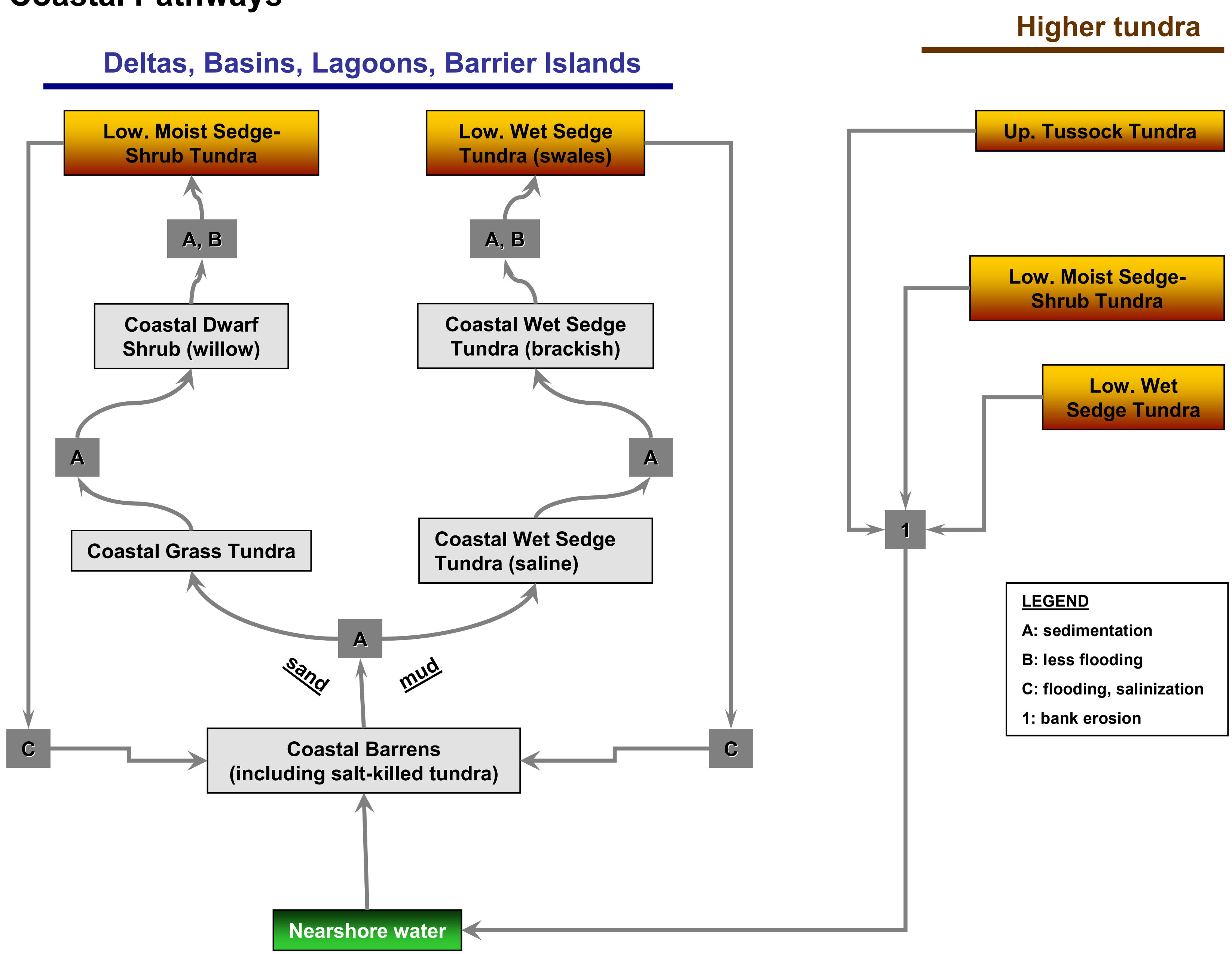
This page intentionally blank

Coastal Pathways



Section 5

Pathways of Ecosystem Change

Ecosystems will change in response to vegetation succession over time, soil development, erosional and depositional processes associated with geomorphic processes, permafrost dynamics, hydrologic shifts, and climate change. Assessment of the potential changes in vegetation and associated ecosystem characteristics can be organized by ecoregion, or broad physiographic characteristics, to better partition the variability in ecosystem responses. Presented below are conceptual models of ecological pathways, or the shifts from one ecosystem to another in response to environmental changes, for the coast, coastal plain, floodplain (riverine), and foothill (uplands) physiographic environments of northern Alaska. The pathway diagrams identify the patterns (classes of ecotypes) and processes responsible (indicated by arrows and accompanying text). The diagrams illustrate what we can expect to be "winners" and "losers" from predicted climate change.

