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Flood Potential Assessment and Discharge Prediction: Lightning Creek Watershed

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Summary

To serve the needs of the Idaho Panhandle National Forests, a flood potential assessment of the Lightning Creek watershed was performed. This assessment provides a general overview of flooding characteristics, from regional to catchment scales. Results are detailed within this report, for use by Forest Service staff and other interested parties.

This area (zone 42N) experiences unusual flooding in comparison with other parts of the Rocky Mountains, with flooding characteristics similar to the Cascades and Coastal Ranges of the Pacific Northwest. Flood magnitudes in zone 42N are substantially larger than in adjacent zones in the Northern Rockies ($P_f = 10.9$; up to 11 times larger), with relatively larger floods experienced in larger-sized watersheds ($R_f = 1.23$), low variability ($V_f = 1.50$), and low flashiness (see Appendix A for definitions of terms). The seasonality of large floods peaks in December (as well as January and February), with a second (lesser) peak in April. This dominant winter season coincides with atmospheric river and rain-on-snow events experienced in the Pacific Northwest; this zone is the only area of the Rocky Mountains that experiences dominate flooding during the winter season, and is an eastern-most extent of direct contributions of atmospheric river activity to large floods. Streamgage data also indicate that there are no significant or possible trends in flood magnitudes and frequency within zone 42N; at this time, large floods are not becoming larger or more frequent due to climate change.

Two extreme floods have been documented to have occurred within the Lightning Creek watershed, within Trapper Creek (December 1980) and in Lightning Creek (November 2006). These are the only extreme events recorded within zone 42N. Hence, floods in zone 42N are inherently large, and extreme floods may have a propensity for occurring within the Lightning Creek watershed.

Design flood discharges were determined through the use of multiple methods for the identification of the most appropriate prediction technique, at road-stream crossing and at downstream limits of stream restoration reaches. Recommended values are provided below:

ID	Site Description	Design Flood Discharge, Q_{efp} (cfs)	Freeboard Discharge, Q_{mlf} (cfs)
RC1	Rattle Creek at NFS-419	1610	2200
MNK1	Mink Creek at NFS-419	230	314
MDC1	Mud Creek at NFS-419	380	510
S18C1	Section 18 Creek at NFS-419	280	380
STC1	Silvertip Creek at NFS-419	340	460
TC1	Trapper Creek at NFS-419	340	460
LC2	Lightning Creek above East Fork Confluence	7060	9530
EFC1	East Fork Creek above Lightning Creek Confluence	3200	4310
LC1	Lightning Creek at Clark Fork, Idaho	11,400	15,300

Introduction

The Idaho Panhandle National Forests require planning and design flood discharge predictions for projects within the Lightning Creek watershed. The Forest Service National Stream and Aquatic Ecology Center was asked to provide recommended predictions of flood design discharges as part of a larger project to support the Forest with planned transportation system enhancements and restoration efforts.

This portion of the Idaho Panhandle experiences unusual flood events in comparison with other parts of the Rocky Mountains, with flooding characteristics similar to the Cascades and Coastal Ranges of the Pacific Northwest. Using the flood potential method, an assessment of flood hazards was provided at multiple scales, from the regional to catchment levels. Redundant methods were used to assess the appropriateness of a variety of flood prediction methods for the determination of flood design discharges. This report details the flooding characteristics of this area and makes recommendations of the most appropriate method for the selection of flood design discharges for this watershed.

Flood Potential Characterization

The flood potential method (Yochum et al., 2019; Yochum, 2019) was utilized as a framework for understanding flood hazards and the development of appropriate design flood discharges within the Lightning Creek watershed. For reference, **a glossary of terms is provided in Appendix A.** Additional information is also available here.

