Potential Effects of Timber Harvest and Water Management on Streamflow Dynamics and Sediment Transport

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Abstract — The sustainability of aquatic and riparian ecological systems is strongly tied to the dynamics of the streamflow regime. Timber harvest can influence the flow regime by increasing total flow, altering peak discharge rate, and changing the duration of flows of differing frequency of occurrence. These changes in the energy and sediment transporting capability of the fluvial system can cause an alteration in both channel morphology and aquatic habitat. Depending on practices used, timber harvest can increase the rate of sediment introduction to the channel system, thus further confounding the energy/transport relationship.

Diversion and augmentation also alter the natural flow regime and disrupt the energy distribution in the system. Diversion decreases the energy regime available to transport the sediment load and may cause aggradation and vegetation encroachment. Elevated flow regimes from augmentation may result in extensive scour, loss of aquatic habitat, and ultimately a change in the relationship between the aquatic and terrestrial components.

This paper addresses the flow parameters which influence sediment transport and the implications of changing flow dynamics, whether from flow or forest management, and the effect it has on the transport process.

INTRODUCTION

Riparian and wetland areas provide productive fisheries and wildlife habitat, diversity of aesthetic scenery and recreation sites, sediment filtering and flood reduction, high quality water, points of recharge for ground water, commercial timber, and sustainable forage for domestic livestock and wildlife. Riparian and aquatic conditions provide a good index to overall watershed condition.

The Organic Act of 1897 identifies two key goals in establishment of the National Forests: maintaining a continuous supply of timber and securing favorable conditions of streamflow. In essence, the latter charge, as expanded by the 1964 Multiple-Use Sustained Yield Act, implies upland watershed conditions be maintained such that ecosystem diversity and integrity be managed to sustain beneficial use of the aquatic ecosystem both on national forest lands and to downstream users. One may also assume a charge to maintain and protect the physical and biological continuity in the aquatic system. The implications are the same to all of us whether the land is public or private, and if public, regardless of the administering agency.

Although only 6 to 8 percent of the lands in the West are classified as riparian, the vast majority of biological diversity is found in these areas. The riparian ecosystem, both its terrestrial and aquatic components, is an extremely important part of the landscape. Maintaining the condition, productivity, and integrity of these systems is extremely critical to sustaining productivity and biological diversity at the landscape level. One of the most important parameters in developing, maintaining, and sustaining the viability of these riparian ecosystems is the streamflow regime.

The flow regime, so critical to maintaining viability, varies naturally, as the result of land management practices, and through water management. We have little control over natural variability, but we must recognize its existence. This natural variability may be further modified by land management practices and streamflow manipulation.

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Timber harvest can influence the flow regime by increasing total flow, altering peak discharge rates, and changing the duration of flows of differing frequency of occurrence. These changes in flow alter the energy and the within-channel sediment transporting capability of the fluvial system and can result in an alteration in both channel morphology and aquatic habitat. Depending on practices used, soil disturbance associated with timber harvest can increase the rate of sediment introduction to the channel system, and further confound the energy/transport relationship.

Water management (diversion/augmentation) also alters the natural flow regime and disrupts energy distribution in the system. Diversion decreases flow and the attendant energy available to transport sediment and may cause aggradation and subsequent vegetation encroachment into the channel system. Elevated or extended flow regimes, due to augmentation, may result in extensive scour, loss of aquatic habitat, and ultimately a change in the gradient between the aquatic and terrestrial components.

This paper will first address the relationship between flow dynamics and sediment transport, then characterize the effect of forest disturbance and water management on the flow and energy regime, and lastly draw inference about the effect of flow change activities on sediment transport.

INSTREAM FLOW REQUIREMENTS

In order to maintain the physical and biological integrity of the aquatic system, one might argue the entire or natural "run of the river" is needed. After all, this regime produced what one sees in an undisturbed system. However, given the competing demands for water, and the need to manage other resources, this is not often a feasible alternative; so one must consider flow in terms of key components necessary to ensure some desired future condition. *Overbank flows* are needed to help sustain the terrestrial component and deliver nutrient laden sediments and export detritus or organic material. *Low or base flows* are needed to sustain and ensure survival of the biological component of the aquatic system. Other *effective discharges* are also needed to physically maintain the channel system or conduit. In general, instream flow needs require some frequency of occurrence and duration of a wide range of flow levels.

