REGIONAL ANALYSIS OF HYDROLOGIC INFORMATION
FOR THE COPPER-NICKEL REGION,
NORTHEASTERN MINNESOTA

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FINAL REPORT

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INTRODUCTION

The hydrologic impact of proposed copper-nickel mining in north­
eastern Minnesota is one of the critical assessments to be made by the
State. The extent and degree of impacts on water resources and aquatic
ecosystems are of primary interest. In order to make such an impact
assessment, the existing surface water systems need to be characterized.
Peak streamflow discharges and low-flow discharges of specified recur­
rence intervals should be identified for streams likely affected by
mining and related activities. This information thus provides a basis
for comparison with peak and low-flow discharges associated with mining.
Hydrologic computer models such as the SSARR can be used to simulate the
hydrology of watersheds modified by mining development. Physically, such
mining effects may consist of changing the contributing drainage areas to
some streams, the establishment of small reservoirs or tailings basins,
or perhaps removing water and returning flows at certain locations along
a stream.

The limited number of streamflow gages in the approximately 2800
square mile study area necessitates a regional hydrology analysis.
Continuous streamflow records for 10 stations and partial records for
another 12 stations exist in the watersheds of the Kawishiwi, Isabella,
Stony, Upper Cloquet, Upper St. Louis, Partridge, Embarrass and Dunka
rivers. The Basswood and Vermillion Rivers were also included in the
analysis because of their long periods of record and proximity to the
study area. Five stations in the study area were not included in the
analysis because their lengths of record were too short. With regional analysis, watershed characteristics can be related to specific hydrologic characteristics of interest, for example the 100-year recurrence interval flood (HBC, 1972). Thus, with only watershed characteristics, estimates of hydrologic information can be obtained for areas without streamflow records.

The objective of this study is to provide a regional analysis of hydrologic information for the copper-nickel region of northeastern Minnesota, including:

(1) Annual peak streamflow frequency analyses in which spring snowmelt events and summer rainfall events were evaluated.

(2) Low-flow frequency analyses of the 1-, 7-, and 30-day duration for 10- and 20-year recurrence intervals.

(3) Annual volumes of runoff vs. annual precipitation for selected watersheds.
PART I

Peak Streamflow Frequency Analysis

Annual peak streamflow analysis was performed for 19 stations in the region (Table 1) according to the guidelines established by the U.S. Water Resources Council (1976). Because annual peak discharges can be caused by either snowmelt or rainfall events, the procedure by Beard (1962) was used to separate the analyses and then combine frequency curves. Snowmelt events were considered from November 15 - May 31 and rainfall events from June 1 - November 14. These dates were only used as guides; precipitation and air temperature data were used to estimate the cause of peak flow. Many annual peak-flow events were attributed to a combination of rainfall and snowmelt events. Although initially we intended to develop frequency curves for both snowmelt and rainfall events, this became impractical because of separation problems. Special care was also taken to insure that peak-flow discharges were independent.

Frequency curves of annual peak discharge and associated confidence limits for the 19 stations are presented in Appendix I. These curves were developed using a regional skew coefficient of -0.1 based on the values presented by WRC (1976). The following criteria were used to determine an adopted skew for each station (WRC 1976):

1) If the station had 100+ years of record, the skew determined from the data itself (called a computed skew) became the adopted skew.
Table 1. Stream gaging stations used in the regional frequency analysis.