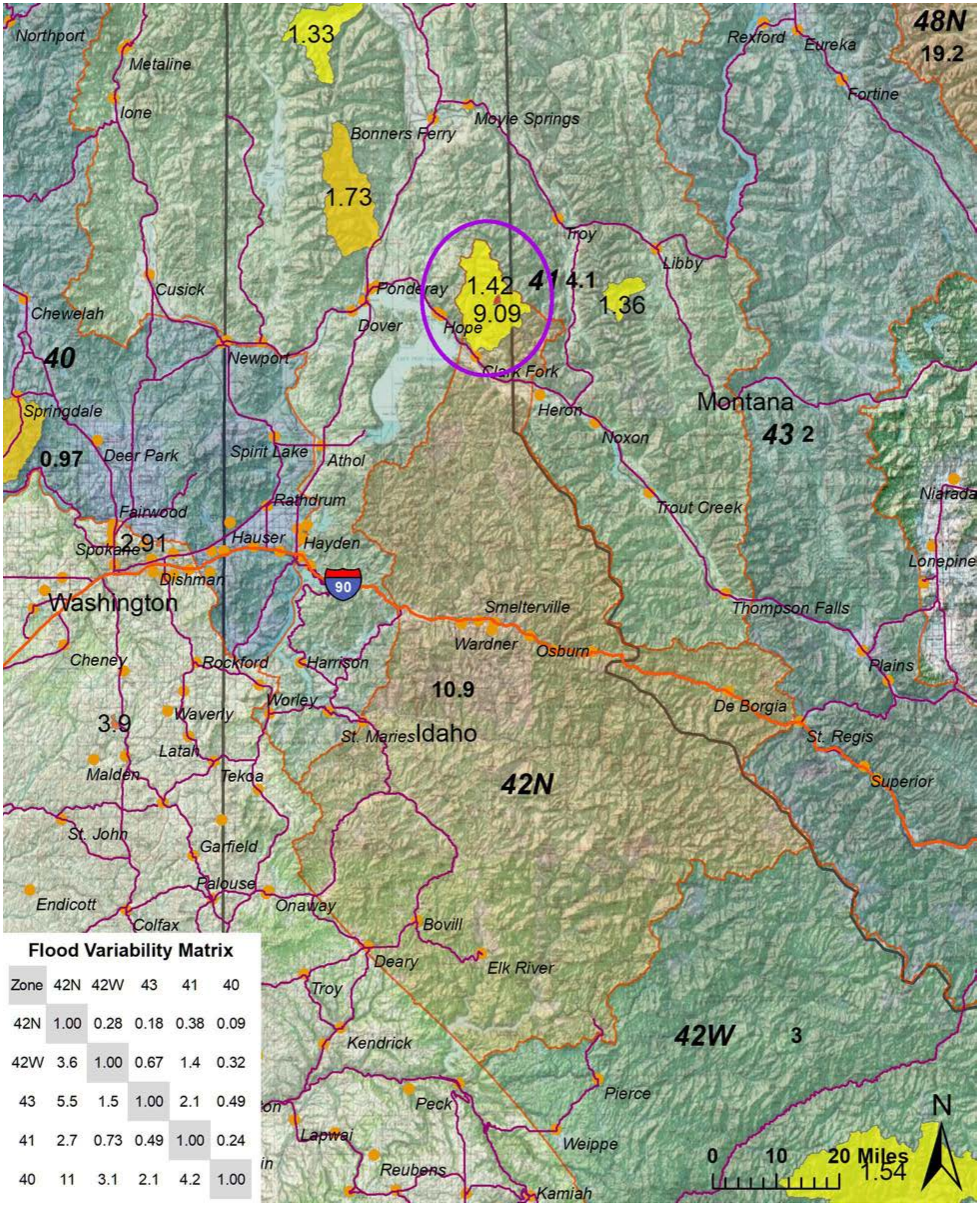
The flood potential method quantifies the central tendency of large flood magnitudes across zones of similar flood response. This central tendency is the *expected flood potential*, a regression of the maximum recorded (record) discharges for streamgages within each zone. Floods of this size can reasonably be expected to occur at a stream valley point of inteest. The expected flood potential discharge (Q_{efp}) has been found to not be statistically different from the 100-year flood (Q_{100}; Yochum et al., 2019). The flood potential method has an advantage over flood-frequency methods for addressing bimodal peak flow magnitudes due to mixed populations, as well as sidestepping issues stemming from varied streamgage lengths and periods of record. The 90% prediction limit of the regressions is the *maximum likely flood potential*. Floods with discharges (Q) greater than the maximum likely flood potential discharge (Q_{mlf}) are quantitatively defined as extreme, with the departure above this limit indicating the degree of extremity. Each zone has flood potential plots that vary in scale (variability of flood magnitudes between zones) and slope (variability of how watersheds of different sizes experience floods). Such characteristics are quantified and compared between zones through the use of indices. The flood potential method also simplifies the assessment of trends in flood magnitudes and frequencies, and provides correction factors for flood design discharge where there are trends in magnitudes.

Comparisons of flooding characteristics are illustrated in the Flood Potential Portal, a decision support system developed for enhancing the understanding of riverine flood hazards across the United States. The Portal presents the flood potential method as well as the results of traditional flood-frequency analyses.

Zone 42N

This watershed is within the northern portion of zone 42N (Figure 1), one of the highest flood potential zones in the Rocky Mountains. Floods experienced in zone 42N are substantially larger in magnitude than in adjacent zones, for a given watershed size, and are substantially larger than all but one of the zones that comprise the core, high-elevations areas of the Northern, Central, and Southern Rocky Mountains.

Zone 42N is a mountainous and sparsely-populated area of the Idaho panhandle, within and adjacent to the Kaniksu, Coeur d'Alene, and St. Joe National Forests (Idaho Panhandle National Forests), as well as small portions of the Kootenai, Lolo, and Nez Perce-Clearwater National Forests. The Clark Fork, Coeur d'Alene, St. Joe, St. Maries, and St. Regis Rivers primarily drain this Columbia River Basin zone.