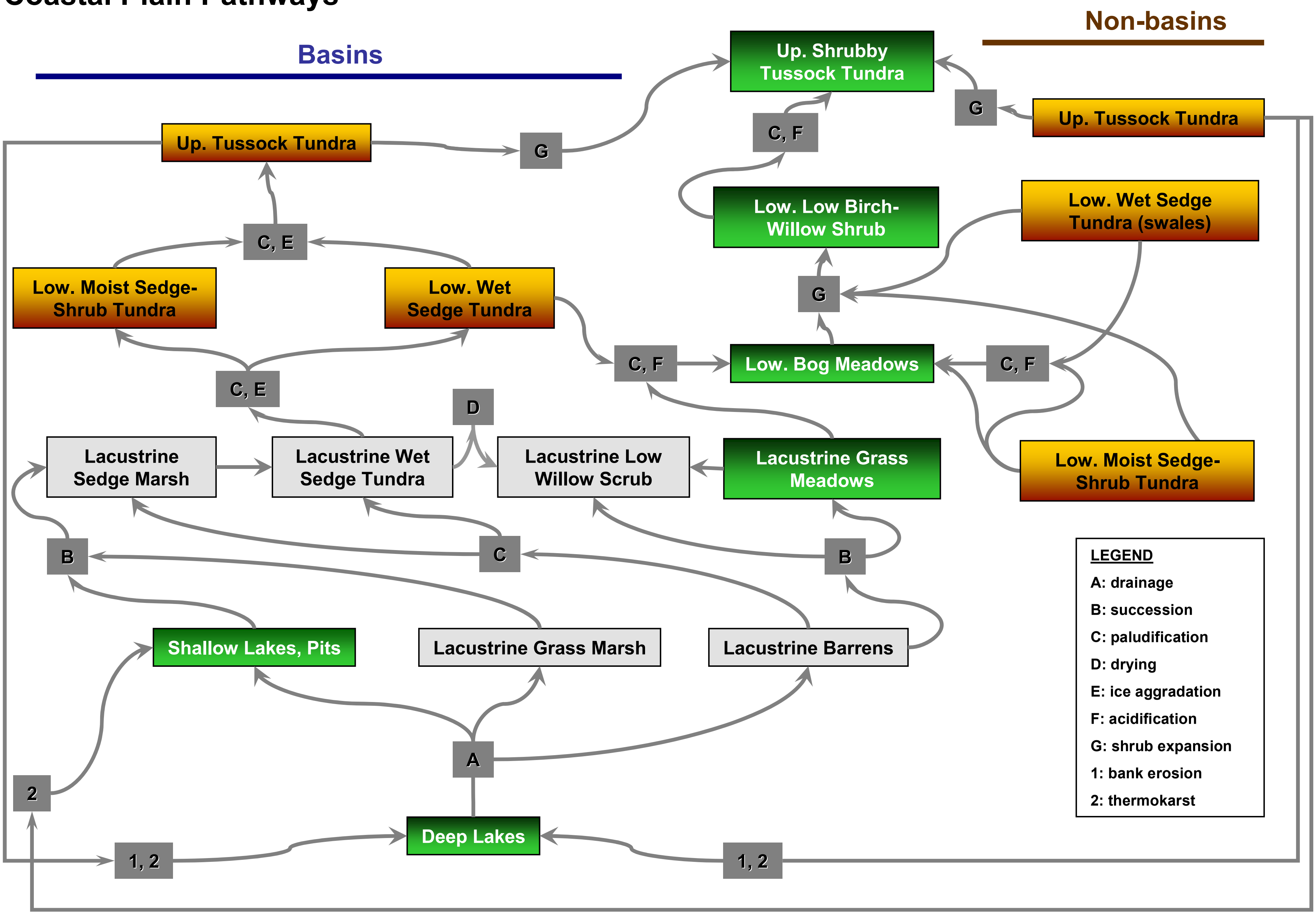
Coastal Ecosystems

Coastal ecosystems are dominated by coastal water, coastal barrens (mudflats, barrier islands, spits, sand dunes), coastal wet sedge tundra (saline, dominated by *Carex subspathaceae* and *Pucinellia phryganodes*), coastal sedge tundra (brackish, dominated by *Carex aquatilis, Dupontia fisheri*), coastal grass tundra (*Leymus mollis*), and coastal dwarf shrub (*Salix ovalifolia*). Distribution of these ecotypes are affected by shoreline erosion, flooding from storms and sea-level rise, salinity, sedimentation, and soil drainage related to soil texture and topographic position (Figure 5.1).

