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## Hydrologic Response of the Pack River, Idaho, to the Sundance Fire

### Abstract

The Sundance Fire of 1967 burned 26 percent of the Pack River watershed in Idaho. Removal of the forest canopy was hypothesized to produce an increase in annual streamflow from the basin and an advance of the peak flows by virtue of decreased transpiration losses and earlier snowmelt runoff generation. Comparison of mean annual streamflow and mean monthly streamflow in the pre- and post-fire periods do not support an increase in water yield but do suggest an earlier peak flow. The assessment of annual water yield is complicated in this case by a probable decrease in post-fire precipitation amounts and a substantial increase in precipitation variability. The average half-flow date of the Pack River advanced five days following the fire. March experienced a 40 percent increase in average streamflow while June experienced a 23 percent decrease. Simulated monthly discharges, based on regression equations relating Pack River flow to that of nearby Boundary Creek, substantiate these findings. Post-fire estimates of Pack River flows, based on pre-fire regression equations, produce residuals biased in the direction indicated by the mean monthly comparisons: the March equation substantially underestimates post-fire Pack River discharge and the reverse is true for June. These results suggest that removal of canopy cover over a substantial portion of a stream basin produces earlier snowmelt and earlier peak flows in snowmelt runoff dominated watersheds. These findings have application to watershed management, prescribed burning programs, and reservoir operation in forested stream basins.

### Introduction

Consideration of the storages and transfers within the basin hydrologic cycle implies that modifications of basin vegetation cover influence both the timing and amount of streamflow (More 1969). This is especially true for basins in the western United States where much of the annual streamflow is snowmelt-derived (Packer 1962). Devegetation by wildfire, logging, development and/or disease might reasonably be expected to decrease canopy storage and evapotranspiration and hasten the onset of snowmelt. Less evapotranspiration would tend to produce an increase in streamflow volume, and earlier melt to produce an advance in the annual peak flow in the affected watershed.

Numerous studies have noted increases in snow accumulation in areas cleared of canopy cover (Bates and Henry 1928, Hoover 1960, Haupt 1979a, 1979b, Gary 1979) although there is some controversy regarding the nature of this increase; whether it is real—derived from decreased sublimation—or redistributed from surrounding forest via wind (Anderson 1969, Gary 1975, Hoover and Leaf 1967). It appears likely that the increase is real in areas with warmer snowpacks where wind redistribution is less

significant (Haupt 1979b, Christner and Harr 1982).

Studies have also illustrated a general increase in soil moisture after logging and/or wild-fire, an effect attributed to decreased transpiration (Helvey 1980, Hart and Lomas 1983, Megahan 1983). Although there is some suggestion of proportionality, the effects of marginal disturbances (10-20%) to the vegetation cover are difficult to document (McMinn and Hewlett 1975, Bosch and Hewlett 1982).

The effects of reduced canopy cover on the snowpack energy balance equation suggest a probable change in the timing of snowpack ripening and melt. Increased shortwave flux should hasten the onset of snowmelt-derived runoff. Removal of canopy cover may also increase both Hortonian overland flow and return flow; the former due to a reduction in surface infiltration and increased water repellency of soils (Debano and Rice 1975, Morris and Moses 1987) and the latter as a consequence of a higher piezometric surface (Dunne 1978, Megahan 1983).

The Sundance Fire of northern Idaho provided an opportunity to evaluate potential changes in water yield and snowmelt timing in the Pack River watershed.

## The Sundance Fire, Pack River Basin, Idaho

The Pack River drainage is located on the eastern flank of the Selkirk Crest in the Panhandle region of northern Idaho (Figure 1). Mixed coniferous forest covers approximately 95 percent of the basin, which drains 326 km<sup>2</sup> of the Kiniksu Batholith. Elevations range from 650 m to 2300 m. Slopes in the basin range from 20-35 percent, approaching 80 percent near the drainage divide, and floodplain area accounts for less than 6 percent of the basin.