Flood Variability Matrix

Zone	42N	42W	43	41	40
42N	1.00	0.28	0.18	0.38	0.09
42W	3.6	1.00	0.67	1.4	0.32
43	5.5	1.5	1.00	2.1	0.49
41	2.7	0.73	0.49	1.00	0.24
40	11	3.1	2.1	4.2	1.00

Figure 1: Flood potential zones within and adjacent to the Idaho panhandle, in the Northern Rocky Mountains. The ellipse envelopes the Lightning Creek watersheds, within zone 42N. The labels include the zone IDs (larger font, italics) and the flood potential index values (P_f; smaller font). The colors of the polygons are associated with P_f, with warmer colors for higher values and higher values indicating greater flood potential. Watersheds that have experienced extreme floods are also illustrated, with flood extreme index values ($\boldsymbol{E_f}$) labeling.

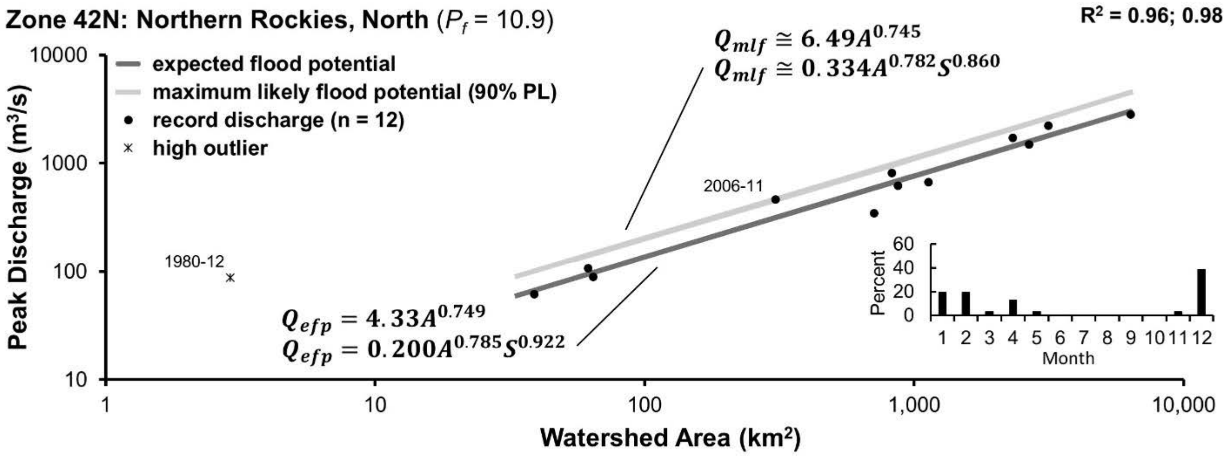


Figure 2: Flood potential and seasonality plots for zone 42N, with expected flood potential and maximum likely flood potential prediction equations. The explained variance (R^2) were 96 and 98% for the area only and multiple-variable regressions, respectively.

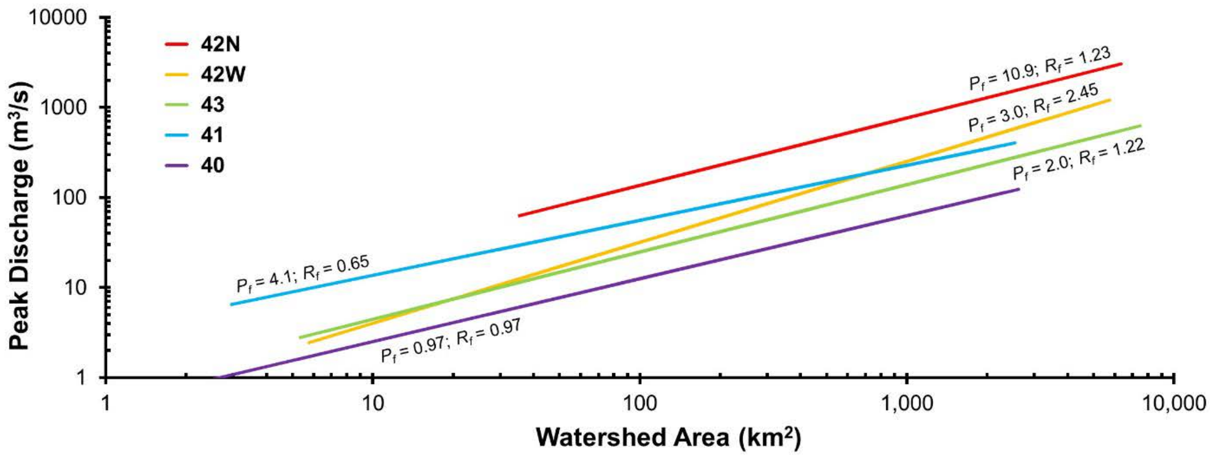


Figure 3: Comparative flood potential plot for zone 42N and neighboring Northern Rocky Mountains zones. P_f = flood potential index; R_f = watershed scale ratio.

