CHAPTER 3. ECOLOGICAL DRIVERS

Management Scale

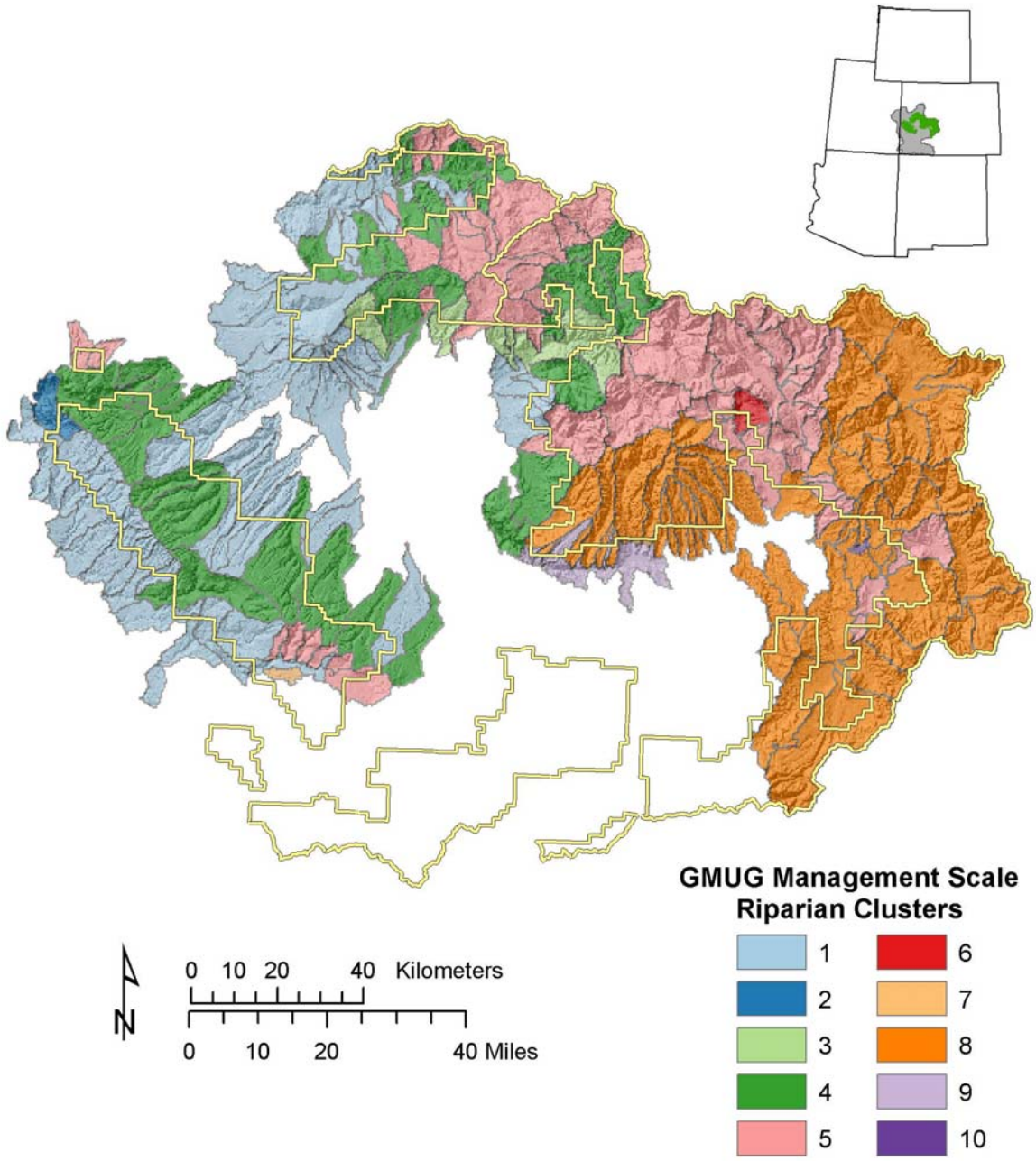
Riparian Analysis

This chapter contains the results of the ecological driver analysis associated with the GMUG. Results at this scale are influenced most directly by natural processes and management activities within the National Forest boundary (Winters et al., 2004a). Ecological processes (including species dynamics) are not limited by administrative boundaries but by ecological processes. As a result, entire HUBs are considered wherever possible instead of ending the assessment at the Forest Service boundary.

The cluster analysis of the 184, 6th level watersheds comprising the GMUG management scale produced 10 groups of watersheds (Figure 1). In order to explain the importance of and differences between hydrologic unit boundaries (HUBs), we have prepared the following section. These sections will:

1) Provide a description of the cluster analysis methodology
2) Describe the individual clusters
3) Describe the relative importance of the clusters to fisheries and aquatic productivity
4) Describe the relative importance of the clusters to riparian ecosystems and vegetation
5) Describe the sensitivity of the clusters to alterations of the sediment regime and hydrology from natural and anthropogenic disturbances

Figure 1. Map of the management scale ecological driver cluster analysis for aquatic and riparian systems.



Cluster Identification

A dendrogram is used to illustrate the results associated with the clustering technique (Figure 2). The numbers and colors identify the resultant cluster number, while the letters within the dendrogram identify the significant breakpoints within the data. This cluster process is further described in detail by Winters et al., (2004a). Tabular data identifying the mean percentages of each driver within each break group is represented in Table 1. The purpose of the following section is to present and explain the differences in

the distribution of ecological drivers and show how the clusters were subdivided into similar groups.

Figure 2. Dendrogram of the management scale ecological driver cluster analysis for the GMUG. Colors and numbers identify clusters, while letters identify significant differences in the distribution of ecological drivers.

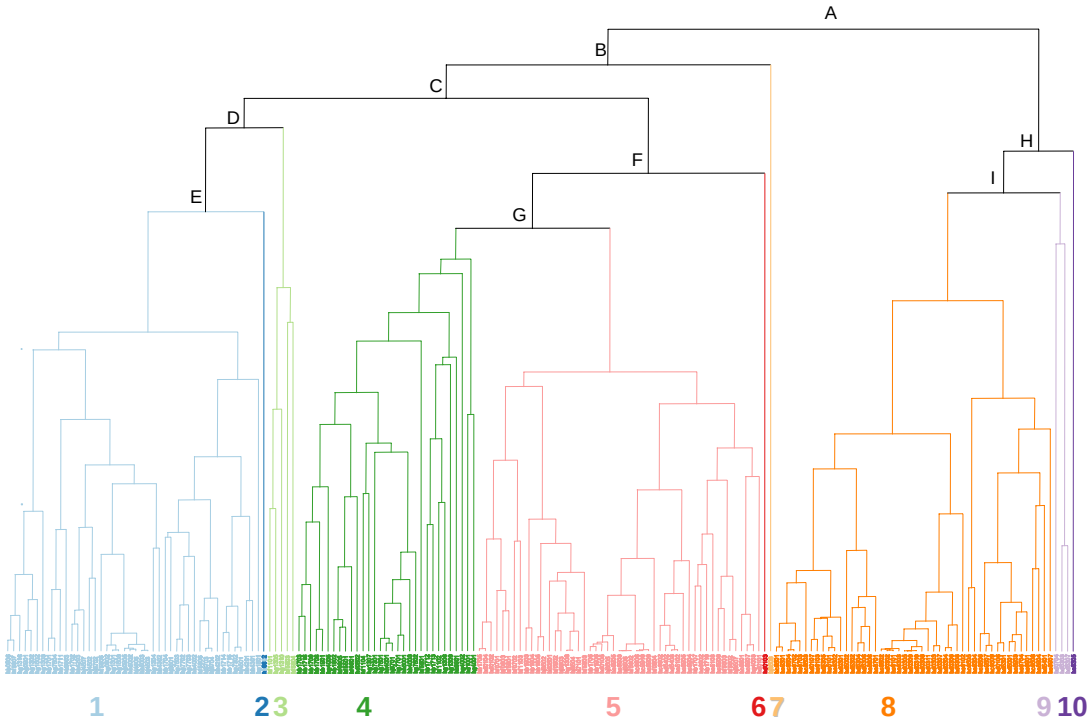


Table 1. Mean percent area for each ecological driver summarized by breakpoint.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
A1 (clusters 1r- 7r)	7.20	**92.80**	**95.28**	4.72	32.20	18.34	**49.46**	**76.07**	17.73	6.20
A2 (clusters 8r – 10r)	2.43	**97.57**	22.39	**77.61**	0.16	4.66	**95.17**	**76.08**	16.15	7.77
B1 (clusters 1r – 6r)	7.25	**92.75**	**95.24**	4.76	32.41	17.79	**49.80**	**76.48**	17.49	6.03
B2 (cluster 7r)	0.00	**100.00**	**100.00**	0.00	4.39	**90.50**	5.11	22.44	**48.85**	28.71
C1 (clusters 1r – 3r)	7.06	**92.94**	**96.59**	3.41	**68.72**	16.98	14.30	**69.09**	24.60	6.31
C2 (clusters 4r – 6r)	7.37	**92.63**	**94.41**	5.59	10.00	18.29	**71.72**	**81.04**	13.11	5.85
D1 (clusters 1r, 2r)	1.49	**98.51**	**96.22**	3.78	**72.45**	15.70	11.85	**66.31**	26.91	6.78
D2 (cluster 3r)	**57.16**	42.84	**99.94**	0.06	35.12	28.59	36.29	**94.06**	3.79	2.15
E1 (cluster 1r)	1.53	**98.47**	**97.22**	2.78	**72.74**	15.34	11.92	**65.67**	27.41	6.92
E2 (cluster 2r)	0.00	**100.00**	52.32	47.68	**59.73**	31.52	8.76	**94.76**	4.82	0.42
F1 (cluster 4r, 5r)	6.66	**93.34**	**94.34**	5.66	10.12	18.52	**71.36**	**81.00**	13.11	5.89
F2 (cluster 6r)	**64.34**	35.66	**100.00**	0.00	0.00	0.00	**100.00**	**83.62**	13.27	3.11
G1 (cluster 4r)	5.32	**94.68**	**93.27**	6.73	23.85	33.11	43.04	**79.85**	14.02	6.13
G2 (cluster 5r)	7.50	**92.50**	**95.02**	4.98	1.44	9.28	**89.28**	**81.73**	12.53	5.73
H1 (cluster 8r, 9r)	2.48	**97.52**	21.99	78.01	0.17	4.75	**95.08**	**77.13**	16.25	6.61
H2 (cluster 10r)	0.00	**100.00**	42.41	57.59	0.00	0.00	**100.00**	22.32	11.03	**66.66**
I1 (cluster 8r)	2.63	**97.37**	23.03	76.97	0.04	3.74	**96.22**	**79.54**	14.46	6.00
I2 (cluster 9r)	0.00	**100.00**	5.37	94.63	2.14	21.02	**76.84**	38.57	45.01	16.42

Highest value is in bold
Similar Values are underlined

Mb: Metal Bearing
Mn: Non - Metal Bearing
Rs: Sedimentary Geology
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Most of the cluster groups exhibited distinctive differences among and between the driver combinations. These results would indicate a considerable difference in the way ecological processes "operate" between groups of clusters (Table 1). These differences should have important influences on physical, biological and chemical characteristics at lower scales (Winters et al., 2004 a). It is important to note that without a thorough knowledge of the anthropogenic influences within the HUBs identified, the "natural" conditions produced by the ecological drivers could be influenced heavily.

All but 2 of the "groups of clusters were dominated by non-metal producing geology, with sedimentary bedrock (Table 1). Additionally, most of the groups of HUBs were located in the snowmelt, high elevation areas of the mountains where steep terrain and stream gradients dominated. These are general observations of the cluster groups, and more detailed results of individual clusters are presented next.

Breakpoint A

Breakpoint A distinguishes clusters 1r – 7r (a1) from clusters 8r – 10r (a2) (Figure 3). 6th level watersheds in a1 tend to have a much greater proportion of their stream lengths within sedimentary geology than those in a2 (Table 2). Watersheds in a2 also tend to be at a much higher elevation as is evident in the percentage of stream length within the

snowmelt hydroclimatic regime. Non-metal bearing geology dominates both groups of clusters. This breakpoint represents the biggest deviation or least similarity between cluster groups, with group a1 being located mostly in the north west portion of the GMUG and group a2 being in the southeast portion of the Forest.

Figure 3. Cluster division associated with breakpoint A.

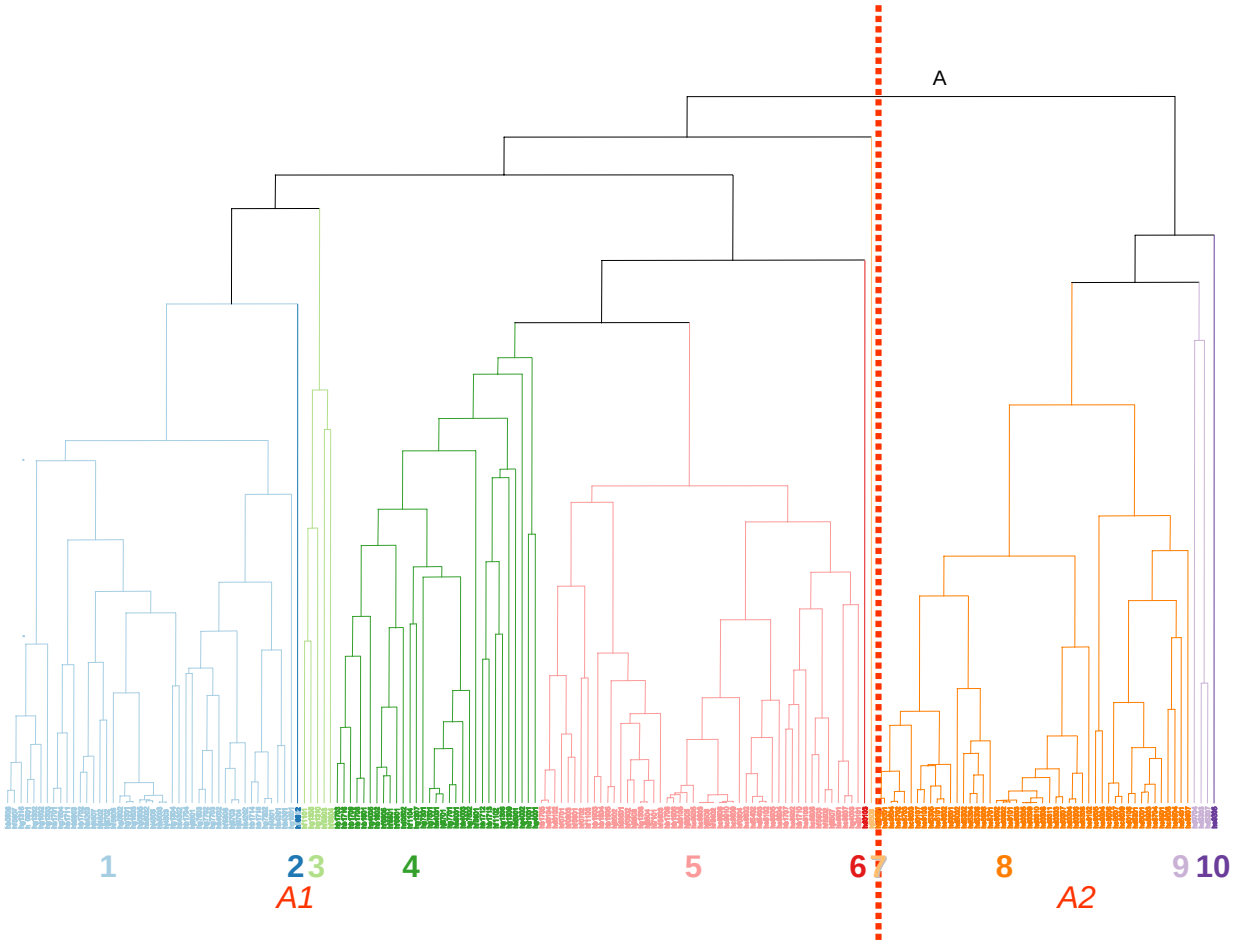

Table 2. Mean percent area for each ecological driver for breakpoint A.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
A1 (clusters 1r- 7r)	7.20	**92.80**	**95.28**	4.72	32.20	18.34	49.46	**76.07**	17.73	6.20
A2 (clusters 8r – 10r)	2.43	**97.57**	22.39	**77.61**	0.16	4.66	**95.17**	**76.08**	16.15	7.77

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High: High Gradient (> 4.0)

Breakpoint B

Breakpoint B distinguishes clusters 1r – 6r (b1) from cluster 7r (b2) (Figure 4). The HUB comprising cluster 7r is considerably different than HUBs in group b1. The HUB in b2 has a greater proportion of its stream length in the low and medium stream gradient categories (Table 3). Group b1 also has considerably more elevational range than b2, with approximately 91% of the elevation of b2 being in the rain on snow (Prs) range.