This paper deals primarily with the effect of flow dynamics on sediment transport and subsequent implications of impact on channel morphology and aquatic habitat. Examples drawn from the long-term data sets, collected in the subalpine environment of the Fraser Experimental Forest, CO, demonstrate the relationship between flow and sediment movement. In general the streams in this and most upland forested environments are either step-pool or riffle-pool systems and for the most part, suspended sediment transport would tend towards being supply limited while bedload transport, at times, would be energy limited (Knighton 1984).

Beginning with the Fool Creek Watershed, streamflow from watersheds on the Fraser Experimental Forest has been monitored since 1941. In total, nine watersheds are currently gaged and six of those nine have stilling ponds associated with the V-notch or Cypoletti weir being used. The hydrographs from these watersheds are snowmelt dominated and peak annual flow has never been rain fall dominated during the 50 years of observation (see Troendle and Kaufmann 1987, Troendle 1991). The record is such that instantaneous flow values (15 minute intervals) are available for all watershed years of record. Instantaneous flows are integrated into hourly, daily, monthly, and seasonal (April 15 - October 1) streamflow estimates.

Leaf (1970) demonstrated that weir ponds, or stilling ponds, are effective sediment traps. Virtually all of the suspended sediment and bedload drops out in the ponds. Each year the material accumulated must be removed. Prior to removal, the ponds are drained and an intensive survey made of the surface elevation of the material in the pond. The accumulated material is then removed, and the survey repeated. The difference in mean elevation of the two surveys is used to calculate the volume of material removed. The organic constituent is variable so density of the material removed varies from a specific weight of 1.4 to 1.7, for differing watersheds. The material removed from the ponds is an index of total sediment export for the runoff period (April - September). For some watersheds, records of sediment export have been kept since 1956. The hydrologic record indicates that the wettest (1957 or 1983) and driest (1977) years in the last 50 occurred during the period when sediment data was being collected.

East St. Louis Creek is an 803 ha control watershed. Draining to the north, it ranges in elevation from 2895 m to 4002 m, and has been gaged since 1943 with sediment data collected since 1965. Lexen Creek, a 124 ha control watershed, ranges in elevation from 3002 m to 3536 m and flow and sediment records date to 1955. Main Deadhorse Creek, a 270 ha watershed, ranging in elevation from 2880 m to 3536 m, has also been monitored since 1955. Main Deadhorse Creek also contains two subdrainages; the North Fork, a 40 ha south facing drainage gaged since 1970, and Upper Basin, a 78 ha subbasin gaged since 1975. Sediment data from Deadhorse Creek and its two subbasins coincides with the start of the hydrologic record.

Deadhorse Creek is also a treatment watershed. The main basin was undisturbed from 1955-1970 at which time an access road to the North Fork gaging site was built and the streamgage, a 90° V-notch weir, installed. In 1975 the access system was extended to the Upper Basin gaging site and the stream gage, also a 90° V-notch weir, installed. In 1977 and 1978, a road system was built into the North Fork subdrainage and 36 percent of the North Fork was harvested in small clearcuts (Troendle, 1983a). The north slope of Main Deadhorse Creek (an area outside the two gaged subbasins) was harvested using a shelterwood harvest in 1981 (Troendle and King, 1987). Twenty-six percent of the Upper Basin was harvested in 1983 and 1984 using small irregularly shaped clearcuts. Timber harvest, and its attendant impact, has caused a significant increase in sediment production from the North Fork of Deadhorse Creek only (Troendle, 1983a). Changes in sediment production have not been detectable at the main gage nor from the Upper Basin (Troendle 1983a, Troendle and King 1987).

