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12. APPENDICES

APPENDIX A. HYDROLOGY

Table A1. Metrics for evaluating the accuracy of calibration model for hydrological analyses. Daily Flow Statistics at USGS Gage 12108500 (Oct 1999 – Sep 2002).

| Statistic | Sim (cfs) | Obs (cfs) | Diff (cfs) | Diff (%) |
|------------------------------|-----------|-----------|------------|----------|
| Mean | 54.77 | 55.12 | -0.34 | -0.6 % |
| Geometric Mean | 38.08 | 39.20 | -1.12 | -2.9 % |
| Standard Deviation (SD) | 56.48 | 56.08 | | |
| Correlation Coefficient | 0.94 | | | |
| Coefficient of Determination | 0.88 | | | |
| Mean Error | -0.35 | | | |
| Mean Absolute Error | 9.87 | | | |
| Root Mean Square (RMS) Error | 19.82 | | | |
| Nash Sutcliffe | 0.12 | | | |
| Model Fit Efficiency | 0.88 | | | |
| Skill Score [†] | 0.65 | | | |

[†] The skill score is computed as $1 - (\text{RMS Error} \cdot \text{SD}^{-1} \text{ of the observed flow})$.

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Table A2. Expert System Statistics at USGS Gage 12108500 (Oct 1998 – Sep 2002).

| Variable | Sim | Obs | Diff | Diff (%) | Criteria (%) | Meets Criteria |
|--------------------------|-------|-------|--------|----------|--------------|----------------|
| Total (in) | 28.69 | 28.87 | -0.183 | -0.6% | 10% | Excellent |
| 10% high (in) | 9.86 | 9.66 | 0.196 | 2.0% | 10% | Excellent |
| 25% high (in) | 16.95 | 6.53 | 0.422 | 2.6% | 15% | Excellent |
| 50% low (in) | 5.26 | 5.66 | -0.395 | -7.0% | 15% | Good |
| 25% low (in) | 1.99 | 1.99 | 0.002 | 0.1% | 15% | Excellent |
| 10% low (in) | 0.69 | 0.67 | 0.024 | 3.6% | 15% | Excellent |
| storm volume (in) | 8.87 | 9.00 | -0.127 | -1.4% | 20% | Excellent |
| average storm peak (cfs) | 246.9 | 282.0 | -35.07 | -12.4% | 15% | Fair |
| summer volume (in) | 3.39 | 3.64 | -0.249 | -6.9% | 15% | Good |
| winter volume (in) | 11.82 | 11.70 | 0.114 | 1.0% | 10% | Excellent |
| summer storms (in) | 0.28 | 0.15 | 0.135 | 91.7% | 10% | Poor |
| winter storms (in) | 2.99 | 2.86 | 0.136 | 4.8% | 15% | Excellent |

Table A3. Impervious surfaces in each sub-basin of Newaukum Creek, in 200 by sub-basin. We estimate the total area of impervious area the entire ecosystem equals 2.96 square miles (1,897 acres). Other landcovers total 23.04 square miles (14,743 acres). Thus, 11% of the Newaukum Creek ecosystem is covered by impervious surface area.

| Sub-basin | Total impervious area (acres) | Other (acres) | Total acres | Percentage of basin area in impervious surfaces |
|-----------|-------------------------------|---------------|-------------|---|
| NEW011 | 60 | 1169 | 1229 | 5% |
| NEW021 | 2 | 81 | 83 | 3% |
| NEW031 | 44 | 323 | 367 | 12% |
| NEW041 | 33 | 860 | 893 | 4% |
| NEW051 | 21 | 331 | 352 | 6% |
| NEW061 | 14 | 368 | 381 | 4% |
| NEW071 | 13 | 274 | 287 | 5% |
| NEW081 | 78 | 1047 | 1126 | 7% |
| NEW091 | 40 | 375 | 415 | 10% |
| NEW101 | 264 | 564 | 828 | 32% |
| NEW111 | 169 | 1294 | 1464 | 12% |
| NEW121 | 39 | 361 | 400 | 10% |
| NEW131 | 115 | 721 | 836 | 14% |