Figure 4. Cluster division associated with breakpoint B.

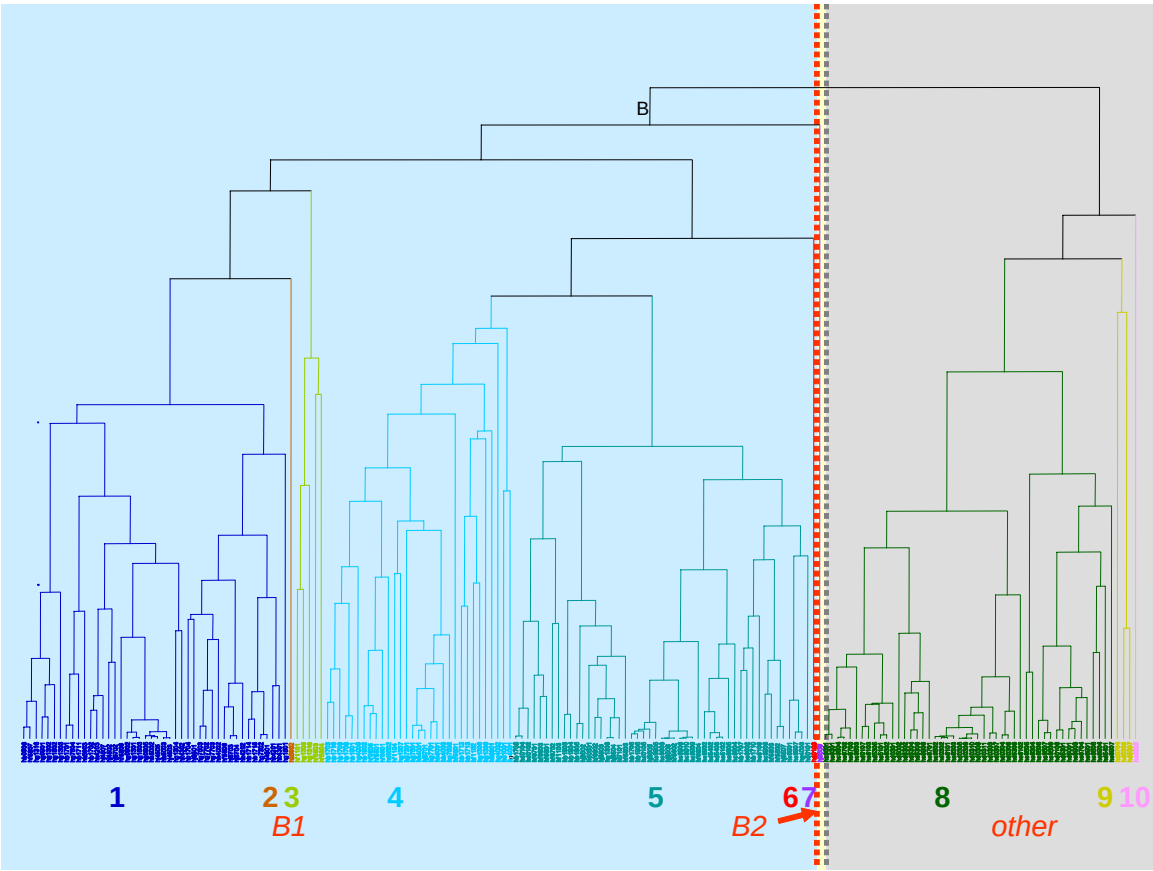

Table 3. Mean percent area for each ecological driver for breakpoint B.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
B1 (clusters 1r – 6r)	7.25	**92.75**	**95.24**	4.76	32.41	17.79	49.80	**76.48**	17.49	6.03
B2 (cluster 7r)	0.00	**100.00**	**100.00**	0.00	4.39	**90.50**	5.11	22.44	**48.85**	28.71

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High: High Gradient (> 4.0)

Breakpoint C

Breakpoint C distinguishes clusters 1r – 3r from cluster 4r – 6r (Figure 5). The major difference between c1 and c2 are found in hydroclimatic regime (Table 4). Relative to c1, c2 has a greater proportion of its stream length in a high elevation, snow driven hydroclimatic regime. C2, relative to c1 has a greater proportion of its area within a lower elevation, rainfall driven hydroclimatic regime. These differences could account for a considerable difference in species of aquatic and semi-aquatic taxa found there.

Figure 5. Cluster division associated with breakpoint C.

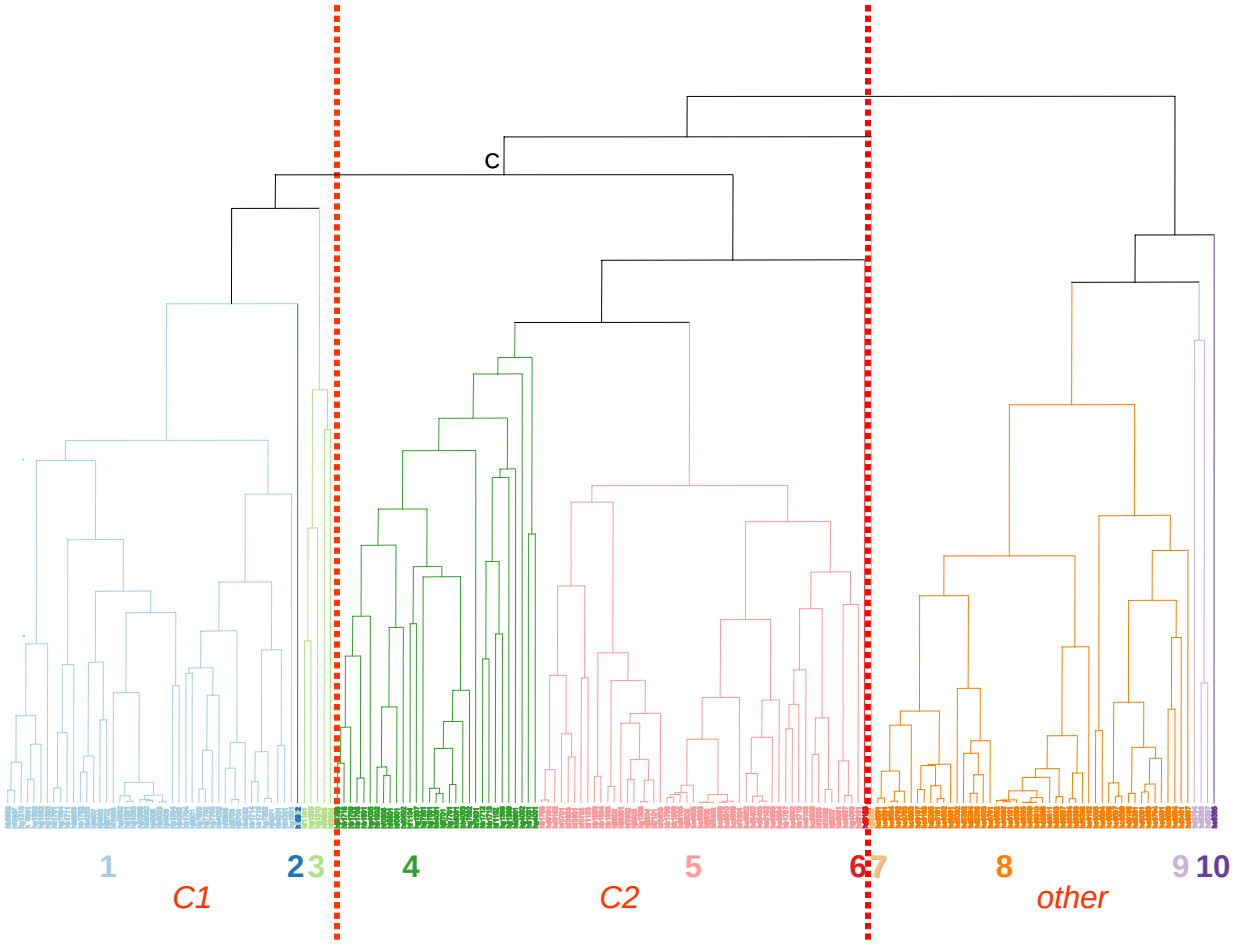

Table 4. Mean percent area for each ecological driver for breakpoint C.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
C1 (clusters 1r – 3r)	7.06	**92.94**	**96.59**	3.41	**68.72**	16.98	14.30	**69.09**	24.60	6.31
C2 (clusters 4r – 6r)	7.37	**92.63**	**94.41**	5.59	10.00	18.29	**71.72**	**81.04**	13.11	5.85

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High: High Gradient (> 4.0)

Breakpoint D

Breakpoint D distinguishes clusters 1r and 2r (d1) from cluster 3r (d2) (Figure 6). Differences are apparent in the proportion of stream length within the geologic

composition, hydroclimatic regime and stream gradient parameters (Table 5). D2 has a much greater proportion of its area within metal bearing geologic strata than does d1, while d1 has a greater proportion of its area within the rainfall hydroclimatic regime. D2 also tends to have a greater proportion of its stream length within the high gradient category than d1.

Figure 6. Cluster division associated with breakpoint D.

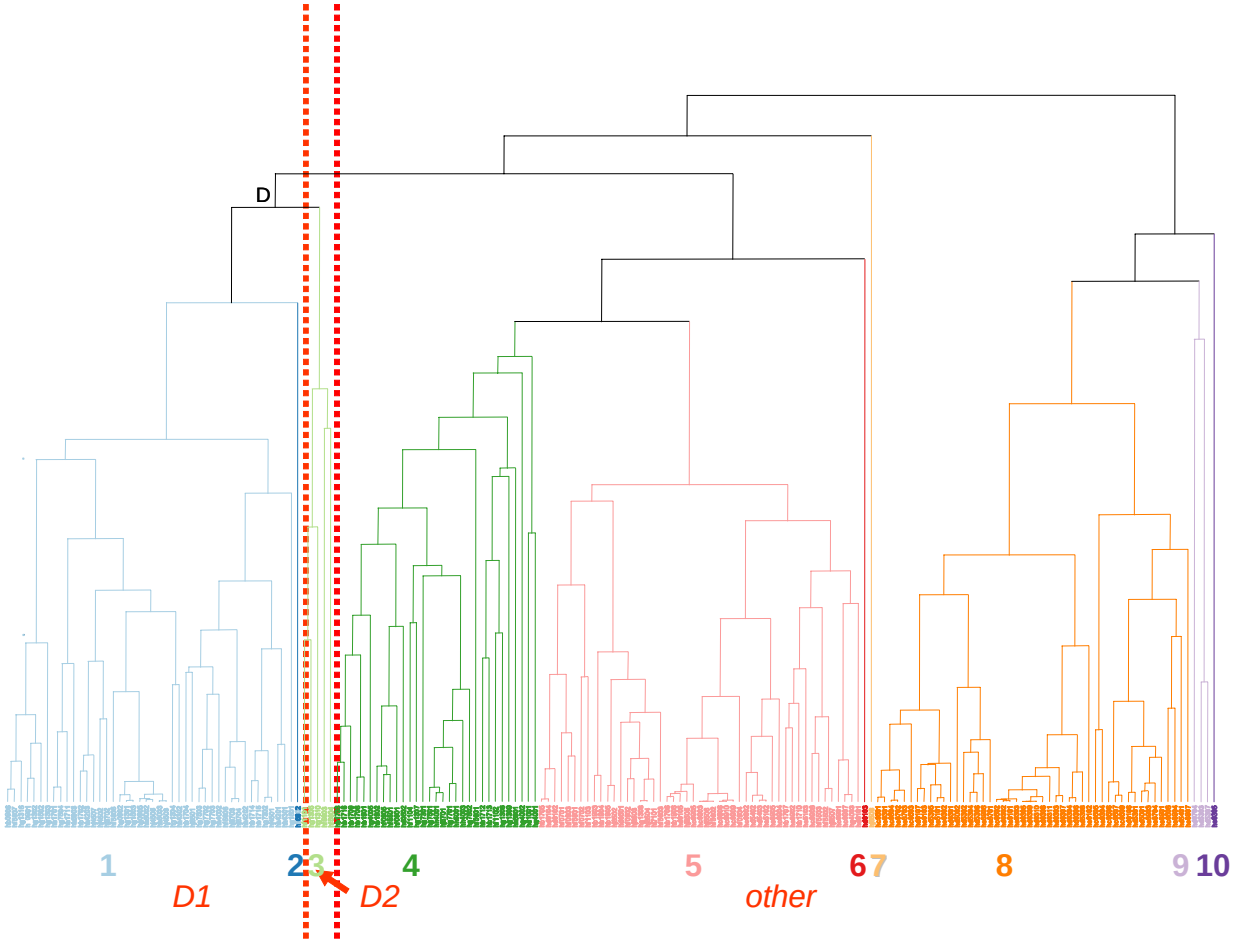

Table 5. Mean percent area for each ecological driver for breakpoint D.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
D1 (clusters 1r, 2r)	1.49	**98.51**	**96.22**	3.78	**72.45**	15.70	11.85	**66.31**	26.91	6.78
D2 (cluster 3r)	57.16	42.84	**99.94**	0.06	35.12	28.59	36.29	**94.06**	3.79	2.15

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High: High Gradient (> 4.0)

Breakpoint E

Breakpoint E distinguishes cluster 1r (e1) from cluster 2r (e2) (Figure 7). Relative to e1, e2 has a lesser proportion of its stream length underlain by sedimentary geology (Table 6). Both e1 and e2 are found on non-metal bearing strata, are largely within the rainfall hydroclimatic regime, and have a large proportion of high gradient stream channels.

Figure 7. Cluster division associated with breakpoint E.

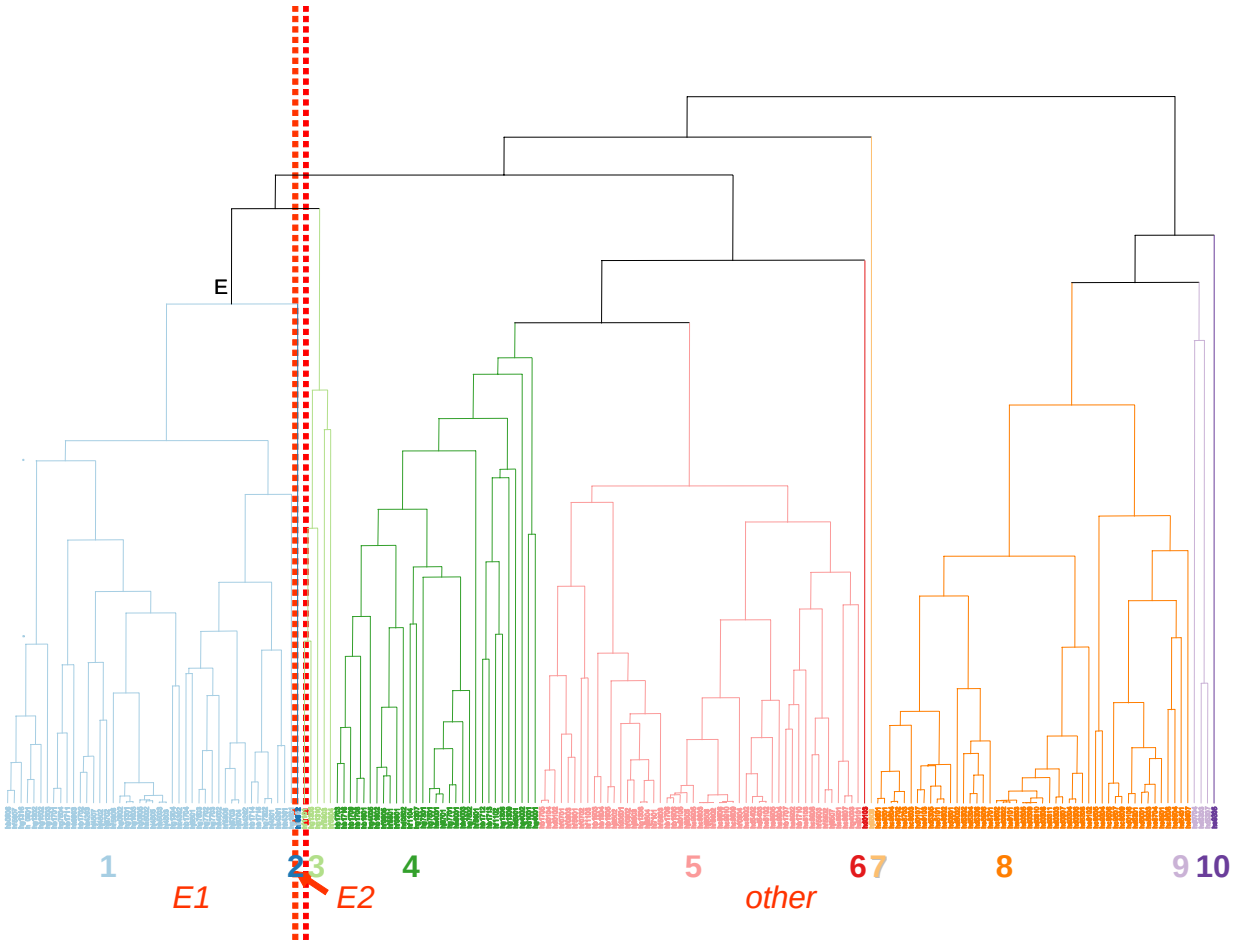

Table 6. Mean percent area for each ecological driver for breakpoint E.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
E1 (cluster 1r)	1.53	**98.47**	**97.22**	2.78	**72.74**	15.34	11.92	**65.67**	27.41	6.92
E2 (cluster 2r)	0.00	**100.00**	52.32	47.68	**59.73**	31.52	8.76	**94.76**	4.82	0.42

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Medium: Medium Gradient (2.0 - 4.0)
High: High Gradient (> 4.0)

Breakpoint F

Breakpoint F distinguishes cluster 6r (f2) from clusters 4r and 5r (f1) (Figure 8). Geologic composition provides the means of differentiation, with f2 having a higher proportion of stream length underlain by metal bearing geology than f1 (Table 7).