<table>
<thead>
<tr>
<th>Station Name</th>
<th>USGS Number</th>
<th>Drainage Area (mi²)</th>
<th>Period of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Cr. near Ely</td>
<td>05127210</td>
<td>5.29</td>
<td>1968-1976</td>
</tr>
<tr>
<td>Basswood R. near Winton</td>
<td>05127500</td>
<td>1740</td>
<td>1932-1976</td>
</tr>
<tr>
<td>Bear Island R. near Ely</td>
<td>05126500</td>
<td>68.5</td>
<td>1952-62, 1975-76</td>
</tr>
<tr>
<td>Burgo Cr. near Ely</td>
<td>05127220</td>
<td>3.04</td>
<td>1968-1976</td>
</tr>
<tr>
<td>Burntside R. near Ely</td>
<td>05127205</td>
<td>-</td>
<td>1968-1976</td>
</tr>
<tr>
<td>Dunka R. near Babbitt</td>
<td>05126000</td>
<td>53</td>
<td>1952-62, 1975-76</td>
</tr>
<tr>
<td>Embarrass R. near Embarrass</td>
<td>04017000</td>
<td>93</td>
<td>1943-1963</td>
</tr>
<tr>
<td>Isabella R. near Isabella</td>
<td>05124500</td>
<td>341</td>
<td>1953-1960</td>
</tr>
<tr>
<td>Kawishiwi R. near Ely</td>
<td>05124480</td>
<td>253</td>
<td>1967-1976</td>
</tr>
<tr>
<td>Kawishiwi R. near Winton</td>
<td>05127000</td>
<td>1200</td>
<td>1906, 1914, 1924-76</td>
</tr>
<tr>
<td>Longstorff Cr. near Ely</td>
<td>05127215</td>
<td>8.84</td>
<td>1967-1976</td>
</tr>
<tr>
<td>Partridge R. near Aurora</td>
<td>04016000</td>
<td>156</td>
<td>1943-1976</td>
</tr>
<tr>
<td>Pike R. near Embarrass</td>
<td>05128500</td>
<td>115</td>
<td>1954-1959</td>
</tr>
<tr>
<td>St. Louis R. near Aurora</td>
<td>04016500</td>
<td>312</td>
<td>1943-1976</td>
</tr>
<tr>
<td>Second Cr. near Aurora</td>
<td>04015500</td>
<td>26.3</td>
<td>1955-1976</td>
</tr>
<tr>
<td>Shagawa R. near Ely</td>
<td>05127230</td>
<td>-</td>
<td>1968-1976</td>
</tr>
<tr>
<td>S. Kawishiwi R. near Ely</td>
<td>05125000</td>
<td>-</td>
<td>1952-1960</td>
</tr>
<tr>
<td>Stony R. near Isabella</td>
<td>05125500</td>
<td>180</td>
<td>1953-1960</td>
</tr>
<tr>
<td>Vermillion R. below Vermillion Lake</td>
<td>05129000</td>
<td>483</td>
<td>1929-1976</td>
</tr>
</tbody>
</table>
(2) If the station had <25 years of record, the regional skew coefficient of -0.1 became the adopted skew.

(3) If the station had from 25-99 years of record, the adopted skew = computed skew \[(N-25)/75\] + generalized skew \[1 - ((N-25)/75)\], where N = number of years of record.

The adopted skew, along with mean and standard deviation, was then used to characterize the frequency curve for each station.

Final frequency curves were developed using records based on the regional frequency computation computer program (HEC, 1972). This program was used to estimate missing events and to extend short-record station data on the basis of correlations with long-record stations. These frequency curves are presented in Appendix II. The regional skew of -0.1 was again used. The resultant exceedance frequency curves were the basis for the regional frequency analysis.

The regional frequency analysis was performed with regression analyses as described by HEC (1975). Frequency curve statistics and characteristics for each station were regressed against basin characteristics. Prediction equations were developed with the University of Minnesota computer program MULTREG (Weisburg, 1977).

Watershed characteristics were not readily available for all watersheds in the study area. Basin area was available for 16 of 19 stations, main channel slope and storage area (area in lakes, swamps, etc.) were available for 8 of the 19 stations, and main channel length was available for 7 of the 19 stations. Consequently, regression equations were developed by:
(1) determining a simple linear regression with area as the independent variable for the 16 stations, and

(2) developing multiple regression using all 4 basin characteristics as independent variables with 7 stations.

By convention all independent and dependent variables were expressed as log$_{10}$ values.

A Log Pearson Type III curve is characterized by the mean, standard deviation, and skew. Since skew was assumed to be -0.1 for all the stations the frequency curve for an ungaged station could be estimated by predicting only the mean and standard deviation. An alternative way to predict the curve (or a portion of it) is to predict certain points on the curve (such as the .01\(^1\) event, the .10 event, etc.) and connect the points. In total, six dependent variables were examined and included the base 10 logarithm of the .01, .02, .05, .10, .50 (mean) values of discharge and the standard deviation.

The regression equations for 16 stations using only drainage areas as the independent variable are listed in Table 2. Because of the low coefficient of determination for predicting the standard deviation ($R^2 = .26$), the best estimates of exceedance frequencies for an ungaged area would be determined by predicting peaks associated with .01, .02, .05, .10 and .50 and drawing a "best fit" line. Annual peak flows can be determined graphically using Figure 1 with basin area as the only watershed characteristic.