Coastal water is expected to expand in area, at the expense of lowland wet sedge tundra, lowland moist sedge-shrub tundra, and upland tussock tundra, as a result of shoreline erosion. Accelerated shoreline erosion is anticipated in response to decreased sea ice, increased open-water fetch, and longer ice-free season. Lacustrine wet sedge tundra and lacustrine moist sedge-shrub tundra in low-lying drained-lake basins also will decrease due to flooding and salinization of inland habitats. Most coastal ecosystems are likely to maintain current abundance, however, because they are well adapted to the highly dynamic coastal margin.

Figure 5.1 (facing page). Predicted pathways of changes in coastal ecosystems in response to climate change and geomorphic processes. For ecotypes, green boxes indicate an increase, grey boxes indicate little change, and orange boxes indicate a decrease.

Coastal Plain Pathways

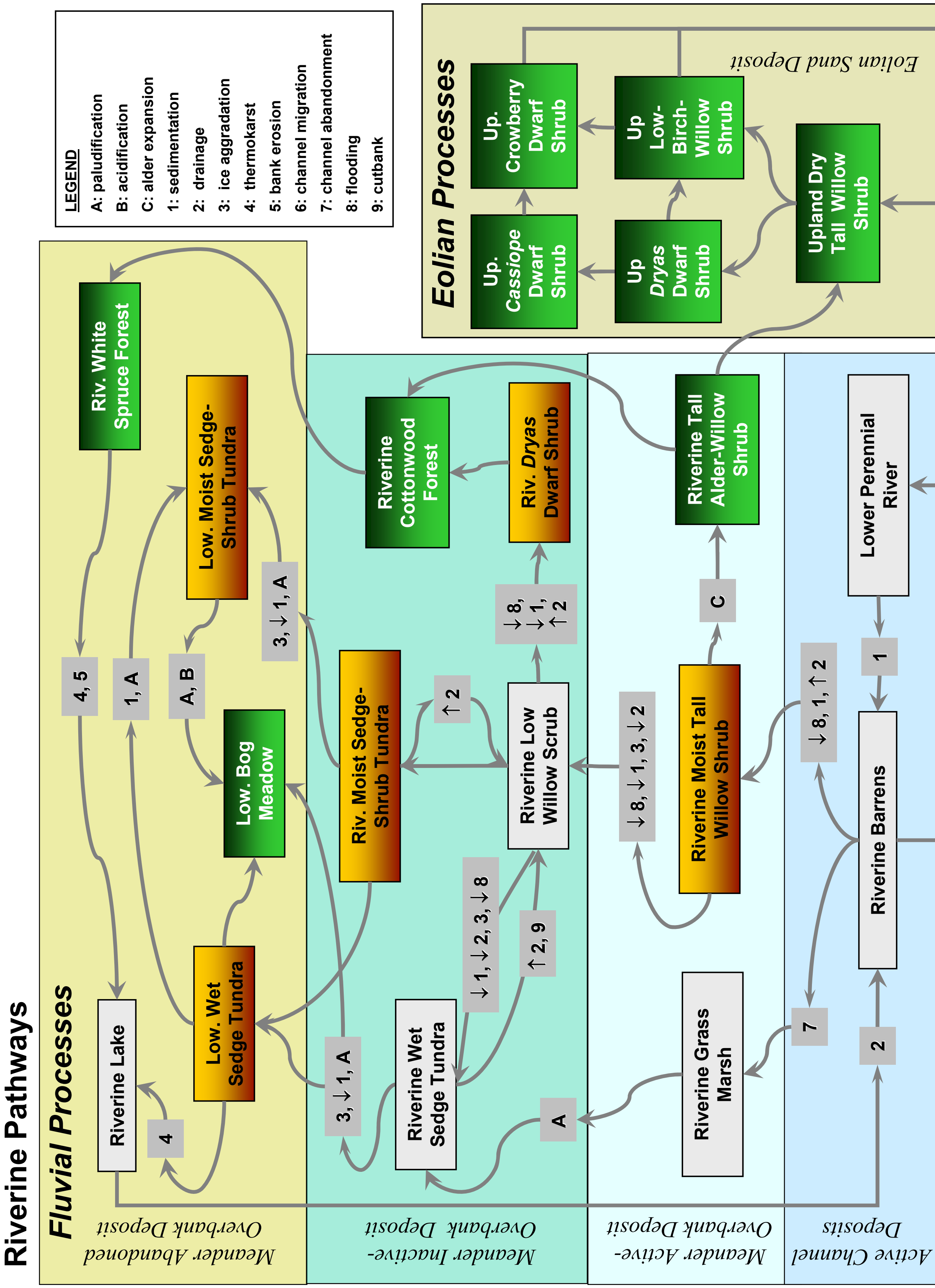


Coastal Plain Ecosystems

The coastal plain has a wide diversity of ecosystems that includes early successional lacustrine ecosystems that are closely linked to fluctuating lake levels and recently exposed sediments in drained-lake basins. Lacustrine ecosystems evolve into late-successional lowland ecosystems that develop in ice-rich drained lake basins, where polygonal networks of ice-wedges impede surface-water and nutrient flow and create higher microsite variability (Figure 5.2). The higher terrain in between the lakes and basins support both upland and lowland ecosystems. Lacustrine ecosystems include deep lakes (>1.5 m), shallow lakes and ponds (<1.5 m), lacustrine grass marsh (dominated by *Arctophila fulva* in water >0.3 m deep), lacustrine sedge marsh (*Carex aquatilis* and *Eriophorum angustifolium* in water 0.1–0.3 m deep), lacustrine wet sedge tundra (*Carex aquatilis, Eriophorum angustifolium*, forbs and mosses in water <0.1 m deep), lacustrine low willow shrub (*Salix lanata, S. planifolia*). In warmer regions, lacustrine grass meadows (*Calamagrostis canadensis*) are abundant in moist, recently drained lake basins. Lowland ecotypes in older basins characterized by well developed ice-wedge polygons include lowland wet sedge tundra and lowland moist sedge-shrub tundra (*C. aquatilis, C. bigelowii, Dryas integrifolia, S. lanata, S. planifolia*). Where ice-aggradation causes substantial surface heave, such as in the silt-rich centers of old, drained lake basins, upland tussock tundra (*Eriophorum vaginatum*) can replace earlier ecotypes. The older, higher terrain between basins also support lowland wet sedge tundra in swales, lowland moist sedge-shrub tundra on lower slopes, and upland tussock tundra on upper slopes and gentle ridges.