Figure 8. Cluster division associated with breakpoint F.

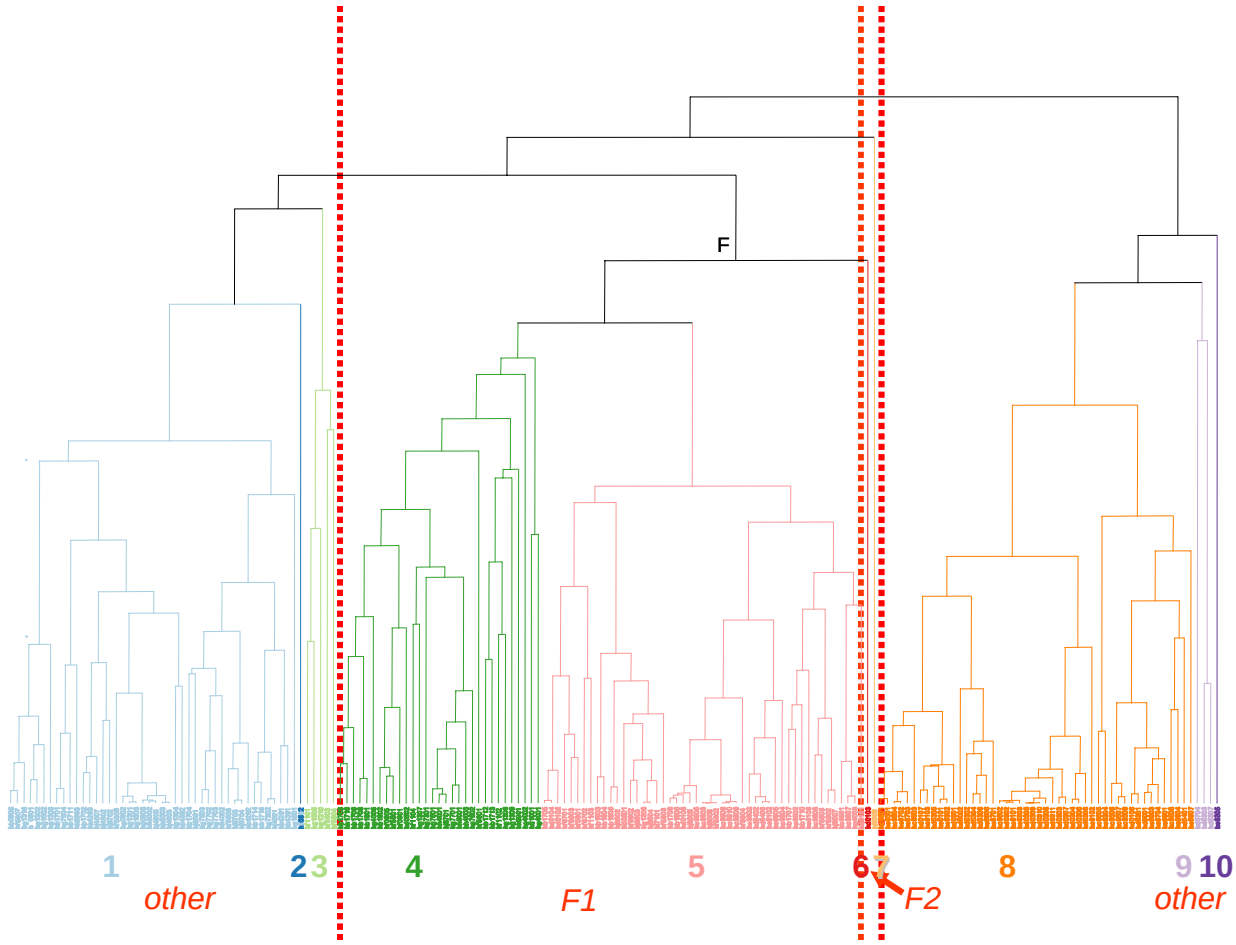

Table 7. Mean percent area for each ecological driver for breakpoint F.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
F1 (cluster 4r, 5r)	6.66	**93.34**	**94.34**	5.66	10.12	18.52	**71.36**	**81.00**	13.11	5.89
F2 (cluster 6r)	**64.34**	35.66	**100.00**	0.00	0.00	0.00	**100.00**	**83.62**	13.27	3.11

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High: High Gradient (> 4.0)

Breakpoint G

Breakpoint G distinguishes cluster 4r (g1) from cluster 5r (g2) (Figure 9). The major difference between g1 and g2 is found in the hydroclimatic regime (Table 8). Relative to g1, g2 has a greater proportion of its stream length within the snowmelt driven hydroclimatic regime, and less length within the rainfall and rain and snow hydroclimatic regimes.

Figure 9. Cluster division associated with breakpoint G.

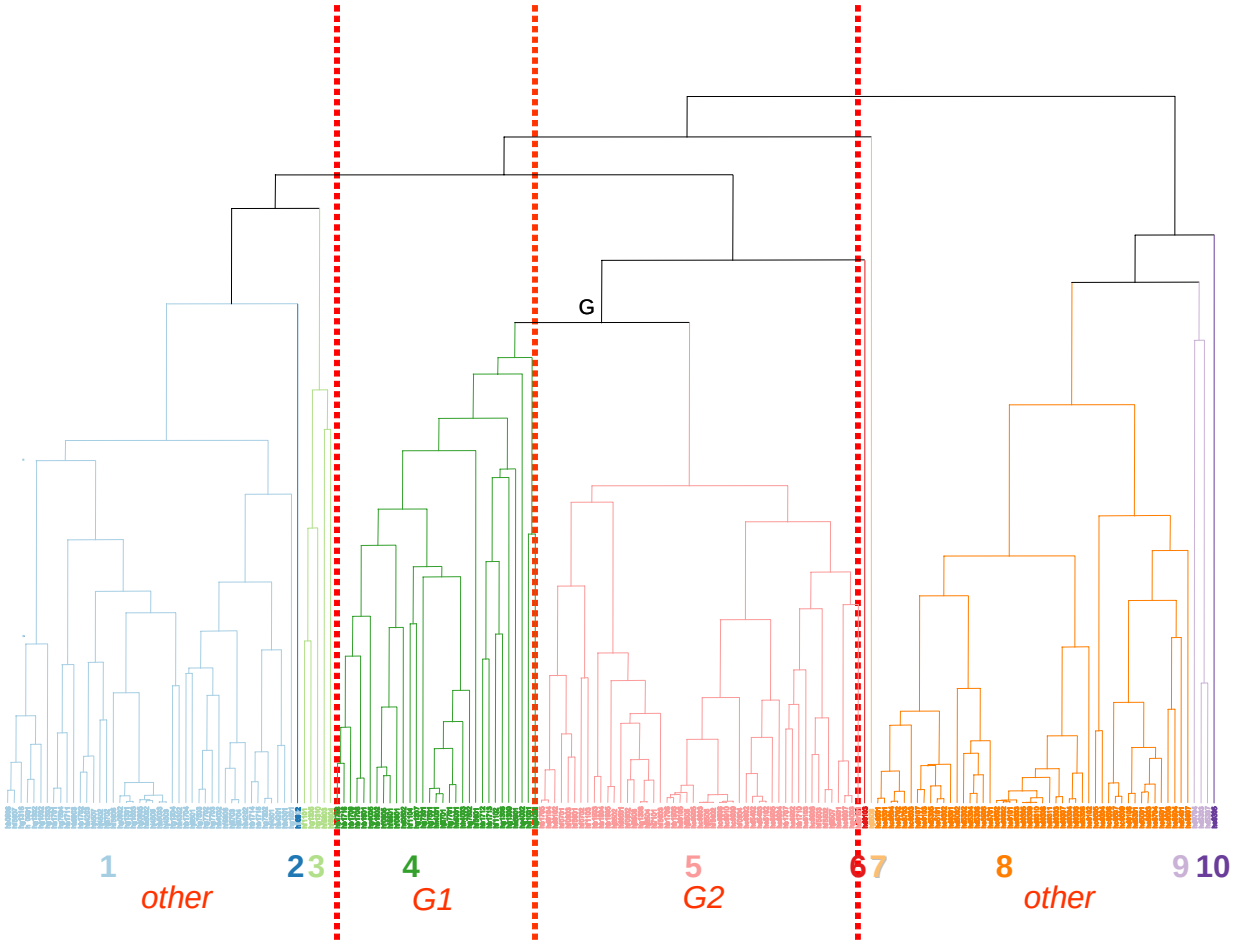

Table 8. Mean percent area for each ecological driver for breakpoint G.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
G1 (cluster 4r)	5.32	**94.68**	**93.27**	6.73	23.85	33.11	43.04	**79.85**	14.02	6.13
G2 (cluster 5r)	7.50	**92.50**	**95.02**	4.98	1.44	9.28	**89.28**	**81.73**	12.53	5.73

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High: High Gradient (> 4.0)

Breakpoint H

Breakpoint H distinguishes cluster 8r and 9r (h1) from cluster 10r (h2) (Figure 10). The major difference between h1 and h2 is found in the stream gradient parameter (Table 9). Relative to h1, h2 has a greater proportion of its stream length within the low gradient category, and less proportional length the high gradient category. Group H1also has a relatively less amount of sedimentary geology and H2.

Figure 10. Cluster division associated with breakpoint H.

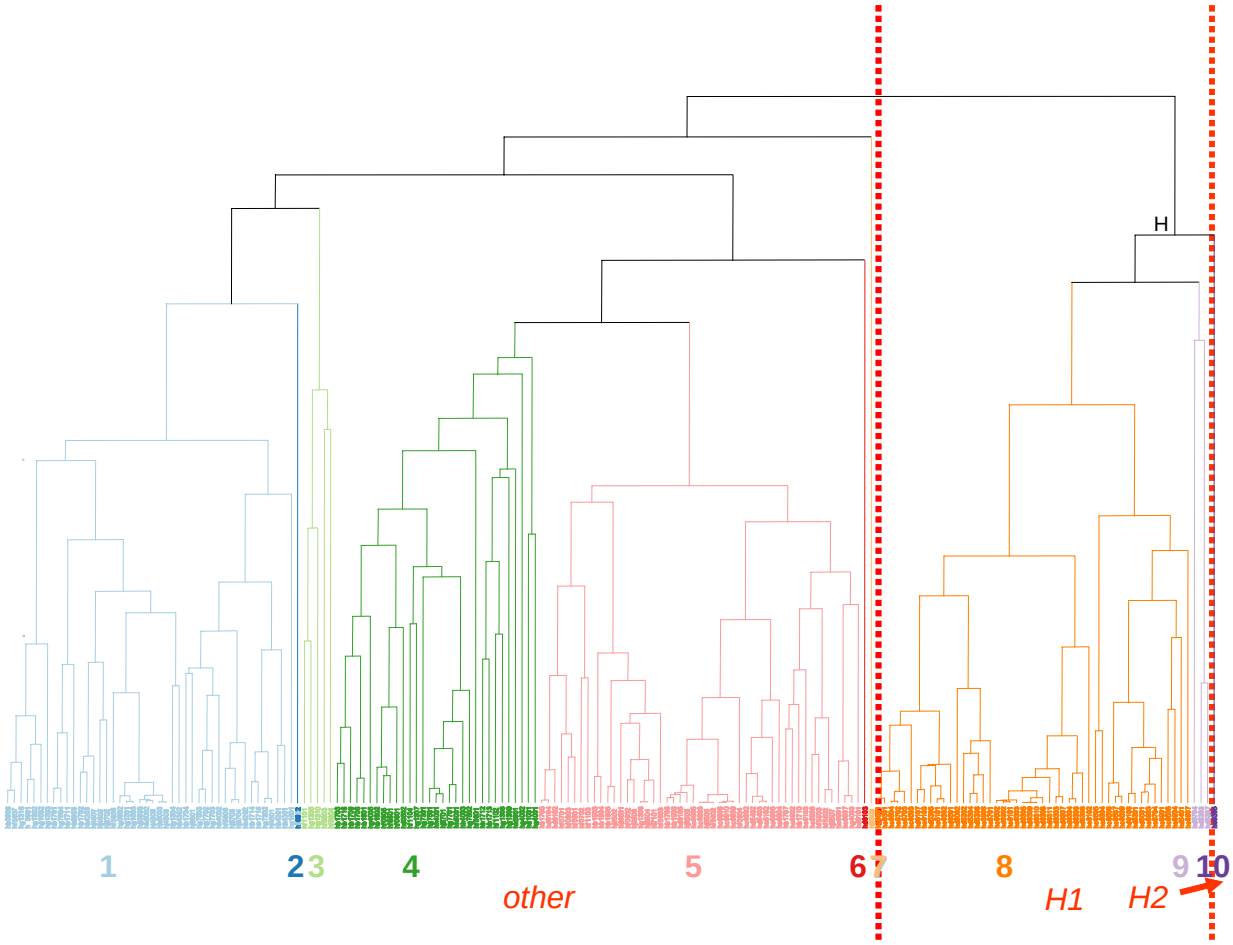

Table 9. Mean percent area for each ecological driver for breakpoint H.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
H1 (cluster 8r, 9r)	2.48	**97.52**	21.99	**78.01**	0.17	4.75	**95.08**	**77.13**	16.25	6.61
H2 (cluster 10r)	0.00	**100.00**	42.41	57.59	0.00	0.00	**100.00**	22.32	11.03	**66.66**

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High: High Gradient (> 4.0)

Breakpoint I

Breakpoint I distinguishes cluster 8r (i1) from cluster 9r (i2) (Figure 11). The major difference between h1 and h2 is found in the stream gradient parameter (Table 10). Relative to i2, i1 has a greater proportion of its stream length within the high gradient category.

Figure 11. Cluster division associated with breakpoint I.