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1 .01 refers to the probability that a particular discharge will be equaled or exceeded in a given year, i.e. there is a 1 in 100 chance that the .01 event will occur in a given year. This is sometimes referred to as the "100 year event."
Table 2. Regression equations of the form \( \log Q_{cfs} = b_1 + b_2 \log \text{area} (\text{mi}^2) \) developed from 16 stations.

<table>
<thead>
<tr>
<th>( \hat{Y} )</th>
<th>Regression</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Q .01</td>
<td>( \hat{Y} = 1.7446 + .7309 \log \text{area} )</td>
<td>.9042</td>
</tr>
<tr>
<td>Log Q .02</td>
<td>( \hat{Y} = 1.6636 + .7419 \log \text{area} )</td>
<td>.9138</td>
</tr>
<tr>
<td>Log Q .05</td>
<td>( \hat{Y} = 1.5522 + .7538 \log \text{area} )</td>
<td>.9272</td>
</tr>
<tr>
<td>Log Q .10</td>
<td>( \hat{Y} = 1.4470 + .7675 \log \text{area} )</td>
<td>.9374</td>
</tr>
<tr>
<td>Mean (log Q .50)</td>
<td>( \hat{Y} = 1.0794 + .8135 \log \text{area} )</td>
<td>.9595</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>( \hat{Y} = .2819 - .0337 \log \text{area} )</td>
<td>.2605</td>
</tr>
</tbody>
</table>

n = 16 stations

Multiple regression analyses performed on 7 stations with area (\( \text{mi}^2 \)), slope (ft/mile) and main channel length (miles) as independent variables were unsatisfactory. More stations (samples) would be needed to develop satisfactory prediction equations.
Figure 1. Regional relationships between watershed area and annual peak streamflow for .01, .02, .05, .10, and .50 exceedance frequencies, for the Copper-Nickel Study Area.
PART II

Low-Flow Frequency Analysis

The three different low-flow "periods" analyzed, were annual, winter, and summer. The winter period was between November 15 and May 31; the summer period ran from June 1 to November 14. One-day, seven-day, and thirty-day low-flow were computed for the whole year (annual) as well as for summer and winter periods.

Unlike the peak flow frequency analysis, low-flow curves were determined by the graphical method (Beard, 1962). This method simply involves assigning a plotting position to each flow according to its rank within the period of record. Once the points are plotted, a smooth curve is subjectively drawn through the points. Annual, winter, and summer frequency curves are presented in Appendices III, IV, and V, respectively.

For the regional analysis, prediction equations were developed for the .05 and .10 streamflow events for 1-day, 7-day, and 30-day low-flow for the annual, winter, and summer periods. The dependent variable was the log10 of the streamflow and the independent variable was the log10 of watershed area. Values less than or equal to .10cfs were all assigned log10 values of -1.000 since .10cfs was judged to be the minimum value that could be recorded at the gaging station.

The prediction equation developed using MULTREG (Weinberg, 1977) are summarized in Tables 3, 4, and 5 and are shown as curves in Figures 2, 3, 4, 5, 6, and 7. Fifteen of the nineteen stations in the study area were
used to develop these equations. The Kawishiwi River near Winton was considered an outlier because of extensive regulation at low-flows and was, therefore, omitted from the analysis.

The annual precipitation -- annual runoff volumes were not completed for this report. Precipitation analyses were not available to the authors.
Table 3. Prediction Equations for 1-day Low-Flows

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual .10 ($\log_{10}$)</td>
<td>$Y = -1.9304 + 1.2254 \log_{10} Area$</td>
<td>.89</td>
</tr>
<tr>
<td>Annual .05</td>
<td>$Y = -1.9356 + 1.1633 \log_{10} Area$</td>
<td>.83</td>
</tr>
<tr>
<td>Summer .10</td>
<td>$Y = -1.8843 + 1.2349 \log_{10} Area$</td>
<td>.88</td>
</tr>
<tr>
<td>Summer .05</td>
<td>$Y = -1.9133 + 1.1788 \log_{10} Area$</td>
<td>.82</td>
</tr>
<tr>
<td>Winter .10</td>
<td>$Y = -1.7425 + 1.2146 \log_{10} Area$</td>
<td>.95</td>
</tr>
<tr>
<td>Winter .05</td>
<td>$Y = -1.8384 + 1.2004 \log_{10} Area$</td>
<td>.94</td>
</tr>
</tbody>
</table>