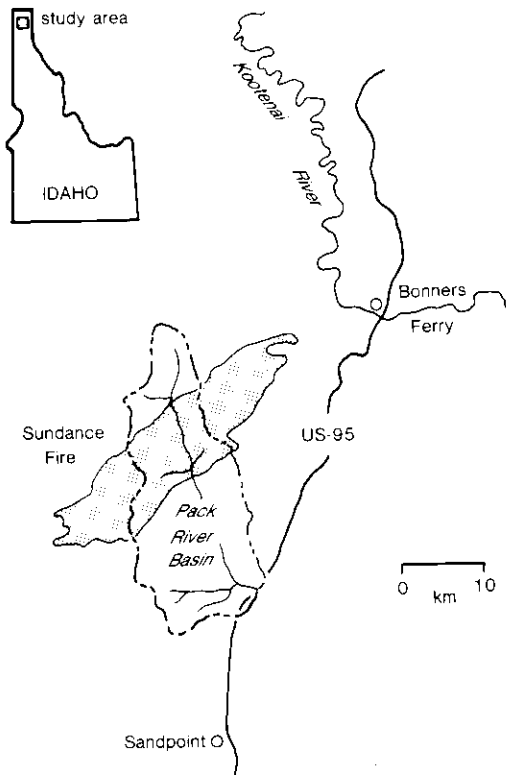


Figure 1. Location of Pack River drainage basin. Shaded portion shows extent of Sundance Fire.

The Sundance Fire was one of several large fires that occurred in the Inland Northwest during the summer of 1967 and was the subject of an extensive USDA-Forest Service report (Anderson 1968). Between 11 August and 2 September over 20,000 ha burned, including 26 percent of the Pack River watershed. Revegetation in the Pack River watershed has been

studied extensively by Stickney (1984). During the first decade of regrowth, ground cover species dominated, and trees did not exceed 10 percent of the total vegetation cover within the burned area. Stickney further estimated that only two of 18 study sites would establish a tree stage in the second decade of regrowth.

## Methods

Changes in the post-fire hydrology of the Pack River were assessed using both single- and paired-basin methodologies. Daily discharge data for the Pack River came from a USGS gaging station (#12-392300) near Colburn, Idaho, 15 km upstream from the inlet into Lake Pend Oreille. Precipitation data are limited to a single station at the Priest River Experiment Station (elevation 725 m) and Benton Spring snowcourse (elevation 1500 m). Both are located within the Priest River Experimental Forest, 20 km southwest of the Pack River gaging station. The total length of record was analyzed, and includes nine pre-fire years (WY 1959-1967) and 15 post-fire years (WY 1968-1982). The gaging station was discontinued in 1982. These basic data provide for comparison of average streamflow conditions during the two periods. Corroborative analyses were done using a paired-basin approach; pre-fire discharge of the Pack River was correlated with that of Boundary Creek near Porthill, Idaho (International gaging station #12-321500). This stream drains 250 km<sup>2</sup> of similar terrain approximately 40 km north of the Pack River basin. Both annual and monthly regression equations were calibrated. Similar equations were estimated using the post-fire discharge record. Differences in the pre- and post-fire regression equations were assessed in light of the residuals from pre-fire based predictions and observed Pack River discharges.

## Results

Prior to the Sundance Fire, a nine-year record of streamflow suggests an average annual runoff of 899 mm. This pre-fire distribution of annual runoff has a standard deviation ( $s$ ) of 113 mm. Individual years ranged from 743 mm (WY 1965) to 1063 mm (WY 1961). The mean half-flow date, the day representing the passage of 50 percent of the annual runoff, was 14 May. The shortest one-half flow interval, the shortest time within

which 50 percent of the annual runoff was measured, averaged 51.1 days.

Mean annual runoff of the 15 post-fire years was 877 mm ( $s = 289$  mm). A simple comparison of means test reveals the difference to be statistically non-significant ( $t = 0.22$ ,  $\alpha = 0.41$ ). Mean precipitation amount and maximum snow water equivalent of the Benton Spring snowcourse likewise reveal no significant differences between the two time periods (Table 1), although these are both single point measurements, and not especially representative of the Pack River watershed. Post-fire runoff, precipitation and snow water content were 98 percent, 97 percent, and 98 percent of their respective pre-fire values. The dramatic increase in post-fire precipitation and runoff variance make it difficult to demonstrate statistically significant differences between the mean values.

TABLE 1. Statistical comparisons of annual runoff and precipitation during pre-fire versus post-fire periods.<sup>a</sup>

<i>Population Means</i>				
	Pre-fire	Post-fire	t-value	alpha
Runoff	899	878	0.22	0.41
Precipitation	839	812	0.41	0.34
Maximum Snowpack Water Equivalent	505	496	0.14	0.44
<i>Population Variances</i>				
	Pre-fire	Post-fire	F-value	alpha
Runoff	12,746	83,289	6.52	0.01
Precipitation	5,574	34,948	6.27	0.01
Maximum Snowpack Water Equivalent	12,890	29,741	2.31	0.11

<sup>a</sup>Runoff, precipitation, and maximum snow water content are given in mm.