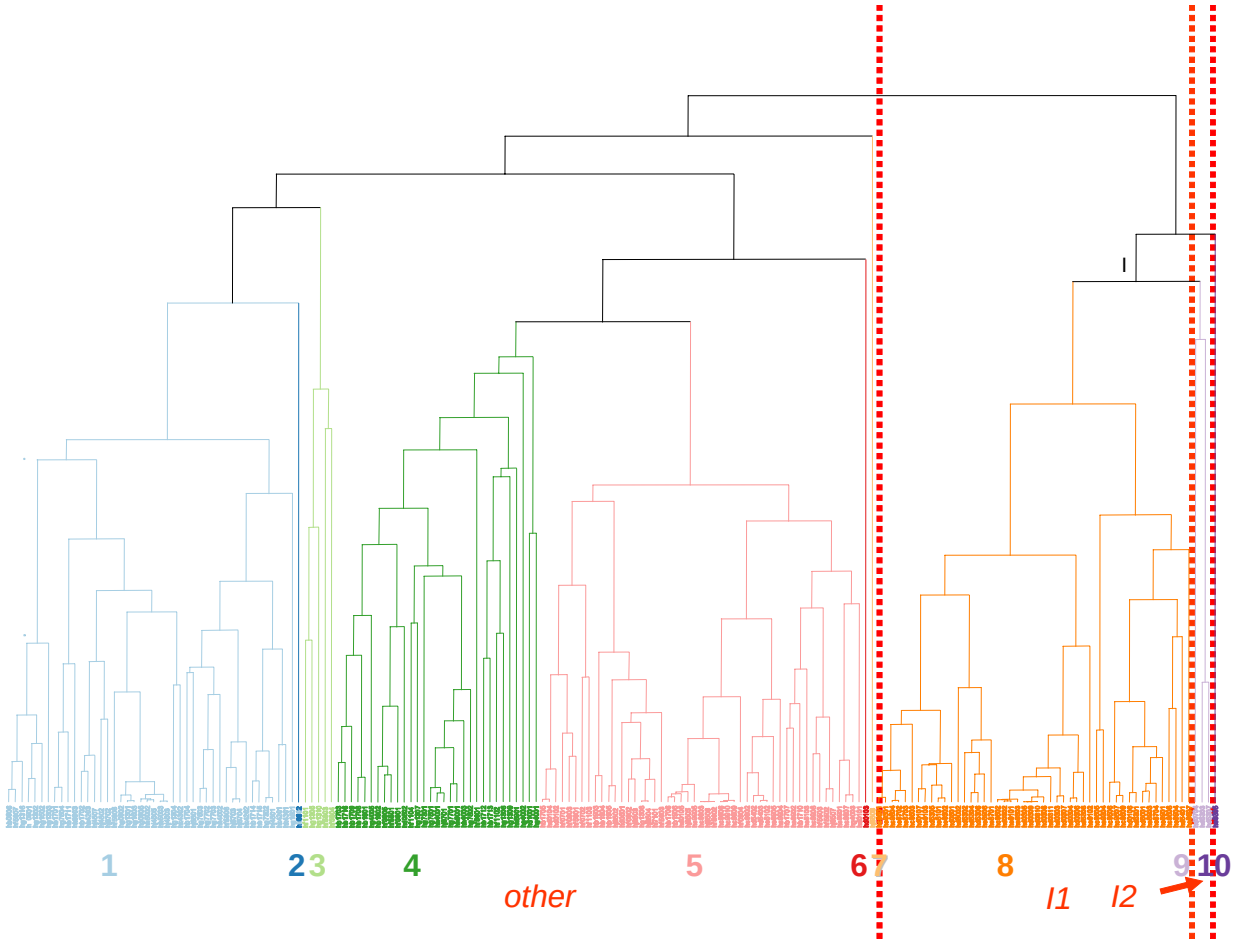

Table 10. Mean percent area for each ecological driver for breakpoint H.

Break Category	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
I1 (cluster 8r)	2.63	**97.37**	23.03	**76.97**	0.04	3.74	**96.22**	**79.54**	14.46	6.00
I2 (cluster 9r)	0.00	**100.00**	5.37	**94.63**	2.14	21.02	**76.84**	38.57	45.01	16.42

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Description of Management Scale for Riparian Clusters

As discussed for the landscape-scale evaluation of the ecological importance of riparian clusters, it is important to remember that headwater streams are disproportionately important, relative to their spatial extent, in supplying water and sediment to downstream river segments. Using the 10 clusters of driver combinations developed for the management scale in the GMUG study area, streams in clusters 2r, 3r, 6r, 7r, 9r, and 10r are relatively rare on national forest lands (Figure 1). Most of the streams on the forest occur in clusters 1r, 4r, 5r, and 8r. The mean percentages of each driver within the clusters are tabulated within Table 11.

Generally, most of the clusters at this scale are associated with non-metal bearing sedimentary geology (Table 11). While the majority of the HUBs are located in the snowmelt, high elevation areas of the landscape, there are several clusters that exhibit a variety of elevational ranges. High stream gradient reaches dominate the clusters, while 3 exhibit higher percentages of low and moderate gradient stream reaches. This information could be valuable when identifying inventory and monitoring programs. While general ecological characteristics may be similar within clusters with similar anthropogenic influences, comparisons across cluster types could provide very different results. While there are some logical distribution patterns within each cluster, there is also enough variability that comparisons between clusters could easily occur (Figure 1).

Table 11. Mean percent area for each ecological driver summarized by cluster.

Cluster	Mb	Mn	Rs	Ro	Pr	Prs	Ps	High	Medium	Low
Cluster 1r	1.53	**98.47**	**97.22**	2.78	**72.74**	15.34	11.92	**65.67**	27.41	6.92
Cluster 2r	0.00	**100.00**	52.32	47.68	59.73	31.52	8.76	**94.76**	4.82	0.42
Cluster 3r	57.16	42.84	**99.94**	0.06	35.12	28.59	36.29	**94.06**	3.79	2.15
Cluster 4r	5.32	**94.68**	**93.27**	6.73	23.85	33.11	43.04	**79.85**	14.02	6.13
Cluster 5r	7.50	**92.50**	**95.02**	4.98	1.44	9.28	**89.28**	**81.73**	12.53	5.73
Cluster 6r	**64.34**	35.66	**100.00**	0.00	0.00	0.00	**100.00**	**83.62**	13.27	3.11
Cluster 7r	0.00	**100.00**	**100.00**	0.00	4.39	**90.50**	5.11	22.44	**48.85**	28.71
Cluster 8r	2.63	**97.37**	23.03	**76.97**	0.04	3.74	**96.22**	**79.54**	14.46	6.00
Cluster 9r	0.00	**100.00**	5.37	**94.63**	2.14	21.02	**76.84**	38.57	45.01	16.42
Cluster 10r	0.00	**100.00**	42.41	57.59	0.00	0.00	**100.00**	22.32	11.03	**66.66**

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Ecological Importance of Riparian Clusters and Sensitivity to Management

Summary

Hydrology and Sediment Transport

As discussed for the landscape-scale evaluation of the ecological importance of riparian clusters, it is important to remember that headwater streams are disproportionately important, relative to their spatial extent, in supplying water and sediment to downstream river segments. Using the 10 clusters of driver combinations developed for the management scale in the GMUG study area, streams in clusters 2, 3, 6. 7, 9 and 10 are relatively rare within the National Forest boundary (Figure 1). Most of the streams on the Forest occur in clusters 1, 4, 5, and 8. These are all high-gradient streams. Streams in clusters 1, 5, and 8 are dominated by non-metal bearing rock units, whereas cluster 4 streams have metal-bearing rock units. Clusters 1, 4, and 5 have rock units that produce abundant fine sediment, whereas streams in cluster 8 have rock units that produce less sediment. Clusters 4, 5, and 8 have predominantly snowmelt flow regimes; cluster 1 is more dominated by rainfall flow regimes. Most of the streams within the National Forest boundary should thus be only moderately sensitive to hydrology and sediment disturbances because of their high gradient, although clusters 1, 4 and 5 will be slightly more sensitive because of their higher potential for sediment production. Also, as noted in the landscape-scale discussion, high gradient stream segments are relatively less sensitive to disturbance because they pass the excess water and sediment efficiently downstream to lower gradient stream segments. Streams in clusters 7, 9, and 10 all exhibit lower gradients, and are thus more sensitive to hydrology and sediment disturbances. Streams in cluster 7 are the most sensitive to disturbance because of their combined medium gradient and high potential for sediment production. In order to avoid confusion, I suggest that we discuss individual cluster characteristics, similar to the Bighorn report. The above illustrates some of the similarities and differences between clusters, but we also need to describe individual clusters for all resource areas.

For the discussion of hydrology and geomorphology, the discussion of the relative sensitivity of each cluster to natural or human-induced disturbances focuses only on physical characteristics of rivers. In this context, the Mb/Mn driver does not apply. The rationale for assigning relative sensitivity is as follows: Hydrologic sensitivity depends primarily on gradient (H/M/L) and flow regime (Ps/Prs/Pr), and to a lesser extent on sediment supply (Rs/Ro). Sediment sensitivity depends primarily on gradient and sediment supply, and to a lesser extent on flow regime. High-gradient streams are assigned the lowest sensitivity to both water and sediment. The channel bed and banks of these stream segments are composed of very coarse sediment that is less likely to experience a substantial change in mobility as a result of either a decrease or increase in water supply. These so-called transport reaches also usually pass excess sediment downstream fairly efficiently and, if sediment-starved, are less likely to have channel erosion than lower-gradient stream segments. Low-gradient streams are assigned the highest sensitivity to both water and sediment. Sediment forming the channel bed and banks in these stream segments is likely to be the most mobile of all the gradient

categories, and thus most likely to be eroded in response to increased flow or reduced sediment load, or deposited in response to reduced flow or increased sediment load. Streams underlain by rock types that produce abundant fine sediment (*Rs*) are rated more sensitive to sediment disturbances than those underlain by other rock types (*Ro*).

Fisheries

The first division of the hierarchical cluster analysis separated clusters 1r-7r which have largely sedimentary bedrock that weathers to produce lots of fine sediments from clusters 8r-10r that contained other bedrock types that produce less fine sediments. (Table 12). None of the ten clusters is characterized by the optimum set of driver combinations that would be most conducive to fish production, namely mid-elevation watersheds, low stream gradients, and rocks that contain few metals, produce little sediment, but are highly calcareous. Within the region, cluster 9r watersheds appear to have the best conditions for production of coldwater fish in that these watersheds encompass some mid-elevation stream reaches with medium stream gradients and have the highest proportion of calcareous bedrock among all the clusters. Watersheds in clusters 3r and 6r appear to be the least conducive to fish production, primarily because of metal-bearing rocks and in the case of cluster 6r, low water temperatures due to the high elevation.

The ten groups of 6th level HUBs identified in the management-scale cluster analysis will differ in how their fisheries resources respond to changes in hydrology, thermal conditions, sediment inputs, nutrient additions, and biotic alterations associated with introduced species (Table 4).

Table 12. A description of the driver characteristics that were important for the management scale cluster analysis of 6th-level watersheds for the GMUG.

Split	Clusters (drivers)	vs.	Clusters (drivers)
A	1-7 (high *Rs*)	vs.	8-10 (high *Ro*)
B	1-6 (high gradient)	vs.	7 (medium – low gradient)
C	1-3 (*Pr* and *Prs*)	vs.	4-6 (*Ps*)
D	1-2 (high *Mn*)	vs.	3 (moderate *Mn*)
E	1 (high *Rs*)	vs.	2 (medium *Rs*)
F	4-5 (high *Mn*)	vs.	6 (high *Mb*)
G	4 (diverse precipitation)	vs.	5 (high *Ps*)
H	8-9 (high & medium gradient)	vs.	10 (low gradient)
I	8 (high gradient)	vs.	9 (medium gradient)

Riparian Vegetation

Riparian ecosystems are tied to the hydrologic, sediment, and disturbance regime produced by flowing water. Many plant species reproduce only following flood disturbances. Thus, maintaining the hydrologic regime is of utmost importance for maintaining the integrity of riparian plant communities. Riparian plants are relatively insensitive to changes in water temperature, and this variable is not evaluated. Changes in stream sediment load may influence riparian communities. Because many streams in sediment producing HUBs already have high sediment loads, increasing this load will have little effect on riparian ecosystems. However, for higher elevation systems, or those in watersheds that do not naturally produce a large sediment load, increases in sediment could cause impacts to the vegetation. In addition, changes in sediment loads can drive stream adjustments, such as downcutting, which can lower water tables and destroy

floodplains and their water table relationships. Sediment deposition from hillslopes can bury riparian areas, and provide habitat for exotic plants or upland plants to invade. Riparian areas typically have sufficient nutrients for plant growth, and excess nutrients would benefit exotic herbaceous plants. High elevation riparian zones would be naturally the most nutrient poor, and be highly sensitive to changes in nutrient status. Lower elevation riparian zones however are most prone to exotic plant invasions.

This discussion of the relative sensitivity of each cluster to natural or human-induced disturbances focuses only on physical characteristics of rivers. In this context, the Mb/Mn driver does not apply. The rationale for assigning relative sensitivity is as follows: Hydrologic sensitivity depends primarily on gradient (H/M/L) and flow regime (Ps/Prs/Pr), and to a lesser extent on sediment supply (Rs/Ro). Sediment sensitivity depends primarily on gradient and sediment supply, and to a lesser extent on flow regime. High-gradient streams are assigned the lowest sensitivity to both water and sediment. The channel bed and banks of these stream segments are composed of very coarse sediment that is less likely to experience a substantial change in mobility as a result of either a decrease or increase in water supply. These transport reaches also usually pass excess sediment downstream fairly efficiently and, if sediment-starved, are less likely to have channel erosion than lower-gradient stream segments. Low-gradient streams are assigned the highest sensitivity to both water and sediment. Sediment forming the channel bed and banks in these stream segments is likely to be the most mobile of all the gradient categories and thus most likely to be eroded in response to increased flow or reduced sediment load, or deposited in response to reduced flow or increased sediment load. Streams underlain by rock types that produce abundant fine sediment (Rs) are rated more sensitive to sediment disturbances than those underlain by other rock types (Ro).

HUBs in clusters 1r-4r have large areas at lower elevation, yet have high gradient streams, and are likely to have many ephemeral streams, streams that are regularly disturbed by summer rain driven floods, and many areas with exotic tamarisk and Russian olive dominated riparian vegetation. Higher elevation HUBs in clusters 5r and 8r will have many more perennial streams supporting well-developed riparian vegetation, particularly tall willow thickets, stable stream banks, and excellent wildlife habitat.

Aquatic Productivity and Benthic Macroinvertebrates

Ten clusters were formed for the four drivers of Hydroclimatology, Geology, Chemistry, and Stream Gradient, with a total of 36 possible unique combinations of driver levels. The combinations of these drivers is expected to greatly influence the aquatic production and diversity of stream channels in the HUBs of the GMUG.

Clusters 5, 6, 8, 9, and 10 are dominated by snow melt hydrology and comprise the highest elevation HUBs in the forest. These are perennial, coldwater streams that differ primarily in terms of dominant stream gradient and underlying geology and chemistry. Generally, the aquatic productivity of snowmelt driven, coldwater streams would not be expected to be as high as streams in the mid-elevation range. However, it is important to note that other localized factors, such as substrate size and distribution as well as food availability can influence productivity. Clusters 5, 6, and 8 are mostly high gradient, and Cluster 6 is distinguished in this sub-group in that it drains metal-bearing lithology. The

release of metal ions and the reduction of ph associated with natural and human influences can have dramatic reductions in the productivity of these systems, although recovery can be dramatic if they are subsequently reduced (Nelson and Roline, 1996). Cluster 5 has high sediment production, which can limit aquatic productivity, and may be sensitive to anthropogenic disturbance. Clusters 9 and 10 have fewer high gradient streams, with Cluster 10 being comprised mostly of low gradient streams. Lower gradient stream channels generally have a more open riparian canopy, allowing more sunlight to reach the stream channel. If stream substrate size is large enough to support algal and other periphyton communities, productivity can also be elevated.

The remaining 5 clusters are lower in elevation, with Clusters 1 and 2 being predominantly driven by rainfall, Cluster 7 mostly by rain-on-snow, and Clusters 3 and 4 by a mixture of all three hydroclimatological types. All but Cluster 7 have mostly high gradient channels. Cluster 1 has more medium gradient channels and produces fine sediment compared to Cluster 2. Both clusters 3 and 4 produce have high sediment production, but only Cluster 3 lies in a metal-bearing lithology.

Individual Cluster Discussion

Cluster 1r

Cluster 1r is largely within the lower elevation rainfall-driven hydroclimatic regime in the north and west portions of the forest (Figure 1). The predominately high and medium gradient streams in this cluster are underlain by non-metal bearing sedimentary geology. While the headwaters of the HUBs in this cluster are located within the National Forest boundary, the majority of the area within this cluster are located in the low lying areas outside of its boundary. This cluster is located on the flanks of the Uncompahgre Plateau, Grand and Battlement Mesas, and is comprised of 44, 6th level watersheds.

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a rainfall flow regime that is underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment (cluster 2 has a lower percentage of rocks producing abundant sediment). These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams – channel erosion in the case of increased water yield, and deposition in the case of increased sediment yield. Localized areas of low gradient stream channels could be altered however by upstream activities that produce high volumes of sediment.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
1r	*****	*****	**NA**	**NA**	**NA**

Fisheries: These are low elevation watersheds that produce a lot of sediment and include both medium and high gradient stream reaches. The fish assemblages would be a mixture of coldwater species (trout) and coolwater nongame species (suckers and minnows). Productivity would be negatively affected by the high sediment loads and the modest amount of calcareous rock in the drainage.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
1r	**	***	**	**	**

Riparian: HUBs in this cluster occur in low to intermediate elevation watersheds, and have primarily rain drive hydrologic regimes making them subject to flash floods during rain events. They also produce high suspended sediment loads and have high gradient stream channels. Many streams will be intermittent or ephemeral. The floodplains are highly dynamic due to regular sediment erosion and deposition events. Where floodplains have sufficient width and alluvial sediment thickness a well-developed riparian community dominated by Fremont and narrow leaf cottonwoods as well as willows may occur. Many low elevation riparian zones will be dominated by the exotic tamarisk and Russian olive. The most dynamic and flashy streams may be largely devoid of riparian vegetation.