Table 4. Prediction Equations for 7-day Low-Flow

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual .10 ($\log_{10}$)</td>
<td>$Y = -1.9320 + 1.2479 \log_{10} Area$</td>
<td>.92</td>
</tr>
<tr>
<td>Annual .05</td>
<td>$Y = -1.9336 + 1.1951 \log_{10} Area$</td>
<td>.89</td>
</tr>
<tr>
<td>Summer .10</td>
<td>$Y = -1.8681 + 1.2607 \log_{10} Area$</td>
<td>.90</td>
</tr>
<tr>
<td>Summer .05</td>
<td>$Y = -1.8771 + 1.2010 \log_{10} Area$</td>
<td>.85</td>
</tr>
<tr>
<td>Winter .10</td>
<td>$Y = -1.7118 + 1.2114 \log_{10} Area$</td>
<td>.94</td>
</tr>
<tr>
<td>Winter .05</td>
<td>$Y = -1.7939 + 1.1972 \log_{10} Area$</td>
<td>.94</td>
</tr>
</tbody>
</table>
Table 5. Prediction Equations for 30-day Low-Flows

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual .10 (Log$_{10}$)</td>
<td>$Y = -1.7768 + 1.2204 \log_{10} Area$</td>
<td>.94</td>
</tr>
<tr>
<td>Annual .05 &quot; &quot;</td>
<td>$Y = -1.8842 + 1.2091 \log_{10} Area$</td>
<td>.92</td>
</tr>
<tr>
<td>Summer .10 &quot; &quot;</td>
<td>$Y = -1.5180 + 1.1649 \log_{10} Area$</td>
<td>.90</td>
</tr>
<tr>
<td>Summer .05 &quot; &quot;</td>
<td>$Y = -1.6279 + 1.1531 \log_{10} Area$</td>
<td>.86</td>
</tr>
<tr>
<td>Winter .10 &quot; &quot;</td>
<td>$Y = -1.6891 + 1.2198 \log_{10} Area$</td>
<td>.94</td>
</tr>
<tr>
<td>Winter .05 &quot; &quot;</td>
<td>$Y = -1.7619 + 1.2036 \log_{10} Area$</td>
<td>.94</td>
</tr>
</tbody>
</table>
Figure 2. One-day low-flow discharge with 0.10 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
Figure 3. One-day low-flow discharge with 0.05 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
Figure 4. Seven-day low-flow discharge with 0.10 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
Figure 5. Seven-day low-flow discharge with 0.05 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
Figure 6. Thirty-day low-flow discharge with 0.10 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
Figure 7. Thirty-day low-flow discharge with 0.05 non-exceedance frequency versus watershed area for Copper-Nickel Study Area.
REFERENCES


APPENDIX I

Annual Peak Discharge Frequency Curves for
Stations in Copper-Nickel Study Area
BEAR ISLAND R. NEAR ELY
STATION NO. 05126500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
BURGO CR. NEAR ELY
STATION NO. 05127220
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW

DISCHARGE IN CFS
KAWISHIWI R. NEAR ELY
STATION NO. 05124480
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
DISCHARGE IN CFS

KAWISHI R. NEAR WILTON
STATION NO. 01512700
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STORM FLOW

EXCEEDANCE FREQUENCY IN PERCENT
Exceedance Frequency in Percent

Partridge R. Near Aurora
Station No. 04016000
Annual Peak Flow Frequency Curve
Mean Daily Stream Flow
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
SECOND CR., NEAR AURORA
STATION NO. 04015500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
STONY R. NEAR ISABELLA
STATION NO. 05125500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
VERMILLION R. BELOW VERMILLION LAKE
STATION NO. 05129000
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
APPENDIX II

Annual Peak Discharge Frequency Curves for Stations in Copper-Nickel Study Area. Curves based on records extended with the Regional Frequency Computer Program.
BASSWOOD R, NEAR WINTON
STATION NO. 05127500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS

DISCHARGE IN CFS
BEAR ISLAND R. NEAR ELY
STATION NO. 05126500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS
DUNKA R. NEAR BABBITT
STATION NO. 05126000
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS

DISCHARGE IN CFS

10,000
9
8
7
6
5
4
3
2
1

1,000

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.5
0.1
0.05
0.01

99.99
99.90
99.00
98.00
95.00
90.00
80.00
60.00
40.00
20.00
10.00

KAWISHIWI R., NEAR ELY
STATION NO. 05124480
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS
PARTRIDGE R., NEAR AURORA
STATION NO. 04016000
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS
STONY R. NEAR ISABELLA
STATION NO. 05125500
ANNUAL PEAK FLOW FREQUENCY CURVE
MEAN DAILY STREAM FLOW
EXTENDED WITH LONG-RECORD STATIONS
For stations in Copper-Mohave study area
Annual 1-day, 7-day, and 30-day low-flow frequency curves

APPENDIX III
ARMSTRONG CR., NEAR ELY
STATION NO. 05127210
THIRTY-DAY DURATION LOW FLOW
ANNUAL
NON-EXCEEDANCE FREQUENCY IN PERCENT

BASSWOOD R, NEAR WINTON
STATION NO. 05127500
THIRTY-DAY DURATION LOW FLOW
ANNUAL
BEAR ISLAND R, NEAR ELY
STATION NO. 05126500
SEVEN-DAY DURATION LOW FLOW
ANNUAL
BURGO CR. NEAR ELY
STATION NO. 05127220
THIRTY-DAY DURATION LOW FLOW
ANNUAL
BURNTSIDE R. NEAR ELY
STATION NO. 05127205
ONE-DAY DURATION LOW FLOW
ANNUAL
ANNUAL
SEVEN-DAY DURATION LOW FLOW
STATION NO. 05227205
BURNETTE R., NEAR ELY
NON-EXCEEDANCE FREQUENCY IN PERCENT
DISCHARGE IN CFS
BURNTSIDE R. NEAR ELY
STATION NO. 05127205
THIRTY-DAY DURATION LOW FLOW
ANNUAL
NON-EXCEEDANCE FREQUENCY IN PERCENT

DUNKA R. NEAR BABBITT
STATION NO. 05126000
THIRTY-DAY DURATION LOW FLOW
ANNUAL
EMBARRASS R. NEAR EMBARRASS
STATION NO. 04017000
ONE-DAY DURATION LOW FLOW
ANNUAL
EMBARRASS R., NEAR EMBARRASS  
STATION NO. 04017000  
THIRTY-DAY DURATION LOW FLOW  
ANNUAL
ISABELLA R. NEAR ISABELLA
STATION NO. 05124500
ONE-DAY DURATION LOW FLOW
ANNUAL
NON-EXCEEDANCE FREQUENCY IN PERCENT

LONGSTORFF CR. NEAR ELY
STATION NO. 05127215
SEVEN-DAY DURATION LOW FLOW
ANNUAL

DISCHARGE IN CFS
NON-EXCEEDANCE FREQUENCY IN PERCENT

PARTRIDGE R. NEAR AURORA
STATION NO. 04016000
ONE-DAY DURATION LOW FLOW
ANNUAL
NON-EXCEEDANCE FREQUENCY IN PERCENT

PARTRIDGE R., NEAR AURORA
STATION NO. 04016000
THIRTY-DAY DURATION LOW FLOW
ANNUAL
NON-EXCEEDANCE FREQUENCY IN PERCENT

PIKE R. NEAR EMBARRASS
STATION NO. 05128500
ONE-DAY DURATION LOW FLOW
ANNUAL
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
ONE-DAY DURATION LOW FLOW
ANNUAL

NON-EXCEEDANCE FREQUENCY IN PERCENT
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
SEVEN-DAY DURATION LOW FLOW
ANNUAL
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
THIRTY-DAY DURATION LOW FLOW
ANNUAL
SECOND CR., NEAR AURORA
STATION NO. 04015500
ONE-DAY DURATION LOW FLOW
ANNUAL
ANNUAL SEVEN-DAY DURATION LOW FLOW STATION NO. 04015500 SECOND CR. NEAR AURORA