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| Sub-basin | Total impervious area (acres) | Other (acres) | Total acres | Percentage of basin area in impervious surfaces |
|-----------|-------------------------------|---------------|-------------|---|
| NEW141 | 62 | 313 | 375 | 17% |
| NEW151 | 158 | 111 | 269 | 59% |
| NEW161 | 12 | 23 | 35 | 35% |
| NEW171 | 169 | 456 | 625 | 27% |
| NEW181 | 84 | 624 | 708 | 12% |
| NEW191 | 40 | 630 | 671 | 6% |
| NEW201 | 9 | 144 | 153 | 6% |
| NEW211 | 84 | 865 | 948 | 9% |
| NEW221 | 49 | 443 | 491 | 10% |
| NEW231 | 71 | 784 | 855 | 8% |
| NEW241 | 103 | 866 | 969 | 11% |
| NEW251 | 25 | 212 | 237 | 10% |
| NEW261 | 11 | 437 | 447 | 2% |
| NEW271 | 94 | 564 | 658 | 14% |
| NEW281 | 23 | 318 | 341 | 7% |
| NEW291 | 10 | 185 | 195 | 5% |

Table A4. Flow rates (cubic feet per second) for specified return periods (e.g., 10-year flood) for each sub-basin in the Newaukum Creek Basin. Four scenarios are listed. The “Forest” scenario is intended to represent forested conditions. The “LC1995” scenario represents conditions from 1995, based on landcover maps from that year. The “LC2002” is intended to represent current conditions, based on landcover maps from 2002. The “Future” scenario is based on the current zoning of the Basin.

| | | Flow Rates for Specified Return Period (in years) | | | | | | | |
|-----------|----------|---|----|-----|-----|-----|-----|-----|-----|
| Sub-basin | Scenario | 1 | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| 11 | Forest | 10 | 87 | 157 | 218 | 277 | 295 | 356 | 424 |
| | LC1995 | 12 | 95 | 166 | 227 | 284 | 301 | 361 | 425 |
| | LC2002 | 11 | 89 | 159 | 220 | 279 | 296 | 357 | 426 |
| | Future | 11 | 89 | 159 | 220 | 279 | 296 | 357 | 426 |
| 21 | Forest | 1 | 7 | 13 | 18 | 23 | 24 | 29 | 34 |
| | LC1995 | 1 | 8 | 13 | 18 | 23 | 24 | 29 | 33 |
| | LC2002 | 1 | 8 | 13 | 18 | 23 | 24 | 29 | 33 |

