote et al. 2003; NASF 2017b; Ogden and Innes 2008; Spittlehouse and Stewart 2003; Grace and Clinton 2007; Swift 1985; USFS 2011

10-Road storage and decommissioning		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Eliminate runoff from abandoned roads - Stabilize slopes and prevent slope failure
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Closure of roads can reduce erosion and runoff in the long term, but short term effects include increased erosion and potential for slope failure, which are magnified by increased precipitation frequency and severity - Some closed roads may continue to produce sediment even when not used, especially with more severe storm events - With increased invasive species disturbance and sensitivity of native species, road removal and closure may cause excessive damage to ecosystems
	Relative Impact on Functional Processes (BMP Effectiveness)	- Erosion and runoff into waterways- Increased risk of erosion and sediment transport even of closed roads - Slope instability leading to landslides - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term
	Management Adaptation Strategies	- Stay ahead of maintenance needs before degradation occurs - Use appropriate models for road design - Consider precipitation volume and runoff effects in addition to freezing and thawing conditions when maintaining forest roads
	Relative Climate Adaptability	Low
Supporting Literature		
	Supporting Literature	Akay and Sessions 2005; CEC n.d.; Cristan et al. 2016; Grace and Clinton 2007; Gumus et al. 2008; NASF 2017b; Spittlehouse and Stewart 2003; Grace 2005; Ogden and Innes 2008; Swift 1985; Switalski et al. 2004

11-Landing area management		
General Characteristics		
	Geographic applicability	Marine West Coast Forests; Western Forested Mountains; Mediterranean California; Eastern Temperate Forests; Northern Forests; Southern Semi-Arid Highlands; Taiga
	Functions	Reduce erosion and runoff from logging operation landings
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Soil is extensively disturbed at log landings, leading to erosion and runoff. Runoff and erosion from landings is amplified by increased precipitation and storm events
	Relative Impact on Functional Processes (BMP Effectiveness)	- Disturbed soils are further eroded by precipitation and storm events - Management of disturbed soils is complicated by runoff velocity and soil moisture - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies
	Management Adaptation Strategies	- Scatter logging slash over landings and skid trails to stabilize and reduce erosion after operations - Consider placing landings a significant distance from streams likely to be affected by extreme precipitation events
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	AFC 2007; CEC n.d.; Cristan et al. 2016; NASF 2017b; Ochterski 2004b; Ogden and Innes 2008; USDA 2012; Vose et al. 2012b

12-Cable and aerial yarding operation		
General Characteristics		
	Geographic applicability	Marine West Coast Forests; Western Forested Mountains; Mediterranean California; Eastern Temperate Forests; Northern Forests; Southern Semi-Arid Highlands; Taiga
	Functions	- Minimize soil damage during aerial yarding - Reduce introduction of sediment and pollutants to waterways
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Summer temperature
	Climate change sensitivity	- Aerial yarding is used in steep, unstable areas where slope failure is already a risk - Increasing precipitation, melting permafrost, and storm events are likely to increase erosion, runoff, and soil moisture in some areas under climate change scenarios, which increase soil instability and water quality degradation - Aerial yarding operations may become more hazardous as precipitation increases in frequency and severity
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased likelihood of slope failure with aerial yarding infrastructure and precipitation increases - Storms and wind may damage aerial yarding infrastructure and soils - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies
	Management Adaptation Strategies	- Examine sites and avoid aerial yarding infrastructure in areas with unstable soil or risk for extreme precipitation events
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; USDA 2012; Ogden and Innes 2008; Vose et al. 2012b