Ecosystems on the coastal plain are likely to be seriously affected by shoreline erosion and lake drainage, thermokarst, changing hydrologic regimes, paludification and acidification, and shrub expansion. Shoreline erosion by wind-driven waves and lake expansion from thermokarst is expected to continue and may increase with a longer ice-free season and warmer water. Lake expansion may affect ~1–3% of the landscape. Most drained-lake basins formed during a period of extensive drainage during the mid-Holocene, and contemporary lake drainage is uncommon. With expected warming, however, degradation of ice-wedges, which can integrate into drainage channels with a lower base elevation, may increase the drainage of lakes. Degradation of ice wedges creates thermokarst pits and troughs that are initially filled with open water, later colonized by lacustrine sedge marsh, and eventually by lacustrine wet sedge tundra. In terrain where ice wedges are particularly abundant, 20–30% of the landscape could be affected. An increase or decrease in precipitation is likely to have only minor effects on coastal plain ecosystems. The above- and below-ground water storage capacity is filled during snow melt each year, so water levels mostly will be affected during mid-summer. The mid-summer changes probably are not sufficient to alter the distribution of lowland and lacustrine ecotypes. Paludification and acidification are likely to have major effects. Organic-matter accumulation alters micro-topography and can raise the ground surface relative to the water level. Soils can be leached and acidified by increased precipitation or by colonization by *Sphagnum* mosses. *Sphagnum* moss, which can contribute to rapid acidification, is abundant in wet habitats in warmer climates, such as on the Seward Peninsula, and has been observed to be colonizing recent thermokarst pits. Acidification impedes nutrient availability, lowers productivity, and creates habitat for slower growing sedges and ericaceous shrubs. Most lowland wet sedge tundra is likely to shift to lowland bog meadows. Warmer temperatures likely will lead to increased growth of shrubs, although the change will involve a complex interaction of soil temperature, drainage, snow depth, competition, and herbivory.