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| | | Flow Rates for Specified Return Period (in years) | | | | | | | |
|-----------|----------|---|-----|-----|-----|-----|-----|-----|------|
| Sub-basin | Scenario | 1 | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| | Future | 1 | 8 | 13 | 18 | 23 | 24 | 29 | 33 |
| 31 | Forest | 10 | 108 | 199 | 281 | 360 | 384 | 466 | 558 |
| | LC1995 | 17 | 132 | 229 | 311 | 388 | 411 | 490 | 576 |
| | LC2002 | 15 | 125 | 220 | 301 | 378 | 401 | 481 | 569 |
| | Future | 16 | 129 | 225 | 307 | 384 | 407 | 487 | 574 |
| 41 | Forest | 6 | 60 | 109 | 152 | 195 | 207 | 252 | 301 |
| | LC1995 | 8 | 65 | 115 | 158 | 200 | 213 | 257 | 305 |
| | LC2002 | 7 | 61 | 110 | 153 | 196 | 208 | 253 | 302 |
| | Future | 7 | 61 | 110 | 153 | 196 | 208 | 253 | 302 |
| 51 | Forest | 7 | 78 | 147 | 209 | 268 | 285 | 346 | 413 |
| | LC1995 | 11 | 96 | 167 | 228 | 285 | 302 | 359 | 422 |
| | LC2002 | 10 | 90 | 160 | 220 | 277 | 294 | 352 | 416 |
| | Future | 11 | 92 | 163 | 223 | 280 | 296 | 354 | 417 |
| 61 | Forest | 2 | 28 | 54 | 79 | 101 | 108 | 130 | 155 |
| | LC1995 | 4 | 37 | 65 | 87 | 107 | 113 | 132 | 153 |
| | LC2002 | 3 | 31 | 58 | 81 | 102 | 108 | 130 | 153 |
| | Future | 3 | 33 | 60 | 83 | 104 | 110 | 131 | 153 |
| 71 | Forest | 1 | 16 | 31 | 45 | 58 | 62 | 75 | 90 |
| | LC1995 | 3 | 24 | 43 | 59 | 73 | 77 | 92 | 108 |
| | LC2002 | 3 | 26 | 45 | 60 | 74 | 77 | 91 | 105 |
| | Future | 5 | 34 | 54 | 70 | 84 | 88 | 102 | 116 |
| 81 | Forest | 4 | 55 | 105 | 152 | 196 | 209 | 256 | 308 |
| | LC1995 | 11 | 91 | 158 | 216 | 270 | 286 | 342 | 402 |
| | LC2002 | 11 | 88 | 151 | 204 | 253 | 267 | 317 | 371 |
| | Future | 12 | 95 | 164 | 221 | 275 | 291 | 345 | 404 |
| 91 | Forest | 15 | 177 | 336 | 480 | 619 | 660 | 804 | 965 |
| | LC1995 | 33 | 258 | 446 | 606 | 758 | 802 | 957 | 1127 |
| | LC2002 | 32 | 245 | 424 | 576 | 719 | 761 | 908 | 1068 |

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| | | Flow Rates for Specified Return Period (in years) | | | | | | | |
|-----------|----------|---|-----|-----|------|------|------|------|------|
| Sub-basin | Scenario | 1 | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| | Future | 35 | 264 | 454 | 615 | 766 | 811 | 965 | 1133 |
| 101 | Forest | 2 | 16 | 28 | 39 | 49 | 53 | 64 | 78 |
| | LC1995 | 32 | 70 | 99 | 122 | 146 | 154 | 181 | 211 |
| | LC2002 | 92 | 148 | 183 | 208 | 233 | 240 | 265 | 292 |
| | Future | 92 | 149 | 183 | 209 | 234 | 241 | 267 | 294 |
| 111 | Forest | 5 | 73 | 140 | 201 | 259 | 276 | 336 | 402 |
| | LC1995 | 47 | 167 | 252 | 322 | 390 | 411 | 483 | 563 |
| | LC2002 | 120 | 253 | 335 | 398 | 457 | 476 | 537 | 604 |
| | Future | 121 | 263 | 348 | 411 | 471 | 489 | 550 | 616 |
| 121 | Forest | 36 | 354 | 648 | 908 | 1160 | 1234 | 1496 | 1786 |
| | LC1995 | 94 | 527 | 810 | 1025 | 1210 | 1261 | 1433 | 1609 |
| | LC2002 | 146 | 584 | 858 | 1067 | 1253 | 1306 | 1486 | 1674 |
| | Future | 152 | 619 | 903 | 1117 | 1304 | 1356 | 1534 | 1718 |
| 131 | Forest | 27 | 328 | 622 | 887 | 1141 | 1215 | 1479 | 1771 |
| | LC1995 | 98 | 520 | 807 | 1032 | 1231 | 1288 | 1481 | 1684 |
| | LC2002 | 147 | 575 | 856 | 1074 | 1274 | 1333 | 1532 | 1744 |
| | Future | 154 | 610 | 901 | 1125 | 1327 | 1386 | 1584 | 1793 |
| 141 | Forest | 25 | 288 | 543 | 774 | 998 | 1064 | 1300 | 1563 |
| | LC1995 | 86 | 471 | 745 | 963 | 1161 | 1218 | 1412 | 1620 |
| | LC2002 | 138 | 528 | 796 | 1012 | 1215 | 1276 | 1485 | 1712 |
| | Future | 144 | 560 | 839 | 1061 | 1267 | 1328 | 1536 | 1761 |
| 151 | Forest | 0 | 2 | 4 | 6 | 8 | 8 | 10 | 12 |
| | LC1995 | 16 | 25 | 29 | 33 | 36 | 37 | 40 | 43 |
| | LC2002 | 30 | 40 | 46 | 50 | 53 | 54 | 57 | 61 |
| | Future | 30 | 40 | 46 | 50 | 53 | 54 | 57 | 61 |
| 161 | Forest | 0 | 2 | 5 | 6 | 8 | 9 | 11 | 14 |
| | LC1995 | 16 | 26 | 32 | 35 | 39 | 40 | 43 | 47 |
| | LC2002 | 33 | 45 | 52 | 56 | 60 | 61 | 65 | 69 |