The objective of the analysis reported in this section was to determine which, if any, descriptors of flow, measured at the gage, correlated with the accumulation of sediment in the pond. The intent was to determine, over time (years), if one expression of flow or another might be better correlated with the accumulation of sediment.

The expressions of flow used in the analysis included volumetric (total seasonal), instantaneous (peak discharge) and duration (i.e., duration of bankfull).

The total seasonal flow, in acre feet per square mile, was used as the expression for total flow volume while instantaneous flow was expressed as peak daily discharge in cubic feet per square mile. Expressions of flow duration had to be calculated in a more arbitrary manner. Andrews (1980) noted discharges approximating "bankfull" were most effective in moving sediment, over time. As a surrogate for the estimate of "bankfull", we assumed daily flows having a 1.5 year (Weibull distribution annual series) reoccurrence interval approximated the bankfull or effective discharge rate for the systems at Fraser.

Once the 1.5 year return interval daily flow was determined for each of the watersheds, the following flow durations were determined for each year of record. The duration, in days, in which 20, 40, 60, 80, 100, 120, 140, and 160 percent of bankfull flow (1.5 yr.) was equaled or exceeded. Figure 1 represents all the instantaneous peak daily flows observed on East St. Louis Creek for the period of the record, as well as the estimated bankfull discharge and some of its various percentages. For each watershed the data set constructed consisted of a dependent variable, accumulated sediment (a volume) for the year, and several independent flow parameters that included the expression of total volume (total seasonal flow), maximum rate or peak discharge, and the various expressions for duration.

A correlation matrix was then developed identifying the relationship between sediment accumulation and the various flow parameters.

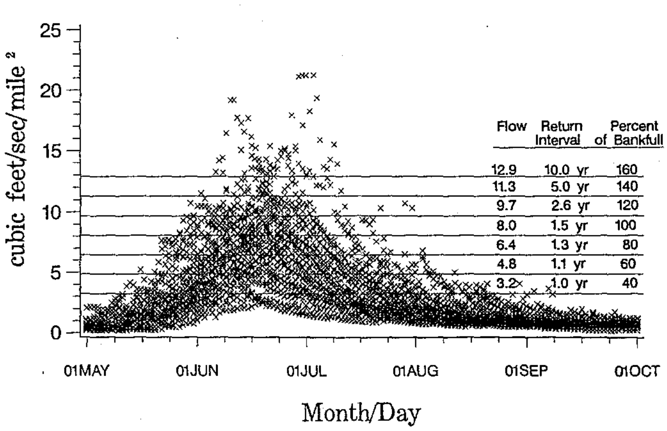

Figure 1. — Instantaneous peak daily flows on East St. Louis Creek for the period of record.

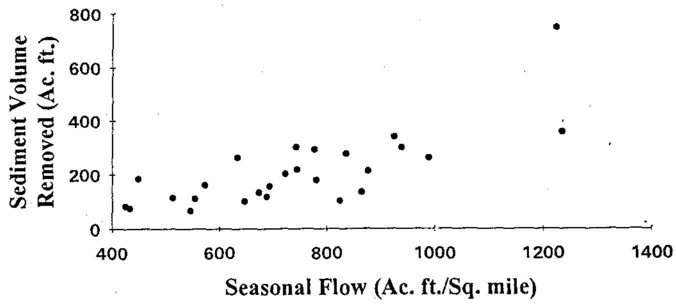

Figure 2. — Sediment volume removed vs. seasonal flow at East St. Louis Creek 1965 - 1990.

Figure 2 represents the relationship between sediment export from East St. Louis Creek (Y) and total seasonal flow. Although the variability is great, as flow increases so does sediment export. The two highest values represent the years 1983 and 1984 with 1983 being the wettest year on record (1943-1992) for this watershed. The R^2 for the relationship shown on Figure 2 is 0.49 (see also Table 1). Export from East St. Louis Creek is better correlated with the duration (number of days) of flow at or exceeding 60 percent of bankfull ("bankfull" being the 1.5 year annual daily flow value) than with total flow alone. Sediment export from St. Louis Creek is also well correlated with peak flow (Table 1).