13-Ground-based skidding and yarding operation		
General Characteristics		
	Geographic applicability	Marine West Coast Forests; estern Forested Mountains; Mediterranean California; Eastern Temperate Forests; Northern Forests; Southern Semi-Arid Highlands; Taiga
	Functions	- Minimize soil damage and forest disturbance during ground-based yarding - Reduce runoff and erosion - Avoid excessive impacts to waterways
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Summer temperature
	Climate change sensitivity	- Erosion and runoff stimulated by ground-based skidding and yarding may be amplified by increasing frequency and severity of precipitation, melting permafrost, and storm events - Increased precipitation may also increase the hazard of slope failure in forested areas where ground-based operations are placed
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increasing precipitation and storm events amplify erosion and runoff stimulated by ground-based skidding operations - Slope failure risk increases with storms and precipitation where operations are located - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Low
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies
	Management Adaptation Strategies	- Establish operational sites on stable soils - Evaluate effects of runoff and erosion at operating sites to assess potential impacts - Consider precipitation and storm potential before establishing skidding and yarding infrastructure
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; Ogden and Innes 2008; USDA 2012; Vose et al. 2012b

14-Erosion prevention and control		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Minimize and control erosion in areas where mechanical vegetation treatments are applied - Reduce soil damage
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Mitigating the effects of mechanical vegetation treatment post-operation will likely increase in difficulty as changing precipitation and storm patters increase erosion, runoff, soil instability, and slope failure
	Relative Impact on Functional Processes (BMP Effectiveness)	- Erosion, runoff, soil instability, and slope failure risk increases with increasing precipitation, rendering erosion management necessary and complex - Runoff into waterways disrupts aquatic nutrient cycles
	Effects on carbon cycle, greenhouse gases	
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Depends on management strategies
	Management Adaptation Strategies	- Adopt practices to minimize risk of sediment runoff and erosion - Perform low-impact harvesting - Adjust harvest schedules to focus on winter harvesting - Consider partial harvests - Switch to pre-operation erosion prevention rather than post-operation control
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; Ogden and Innes 2008; Vose et al. 2012b; USDA 2012

15-Harvest unit planning and design (harvest methods & rotation length)		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Produce lumber products with reduced impacts on water quality and forest health - Augment water supply
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Harvesting increases flood risk, especially where soils are already moist; combined with increased frequency and severity of precipitation events, more flooding is expected to occur with harvesting under climate change - Increased runoff and infrastructure related to harvesting can degrade water quality - Long-term effects of harvesting may include streamflows below pre-harvest levels, magnifying the effect of extreme drought in dry areas.
	Relative Impact on Functional Processes (BMP Effectiveness)	- Some communities use clear-cutting as a way to augment water supplies - Harvesting exacerbates flood risk - C stores are depleted through harvest activities
	Effects on carbon cycle, greenhouse gases	C stores are lost during harvest
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Depends on management strategies and plant needs
	Management Adaptation Strategies	- Adjust harvest schedules to winter-focused to allow access to forested areas accessible only by ice cover and to mitigate impacts of warmer winters, snowmelt, heavy precipitation, and wet soils on harvesting operations - Reduce large-scale clearcutting - Promote natural regeneration - Increase rotation periods in coppices - Specialize harvest activities depending on site
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; Ogden and Innes 2008; SFC 2010; Spittlehouse and Stewart 2003; VDOF 2009; Grace et al. 2006; Jones et al. 2009; Marion et al. 2013; Vose et al. 2012a

16-Selective cutting		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Produce lumber products - Remove damaged or infected trees - Reduce competition to allow productivity of remaining trees
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Summer temperature
	Climate change sensitivity	- Unpredictable precipitation events, permafrost melt, and more extreme precipitation may lead to soil instability, impacting the schedule and efficiency of harvesting - Forests may require increased frequency and intensity of selective cutting due to increased prevalence of insect infestation and disease - Change in community dynamics among trees and pests/diseases
	Relative Impact on Functional Processes (BMP Effectiveness)	- Soil instability increases with increasing precipitation - Changes to harvesting schedule and efficiency - Increased frequency and intensity of selective cutting to remove infected and diseased trees
	Effects on carbon cycle, greenhouse gases	Reduces C stores, but increases productivity of remaining trees
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Monthly to annual
	Management Adaptation Strategies	- Modify harvest schedule to specifically remove stands that are vulnerable to disturbance - Salvage timber from selective cutting to increase socio-economic resilience - Use persistent wood products to mitigate C losses when harvested - Adjust harvest schedules to winter-focused harvesting
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al., 2016; NASF 2017b; Ogden and Innes 2008; Spittlehouse and Stewart 2003; NCFA 2017; Grace et al. 2006