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| | | Flow Rates for Specified Return Period (in years) | | | | | | | |
|-----------|----------|---|-----|-----|------|------|------|------|------|
| Sub-basin | Scenario | 1 | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| | Future | 33 | 45 | 52 | 56 | 60 | 61 | 65 | 69 |
| 171 | Forest | 1 | 5 | 9 | 13 | 17 | 19 | 23 | 28 |
| | LC1995 | 19 | 35 | 48 | 58 | 68 | 72 | 83 | 97 |
| | LC2002 | 32 | 54 | 68 | 79 | 89 | 92 | 104 | 116 |
| | Future | 32 | 54 | 68 | 79 | 90 | 93 | 104 | 117 |
| 181 | Forest | 1 | 6 | 11 | 15 | 20 | 21 | 26 | 32 |
| | LC1995 | 9 | 20 | 29 | 38 | 47 | 51 | 62 | 75 |
| | LC2002 | 10 | 20 | 29 | 37 | 45 | 48 | 58 | 69 |
| | Future | 10 | 21 | 31 | 39 | 48 | 51 | 62 | 75 |
| 191 | Forest | 1 | 6 | 11 | 16 | 21 | 22 | 28 | 35 |
| | LC1995 | 6 | 15 | 24 | 32 | 41 | 44 | 56 | 70 |
| | LC2002 | 6 | 14 | 22 | 29 | 37 | 40 | 50 | 62 |
| | Future | 6 | 17 | 28 | 38 | 49 | 52 | 66 | 84 |
| 201 | Forest | 27 | 286 | 534 | 759 | 979 | 1044 | 1277 | 1537 |
| | LC1995 | 109 | 507 | 790 | 1019 | 1232 | 1295 | 1511 | 1746 |
| | LC2002 | 177 | 587 | 869 | 1095 | 1312 | 1378 | 1606 | 1856 |
| | Future | 184 | 620 | 913 | 1147 | 1369 | 1436 | 1666 | 1916 |
| 211 | Forest | 1 | 7 | 13 | 19 | 25 | 27 | 33 | 40 |
| | LC1995 | 8 | 20 | 30 | 38 | 47 | 50 | 60 | 71 |
| | LC2002 | 6 | 16 | 24 | 30 | 37 | 39 | 46 | 55 |
| | Future | 8 | 19 | 28 | 35 | 42 | 44 | 52 | 61 |
| 221 | Forest | 29 | 289 | 539 | 764 | 986 | 1052 | 1288 | 1552 |
| | LC1995 | 117 | 525 | 815 | 1051 | 1272 | 1338 | 1564 | 1810 |
| | LC2002 | 183 | 599 | 886 | 1117 | 1340 | 1408 | 1643 | 1902 |
| | Future | 191 | 635 | 937 | 1179 | 1409 | 1479 | 1719 | 1981 |
| 231 | Forest | 29 | 293 | 540 | 762 | 976 | 1040 | 1266 | 1517 |
| | LC1995 | 119 | 531 | 823 | 1060 | 1281 | 1347 | 1574 | 1820 |
| | LC2002 | 186 | 602 | 889 | 1120 | 1343 | 1411 | 1646 | 1905 |