Table 1. — Correlation of sediment accumulation and various flow parameters for East St. Louis Creek, Fraser, Colorado.

Parameter	R^2
Total Flow	.49
Peak Flow	.61
60% Bankfull*	.62
80% Bankfull	.52
Bankfull	.62
120% Bankfull	.53

**Bankfull is estimated as the 1.5 year return interval mean daily flow value.*

Five watersheds have similar data of varying length (approximately 80 years of total station record). All data were pooled for a composite analysis. In the process, all flow and sediment parameters were normalized to the mean for their respective watersheds to eliminate individual watershed effect. The duration of flow at or exceeding 80 and 100 percent of bankfull appears to be the most strongly correlated with total accumulation. The variability is, of course, quite large both within and between watersheds (fig. 2), and sediment production from the individual watersheds may correlate with one flow parameter better than another (i.e., compare Table 1 vs. Table 2). It should be noted that all R^2s presented are significant ($P<.05$) but tests were not made to determine significance between R^2s.

Table 2. Correlation of normalized sediment accumulation and various flow parameters for all five watersheds, Fraser Experimental Forest, Fraser, Colorado.

Parameter	R^2
Total Flow	.44
Peak Flow	.48
60% Bankfull*	.44
80% Bankfull	.53
Bankfull	.53
120% Bankfull	.48

**Bankfull is estimated as the 1.5 year return interval mean daily flow.*

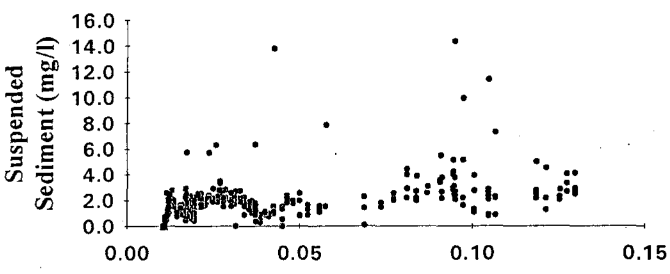

Figure 3. — Suspended sediment vs. discharge at Lexen Creek (5/22/79 to 9/6/79).

The suspended component of total sediment load is more chaotic and seems less predictable. Figure 3 represents the suspended sediment load for Lexen Creek (data not available for East St. Louis Creek) relative to the hydrograph for the one year when automated sampling was done throughout the runoff period. Although the suspended sediment concentration is significantly ($P<.05$) correlated with flow (fig. 3) as is total accumulation (fig. 2 total load), the extreme or highest concentrations appear to be more sporadic and less flow dependent. Approximately one metric ton of suspended sediment was exported in 1979 from Lexen Creek. This compared with approximately 0.75 metric tons of bedload. As a point of reference, the expected dissolved load in 1979 would average 30 mg.l (Stottlemyer 1987)and represent a seven or eight metric ton load over the course of the same runoff season.

MANAGEMENT IMPACTS ON STREAMFLOW DYNAMICS

The flow regime can be impacted by either land use or water management practices. For purposes of this paper, the only land-use practice considered is forest disturbance due to timber harvest. Other disturbance such as insect and disease attack, fire, and to some extent land-use change, also influence flow but will not be specifically considered here as the direction of change is similar to that for timber harvest. Water management can consist of diversion, augmentation, or both. Consideration will be restricted to diversion as it has the potential to reduce flow and alter the availability of water for instream flow needs. The implications associated with flow augmentation are aligned with the increasing energy associated with the response to forest disturbance.

Forest Disturbance

Effect on Water Yield

Bosch and Hewlett (1982) summarized the results of nearly 100 experiments worldwide on the effect of timber harvest on water yield. More specific regional summaries have been presented by Douglass (1983), Harr (1983), Kattleman, et al. (1983), and Troendle (1983b). The basic nature of process response to timber harvest, whether worldwide, regional, or local is conceptually similar. Timber harvest reduces the transpirational draft of water, thus reducing soil water depletion. In addition, canopy interception and subsequent vapor loss of precipitation (rain and snow) can also be significantly reduced, thus delivering a greater percentage of precipitation to the forest floor. The combination of transpiration and evaporation changes represents the net evapotranspiration (ET) change following disturbance. Depending on soil moisture levels, more water (ET savings) may be available to drain from the soil toward the channel. Soils are generally as wet or wetter following harvest as they were before harvest. Because of the wetter soil, a higher percentage of precipitation entering the disturbed site is often available for streamflow due to the reduced storage requirement in the soil.