17-Site preparation and reforestation		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Restore or improve forest soils - Improve regrowth conditions
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - PET/soil moisture
	Climate change sensitivity	- Changes in frequency and intensity of floods and droughts may reduce forest regeneration success - Increased frequency of storms and drought may cause harm to canopy trees and reduce establishment of seedlings - Change in community dynamics among native and invasive species - Competition with invasive species and vines may also hinder regeneration
	Relative Impact on Functional Processes (BMP Effectiveness)	- Reduced forest regeneration success - Increased competition between natives and invasive species hinders forest regeneration
	Effects on carbon cycle, greenhouse gases	- Regrowth of forests slowly rebuilds C stores - Factors that inhibit regeneration inhibit forest delineation as a C sink.
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Depends on management strategies and plant needs
	Management Adaptation Strategies	- Assist plant migration when habitats become too warm or dry - Increase rotation period lengths - Reduce rotation length in susceptible stands - Select hardy tree species in regeneration efforts - Control weeds - Maintain large populations and genetic diversity - Plant in autumn and place saplings in pots to mitigate effects of drought - Change wood processing technology to use different tree species and quality levels to increase post-harvest salvage - Even application of resources and symmetrical development of roots can increase resistance to wind
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Coutts et al. 1999; Cristan et al. 2016; Kolstrom et al. 2011; NASF 2017b; Ogden and Innes 2008; SFC 2010; UAF 2017; Borja 2014; Ochterski 2004a; Rustad et al. 2011; Swetnam and Betancourt 1997; USGS 1997

18-Slash management		
General Characteristics		
	Geographic applicability	Marine West Coast Forests; Western Forested Mountains; Eastern Temperate Forests; Tropical Wet Forests; Southern Semi-Arid Highlands
	Functions	- Mitigate runoff from harvest operations - Remove breeding sites for pests - Reduce fuel loads
Climate Sensitivities		
	Key climatic drivers	- Winter temperature - PET/soil moisture
	Climate change sensitivity	- Inappropriate management of slash can promote proliferation of insect pests, such as bark beetles, by providing breeding habitat - Large quantities of slash also increase fuel loads, increasing fire potential - Increased thinning operations to remove stands damaged by climate changes will produce higher quantities of slash, magnifying these issues
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increases in pest populations pose risks to inappropriately managed slash - Increased fire potential with slash as fuel loads - Thinning operations necessary when pests and disease increase slash quantities - C is lost in harvest but can be managed through slash management
	Effects on carbon cycle, greenhouse gases	C is lost during the removal of trees and decay of slash materials
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Depends on management strategies and plant needs
	Management Adaptation Strategies	- Remove slash manually or by prescribed burning where slash presents an issue as pest breeding habitat or fuel load - Pile slash parallel to logging roads to trap sediment runoff from harvest operations and use slash economically - Remove slash from waterways
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; NASF 2017b; SDSU 2003; Weatherspoon and Skinner 1995; Carey and Schumann 2003; Gara et al. 1999; Grodzki 1997; Jactel et al. 2009; Rothermel 1983; Six et al. 2002; SDSU 2003