Zone 42N experiences flood magnitudes up to 11 times larger than other zones within the Northern Rocky Mountains (see Flood Variability Matrix in Figure 1). The flood potential index (P_f) and watershed scale ratio (R_f) are key indices for quantifying and comparing flood magnitude variability between zones (Figures 1 through 3) Higher P_f values indicate higher flood potential, that is flood discharges are larger in magnitude for a given watershed area. Lesser R_f values indicate that smaller watersheds experience relatively large flood magnitudes and greater R_f values indicate that larger watersheds experience relatively large flood magnitudes. P_f can be used to compare flood potential between any two zones; for example, zone 42N experiences floods 10.9/4.1 = 2.7 times larger than in zone 41, on average, though the slopes of the flood potential curves (Figure 3) differ, with zone 41 experiencing relatively larger floods in smaller watersheds (R_f = 0.65), and zone 42N experiencing relatively larger floods in larger watersheds (R_f = 1.23).

Compared to other zones across the current flood potential analysis extent (which consists of the regions between the Mississippi River and the Pacific Ocean), zone 42N experiences floods with a flood potential (index) at the 60th percentile (40% of zones have higher flood potential, with these zones primarily in the Midwest and West Coast), a watershed scale ratio at the 74th percentile, variability index (V_f = 1.50) at the 22nd percentile, flashiness at the 15th and 26th

percentiles, and a flood hazard index at the 42nd percentile. Hence, floods in 42N are relatively large and consistent, with larger watersheds experiencing larger floods, and with relatively low flashiness and moderate flood hazard.

The seasonality of large floods (frequency of floods by month; Figure 2) peaks in December (39% of events) and higher frequency also in January (19%) and February (19%), and with a second peak in April (13%). This seasonality coincides with winter atmospheric river and rain-on-snow events prevalent on the West Coast, with this zone representing the eastern most extent of direct contributions of atmospheric river activity to large floods. Zone 42N is the only zone in the Rocky Mountains that experiences dominate flooding during the winter season, though zone 41 (to the north) experiences a secondary peak (21%) in large flood frequency during a winter month (January).

There are no significant or possible trends identified in flood magnitudes and frequency within zone 42N; the streamgage record does not indicate that large floods are currently becoming larger or more frequent due to climate change within this zone.

Extreme floods within zone 42N, as quantitatively defined using the flood potential method, have occurred exclusively within the Lightning Creek watershed (Figure 1). This may be due to random storm-generating processes or, alternatively, it may be due to idiosyncrasies of storms and measured floods in this zone, with this northern most portion of zone 42N (and the Lightning Creek watershed) perhaps having a propensity for experiencing extreme floods.

Lightning Creek Watershed

The Lightning Creek watershed is illustrated in Figure 4. This watershed is entirely within zone 42N. Figure 4 includes watershed delineations for contributing areas to flood design discharge computation points for road-stream crossings and planned restoration reaches. All but two of these computation points are at road-stream crossings for National Forest System (NFS) road 419, with streamgaging performed on the mainstem Lightning Creek at Clark Fork (ID: LC1; USGS ID: 12392155; 1989 to 2021) and Trapper Creek (ID: TC1; USGS ID: 12392100; 1962 to 1981).

Trapper Creek, just above the Lightning Creek confluence (TC1) at the road-stream crossing, is a 1.13 square miles watershed, with an extreme flood experienced on 12/26/1980 (3100 cfs). This event was highly extreme, with an flood extreme index (E_f) = 9.13 (9.1 times larger than Q_{efp}). This E_f value is one of the highest (most extreme) observed at streamgaged sites across the continental United States, and is abnormally large for core portions of the Rocky Mountains. Additionally, an extreme flood was also experienced on Lightning Creek at Clark Fork on 11/6/2006 (16,400 cfs). This flood was much less extreme with an E_f = 1.42. Other floods of note have occurred, including 2/9/1996 (4970 cfs), which came close to overtopping the Idaho Route 200 road crossing due to accumulation of flood debris. This was not an especially large flood, with larger events (in addition to the flood of November 2006) on 4/14/2002 (6010 cfs), 5/25/2003 (6220 cfs), 5/18/2008 (5490 cfs), 12/9/2015 (10,500 cfs), 3/16/2017 (5960 cfs), 11/23/2017 (7940 cfs), and 5/31/2020 (6690 cfs). Floods magnitudes for events occurring prior to 1989 are unknown.