Figure 5.2 (facing page). Predicted pathways of changes in lowland and lacustrine ecosystems on the coastal plain in response to climate change and geomorphic processes. For ecotypes, green boxes indicate an increase, grey boxes indicate little change, and orange boxes indicate a decrease.



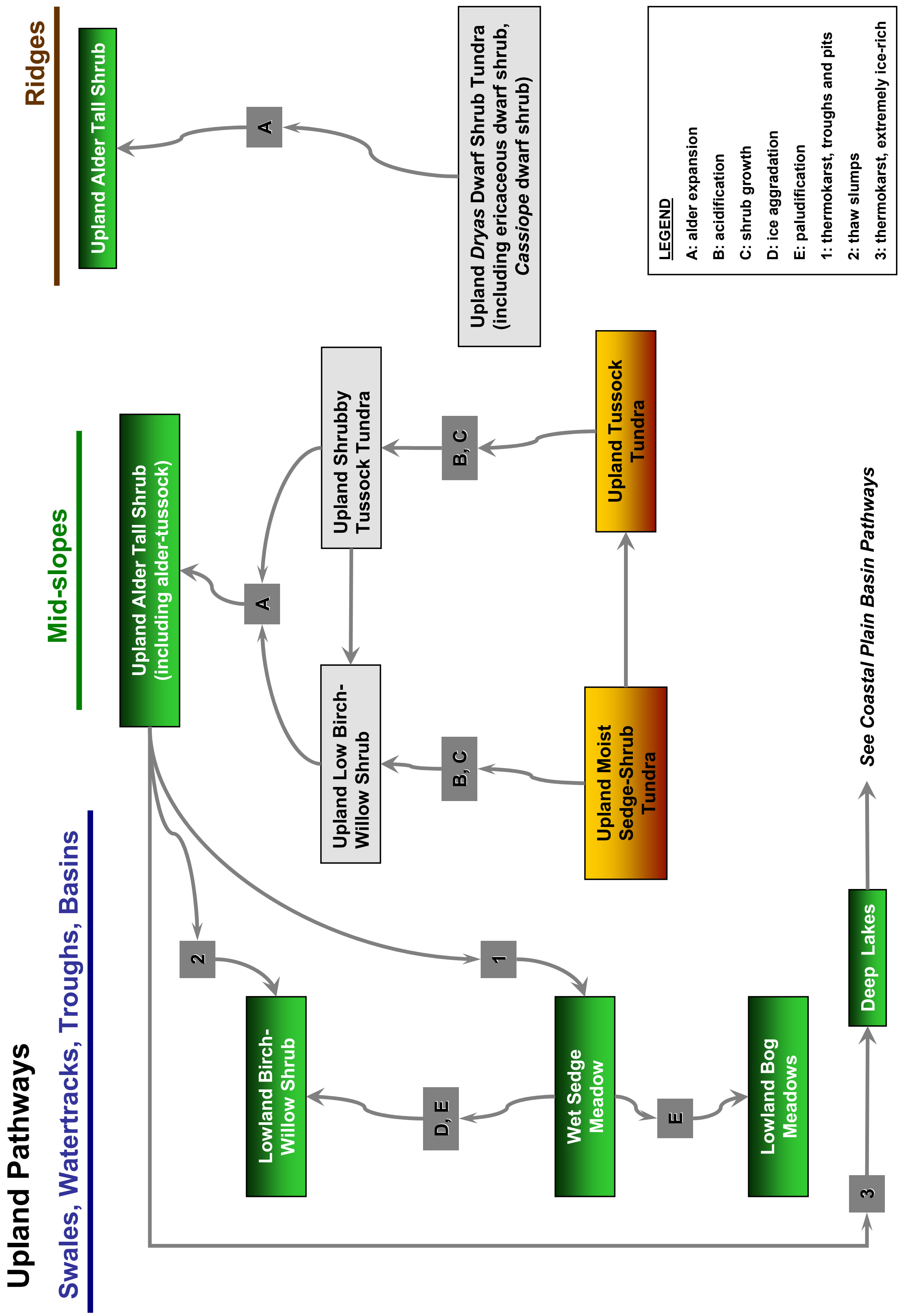
Riverine Pathways
Fluvial Processes
Eolian Processes
LEGEND
A: paludification
B: acidification
C: alder expansion
1: sedimentation
2: drainage
3: ice aggradation
4: thermokarst
5: bank erosion
6: channel migration
7: channel abandonment
8: flooding
9: cutbank
Meander Abandoned Overbank Deposit
Meander Inactive-Overbank Deposit
Meander Active-Overbank Deposit
Active Channel Deposits
Eolian Sand Deposit
Riverine Lake
Low. Wet Sedge Tundra
Low. Bog Meadow
Low. Moist Sedge-Shrub Tundra
Riv. White Spruce Forest
Riverine Wet Sedge Tundra
Riv. Moist Sedge-Shrub Tundra
Riverine Low Willow Scrub
Riverine Cottonwood Forest
Riv. Dryas Dwarf Shrub
Riverine Grass Marsh
Riverine Moist Tall Willow Shrub
Riverine Tall Alder-Willow Shrub
Riverine Barrens
Lower Perennial River
Up. Cassiope Dwarf Shrub
Up. Crowberry Dwarf Shrub
Up Dryas Dwarf Shrub
Up Low-Birch-Willow Shrub
Upland Dry Tall Willow Shrub
4
4, 5
1, A
A, B
3, ↓1, A
3, ↓1, A
↑2
↓1, ↓2, 3, ↓8
↑2, 9
↓8, ↓1, ↑2
A
↓8, ↓1, 3, ↓2
C
7
↓8, 1, ↑2
1
2
5,6