This cluster is underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment (cluster 2 has a lower percentage of rocks producing abundant sediment). These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams – channel erosion in the case of increased water yield, and deposition in the case of increased sediment yield.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
1r	***	*	-	NA	***

Aquatic Productivity and Benthic Macroinvertebrates: These low elevation HUBs produce a considerable amount of sediment that is not metal-bearing. Stream channel gradients are mostly high, although medium gradient channels are also common. The relatively warmer temperatures would promote relatively high productivity, and the availability of channels other than high gradient would enhance retention of organic material and biota. However, the fine sediments produced in these HUBs may limit productivity and diversity, especially in the lower gradient sections, where sediment storage is expected to be high. Anthropogenic influences that produce large amounts of fine sediment would be expected to reduce productivity

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
1r	**0/***	**(**-***)**	*	*	NA

Cluster 2r

The single HUB in Cluster 2r contains predominately high gradient streams that are underlain exclusively by non-metal bearing geology (Table 11). Geologic type is not a defining characteristic, as there is an even distribution of sedimentary and crystalline lithologies. The hydroclimatic regime is driven by rainfall and rain-and-snow

precipitation. There is a composite of various ecological drivers comprising this HUB which make it unique for this analysis. The single HUB in this cluster is located on the flanks of the Uncompahgre Plateau (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a rainfall flow regime that are underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment (This cluster has a higher percentage of rocks producing abundant sediment than cluster 1). These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams – channel erosion in the case of increased water yield, and deposition in the case of increased sediment yield.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
2r	*****	*****	**NA**	**NA**	**NA**

Fisheries: This single watershed encompasses to low to middle elevations and has an intermediate level of sediment production. Fish assemblages would be a mixture of coldwater species (trout) and coolwater nongame species (suckers and minnows). Fish production would be limited by high stream gradients and the absence of calcareous rocks.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
2r	******	******	******	******	******

Riparian: The single HUB in this cluster is unique among low elevation HUBs because it has primarily high gradient streams, owing to its position on the northern end of the Uncompahgre Plateau. The plateaus in this area are quite level, and have high sediment producing rock. Smaller streams will be mostly rain driven. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams – channel erosion in the case of increased water yield, and deposition in the case of increased sediment yield. Riparian vegetation will be largely of willow and tamarisk.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
2r	*******	*****	**-**	**NA**	*******

Aquatic Productivity and Benthic Macroinvertebrates: This single HUB has both rain and rain-on-snow hydrology, indicating its presence at low to middle elevations. Gradients are uniformly high and sediment production is intermediate and not metal-bearing. The warmer temperatures associated with this HUB will promote relatively high productivity, but this will be counteracted by high gradient channels.

	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
2r	**0/***	*****	*****	*****	**NA**

Cluster 3r

Cluster 3r HUBs are typified by high gradient streams underlain by sedimentary rock units (Table 11). The hydroclimatic regime and is not defining characteristic, as these watersheds occupy almost equal percentages of the three hydroclimatic zones. Of particular note is the relatively high percentage of metal-bearing bedrock. Less than 50% of the HUBs within this cluster are located within the National Forest boundary. The 5 HUBs within this cluster are located in the North Fork Gunnison Valley, on the southwest slopes of Grand Mesa (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a snowmelt flow regime (cluster 3 also has moderate percentages of stream with rainfall and mixed snowmelt-rainfall flow regimes) that are underlain by bedrock that produces dissolved metals and/or salts and also produces abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
3r	*****	*****	**NA**	**NA**	**NA**

Fisheries: These watersheds span a range of elevations and contain high percentages of metal-rich rocks and sediment-producing rocks. The fish assemblages would be dominated by coldwater species (trout) at higher elevations with the addition of coolwater nongame species (suckers and minnows) at lower elevations. Fish production would be limited by high stream gradients and high ion concentrations produced by metal-rich rocks.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
3r	******	******	******	******	*****

Riparian: HUBs in this cluster are largely underlain by Mancos shale, which liberates salts and high sediment loads. They are located in the North Fork Gunnison valley, on the SW slopes of Grand Mesa. The slopes above streams tend to be steep and unstable and are subject to frequent slumps, which cause episodic inputs of sediment into streams. These watersheds have higher elevation headwaters, reach to low elevations and are subject to both snow accumulation and snow melt driven flow, as well as common

summer rain driven floods. Thus, they may be highly unstable. Riparian vegetation is Fremont and narrow leaf cottonwood, tamarisk and Russian olive dominated at low elevations, with willows, alders and river birch at higher elevations.

This cluster is dominated by high-gradient streams with a snowmelt flow regime (cluster 3 also has moderate percentages of stream with rainfall and mixed snowmelt-rainfall flow regimes) that are underlain by bedrock that produces dissolved metals and/or salts and also produces abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
3r	*****	*****	**-**	**NA**	*****

Aquatic Productivity and Benthic Macroinvertebrates: These HUBs span a wide range of elevation, as indicated by the even distribution of all three hydroclimatologies. Much sediment is produced, about half of which comes from metal-bearing rocks. Aquatic production would be limited by high stream gradients and high ion concentrations produced by metal-rich rocks, although the joint spatial distribution of elevation and metal-bearing rocks in particular drainages could generate a lot of variation in biological response throughout the HUBs. Anthropogenic influences that result in increased ion production and reduced ph could have a major influence on stream productivity.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
3r	*****	*****	*****	******	**NA**

Cluster 4r

Cluster 4r is characterized by predominately high gradient streams underlain by non-metal bearing geologic units that are of sedimentary origin (Table 11). Hydroclimatic regime is not a defining characteristic in this cluster, as there are similar amounts of the three hydroclimatic zones located here. These 31 watersheds occur on the eastern slope of the Uncompahgre Plateau, the western slopes of the West Elk Range, and on Grand Mesa (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
4r	*****	*****	**NA**	**NA**	**NA**

Fisheries: These watersheds encompass a wide elevation range but contain primarily high gradient stream reaches and rocks that produce a large amount of sediment. The fish assemblages would be dominated by coldwater species (trout) at higher elevations with the addition of coolwater nongame species (suckers and minnows) at lower elevations. Fish production would be limited by high stream gradients and high sediment loads.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
4r	**	**	**	**	**

Riparian: These HUBs occur on the eastern slope of the Uncompahgre Plateau, the western slopes of the West Elk Range, and on Grand Mesa. Each HUB may encompass a large elevation range, but contain primarily high gradient stream reaches and rocks that produce large sediment loads. Because each HUB may have a high elevation portion of its watershed, it may have snowmelt driven peak floods, as well as summer rain driven floods. Riparian vegetation will be highly variable, with cottonwoods along larger low elevation stream reaches, and river birch, alder and willow along higher elevation reaches.

This cluster group is dominated by high-gradient streams with a complex flow regime that is underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams. It is important to note that approximately 6% of the total stream reach length is low gradient. These localized reaches could be influenced considerably by upstream activities.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
4r	***	**	-	NA	*

Aquatic Productivity and Benthic Macroinvertebrates: HUBs in this cluster are similar to those in Cluster 3 except sediments are not metal-bearing. There are lower to medium gradient channels and this, combined with lack of high ion concentrations, should enhance aquatic production relative to Cluster 3. Highest production might be expected in lower elevation, medium gradient channels where sediment storage is minimized (yet substrate heterogeneity is high). Production would be more limited at higher elevations, dominated by snowmelt, especially in steep channels.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
4r	***	*	***	**	NA

Cluster 5r

Cluster 5r HUBs are mostly high elevation, snowmelt-driven systems. Streams are characteristically high gradient, and underlain by non-metal bearing geology of sedimentary origin (Table 11). This cluster contained the highest number of HUBs (49),

which occur in the high elevation regions of the West Elk and Elk Range mountains and on Grand Mesa, although there are smaller groups of HUBs throughout the analysis area (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a snowmelt flow regime that is underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
5r	*	*	NA	NA	NA

Fisheries: These watersheds have a set of characteristics that are not conducive to high levels of fish production. They are primarily at high elevations, are dominated by rocks that produce a lot of sediment and contain primarily high gradient stream reaches. The fish assemblages would be dominated by coldwater species (trout) at relatively low abundances.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
5r	**	*	**	*	**

Riparian: These HUBs occur in the high elevation regions of the West Elk and Elk Range mountains and on Grand Mesa. They support snowmelt driven streams and many perennial streams. Springs will be common, supporting herbaceous and willow communities. Riparian vegetation at high elevation will be dominated by short height willow communities, particularly in snowmelt basins. In the lower subalpine zone taller willow communities will occur in reaches with moderate gradients, although higher gradient reaches will be dominated by river birch, alder, and narrow leaf cottonwood.

These cluster groups are dominated by high-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams. However, where low gradient reaches are found, localized influences from sediment deposition could be considerable.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
5r	***	**	*	NA	*

Aquatic Productivity and Benthic Macroinvertebrates: These HUBs have high elevation streams with steep channels and abundant sediment production. In general, aquatic production and diversity would be relatively low in these settings. Biotic

potential would be higher in the available low to medium gradient channels that occur in the cluster.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
5r	***	*	***	**	**NA**

Cluster 6r

Stream channels in cluster 6r are predominately high gradient, and are underlain exclusively by sedimentary lithology (Table 11). The single watershed within this cluster is located only in a high elevation, snowmelt-driven hydroclimatic regime of the National Forest. Both metal-bearing and non-metal bearing rock units are found in this cluster. However, this cluster has the highest proportion of its stream length underlain by metal bearing geology than any other cluster in the GMUG management scale. This watershed is located in the headwaters of the Gunnison Basin (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a snowmelt flow regime that is underlain by bedrock that produces dissolved metals and/or salts and also produces abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
6r	*	*	**NA**	**NA**	**NA**

Fisheries: This cluster contains a single HUB which has a set of characteristics that are the least conducive to fish production among all the clusters. It is located at a high elevation, is dominated by rocks that produce a considerable amount of sediment and contains primarily high gradient stream reaches. The fish assemblages would be dominated by coldwater fish species at relatively low abundances. This watershed is also distinctive in having a high percentage of metal-bearing rocks, which could lead potential metal toxicity problems for fish.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
6r	**	*	**	*	**

Riparian: This single HUB is located at high elevation and the watershed will produce high sediment loads. It has a snowmelt driven stream flow regime, but will have mostly intermittent streams due to position in the Gunnison Basin, which has low summer precipitation. Riparian vegetation will be largely of willows, although many channels will be ephemeral and support little riparian vegetation.

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by bedrock that produces dissolved metals and/or salts and also

produces abundant fine sediment. These streams have a relatively high natural sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams. While localized influences to low gradient stream channels could be high, here are relatively few (app. 3% of total stream length) in this cluster.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
6r	***	**	*	**NA**	**-**

Aquatic Productivity and Benthic Macroinvertebrates: This cluster contains a single HUB located at high elevation, with high gradient channels characterized by abundant sediment production, much of which comes from metal-bearing rocks. Aquatic production and diversity here would be expected to be at the lowest levels for all the clusters. In addition, anthropogenic influences could lower production even further.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
6r	***	*	***	**	**NA**

Cluster 7r

Steam channels in cluster 7r are underlain exclusively by non-metal bearing rock layers of sedimentary origin (Table 11). Nearly the entire stream length is situated within the rain-and-snow hydroclimatic regime. Stream gradient conditions are unique in this analysis, as the moderate and low gradient classes dominate the stream reaches. This single watershed is located on the southern flank of the Uncompahgre Plateau (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by medium-gradient streams with a mixed snowmelt and rainfall flow regime that are underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. These streams have a lower sediment transport capacity, so natural disturbances or management that increase sediment yield to the streams are likely to result in deposition along the stream channels. Increased water yield will likely result in some channel erosion.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
7r	**	**	**NA**	**NA**	**NA**

Fisheries: This cluster contains a single watershed that encompasses a middle elevation range and is dominated by medium and low gradient stream reaches. These factors would be conducive to high fish production. This HUB is exclusively comprised of calcareous geology that would promote fish production. The fish assemblages would be dominated by coldwater species (trout). Based on these results, this HUB could exhibit the highest potential for fishery production at this scale, given the drivers evaluated.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
7r	**	**	***	**	***

Riparian: This single HUB occurs on the southern edge of the Uncompahgre Plateau, a middle elevation site with medium gradient stream reaches. Any perennial streams will support large willow riparian vegetation complexes.

This HUB is dominated by medium-gradient streams with a mixed snowmelt and rainfall flow regime that are underlain by bedrock that does not produce dissolved metals or salts but does produce abundant fine sediment. There is a high percentage of low gradient streams (app. 29% of total stream length) in this HUB as well. These streams have a lower sediment transport capacity, so natural disturbances or management that increase sediment yield to the streams are likely to result in deposition along the stream channels. Increased water yield will likely result in channel erosion.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
7r	***	*	-	NA	-

Aquatic Productivity and Benthic Macroinvertebrates: This cluster contains a single HUB at middle elevation. Stream channels are a mixture of gradients and sediment production is high, but not from non metal-bearing rocks. The high proportion of medium gradient channels should enhance aquatic production and invertebrate diversity. Production and diversity would be lower in low gradient channels due to storage of fine sediments. Anthropogenic influences that produce further sediment would be expected to suppress productivity further.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
7r	***	**	**	***	NA

Cluster 8r

Cluster 8r is characterized by high elevation, snowmelt-driven HUBs. High gradient stream channels underlain by predominately non-metal bearing rock layers of igneous or metamorphic origin dominate this large cluster (Table 11). This HUB contains the highest percentage of non-sedimentary geology at this scale. This cluster contained the second highest number of HUBs (48 HUBs) that are scattered in the eastern mountain ranges of the management scale, including the southern West Elk Range and the Sawatch Range (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management

activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
8r	*****	**0**	**NA**	**NA**	**NA**

Fisheries: These HUBs are located at high elevations and contain primarily high gradient stream reaches; factors that are not conducive to high levels of fish production. However, these watersheds contain little sediment producing rock and a moderate amount of calcareous rock; factors that would enhance fish production. The fish assemblages would be dominated by coldwater species (trout) at moderate to high abundances.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
8r	******	*****	*****	*****	******

Riparian: HUBs in this cluster occupy most of the eastern portion of the study area, particularly the Sawatch Range and southern West Elk Range. Rocks in these areas are highly stable producing low sediment loads, and the watersheds have largely snowmelt driven hydrologic regimes, and are likely the most stable floodplains in the study area. Broad willow dominated floodplains will be found just below tree line in many valleys, and there will be springs, seeps and beaver pond complexes in many valleys as well. At lower elevations and in steeper gradient reaches alder, river birch, and cottonwood stands will be common.

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
8r	*******	******	*****	**NA**	**-**

Aquatic Productivity and Benthic Macroinvertebrates: These high elevation HUBs are comprised primarily of high gradient channels with moderate levels of sediment production from non metal-bearing rocks. The high gradient combined with cold temperatures would lead to relatively reduced aquatic production and invertebrate diversity.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
8r	*******	******	*******	******	**NA**

Cluster 9r

Cluster 9r is characterized by a high elevation, snowmelt-driven hydroclimatic regime (Table 11). Most stream channels in this cluster are underlain by crystalline geologic units of exclusively non-metal bearing geochemistry. Stream gradient is not a defining characteristic of this cluster, as medium gradient channels occupy a slightly higher percentage of the stream length than high gradient channels. The three watersheds in this cluster are found on the southern flanks of the West Elk Mountains (Figure 1).

Hydrology and Sediment Transport: This cluster group is dominated by medium-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
9r	*****	*****	**NA**	**NA**	**NA**

Fisheries: These Hubs are located at moderate to high elevations and contain moderate to high gradient stream reaches. However, here is a relatively high amount of low gradient channels (>16%) as well. These watersheds contain little sediment producing rock and a low amount of calcareous rock; factors that would limit fish production. The fish assemblages would be dominated by coldwater species at moderate to high abundances.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
9r	******	*****	*****	******	******

Riparian: The few HUBs in this cluster occur on the southern edge of the West Elk Mts. on south facing watersheds. They will have perennial streams flowing from the higher mountains and numerous intermittent and ephemeral streams. Perennial streams will support large willow riparian vegetation complexes, while ephemeral streams may be unvegetated.