Hence, floods in zone 42N are inherently large, compared to other parts of the Rockies, substantial floods that mobilize large quantities of wood debris occur frequently in the Lightning Creek watershed, and extreme floods may have a propensity for occurring within this watershed. Considering this setting as well as the recent wildfire occurrences in the Lightning watersheds (which, generally, tend to have more impacts within smaller-scale watersheds), there is a prevalence within this watershed for flood events inducing high velocities and stream power, substantial inundation, high levels of sediment and wood liberation from headwaters, and substantial mobilization of sediment and large wood within stream valleys, especially from the smaller-scale watersheds above NFS Road 419. Hence, there is a tendency for events that overtop, erode, or bury road-stream crossings, as well as negatively impact restoration projects within the primary tributary and mainstem reaches.

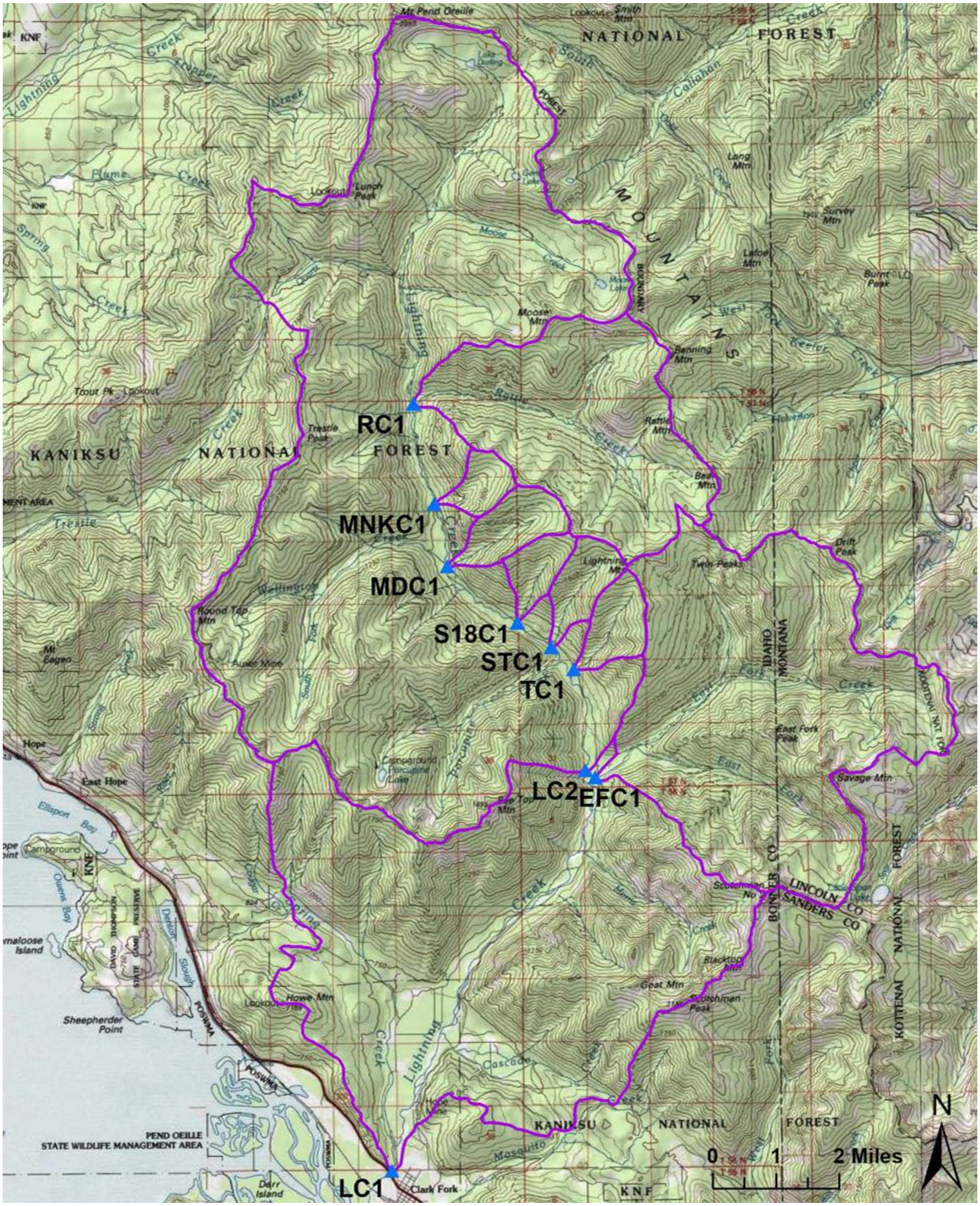


Figure 4: Lightning Creek watershed within flood potential zone 42N, with design flood discharge computation points and contributing watershed delineations.