Maximum (instantaneous) flows increased an average of 25 percent following the fire and the five highest flows on record all occurred in the post-fire period. Four of these, however, corresponded to above-average precipitation and snow water equivalent conditions, and the statistical

significance of this increase is marginal ( $\alpha = 0.11$ ). Although minimum flows increased an average of 11 percent following the fire, this difference was statistically non-significant ( $\alpha = 0.21$ ).

The average shortest one-half flow interval remained essentially unchanged (51.0 days), although the average half-flow date advanced from 14 May (pre-fire) to 9 May (post-fire). This advance is reflected in the monthly streamflow comparisons. Three months appear to have experienced post-fire changes: March (40% increase), June (23% decrease) and August (24% increase). Significance levels associated with these comparisons are 0.12, 0.09, and 0.13 respectively.

These results were the focus of paired-basin analyses utilizing discharge data from nearby Boundary Creek. The nine years of Pack River daily discharge data from the pre-fire period show close correlation with data from Boundary Creek ( $R^2 = 0.89$ ). This correlation is statistically significant although the root mean square error is 43 percent of the mean Pack River flow. Furthermore, an examination of the average residuals from this regression strongly suggests a difference in the timing of streamflow between the two watersheds (Figure 2). The average half flow date of Boundary Creek is 25 May, 11 days later than that for the (pre-fire) Pack River.

Month interbasin correlations between the Pack River and Boundary Creek provide additional support for the post-fire increase in March streamflow and decrease in June streamflow in

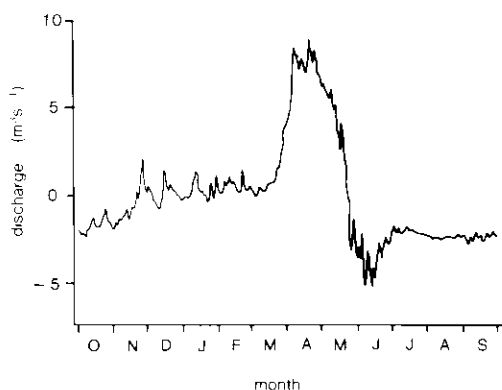


Figure 2. Average residuals from regression equation predicting daily Pack River discharge from Boundary Creek discharge for pre-fire period (1959-1967).

the Pack River basin. These regressions reveal statistically significant changes in slope coefficients between pre- and post-fire discharge estimates in the direction suggested by the comparison of mean monthly flows (Table 2). Changes in the regression parameters for August flows were not statistically significant.

TABLE 2. Comparison of pre- versus post-fire calibrated regression equations for daily flows in the months of March, June, and August. Pack River versus Boundary Creek.

	Intercept	Slope	Prob > F	R <sup>2</sup>
<i>Pre-fire</i>				
March*	26.80	2.82	0.0001	0.86
June*	64.60	1.11	0.0001	0.91
August	7.81	1.07	0.0001	0.77
<i>Post-fire</i>				
March*	12.67	3.28	0.0001	0.75
June*	19.58	0.06	0.0001	0.91
August	5.47	0.96	0.0001	0.81

\*differences in regression slope (pre- vs. post-fire) significant at  $\alpha=0.10$

Pre-fire regression equations were also used to predict pre- and post-fire streamflow for the Pack River. These predicted values were compared to observed discharges. Pre-fire residuals for March and June are generally small, although the phase differential is still apparent (Figure 3). In contrast, residuals from the post-fire period are much larger and exhibit a much more prominent bias; the pre-fire regression equations substantially underestimate post-fire streamflow for March and overestimate post-fire streamflow for June (Figure 4). Although this procedure also resulted in overestimation of August streamflow, the non-significant pre- versus post-fire regression parameter differences, and the very small residuals involved ( $\cong 0.2 \text{ m}^3 \text{ s}^{-1}$ ) precludes unequivocal assessment.