This cluster group is dominated by medium-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a relatively high sediment transport capacity, so natural disturbances or management activities that increase either water or sediment are likely to cause only slight to moderate changes in these streams.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
9r	*******	*****	**-**	**NA**	*****

Aquatic Productivity and Benthic Macroinvertebrates: HUBs in this cluster occur at medium to high elevations and have a diversity of channel gradients. Sediment

production is low. Aquatic production and diversity should be among the highest values in the study region, especially for the medium elevation sites in low to medium gradient channels.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
9r	***	**/***	***	**	**NA**

Cluster 10r

The single Cluster 10r HUB contains mainly low gradient streams in an exclusively high elevation, snowmelt-driven hydroclimatic regime underlain by non-metal bearing geologic units. Geologic origin is not a defining characteristic for this cluster. This HUB does not intersect the GMUG (Figure 1). However, because of its position in the center of the analysis area it was decided that it should be included in this analysis.

Hydrology and Sediment Transport: This cluster group is dominated by low-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a lower sediment transport capacity, so natural disturbances or management that increase sediment yield to the streams are likely to result in deposition along the stream channels. Increased water yield will likely result in some channel erosion.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
10r	*	**	**NA**	**NA**	**NA**

Fisheries: This single HUB is unusual in being at a high elevation but containing a large proportion of low gradient stream reaches. The geology in this HUB produces a moderate amount of sediment and contains a moderate amount of calcium. The high elevation and resulting cold water temperatures would limit fish production but there could be an accumulation of fish biomass in low gradient reaches, especially where fishing pressure is low.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	NON-NATIVE BIOTA
10r	**	*	**	*	**

Riparian: The single HUB occurs at intermediate elevation and has low gradient streams, but with snowmelt driven hydrologic regimes. Any perennial streams will support large willow riparian vegetation complexes.

This cluster group is dominated by low-gradient streams with a snowmelt flow regime that are underlain by bedrock that does not produce dissolved metals or salts and does not produce abundant fine sediment. These streams have a lower sediment transport capacity, so natural disturbances or management that increase sediment yield to the streams are likely to result in deposition along the stream channels. Increased water yield will likely result in channel erosion, reducing riparian development.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
10r	***	*	-	NA	*

Aquatic Productivity and Benthic Macroinvertebrates: The single HUB in this cluster is unique in its combination of high elevation setting and large fraction of low gradient stream channels. Sediment production is intermediate and not associated with metals. Aquatic production would be limited by cold temperatures, yet the low gradient streams suggest the potential for lake development and thus a high degree of habitat heterogeneity, which would increase invertebrate diversity above the levels typically expected for streams at this elevation.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
10r	***	***	***	***	**

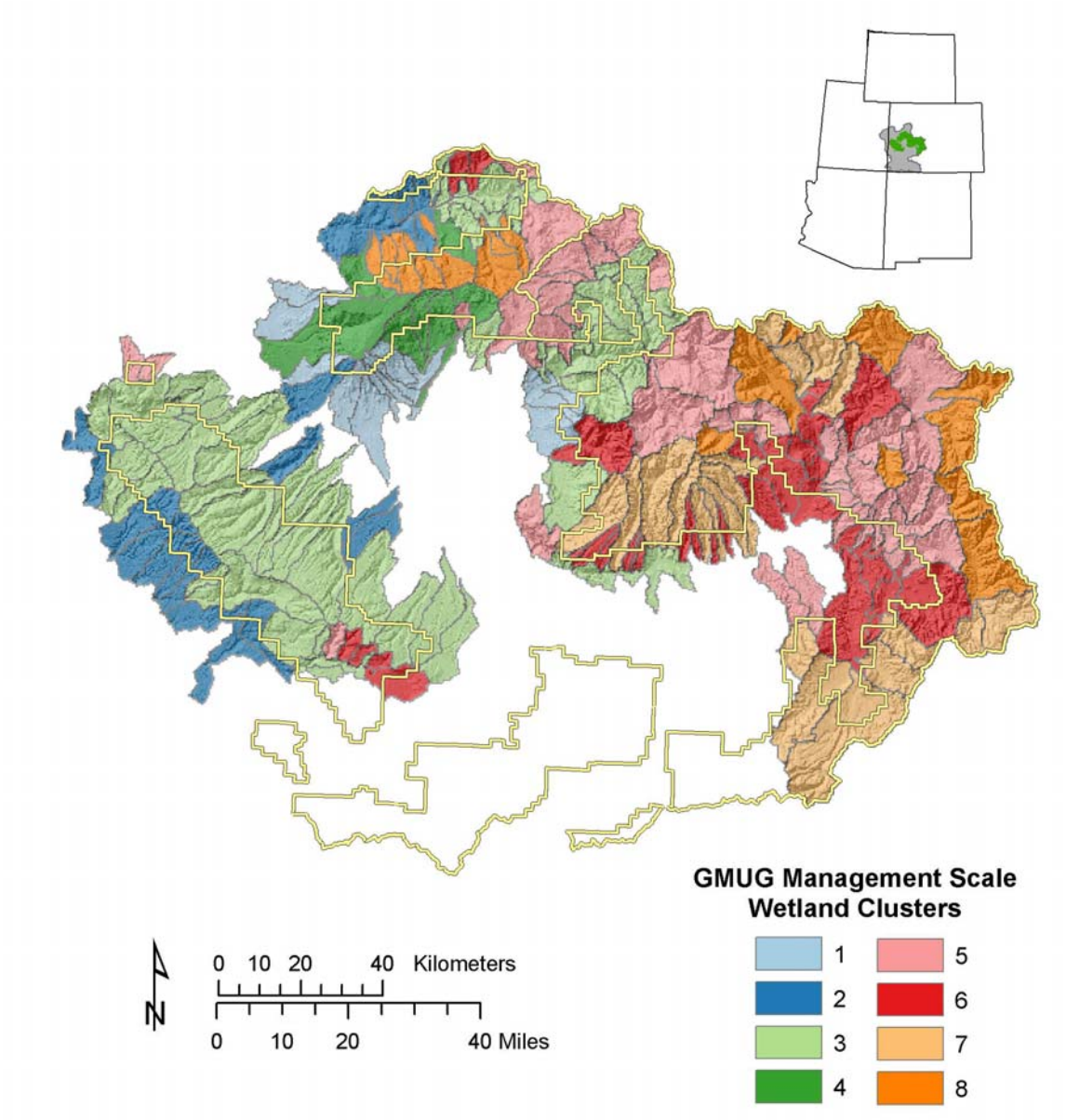
Wetland Analysis

Management-scale agglomerative cluster analysis divided the 184, 6th level HUBs intersecting the GMUG into 8 clusters for the wetland analysis (Figure 12). Geology (calcareous and non-calcareous), hydroclimatology and extent of Pleistocene glaciation were included as drivers in this analysis. Complete map coverage of Pleistocene glacier extent was not available. Dr. Keith Brugger, University of Minnesota at Morris, outlined the extent of Pleistocene glaciers known to him from his recent field work in the Sawatch, Elk, and West Elk Ranges. He had information for 24 HUBs. Using these data we developed a regression of % HUB area above 10,000 feet elevation vs. % HUB covered by glaciers. This regression, $y = 1.1141x$ had an $R^2 = 0.7148$, and was used to calculate the approximate area of glaciers that would have occurred in HUBs for which map information was unavailable. We applied this regression analysis only to the Sawatch, Elk, and West Elk Ranges. On Grand Mesa we had adequate glacier coverage maps from Yeend (1976), and extended his analysis to the southern side of the Mesa by using the elevations at which he identified glaciers.

There was very little quantitative mapping information on wetland or riparian ecosystems for this assessment. For the Bighorn National Forest ARW assessment this information was available in the form of National Wetland Inventory (NWI) mapping, as well as an intensive photographically interpreted riparian inventory (Winters et al., 2004b). Because there were opportunities to use this mapping data to “strengthen” the conclusions we made, we were confident in our findings. However, because this inventory information was not available for the GMUG study we are not able to make.

Because of the very steep topographic gradient from the low elevation river valleys to the high forests, many HUBs include large areas of low elevation watershed, and these may cover a larger area than higher elevation headwaters. This results in a number of HUBs, particular on the edges of the Uncompahgre Plateau and Grand Mesa having rain-driven hydrologic regimes. Thus, the management scale analysis still includes the full range of drivers and climate conditions.

Figure 12. Map of the results of the management scale ecological driver cluster analysis for wetland systems.



Break Analysis

The cluster analysis produced a dendrogram from which the ecological driver clusters were identified (Figure 13). Ecological driver clusters are identified by number (1w – 8w) and color. Significant breakpoints are identified by the letters A – G. At each breakpoint, the HUBs are divided into groups (Table 13). For example, at breakpoint E, there is E group 1 (E1) that includes HUBs in cluster 2w, E group 2 (E2), which includes HUBs in cluster 3, and those HUBs not associated with the particular breakpoint (other).

The following discussion is intended to identify the predominant ecological driver characteristics associated with the major break points, the characteristics of the individual clusters, and the expected distribution and sensitivity of the wetlands within each cluster.

Table 13. Mean percent area for each ecological driver summarized by breakpoint.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
A1 (Clusters 1w – 7w)	14.12	**85.88**	31.50	**68.50**	**66.37**	13.73	19.90
A2 (Cluster 8w)	**84.61**	15.39	12.67	**87.33**	**87.87**	4.68	7.45
B1 (Clusters 1w – 5w)	9.29	**90.71**	14.26	**85.74**	**53.12**	18.37	28.51
B2 (Clusters 6w – 7w)	25.10	**74.90**	**70.72**	29.28	**96.50**	3.18	0.32
C1 (Cluster 1w)	2.04	**97.96**	**63.22**	36.78	12.58	8.42	**79.00**
C2 (Clusters 2w- 5w)	10.21	**89.79**	8.09	**91.91**	**58.23**	19.62	22.14
D1 (Clusters 2w – 3w)	1.72	**98.28**	8.90	**91.10**	34.80	29.13	36.08
D2 (Clusters 4w – 5w)	21.15	**78.85**	7.04	**92.96**	**88.44**	7.37	4.18
E1 (Cluster 2w)	2.60	**97.40**	5.11	**94.89**	8.75	16.37	**74.89**
E2 (Cluster 3w)	1.36	**98.64**	10.47	**89.53**	45.60	34.42	19.98
F1 (Cluster 4w)	35.99	**64.01**	9.36	**90.64**	**60.60**	15.45	23.95
F2 (Cluster 5w)	18.42	**81.58**	6.61	**93.39**	**93.57**	5.89	0.54
G1 (Cluster 6w)	8.12	**91.88**	**62.41**	37.59	**94.81**	4.65	0.54
G2 Cluster 7w)	49.36	50.64	**82.59**	17.41	**98.92**	1.07	0.00

Highest value is in bold
Similar values are underlined

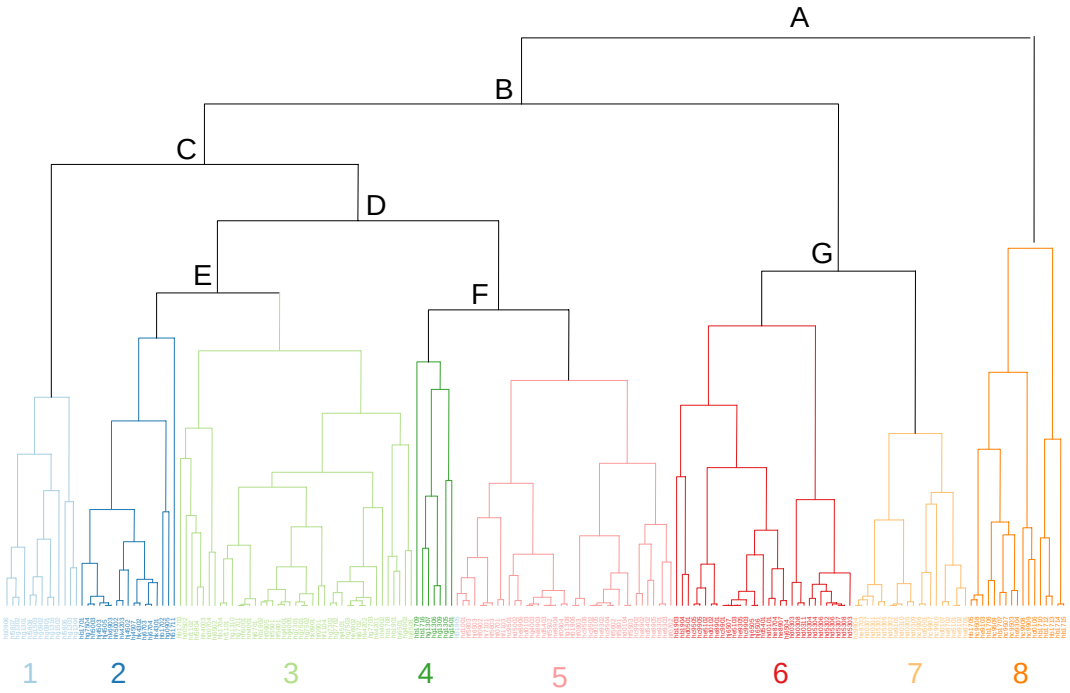
Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology

Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

The composition of the "break groups" for individual drivers is presented in Table 13. Probably the most important finding in this analysis is the lack of glaciation in the project area. Winters et al., (2004a) described that the extent of glaciation is one of if not the key predictor of the abundance of wetlands in the Rocky Mountains. The scouring action of glaciers resulted in broad flat valleys conducive to wetland development. In addition, these areas are typically at high elevations where precipitation is high compared to lower elevations. Only one cluster (8w) exhibited a mean percentage greater than 50%

Of its total area containing this land form, while cluster 7w had slightly less than 50%. A more detailed description of the importance of these clusters will be presented in the following section.

Figure 13. Dendrogram of the GMUG management scale wetland cluster analysis. The letters (A – G) identify breakpoints within the analysis. The numbers (1 – 8) identify the cluster number.



Breakpoint Analysis

Breakpoint A

Two groupings of HUBs are identified at breakpoint A (Figure 14). Clusters 1w – 7w comprise A1, while cluster 8w comprises A2. The major split between A1 and A2 is the degree of glaciation and to a lesser degree the precipitation regime type (Table 14). A1 is typified by non-glaciated landscapes, while A2 is typified by glaciated landscapes. A1 is not associated with any particular precipitation regime, while A2 is typified by snowmelt precipitation. The extent of Pleistocene glaciation has been shown to be a significant predictor for the extent of wetlands in the Rocky Mountains (Winters et al., 2004a). The relatively few HUBs in breakpoint group A2 as compared to A1 would be an indication that areas of concentrated wetlands are limited in the analysis area.

Figure 14. Cluster division associated with breakpoint A.

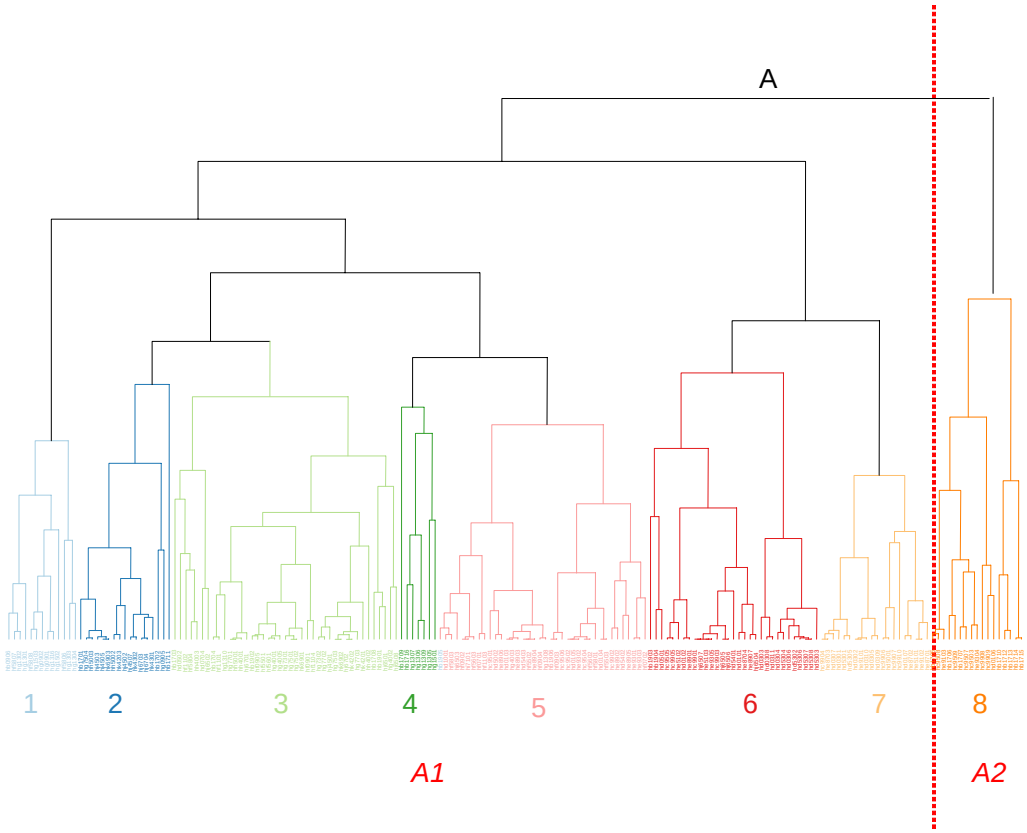


Table 14. Mean percent area for each ecological driver for breakpoint A.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
A1 (Clusters 1w – 7w)	14.12	**85.88**	31.50	**68.50**	**66.37**	13.73	19.90
A2 (Cluster 8w)	**84.61**	15.39	12.67	**87.33**	**87.87**	4.68	7.45

Highest value is in bold

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint B

Two groupings of HUBs are identified at breakpoint B (Figure 15). Clusters 1w – 5w comprise B1, clusters 6w and 7w comprise B2, and cluster 8w is not associated with breakpoint B. B1 differs from B2 by lithology and precipitation Regime (Table 15). B2 is underlain by predominately calcareous geology, while B1 is typically non-calcareous. B2 also tends to be located in a higher altitude, snow-dominated hydroclimatic regime, while B1 is typified by lower elevation, rain and rain and snow driven systems.