Design Flood Discharges

Multiple methods were utilized to characterize flood hazards and quantify design flood discharge values within the Lightning Creek watershed. These analyses were:

1. Flood potential method
2. Index flood frequency, utilizing flood potential zones
3. USGS regional regression flood frequency (Streamstats)
4. Streamgage flood frequency, using logPearson distribution

These analyses were performed at nine calculation points illustrated in Figure 4 and listed in Table 1, with all the methods utilized where sufficient data and modeling capabilities exist, and at least the flood potential and USGS regional regression analyses performed at each point. All of the results are presented in Table 2, with recommended flood design discharges provided in Table 3.

Flood potential estimates (Q_{efp}, Q_{mlf}) are provided in the 2nd and 3rd columns of Table 2. The expected flood potential discharge is the central tendency of large floods within zone 42N, as computed through a regression of the record peak discharges for the zonal streamgages, using watershed area and average slope as explanatory variables (Figure 2). The maximum likely flood potential discharge is the upper 90% prediction limit, with floods beyond this quantified as extreme. Generally, flood design discharges should not exceed the maximum likely flood potential discharge, since it is unreasonable to design most stream valley infrastructure to accommodate extreme floods. For the Lightning Creek watershed, these values were computed using the Flood Potential Portal at the sites with larger watershed areas, with manual computations performed for the smaller watersheds since these areas are a substantial extrapolation from the streamgages used to develop the flood potential regressions in zone 42N.

The index flood frequency values were computed using flood potential zones. This is important, since zone 42N experiences substantially larger floods than neighboring zones in the Northern Rockies (2.7 to 5.5 times larger; Figure 1). Index flood values were computed using watershed area and average annual precipitation. The Lightning Creek at Clark Fork streamgage has an average annual precipitation of 63.9 inches (from 1980-2010 PRISM) for this 115 mi^2 watershed area. Within the Lightning Creek watershed, the index flood method yields the largest 100-year flood values (Table 2), with flood magnitudes estimates for the Lightning Creek streamgage being twice the magnitude of USGS regional regression results (16,600 cfs v. 8230 cfs).

Table 1: Design flood discharge computation points.

ID	USGS ID	Site Description	Watershed Area (mi^2)	Average Watershed Slope (deg.)
RC1	----	Rattle Creek at NFS-419	10.51	21.6
MNK1	----	Mink Creek at NFS-419	0.73	25.4
MDC1	----	Mud Creek at NFS-419	1.32	26.3
S18C1	----	Section 18 Creek at NFS-419	0.83	27.9
STC1	----	Silvertip Creek at NFS-419	1.10	27.0
TC1	12392100	Trapper Creek at NFS-419	1.12	27.1
LC2	----	Lightning Creek above East Fork Confluence	65.03	22.8
EFC1	----	East Fork Creek above Lightning Creek Confluence	20.38	26.0
LC1	12392195	Lightning Creek at Clark Fork, Idaho	117.34	23.5

Table 2: Flood analysis results for all investigated methods, for each analysis point. Flood-frequency methods: (1) USGS regional regression (Streamstats); (2) index, by flood potential zone; (3) logPearson streamgage analysis; (4) logPearson streamgage analysis, without extreme flood

ID	Q_{efp}	Q_{mlf}	Flood Frequency (cfs) 67% 1.5 yr	50% 2 yr	20% 5 yr	10% 10 yr	4% 25 yr	2% 50 yr	1% 100 yr	0.5% 200 yr	Method
RC1	1610	2200	----	660	980	1170	1450	1670	1960	2200	(1)
			680	840	1310	1680	2240	2730	3280	3920	(2)
MNK1	230	314	24	30	49	63	83	98	120	140	(1)
MDC1	380	510	49	61	98	120	160	190	230	260	(1)
S18C1	280	380	19	25	41	53	70	83	100	120	(1)
STC1	340	460	38	48	78	99	130	150	180	210	(1)
TC1	340	460	22	29	48	61	80	95	110	130	(1)
			----	33	85	200	680	1770	4720	12,800	(3)
			----	35	62	93	160	230	340	490	(4)
LC2	7060	9530	----	2310	3290	3880	4690	5320	6110	6770	(1)
			2300	2850	4430	5700	7590	9240	11,100	13,300	(2)
EFC1	3200	4310	----	810	1200	1430	1770	2030	2360	2650	(1)
			990	1230	1910	2460	3270	3980	4800	5720	(2)
LC1	11,400	15,300	----	3200	4530	5300	6380	7190	8230	9070	(1)
			3430	4250	6620	8500	11,300	13,800	16,600	19,800	(2)
			----	3850	5920	7650	10,300	12,700	15,500	18,700	(3)
			----	3870	5480	6600	8070	9200	10,400	11,600	(4)

The USGS regional equation equations were computed using the Flood Potential Portal (which downloads values computed within Streamstats), and through the direct use of Streamstats (for smaller watersheds). Other than Rattle Creek, these regional regression results for 100-year discharges consistently provided the smallest values under consideration for flood design discharges (Table 2). The regional regression equations developed for this area (Wood et al., 2017) lumps zone 42N in with zone 41. Considering that P_f for zone 41 is only 38% of zone 42N, substantially different R_f values, and a different dominant flood seasons that indicates varying flood-producing mechanisms, it can be understood why these USGS regional regression results are low and may likely be unsuitable for application in the Lightning Creek watershed.