### Conclusions

This study is significant in that the Pack River Basin is an order of magnitude larger than basins where the effects of vegetation cover removal on streamflow have been extensively studied (Bosch and Hewlett 1982), and the disturbed area (26%)

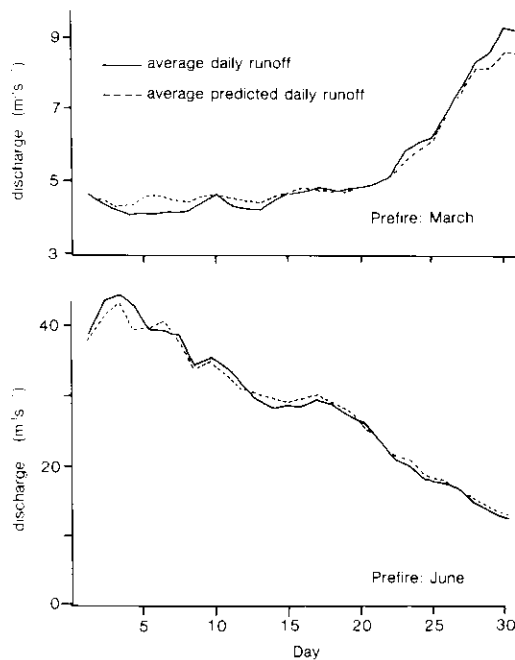


Figure 3. Average residuals for March and June from pre-fire monthly regression equations (Table 2) predicting Pack River discharge from Boundary Creek discharge.

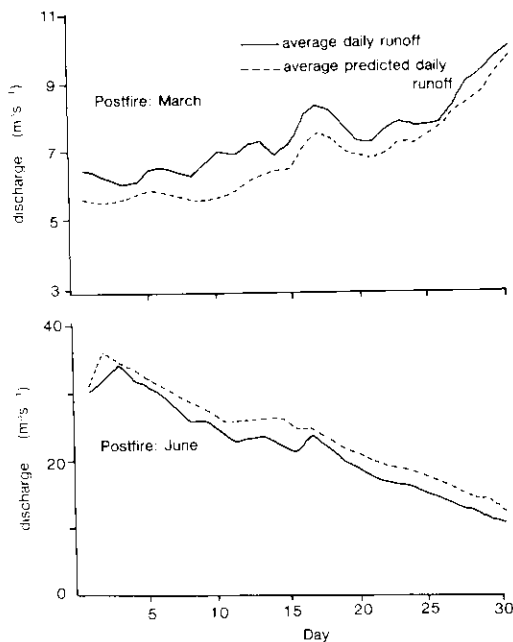


Figure 4. Average residuals for March and June from post-fire period using pre-fire predictive equations (Table 2) and post-fire observations of Pack River streamflow.

was near the lower limit of measurable hydrologic response owing to removal of canopy.

The hypothesized changes following the Sundance Fire, an increase in water yield and an earlier peak flow, are partially supported by analysis of mean Pack River streamflow and estimates of streamflow based on correlations with Boundary Creek. Although no statistically significant change in annual streamflow was discerned, this assessment is complicated by an increase in post-fire precipitation variance. Post-fire streamflow decreased 2.4 percent while post-fire precipitation declined 3.2 percent. These figures do not provide much confirmation, however, due to the probable errors in the measurement of both elements. In addition, the precipitation data (precipitation and maximum snow water equivalent) were limited to a single station whereas the watershed spans 1500 m of elevation.

Analysis of monthly streamflow and comparison of Pack River and Boundary Creek discharge do support statistically significant ( $\alpha=0.1$ ) increases in post-fire March streamflow and decreases in June. Comparison of the average pre- and post-fire hydrographs clearly illustrates the change in the timing of streamflow

suggested by these analyses (Figure 5). Post-fire streamflow appeared to peak earlier. Although maximum instantaneous flow also increased in the post-fire period, mean monthly peaks decreased slightly. We interpret this apparent contradiction to result from short-lived peaks produced by rain on snow events in a basin with much diminished canopy cover over one-quarter of its area. Lower average peaks may reflect lower precipitation inputs of the post-fire period.

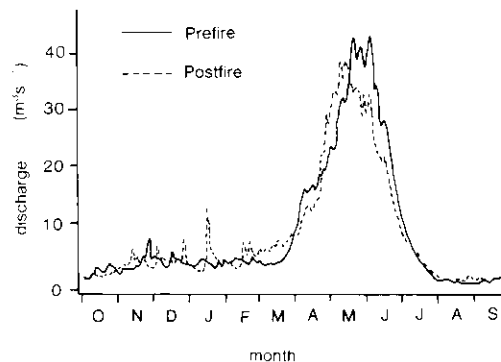


Figure 5. Average pre-fire (1959-1967) and post-fire (1968-1982) hydrographs for the Pack River, Idaho.

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