Figure 15. Cluster division associated with breakpoint B.

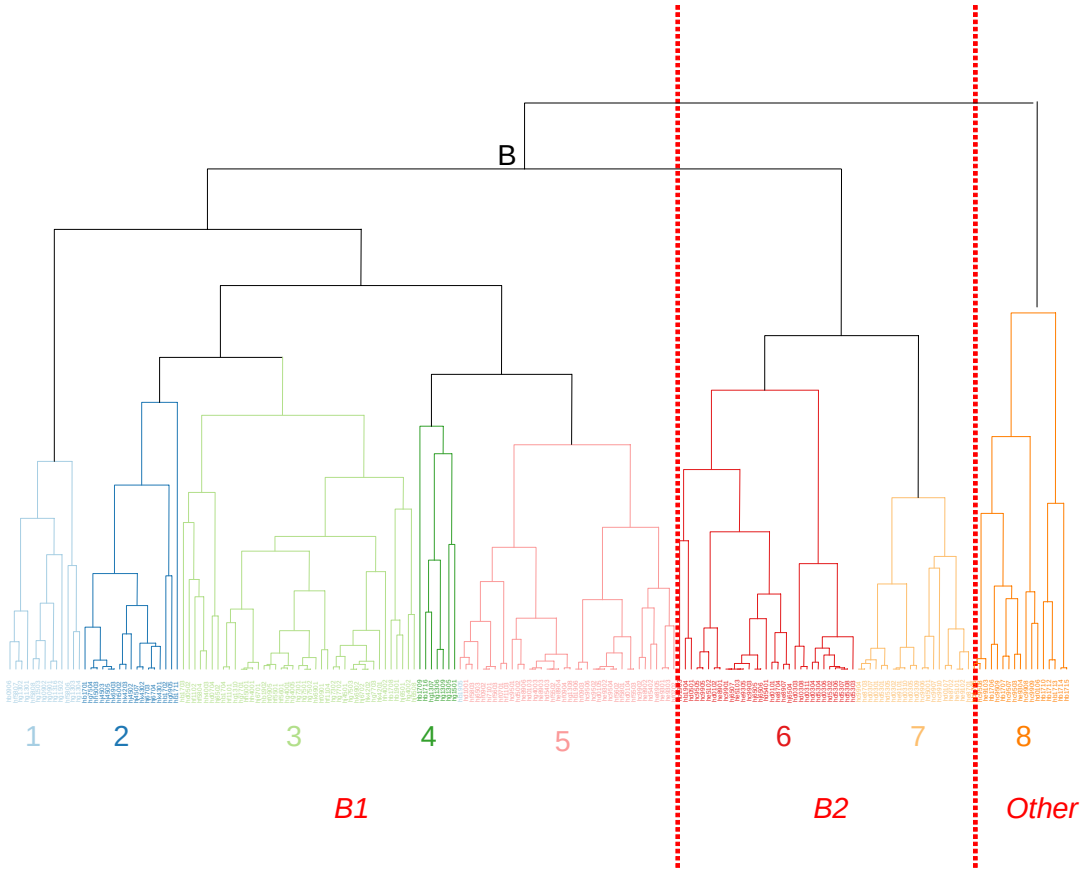


Table 15. Mean percent area for each ecological driver for breakpoint B.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
B1 (Clusters 1w – 5w)	9.29	**90.71**	14.26	**85.74**	**53.12**	18.37	28.51
B2 (Clusters 6w – 7w)	25.10	**74.90**	**70.72**	29.28	**96.50**	3.18	0.32

Highest value is in bold

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint C

Breakpoint C distinguishes cluster 1 (C1) from clusters 2w – 5w (C2) (Figure 16). HUBs in C1 are underlain by predominately calcareous geology, while those in C2 are typified by non-calcareous geology (Table 16). C1 also tends to contain a higher proportion of area within the lower elevation rainfall driven precipitation than does C2.

Figure 16. Cluster division associated with breakpoint C.

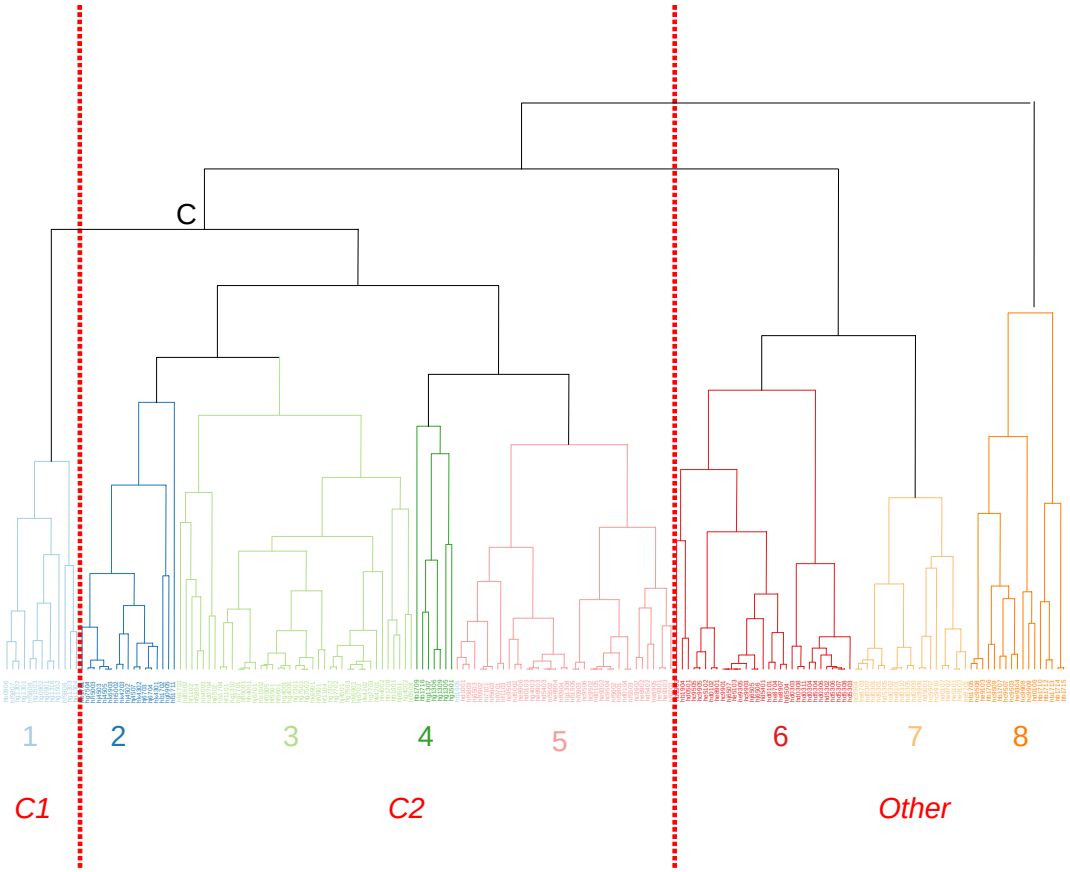


Table 16. Mean percent area for each ecological driver for breakpoint C.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
C1 (Cluster 1w)	2.04	**97.96**	**63.22**	36.78	12.58	8.42	**79.00**
C2 (Clusters 2w – 5w)	10.21	**89.79**	8.09	**91.91**	**58.23**	19.62	22.14

Highest value is in bold

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint D

Two groupings of HUBs are identified at breakpoint D (Figure 17). Clusters 2w and 3w comprise D1; clusters 4w and 5w comprise D2. D1 and D2 are quite similar in geology and extent of glaciation (Table 17). The major differences are in the precipitation regime, with D1 having a more even distribution of precipitation regimes, while D2 has a majority of its area within the snowmelt driven precipitation regime.

Figure 17. Cluster division associated with breakpoint D.

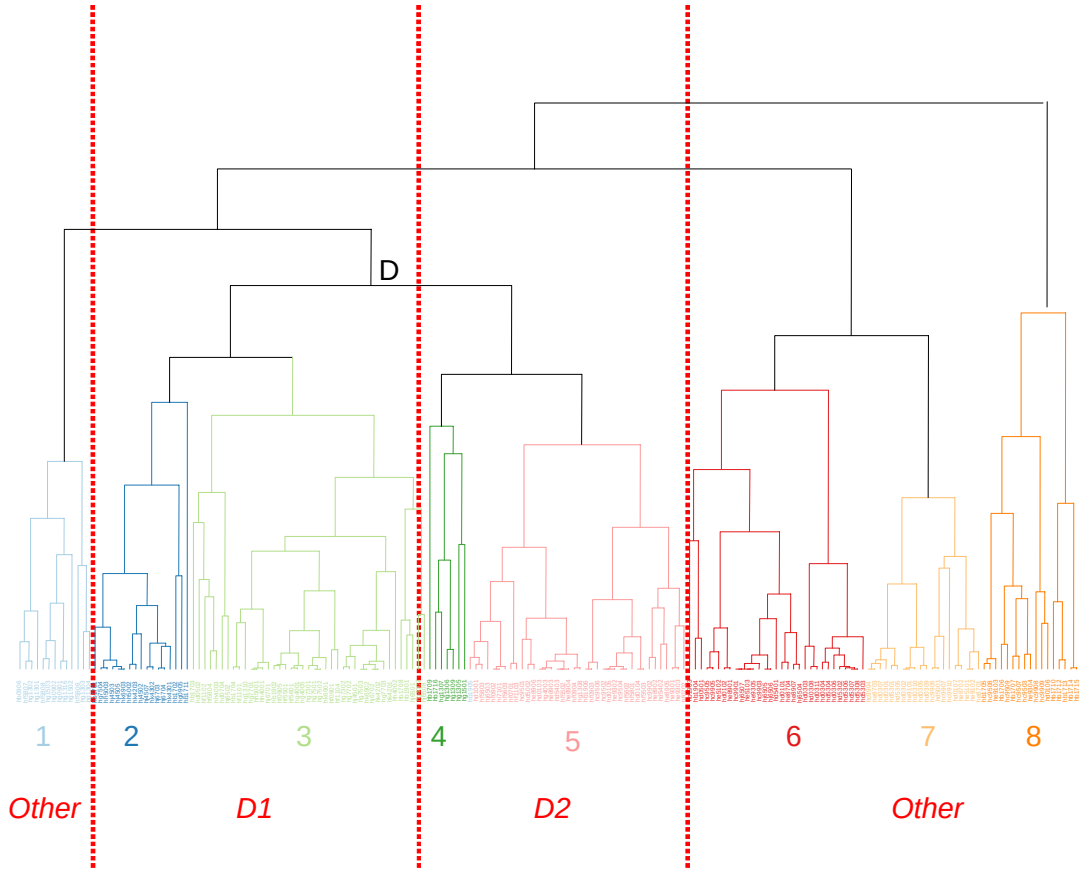


Table 17. Mean percent area for each ecological driver for breakpoint D.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
D1 (Clusters 2w – 3w)	1.72	**98.28**	8.90	**91.10**	34.80	29.13	36.08
D2 (Clusters 4w – 5w)	21.15	**78.85**	7.04	**92.96**	**88.44**	7.37	4.18

Highest value is in bold
Similar values are underlined

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint E

Breakpoint E distinguishes watersheds in Cluster 2w from those in Cluster 3w (Figure 18). E1 and E2 are quite similar in geology and extent of glaciation (Table 18). The major differences are in the precipitation regime, with E1 having a more even distribution of precipitation regimes, while E2 has a majority of its area within the rainfall driven precipitation regime.

Figure 18. Cluster division associated with breakpoint E.

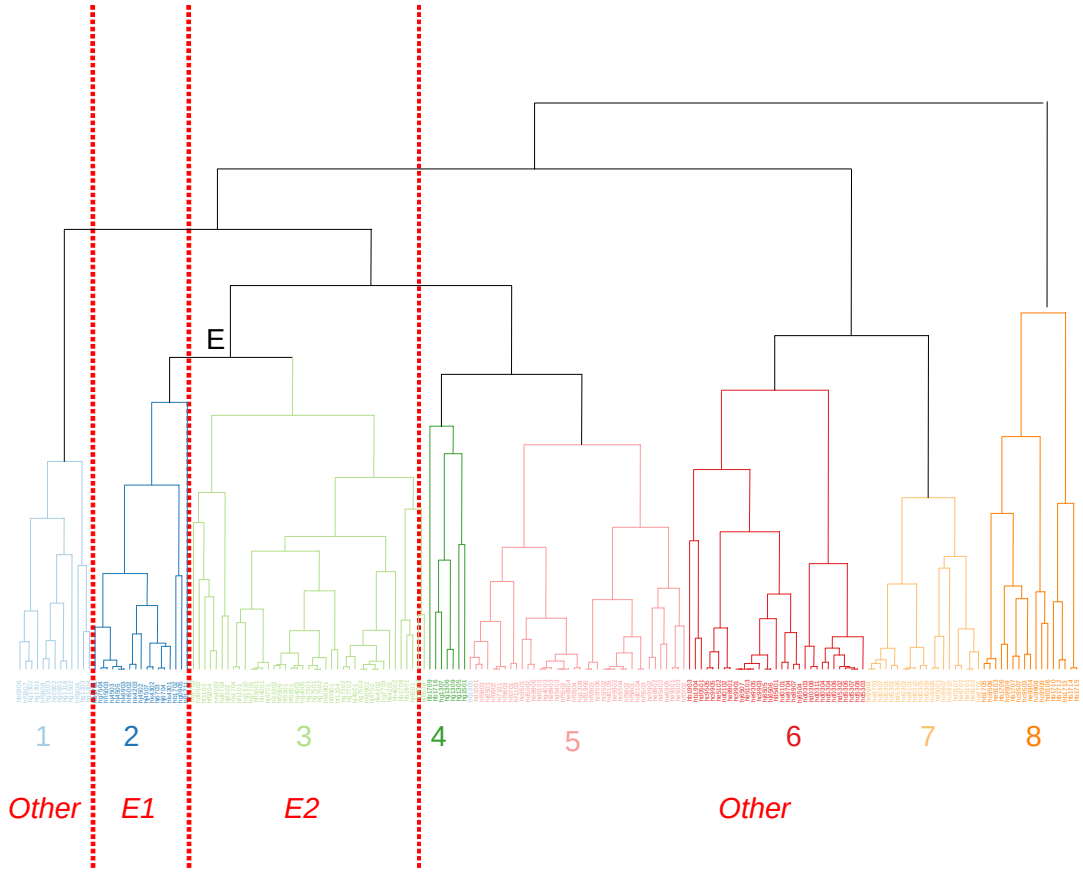


Table 18. Mean percent area for each ecological driver for breakpoint E.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
E1 (Cluster 2w)	2.60	**97.40**	5.11	**94.89**	8.75	16.37	**74.89**
E2 (Cluster 3w)	1.36	**98.64**	10.47	**89.53**	45.60	34.42	19.98

Highest value is in bold
Similar values are underlined

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint F

Breakpoint F distinguishes cluster 4w (F1) and cluster 5w (F2) from the rest of the clusters (Figure 19). The only significant differences are found in the precipitation regime driver (Table 19). While both clusters are dominated by snowmelt-driven precipitation regimes, F2 has a greater percentage in this particular class. F1 also has a small percentage of its area within the rainfall class, while F2 does not have any area in these lower elevation areas.