Streamgage flood frequency analyses were performed using the 17B methodology (IACWD, 1982), to determine a flood-frequency relationship from the annual peak discharge data. It is helpful that the Lightning Creek watershed has a currently-operating streamgage on Lightning Creek at Clark Fork, as well as a previously-operated streamgage on Trapper Creek. Both of these two datasets are and were continuously operated during their periods of record, without any gaps nor the inclusion of historic peaks. However, it should not be assumed that a streamgage analysis provides the most appropriate design flood discharges, since this single gage may produce a biased result due to the nature of the record. Generally, a streamgage record may be missing a larger scale flood magnitude that neighboring (zonal) streamgaged watersheds indicate as being expected, resulting in underprediction, or this gage may have a preponderance of larger flood magnitudes in an area that experiences bimodal floods, resulting in overprediction. For the Lightning Creek streamgages, the presence of extreme floods within the records may be biasing the analysis results.

Identified extreme floods are included in these two streamgage datasets, with a highly extreme event (E_f = 9.13; high outlier in flood potential analysis) experienced in Trapper Creek, and a slightly extreme event (E_f = 1.42) experienced in Lightning Creek. To assess the influence these extreme floods have, analyses were performed both with and without these extreme events. The influence of the Trapper Creek extreme flood was very substantial, with a Q_{100} = 4720 cfs with this event and Q_{100} = 340 cfs without this event (Table 2); considering the small watershed size and the heavy influence this extreme flood has on results, exclusion of the December 1980 flood from the analysis is appropriate. In contrast, a decision on exclusion of the November 2006 extreme flood from the Lightning Creek analysis is less clear, with a Q_{100} = 15,500 cfs with this event and Q_{100} = 10,400 cfs without this event (Table 2).

The flood potential estimates provide Q_{efp} values that are typically larger than the Q_{100} results of the USGS regional regression equations and smaller than the Q_{100} predicted using the index flood method. The Q_{efp} values are also identical to the streamgage flood-frequency analysis results for Trapper Creek (without the extreme flood) and similar to the Lightning Creek results, though Q_{efp} is a bit low compared to this Q_{100} as predicted while including the extreme flood in Lightning Creek. However, considering the tradition of utilizing freeboard in the design of road-stream crossings (an additional amount of height above the design flood discharge level, as a factor of safety), there is opportunity for designating the Q_{mlf} as the freeboard discharge, to convey all floods that are not extreme.

Recommendations

Through the comparison of possible flood design discharge values computed using the flood potential, index, USGS regional regression, and streamgage analyses methods, it is recommended that the flood potential method results be utilized for design and planning purposes within the Lightning Creek watershed. Specifically, the expected flood potential discharges (Q_{efp}) are recommended to be used as the design flood discharge and the maximum likely flood potential discharge (Q_{mlf}) used as the freeboard discharge for road-stream crossings, to safely pass all but extreme floods as identified through an analysis of the streamgage records across zone 42N. The high bedloads and large wood transport observed during flooding within this watershed also support the need for safe conveyance of Q_{mlf} flood magnitudes through road-stream crossings. Other watershed projects, such as stream restoration, should utilize Q_{efp} values as the design flood discharge. These results for the nine computation points are provided in Table 3.

This approach essentially utilizes the median flood prediction value consistently across the Lightning Creek watershed for planning and design efforts. If additional locations where needed flood design discharges are identified, the Flood Potential Portal can be used to provide these values. Additionally, when used in combination with geomorphic approaches, flood frequency results presented in Table 2 or downloaded from the Portal can also be used for helping to identify bankfull discharge for stream restoration projects.

Table 3: Recommended flood design and freeboard discharges for the computation points illustrated in Figure 4.

ID	Design Flood Discharge, Q_{efp} (cfs)	Freeboard Discharge, Q_{mlf} (cfs)
RC1	1610	2200
MNK1	230	314
MDC1	380	510
S18C1	280	380
STC1	340	460
TC1	340	460
LC2	7060	9530
EFC1	3200	4310
LC1	11,400	15,300

Acknowledgements

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Appendix A: Glossary of Terms

100-year flood/discharge: A flood magnitude that has a 1% chance of occurrence in any year (Q_{100}), as determined through a flood-frequency analysis.