The largest differences in the nature and timing in flow response, observed either regionally or nationally, reflect differences in the climatic regimes that drive the respective systems. In humid areas, with frequent large rainfall events, treatment response is demonstrated as increases in individual, and frequent storm flows, as well as reflected in elevated base flows between storms or in non-storm periods — a reflection of frequent wetting and draining of the wetter soil. In arid areas, the rainfall may be intercepted and vaporized in a different manner or pathway following harvest; thereby, greatly reducing the opportunity for flow change in all but the wettest seasons or years. In the subalpine, for example, the summers are often arid (precipitation limited) and demonstrate little response while the winters accumulate snowpack (energy limited) that upon melting and entering the wetter soil, causes a large, concentrated increase in flow early in the runoff period. The timing and magnitude of hydrologic response to forest disturbance varies from region to region but there are more similarities in the processes being altered and the response that occurs than there are differences.

The original paired watershed experiment (water balance study) in the United States was done at Wagon Wheel Gap at the head of the Rio Grande River in southwestern Colorado (Bates and Henry, 1928). Streamflow from two watersheds was monitored from 1911 to 1919 and then one of them was cut. Of the 530 mm of precipitation falling on the watersheds, approximately 150 mm was returned as streamflow prior to harvest with the remaining 380 mm lost to evapotranspiration. Following harvest, flow increased on the disturbed watershed by an average 25 mm with as much as 50 mm occurring in the wet years.

The more classic experiment, because of duration of both record and response, has been the Fool Creek Watershed on the Fraser Experimental Forest , CO (Troendle and King, 1985). Forty percent of the 290 ha drainage was harvested in alternating clearcut and leave strips during 1954-1956. The average hydrograph for before and after treatment is depicted in figure 4. On average, total seasonal flow increased by 40 percent, peak flow increased by 20 percent, and most all the detectable change occurred in the month of May (Troendle and King, 1985). The response at Fool Creek depicts the nature of the change that occurs, either annually or on an event basis, when we disturb the forest in the subalpine environment. First, total flow tends to increase (in this case by almost 90 mm). Oftentimes the peak flow increases (in this case by 20 percent) and usually the duration, or period of time the higher flows occur, increases. The same type of response occurs almost everywhere else, but reflected on either an annual or event basis, depending on the climatic regime. However, we do not usually see the strong relation or positive correlation between annual precipitation and flow changes in humid areas that we observe in more arid regions. Where precipitation is limiting we tend to observe a precipitation dependent response. Where energy is limiting (humid areas) we tend to observe a more consistent response dependent on degree of disturbance. A similar relationship holds with peak flows; generally smaller peaks (precipitation limited) are influenced proportionally more than large peaks with the largest, or extreme events probably not effected by treatment.

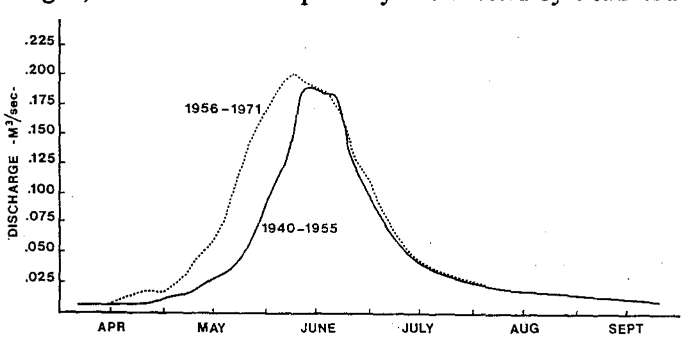

Figure 4. — Average annual hydrographs for Fool Creek for the period before (1940-1955) and after (1956-1971) timber harvest.