Riverine Ecosystems

Riverine ecosystems that develop on floodplains include: early to mid-successional ecosystems that develop on active and inactive floodplains subject to frequent flooding and sedimentation; late successional lowland ecosystems that develop on abandoned floodplains that are rarely flooded; and upland ecosystems that develop on well-drained dunes that develop downwind of barren riverbars (Figure 5.3). Riverine ecotypes include: flowing rivers; riverine lakes and riverine grass marsh (*Arctophila fulva*) that form in abandoned channels; riverine barrens; riverine tall alder-willow shrub (primarily *Salix alaxensis* on North Slope) with well-drained soils; riverine low shrub (*Salix lanata, S. planifolia*) on moderately drained soils, riverine wet sedge tundra on wet soil, riverine moist sedge-shrub on moist soils, and riverine *Dryas* dwarf shrub (*D. integrifolia, D. drummondii*). Lowland ecotypes on older, abandoned floodplains include lowland wet sedge tundra and lowland moist sedge-shrub tundra. Sand dunes with active deposition of wind-blown sand support upland dry tall willow shrub and inactive dunes support the late-successional ecotypes upland *Dryas* dwarf shrub and upland *Cassiope* dwarf shrub. In warmer climates, such as the lower Noatak valley, riverine tall alder-willow shrub (*Alnus crispa, A. tenuifolia, Salix alaxensis*), riverine cottonwood forest (*Populus balsamifera*), and riverine white spruce forest (*Picea glauca*) develop on active and inactive floodplains.

Riverine ecotypes are affected by channel migration and bank erosion, flooding and sedimentation, ice aggradation during floodplain evolution, thermokarst, paludification, and tree and shrub migration. Channel migration erodes late successional riverine and lowland ecotypes and converts terrestrial ecosystems to water. Flooding, sedimentation, and nutrient input are closely interrelated; lower floodplains receive more flooding and coarser-textured sediment, and higher floodplains receive less flooding and finer-textured sediments. As the sediments build up, flooding, sedimentation, and nutrient input are reduced. Ice aggradation during floodplain development under cold climates also raises the surface and, thus, affects flooding frequency. The ice aggradation also makes the ground more sensitive to thermokarst, and thermokarst lakes are abundant on older floodplains. Vegetation development on floodplains contributes to organic matter accumulation. Organic-matter accumulation and leaching over time contribute to acidification of late-successional ecotypes. Lowland wet sedge tundra and lowland moist sedge-shrub tundra are likely to be colonized by *Sphagnum* mosses and replaced by lowland bog meadows. Thermokarst on ice-rich abandoned floodplains is likely to increase and create more riverine lakes and riverine barrens after the lakes are tapped and drained. Floodplains make good corridors for rapid migration of alder, cottonwood, and white spruce because of the transport of seed by flowing water. With climate warming, riverine moist low willow shrub common on the North Slope is likely to be replaced by riverine tall alder-willow shrub common in the southern Brooks Range. Riverine cottonwood forests are likely to expand quickly, while the migration of riverine white spruce forests likely will be slow.