19-Streamside management zones (SMZs)		
General Characteristics		
	Geographic applicability	All forested ecoregions
	Functions	- Reduce impact of land use activity - Trap sediment from runoff - Reduce soil erosion impacts - Reduce nutrient input - Provide shade to keep stream temperatures low
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity
	Climate change sensitivity	- Increased frequency and intensity of extreme precipitation events associated with climate change could increase flow velocity and thereby decrease efficiency of buffer filtering - Extreme precipitation events may also form gullies in buffers, which disrupt sediment trap processes - Changes in forest species composition may change nutrient filtering and shading capabilities - Increased tree mortality changes the width, density, and composition of buffers, which could reduce their efficiency - In some cases, increased CO_2 may increase tree growth and therefore density of buffers, increasing their utility
	Relative Impact on Functional Processes (BMP Effectiveness)	- Increased flow velocity and decreased efficiency of filtering - Disrupted sediment trap processes - Change in species composition may change nutrient filtering and shading abilities - Tree mortality decreases width, density, and efficacy of buffers - (Wetter growing season) Increased growth rates and ability to filter nutrients - (Drier growing season) Decreased growth rates and ability to filter nutrients - Increase in tree growth rate associated with increases in CO_2
	Effects on carbon cycle, greenhouse gases	- Increased CO_2 concentrations may increase tree growth rates which would in turn increase SMZ density, however, dry and warm regions are expected to have low growth rates despite increase CO_2. - Use of dense buffers can help maintain C stores by supporting healthy vegetation growth
	Relative Climate Sensitivity	High
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term
	Management Adaptation Strategies	- Increase use of SMZs to protect water quality - Promote buffer width and density where possible to enhance the ability of the buffer to absorb nutrients and filter sediment - Use Effective Function Width tool to assess and maintain effectiveness of stream buffers
	Relative Climate Adaptability	Medium
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; Marion et al. 2013; NASF 2017b; Dillaha et al. 1989 cited in Osborne and Kovacic 1993; Gough 1988 cited in Osborne and Kovacic 1993; Herricks and Osborne 1985 cited in Liu et al. 2008; Leinenbach 2016; Liu et al. 2008; O'Gorman and Schneider 2009; Osborne and Kovacic 1993; Perkey 1990 cited by Osborne and Kovacic 1993; Pinay and Decamps 1988; Rier et al. 2005; Williamson and Zagarese 2003, cited in Palmer et al. 2009

20-Instream large woody debris		
General Characteristics		
	Geographic applicability	Marine West Coast Forests; Western Forested Mountains; Eastern Temperate Forests; Taiga
	Functions	- Provide nutrients to waterways - Create habitat diversity for aquatic life - Establish eddies, cover, anchoring points, and calm water for aquatic organisms - Decrease flow velocity - Increase retention time
Climate Sensitivities		
	Key climatic drivers	- Precipitation volume - Precipitation intensity - Winter temperature
	Climate change sensitivity	- Storm events and variable wind speeds, which are expected to occur more frequently with climate change, may increase the prevalence of LWD - Increased tree mortality as a result of infection, infestations, competition, and wildfires may also increase LWD quantities - Increased frequency and severity of precipitation could increase flooding risk where LWD is present, necessitating more active removal of LWD, which is typically advised against by LWD BMPs
	Relative Impact on Functional Processes (BMP Effectiveness)	- Extreme weather events increase generation of LWD - Increased precipitation intensity increases flood risk, necessitating active removal or management of LWD - Tree mortality due to infection, infestation, competition, and fire increases generation of LWD
	Effects on carbon cycle, greenhouse gases	C remains stored in debris and is slowly released as natural decay occurs; removing LWD inhibits this process
	Relative Climate Sensitivity	Medium
Adaptation Potential		
	Flexibility/ Adaptability	- Long-term - Depends on management strategies and plant needs
	Management Adaptation Strategies	- Avoid removal of LWD in streams where it does not pose an active flood risk - Use debris generated by forestry activities such as logs, slash, litter, and organic soil matter to perform similar functions as LWD (in appropriate quantities) - Show preference for trees leaning away from the streambank during harvest, as those leaning towards the stream will fall and provide stream habitat
	Relative Climate Adaptability	High
Supporting Literature		
	Supporting Literature	CEC n.d.; Cristan et al. 2016; Dressing 2003; Linohss et al. 2012; NASF 2017b; Phillips et al. 2000; Marin County 2007; Pryor and Barthelmie 2010; Vose et al. 2012b

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