Beard flash flood index (F): Quantifies flashiness, with higher values indicating greater differences between the magnitude of the largest and smallest annual peak flows with more typical annual floods. It is computed as the standard deviation of the natural logarithms of the annual peak flow data for each streamgage and is used as a surrogate for indices that quantify flashiness using rates of change in discharge (which can only be computed for more recent streamgage data, where 15-minute interval data are available).

design flood discharge: flood magnitude to be utilized in the design of a stream valley infrastructure or stream restoration project, e.g. 100-year discharge (Q_{100}) or expected flood potential discharge (Q_{efp}).

expected flood potential (Q_{efp}): Large flood magnitude expected for a point of interest given the floods experienced (and recorded) across a flood potential zone.

extreme flood: A major flood that has been quantified as being extreme in magnitude by the flood potential method ($Q > Q_{mlf}$).

flood extreme index (E_f): A unitless index for normalizing any flood magnitude (Q) using the expected flood potential discharge (Q_{efp}), specifically $E_f = Q/Q_{efp}$. Higher values indicate larger or more extreme events, with values less than 1 indicating a flood is less than the expected flood potential discharge. This index is used for ranking floods, and for testing for trends in both the magnitude and frequency of flooding.

flood hazard index (H_f): A summary of overall hazard, accounting for both flood magnitude and flashiness (product of P_f and F), with higher values indicating greater hazard.

flood frequency method: The traditional approach for quantifying flood magnitudes that fits a statistical distribution to annual peak flow records at a streamgage and, from that distribution, estimates a variety of return interval floods (i.e. 100-year flood). In the United States, typically logPearson distributions are used and regional regressions are fit for each return interval using a variety of watershed characteristics as predictors for estimating flood magnitudes at ungaged locations.

flood potential: A general term for describing how flood magnitudes vary between areas of interest. For example, the Colorado Front Range experiences much higher flood potential than the large mountain valleys of the Southern Rocky Mountains (such as South Park).

flood potential index (P_f): A summary index that compares flood magnitudes to a low flood potential reference zone (2), and facilitates comparisons between any zones. This index is computed as:

$$P_f = \frac{\left(\frac{Q_a}{Q_{a,zone2}} + \frac{Q_b}{Q_{b,zone2}} + \frac{Q_c}{Q_{c,zone2}}\right)}{3}$$

where a = 20 km^2, b= 200 km^2, c = 2000 km^2 and $Q_{20,zone2}$ = 4.15 m^3/s, $Q_{200,zone2}$ = 21.0 m^3/s, and $Q_{2000,zone2}$ = 106 m^3/s. Using this index, flood magnitudes can be compared between any two zones: for example, floods in the Los Angeles Ranges (zone 20) have floods 47.4/8.5 = 5.6 times greater, on average, than floods in the Mojave Desert (zone 18NW) and 47.4/2.3 = 20.6 times greater than floods in the Southern Rocky Mountains (zone 3).

flood potential method: A method that sidesteps issues associated with flood-frequency analyses to predict expected and maximum likely flood magnitudes, identifies and ranks extreme floods, and provides indices for communicating about the variability of large floods across regions and continents.

flood potential plot: A zonal plot of the expected flood potential and maximum likely flood potential with the record peak discharges, outliers, regression equations, and other key information. Figures A-1 through A-5 are example flood potential plots.

flood Potential Portal: A decision support system developed by the One Water Solutions Institute at Colorado State University, for serving the results of the flood potential method as well as traditional flood-frequency and regional regression methods.

https://floodpotential.erams.com/

flood variability index (V_f): Describes within-zone flood magnitude variability, with higher values indicating greater variability in both space and time. It is computed as the ratio of the zonal regression intercepts of the expected flood potential and maximum likely flood potential equations. For zone 59N, $V_f = 51.48/36.52 = 1.41$.

freeboard discharge: the discharge associated with an additional amount of height above the design flood discharge level, as a factor of safety. The maximum likely flood potential (Q_{mlf}) can be used as the freeboard discharge, with floods in excess of this being extreme and inappropriately large for the design of most stream valley infrastructure.

major flood event: Large flood events, in regard to the spatial extent or magnitude of the experienced discharge. Major floods are large, but are not necessarily the flood of record and are typically not extreme as quantified by the flood potential method.

maximum likely flood potential (Q_{mlf}): The maximum size flood that can be expected for a point of interest given the history of record peak discharges experienced across a flood potential zone. Flood greater than this are extreme. This value is computed as the upper 90% prediction limit of the expected flood potential regression.

watershed scale ratio (R_f): The ratio of flood potential index computation components for a 2000 km^2 watershed to a 20 km^2 watershed, with lower values indicating that smaller watersheds experience higher flood magnitudes on a relative basis to other zones, while higher values indicating that larger watersheds experience higher flood magnitudes on a relative basis to other zones.

zone (flood potential zone): The area over which a flood potential analysis was performed, with this area experiencing similar flood characteristics in regard to magnitudes, flashiness, and seasonality.