Figure 5.3 (facing page). Predicted pathways of changes in riverine ecosystem types in response to climate change and geomorphic processes. For ecotypes, green boxes indicate an increase, grey boxes indicate little change, and orange boxes indicate a decrease.


Upland Pathways
Ridges
Upland Alder Tall Shrub
A
Upland Dryas Dwarf Shrub Tundra (including ericaceous dwarf shrub, Cassiope dwarf shrub)
Mid-slopes
Upland Alder Tall Shrub (including alder-tussock)
A
Upland Shrubby Tussock Tundra
B, C
Upland Tussock Tundra
Upland Low Birch-Willow Shrub
B, C
Upland Moist Sedge-Shrub Tundra
Swales, Watertracks, Troughs, Basins
2
1
Lowland Birch-Willow Shrub
D, E
Wet Sedge Meadow
E
Lowland Bog Meadows
3
Deep Lakes
See Coastal Plain Basin Pathways
LEGEND
A: alder expansion
B: acidification
C: shrub growth
D: ice aggradation
E: paludification
1: thermokarst, troughs and pits
2: thaw slumps
3: thermokarst, extremely ice-rich

Upland Ecosystems

Upland ecosystems in the Arctic Foothills are dominated by shrub-dominated vegetation. Dominant ecotypes include upland *Dryas* dwarf shrub (*Dryas octopetala, D. integrifolia*, and also lumps together ericaceous- and *Cassiope*-dominated dwarf shrub communities) on dry rocky ridges, upland low birch-willow shrub (*Betula nana, S. planifolia, S. glauca*) on better drained soils, upland shrubby tussock tundra (*Betula nana, S. planifolia, Eriophorum vaginatum*) and upland tussock tundra (*E. vaginatum*) on saturated organic-rich soils, and upland moist sedge-shrub tundra (*C. bigelowii, Dryas integrifolia*) on circum-alkaline soils (Figure 5.4). Less common are lowland wet sedge tundra and lowland low birch-willow shrub that occur in swales, toe-slopes, and basins. Upland tall alder shrub is relatively rare but has been expanding slowly over the past century.

Upland ecosystems are strongly affected by soil drainage, ice aggradation at the top of the permafrost, slope failure, thermokarst, leaching and acidification, and shrub expansion on better-drained soils. Hillsides have a steep soil moisture gradient from dry rocky ridges through moderately drained slopes to poorly drained swales and basins. This gradient will be sensitive to changes in summer precipitation and snow redistribution. Increased air and soil temperatures, and possibly improved soil drainage with thicker active layers, probably will lead to conversion of upland tussock tundra to upland shrubby tussock tundra and to upland tall alder shrub. Upland *Dryas* dwarf shrub will mostly persist but in places could be converted to upland low birch-willow shrub and upland tall alder shrub. Slopes are sensitive to active-layer detachment slides and thaw slumps because of the formation of an ice-rich layer at the top of the permafrost. Sudden thawing of this layer during warm summers can lead to supersaturation of soil at the base of the active layer and downhill saturated flow of the active-layer soil. Once exposed, the permafrost can continue to thaw in retrogressive thaw slumps. Sediments released from these slides usually are transported to streams and alter water quality. Upland tussock tundra and upland shrubby tussock tundra will be highly susceptible to thaw slumps. In areas of extremely ice-rich loess, which is common along the lower foothills, thawing can lead to 10–25 m of ground collapse. In these areas, where upland tussock tundra, upland shrubby tussock tundra, and upland moist sedge-shrub predominate, thermokarst will lead to the formation of deep thaw lakes. Soil chemistry is sensitive to leaching from precipitation inputs. Consequently, soils tend to be alkaline on the coastal plain and lower foothills, where summer precipitation is low, and acidic in the upper foothills, where precipitation is higher. Increased precipitation can increase leaching, but the process is likely to be very slow. *Sphagnum* expansion will accelerate acidification. Upland moist sedge-shrub tundra will be somewhat susceptible to leaching and conversion to upland low birch-willow shrub. Shrub infilling (increased height and coverage) and expansion (colonization of new habitats) will likely be substantial in warming and drying soils as described above for soil drainage effects.

Figure 5.4 (facing page). Predicted pathways of changes in upland ecosystem types in response to climate change and geomorphic processes. For ecotypes, green boxes indicate an increase, grey boxes indicate little change, and orange boxes indicate a decrease.