Figure 19. Cluster division associated with breakpoint F.

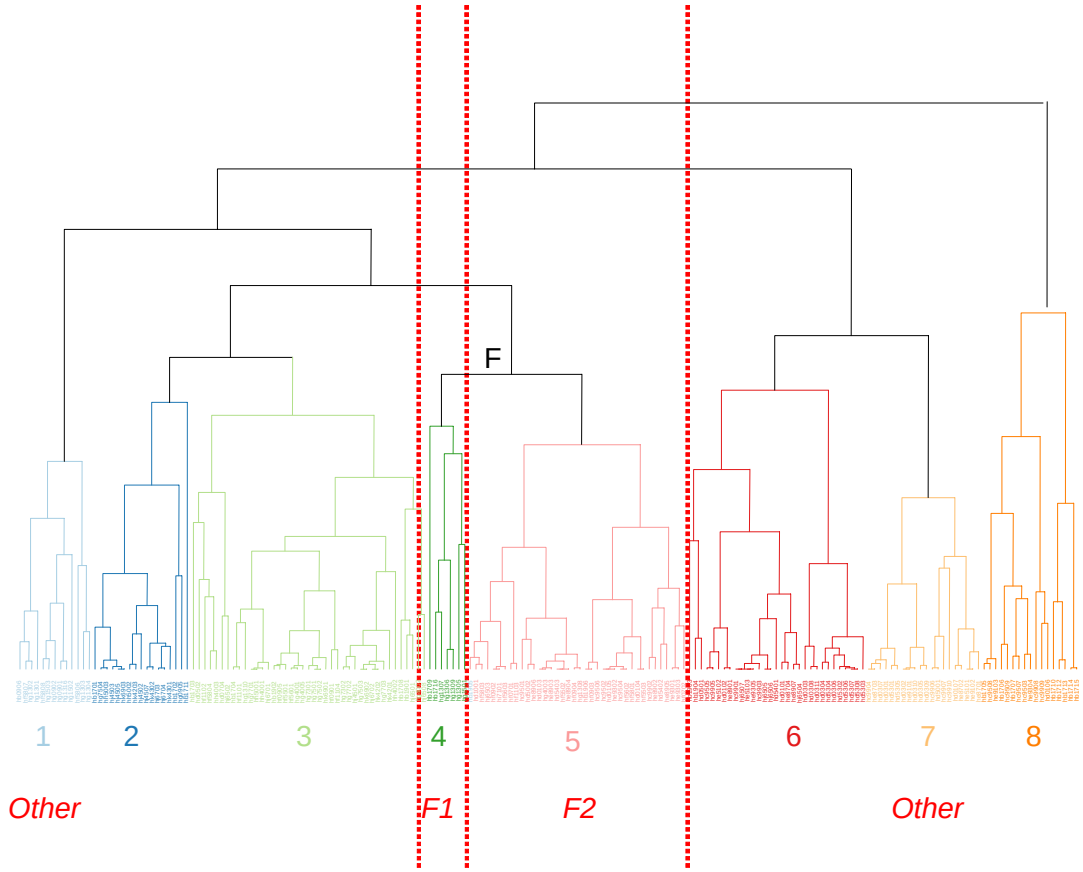


Table 19. Mean percent area for each ecological driver for breakpoint F.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
F1 (Cluster 4w)	35.99	**64.01**	9.36	**90.64**	**60.60**	15.45	23.95
F2 (Cluster 5w)	18.42	**81.58**	6.61	**93.39**	**93.57**	5.89	0.54

Highest value is in bold

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Breakpoint G

Two groupings of HUBs are identified at breakpoint G (Figure 20). Cluster 6 comprises G1, and Cluster 7 comprises G2. The greatest difference between G1 and G2 is in the extent of glaciation (Table 20). HUBs in G1 tend to have an even distribution of glaciated and non-glaciated terrain. HUBs in G2 tend to have a majority of their terrain in a glacially influenced area. Virtually the entire area of both G1 and G2 is in the high elevation snowmelt driven precipitation regime.

Figure 20. Cluster division associated with breakpoint G.

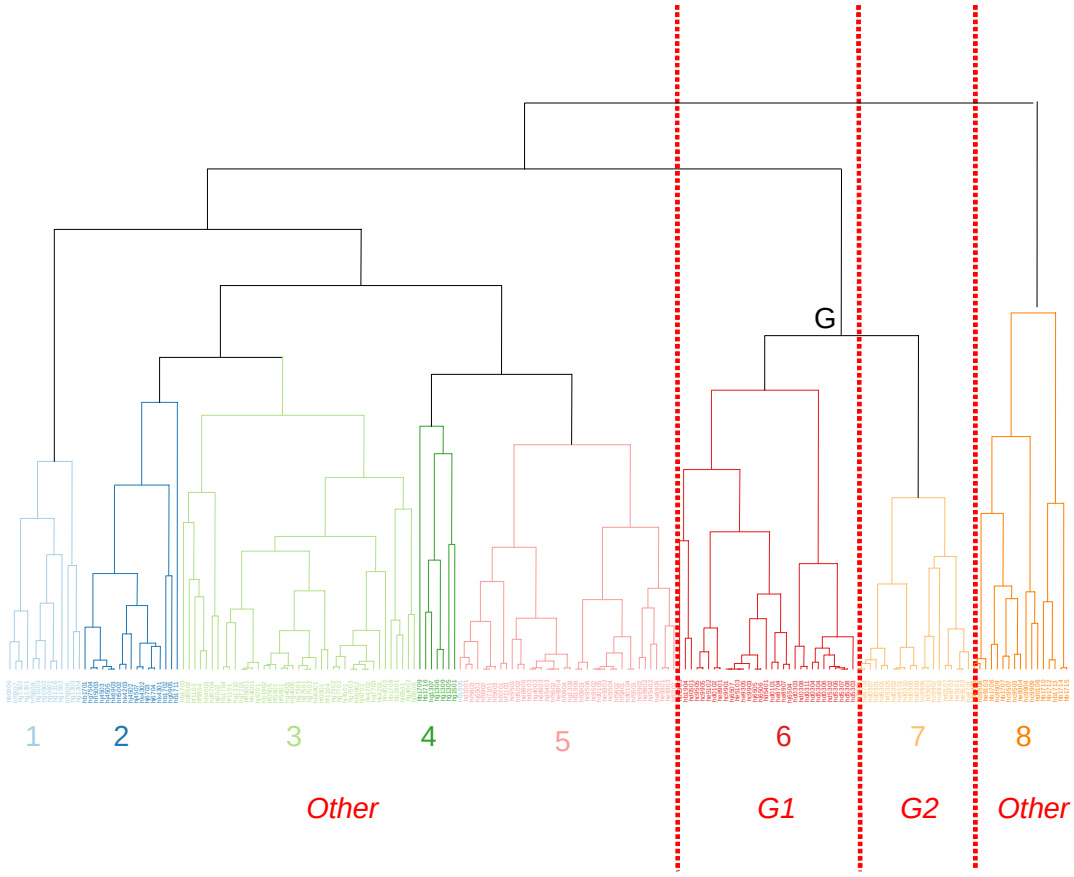


Table 20. Mean percent area for each ecological driver for breakpoint G.

Break Group	Qg	Qn	Ca	Cn	Ps	Prs	Pr
G1 (Cluster 6)	8.12	**91.88**	**62.41**	37.59	**94.81**	4.65	0.54
G2 Cluster 7)	49.36	50.64	**82.59**	17.41	**98.92**	1.07	0.00

Highest value is in bold
Similar values are underlined

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Lithology
Cn: Non-calcaerous Lithology
Pr: Rainfall Precipitation Regime
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime

Description of Management Scale Wetland Clusters

An agglomerative cluster analysis of the spatial distribution of the three ecological drivers identified 8 unique groups of watersheds (Figure 12). The mean percentage of each driver within each cluster is tabulated below (Table 21). The following section is intended to give an overview of the composition and location of each cluster, and then provide a description of the expected influence each cluster has upon the nature and distribution of wetland ecosystems at the management scale of the GMUG Aquatic, Riparian and Wetland Assessment.

Table 21. Mean percentage of each driver within the 10 management scale wetland clusters.

Cluster	Qg	Qn	Ca	Cn	Ps	Prs	Pr
Cluster 1w	2.04	**97.96**	**63.22**	36.78	12.58	8.42	**79.00**
Cluster 2w	2.60	**97.40**	5.11	**94.89**	8.75	16.37	**74.89**
Cluster 3w	1.36	**98.64**	10.47	**89.53**	45.60	34.42	19.98
Cluster 4w	35.99	**64.01**	9.36	**90.64**	**60.60**	15.45	23.95
Cluster 5w	18.42	**81.58**	6.61	**93.39**	**93.57**	5.89	0.54
Cluster 6w	7.89	**92.11**	**62.04**	37.96	**94.97**	4.51	0.52
Cluster 7w	51.78	48.22	**84.16**	15.84	**98.88**	1.12	0.00
Cluster 8w	**84.61**	15.39	12.67	**87.33**	**87.87**	4.68	7.45

Highest value is in bold
Similar values are underlined

Qg: Quaternary Glaciation
Qn: Non-Glaciated
Ca: Calcareous Geology
Cn: Non-Calcareous Geology
Prs: Rain and Snow Precipitation Regime
Ps: Snowmelt Precipitation Regime
Pr: Rainfall Precipitation Regime

Summary

There are several general observations that can be made by examining the results of the wetland cluster analysis. HUBs in clusters 1w-2w occupy the lowlands and foothills of the GMUG, and have rain driven hydrologic regimes, and hot dry summer. They will support salt flat and marsh wetlands, as well as wetlands created by agricultural irrigation. HUBs in clusters 3w and 4w occupy the middle elevation regions in a broad forest belt. These sites will have both snowmelt and rain driven hydrologic regimes, and can support well developed wet meadows and springs. Clusters 5w-8w occupy high elevation HUBs which have snowmelt driven hydrologic regimes. Clusters 5w and 6 w were largely unglaciated while those in clusters 7w and 8w were largely glaciated and have glacial landforms that may produce clusters of wetlands that are not present in other HUBs.

Ecological Importance of Wetland Clusters and Sensitivity to Management

Cluster 1w: Cluster 1 is characterized by a rainfall driven hydroclimatic regime in a non-glaciated physiographic setting (Table 21). Both calcareous and non-calcareous lithological units are found in this cluster. The 13 watersheds in this cluster are located on low elevation slopes of Grand Mesa and the West Elk Mountains in the North Fork Gunnison River and Uncompahgre River drainages (Figure 12).

HUBs in this cluster have a rain driven hydrologic regime, receive little precipitation, have hot and long summers with low humidity, and high evapotranspiration rates. Many areas have Mancos Shale near the ground surface, and have calcareous and alkaline soils, and in some areas highly saline and alkaline soils and waters. Wetlands will occur on benches, at seeps, and toe slopes. Salt flats will be common, and most will have water tables well below the soil surface most of the year. Wet meadows dominated by rushes, sedges and grasses will also be common, and some have been created by irrigation practices. Marshes dominated by cattail and bulrush will also be common, filling with

water from rainstorms or irrigation tail water, yet drying in late summer. Wetlands may absent in many areas due to local aridity and because there is little ground water moving in the shale bedrock.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
1w	***	*	-	-	***

Cluster 2w: The 17 watersheds in cluster 2w are located in low elevation, non-glaciated landscapes underlain by non-calcareous rock units (Table 21). The hydrology of these watersheds is driven by a rainfall-driven hydroclimatic regime. These watersheds are located on the margins of the Uncompahgre Plateau, and the northern flanks of the Grand Mesa (Figure 12).

Open desert scrublands, ponderosa pine forests and Gambel oak shrublands dominate the vegetation and summer temperatures will be high and many wetlands will be ephemeral. Marshes will be most common on relatively level benches with bedrock as shallow depth. Wet meadows will also be common where ground water discharges in part of the summer. There will be many springs, which create important plant and wildlife habitat.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
2w	***	*	-	-	***

Cluster 3w: Cluster 3w is characterized by mid-elevation, non-glaciated watersheds underlain by non-calcareous geology (Table 21). The hydroclimatic regime is not a defining characteristic of this grouping. These 41 HUBs are located in the western portion of the management scale (Figure 12).

Ponderosa pine, Douglas fir and Gambel oak form forests and shrub thickets cover most of these watersheds. Summer temperatures will be high and many wetlands will be ephemeral. Marshes will be most common on relatively level benches with bedrock as shallow depth. Wet meadows will also be common where ground water discharges in part of the summer. There will be many springs, which will have important plant and wildlife values.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
3w	***	**	*	*	**

Cluster 4w: Watersheds in cluster 4w are underlain by calcareous rock units (Table 21). While neither hydroclimatology nor degree of glaciation are defining characteristics, there is a slightly larger percentage of area within the snowmelt regime, and within a non-glaciated geomorphic setting. The 7 watersheds in this cluster are found on the southern flanks of the Grand Mesa, and the bedrock is largely non-calcareous (Figure 12).

This cluster exhibits a largely snowmelt driven hydrologic regime, but it is mixed, with rain driven hydrologic regimes at lower elevation. Wetlands, including fens, wet meadows and springs will be abundant in many areas due to the relatively level topography, and glacial landforms, as well as slump blocks which pool water. Springs

will be common where bedrock and unconsolidated material discontinuities cause ground water to discharge to the soil surface.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
4w	***	**	*	*	*

Cluster 5w: The 38 HUBs in this cluster occupy high elevation snowmelt driven, but unglaciated watersheds on Grand Mesa, the Elk and West Elk and Sawatch Mountains (Figure 12, Table 21). The HUBs in this cluster are typically underlain by non-calcareous rock units.

Some significant areas of many HUBs did support glaciers during the Pleistocene, and bedrock in many areas is calcareous. These HUBs will have abundant wet meadows and fens dominated by sedges in low gradient landscapes and willows in steeper basins. Fens will be present at toe slopes and in basins, and where calcareous parent material occurs, rich and extreme rich fens may occur. Some mountain areas are quite steep and will have few wetlands other than at the toe of avalanche and debris flow deposits. But some high elevation basins will have extensive wetlands.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
5w	***	**	*	*	*

Cluster 6w: The 31 watersheds in cluster 6w are typified by high elevation, snowmelt driven systems in non-glaciated terrain (Table 21). The chemical constituency of the underlying rock units is not a defining factor in this cluster. Watersheds in cluster 6 are found in the West Elk Mountains and in the Tomichi Creek drainage (Figure 12).

There are large areas of sagebrush, Gambel oak shrublands, and Douglas fir forests. Because of the relatively high precipitation and steep land form, there will be numerous springs and seeps which support wet meadows and fens dominated by herbaceous plants. There will also be willow thickets supported by ground water flow both on the edges of floodplains, and in mountain valleys.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
6w	***	***	*	*	*

Cluster 7w: The 20 watersheds in cluster 7w occupy the southern West Elk and Sawatch Range, as well as the Elk Range and have largely calcareous bedrock (Figure 12, Table 21). The HUBs were partly glaciated, and have a snowmelt driven hydrologic regime.

Landforms conducive to wetland formation are present throughout this region, particularly on plateaus at all elevations, at toe slopes and valley bottoms, and in glacial deposits. Ground water flow systems will commonly reach the ground surface and fens will be numerous. Many springs and wet meadows will also occur from the alpine tundra to the lower portions of the subalpine forest. These HUBs have high potential to support calcareous rich fens, a rare ecosystem type in Colorado.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
7w	***	***	**	**	-

Cluster 8w: Cluster 8w is typified by high elevation, snowmelt driven systems underlain by non-calcareous lithology (Table 21). These watersheds have the greatest extent of quaternary glaciation of all of the clusters, and although calcareous geology is not present could have large areas occupied of wetlands. These 17 watersheds are located in the high elevation areas atop Grand Mesa, and at the core of the Elk, West Elk and Sawatch Mountain Ranges (Figure 12).

Most of each HUB was completely covered by glaciers during the Pleistocene, and glacial landforms dominate the landscapes. These HUBs all have snow melt driven hydrologic regimes, although summer rains play a key role in recharging hillslope ground water aquifers. Wetlands will be abundant at all elevations and all landforms except the steepest slopes. Fens are common, and a range of fen types from floating mats, to sloping fens will be present. Wet meadows will be common in areas with seasonally saturated soils.

CLUSTER	HYDROLOGY	SEDIMENT	THERMAL	NUTRIENTS	BIOTA
8w	***	***	**	**	-

References

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