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| Flow Rates for Specified Return Period (in years) | | | | | | | | | |
|---|----------|-----|-----|-----|------|------|------|------|------|
| Sub-basin | Scenario | 1 | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| | Future | 194 | 640 | 942 | 1185 | 1416 | 1486 | 1726 | 1989 |
| 241 | Forest | 1 | 8 | 17 | 27 | 39 | 43 | 60 | 82 |
| | LC1995 | 10 | 30 | 48 | 64 | 83 | 90 | 113 | 141 |
| | LC2002 | 10 | 28 | 45 | 61 | 78 | 84 | 106 | 132 |
| | Future | 10 | 32 | 52 | 71 | 93 | 100 | 126 | 158 |
| 251 | Forest | 1 | 10 | 20 | 32 | 46 | 51 | 69 | 93 |
| | LC1995 | 13 | 36 | 57 | 77 | 99 | 107 | 135 | 169 |
| | LC2002 | 12 | 33 | 53 | 71 | 92 | 100 | 126 | 159 |
| | Future | 13 | 39 | 63 | 86 | 113 | 122 | 155 | 196 |
| 261 | Forest | 30 | 303 | 558 | 786 | 1006 | 1072 | 1303 | 1560 |
| | LC1995 | 127 | 552 | 853 | 1097 | 1326 | 1394 | 1628 | 1882 |
| | LC2002 | 192 | 621 | 915 | 1153 | 1382 | 1452 | 1692 | 1957 |
| | Future | 201 | 662 | 974 | 1225 | 1463 | 1536 | 1784 | 2056 |
| 271 | Forest | 1 | 5 | 11 | 20 | 31 | 35 | 52 | 77 |
| | LC1995 | 6 | 19 | 32 | 45 | 59 | 64 | 83 | 107 |
| | LC2002 | 6 | 19 | 32 | 45 | 60 | 65 | 83 | 107 |
| | Future | 7 | 21 | 36 | 50 | 66 | 71 | 92 | 118 |
| 281 | Forest | 31 | 310 | 569 | 800 | 1024 | 1090 | 1325 | 1586 |
| | LC1995 | 132 | 565 | 872 | 1120 | 1354 | 1424 | 1664 | 1926 |
| | LC2002 | 196 | 633 | 934 | 1176 | 1410 | 1481 | 1727 | 1998 |
| | Future | 206 | 676 | 995 | 1251 | 1495 | 1569 | 1823 | 2102 |
| 291 | Forest | 32 | 311 | 571 | 804 | 1029 | 1096 | 1333 | 1596 |
| | LC1995 | 132 | 566 | 874 | 1123 | 1358 | 1428 | 1669 | 1932 |
| | LC2002 | 196 | 635 | 937 | 1180 | 1415 | 1487 | 1734 | 2007 |
| | Future | 206 | 678 | 999 | 1256 | 1501 | 1576 | 1832 | 2112 |

Figure Captions for Appendix A:

Figure A1. Map of surficial geology for hydrological analyses in Newaukum Creek Basin. Geology was generalized into four types, according to the infiltration characteristics (in parentheses): (1) till (low); (2) outwash (high); (3) bedrock (low, but with possible fissures), (4) saturated soils (high water tables, generally associated with wetland vegetated areas).

Figure A2. Map of slope distributions in the Newaukum Creek basin. Slope is an important characteristic because it affects response time of runoff and potential moisture storage. Four categories are depicted, based on quintiles: flat (< 5%), mild (5-10%), moderate (10-15%), and steep (> 15%).

Figure A3. Map of current (2002) and future landcover, based on current land use zoning.

***Figure A1. Map of surficial geology used in hydrological analyses
PLEASE SEE SEPARATE FILE***

***Figure A2. Map of slope distributions used in hydrologic analyses.
PLEASE SEE SEPARATE FILE***

***Figure A3. Map of 'current' and future landcover conditions.
PLEASE SEE SEPARATE FILE***