DI SC HARGE IN CFS

NON-EXCEEDANCE FREQUENCY IN PERCENT
SHAGAWA R. NEAR ELY
STATION NO. 05127230
THIRTY-DAY DURATION LOW FLOW
ANNUAL
S. KAWISHIWI R. NEAR ELY
STATION NO. 05125000
ONE-DAY DURATION LOW FLOW
ANNUAL

NON-ECEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
ANNUAL SEVEN-DAY DURATION LOW FLOW
STATION NO. 05125000
S. KAWISHI MI R. NEAR ELV
S. KAWISHWI R. NEAR ELY
STATION NO. 05125000
THIRTY-DAY DURATION LOW FLOW
ANNUAL

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS

1000 100 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
STONY R. NEAR ISABELLA
STATION NO. 05125500
ONE-DAY DURATION LOW FLOW
ANNUAL
STONY R. NEAR ISABELLA
STATION NO.05125500
THIRTY-DAY DURATION LOW FLOW
ANNUAL

NON-EXCEEDANCE FREQUENCY IN PERCENT

STONY R. NEAR ISABELLA
STATION NO.05125500
THIRTY-DAY DURATION LOW FLOW
ANNUAL

NON-EXCEEDANCE FREQUENCY IN PERCENT
NON-EXCEEDANCE FREQUENCY IN PERCENT

VERMILLION R. BELOW VERMILLION LAKE
STATION NO: 05129000
SEVEN-DAY DURATION LOW FLOW
ANNUAL

DISCHARGE IN CFS
NON-EXCEEDANCE FREQUENCY IN PERCENT

VERMILLION R. BELOW VERMILLION LAKE
STATION NO. 05129000
THIRTY-DAY DURATION LOW FLOW
ANNUAL
APPENDIX IV

Winter 1-day, 7-day, and 30-day Low-Flow Frequency Curves for Stations in Copper-Nickel Study Area
ARMSTRONG CR, NEAR ELY
STATION NO. 05127210
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-E exceedance FREQUENCY IN PERCENT
ARMSTRONG CR, NEAR ELY
STATION NO. 05127210
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

BASSWOOD R, NEAR WINTON
STATION NO. 05127500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

BASSWOOD R. NEAR WINTON
STATION NO. 05127500
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
BEAR ISLAND R., NEAR ELY
STATION NO. 05126500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
BURGO CR. NEAR ELY
STATION NO. 05127220
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
BURGO CR. NEAR ELY
STATION NO. 05127220
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
BURNTSIDE R, NEAR ELY
STATION NO. 05127205
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CF S

100 99.99 99.9 99.8 99 98 97 96 95 94 93 92 91 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
NON-EXCEEDANCE FREQUENCY IN PERCENT

BURNTSIDE R. NEAR ELY
STATION NO. 05127205
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
BURNTSIDE R. NEAR ELY
STATION NO. 05127205
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
DUNKA R., NEAR BABBITT
STATION NO. 05126000
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

DUNKA R. NEAR BABBITT
STATION NO. 05126000
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

DUNKA R. NEAR BABBITT
STATION NO. 05126000
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

EMBARRASS R., NEAR EMBARRASS
STATION NO. 04017000
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

DISCHARGE IN CFS
ISABELLA R, NEAR ISABELLA
STATION NO. 05124500
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
ISABELLA R. NEAR ISABELLA
STATION NO. 05124500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
ISABELLA R. NEAR ISABELLA
STATION NO. 05124500
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
KAWISHIWI R. NEAR ELY
STATION NO. 05124480
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
KAWISHIMI R. NEAR ELY
STATION NO. 05124480
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
KAWISHIWI R., NEAR ELY
STATION NO. 05124480
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

LONGSTORFF CR. NEAR ELY
STATION NO. 05127215
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

DISCHARGE IN CFS
LONGSTORFF CR, NEAR ELY
STATION NO. 05127215
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CF'S

0.0 0.1 0.2 0.3 1 2 5 10

99 99 98 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0.01 0.05 0.1 0.2 0.3
NON-EXCEEDANCE FREQUENCY IN PERCENT

PARTRIDGE R, NEAR AURORA
STATION NO. 04016000
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

DISCHARGE IN CFS
PIKE R. NEAR EMBARRASS
STATION NO. 05128500
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

PIKE R. NEAR EMBARRASS
STATION NO. 05128500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
ST. LOUIS R. NEAR AURORA
STATION NO. 04016500
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
SECOND CR., NEAR AURORA
STATION NO. 04015500
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
DISCHARGE IN CFS

SECOND CR. NEAR AURORA
STATION NO.: 04015500
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
SECOND CR, NEAR AURORA
STATION NO. 04015500
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
SHAGAWA R. NEAR ELY
STATION NO. 05127230
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
SHAGAWA R. NEAR ELY
STATION NO. 05127230
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
S. KAWISHIWI R, NEAR ELY
STATION NO. 05125000
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
S. KAWISHIWI R. NEAR ELY
STATION NO. 05125000
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
S. KAWISHIWI R. NEAR ELY
STATION NO. 05125000
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
STONY R. NEAR ISABELLA
STATION NO. 05125500
ONE-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
STONY R. NEAR ISABELLA
STATION NO. 05125500
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
NON-EXCEEDANCE FREQUENCY IN PERCENT

VERMILLION R. BELOW VERMILLION LAKE
STATION NO. 05129000
SEVEN-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31
VERMILLION R. BELOW VERMILLION LAKE
STATION NO. 05129000
THIRTY-DAY DURATION LOW FLOW
WINTER, NOV 15 - MAY 31

NON-BELLINGER FREQUENCY IN PERCENT

DISCHARGE IN CFs
APPENDIX V

Summer 1-day, 7-day, and 30-day Low-Flow Frequency Curves for Stations in Copper-Nickel Study Area
BASSWOOD R. NEAR WINTON STATION NO. 05127500
ONE-DAY DURATION LOW FLOW SPRING, JUNE 1 - NOV 14

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
BASSWOOD R., NEAR WINTON
STATION NO. 05127500
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
BASSWOOD R. NEAR WINTON
STATION NO. 05127500
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
BEAR ISLAND R. NEAR ELY
STATION NO. 05126500
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

BEAR ISLAND R, NEAR ELY
STATION NO. 05126500
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

BURGO CR, NEAR ELY
STATION NO. 05127220
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
BURNTSIDE R. NEAR ELY
STATION NO. 05127205
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

BURNTSIDE R. NEAR ELY
STATION NO. 05127205
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
**DUNKA R, NEAR BABBITT**  
**STATION NO, 05126000**  
**ONE-DAY DURATION LOW FLOW**  
**SPRING, JUNE 1 - NOV 14**
NON-EXCEEDANCE FREQUENCY IN PERCENT

DUNKA R. NEAR BABBITT
STATION NO. 05126000
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
EMBARRASS R., NEAR EMBARRASS
STATION NO. 04017000
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

ISABELLA R. NEAR ISABELLA
STATION NO. 05124500
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
KAWISHIWI R, NEAR ELY
STATION NO. 05124480
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
LONGSTORFF CR. NEAR ELY
STATION NO. 05127215
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
LONGSTORFF CR, NEAR ELY
STATION NO. 05127215
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
LONGSTORFF CR, NEAR ELY
STATION NO. 05127215
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
PARTRIDGE R. NEAR AURORA
STATION NO. 04016000
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

PARTRIDGE R. NEAR AURORA
STATION NO. 04016000
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT.

PIKE R. NEAR EMBARRASS

STATION NO. 05128500
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
SPRING, JUNE 1 - NOV 14
SEVEN-DAY DURATION LOW FLOW
STATION NO. 04016500
ST. LOUIS R. NEAR AURORA

NON-EXCEEDANCE FREQUENCY IN PERCENT
SECOND CR. NEAR AURORA
STATION NO. 04015500
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
SECOND CR, NEAR AURORA
STATION NO. 04015500
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
SHAGAWA R, NEAR ELY
STATION NO. 05127230
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14

NON-EXCEEDANCE FREQUENCY IN PERCENT

DISCHARGE IN CFS
SHAGAWA R. NEAR ELY
STATION NO. 05127230
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
SHAGAWA R, NEAR ELY
STATION NO. 05127230
THIRTY-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
STONY R. NEAR ISABELLA
STATION NO. 05125500
SEVEN-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14
NON-EXCEEDANCE FREQUENCY IN PERCENT

VERMILLION R., BELOW VERMILLION LAKE
STATION NO. 05129000
ONE-DAY DURATION LOW FLOW
SPRING, JUNE 1 - NOV 14

DISCHARGE IN CFS