To better demonstrate the nature of the change in flow regime or flow duration that occurs following harvest, Fool Creek can also be used. Equations developed between Fool Creek and its control, East St. Louis Creek, for the calibration period (1943-1954) allow the prediction of the expected duration, or frequency of occurrence, of flows of various magnitudes. The expected frequency can then be compared with the observed frequency to determine effect of treatment. Figure 5 represents the percentage of time flows ranging from 40 to 180 percent of bankfull (1.5 year return interval flow is the surrogate for bankfull) would be expected to occur based on pre-harvest conditions, and the percentage of time they occur following harvest. At approximately "bankfull" (or Q_n/Q_b = 1.0) the duration of flow went from 3.5 days before to over 7 days following or was more than doubled. The highest flow durations were unaffected, lower flow durations were less affected. The duration of flows in the range from 80 to 120 percent of bankfull appear to have been most affected.

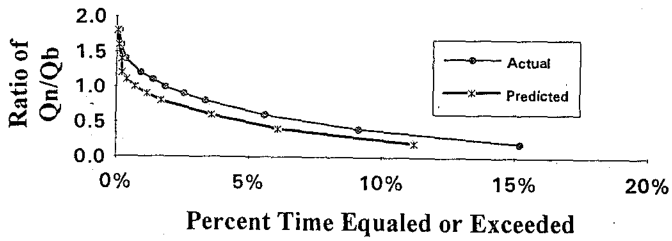

Figure 5. — Flow duration curve for Fool Creek (1957-1991) comparing the mean duration predicted from East St. Louis Creek vs. the actual mean.

Effect on Sediment Transport

Numerous studies have shown forest disturbance can increase the amount of introduced sediment to channel systems. Any increased introduction of fine material to the channel system would probably result in an increase in suspended sediment export. This has been demonstrated to have happened on Fool Creek (i.e., Leaf, 1970), and elsewhere. Following partial clearcutting of the North Fork of Deadhorse Creek in 1977-1978, a significant increase in both sediment export and flow was observed (Troendle, 1983a). Peak flow rate significantly increased by 50 percent (Troendle and King, 1987).

A covariance analysis was conducted to evaluate the interaction of flow and sediment on the North Fork and Lexen Creek (control) with a dummy variable for treatment. Both 1983 and 1984 were wet years, and dominated the post treatment period as the remaining post treatment years were quite low in both flow and sediment production. However, the analysis indicated sediment accumulation is strongly flow related and not significantly related to disturbance, at least for the two largest values. The adjusted slope of the flow/sediment relation was the same for both the pre- and post-harvest periods on the North Fork of the Deadhorse Creek. The intercept of both lines was also the same. The increase in sediment was from within channel and not the result of increased sediment introduction following road building and harvest. The total volume of sediment removed from the weir pond is strongly correlated with flow, whether before or after treatment (fig. 6).

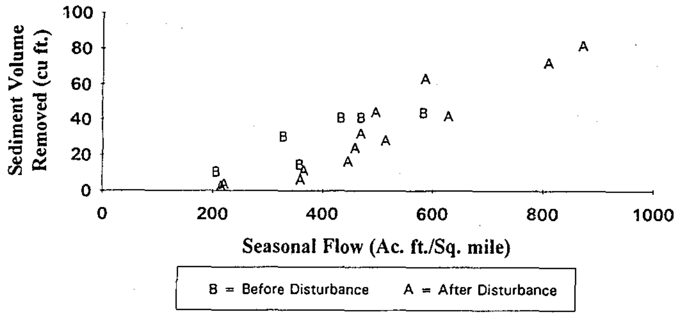

Figure 6. — Sediment volume removed vs. seasonal flow at Deadhorse (north) Creek.

Figure 7 represents the relationship between sediment accumulation and flow at Main Deadhorse Creek. Main Deadhorse Creek contains the North Fork, as well as the Upper Basin and the North Slope harvest sites. In total, approximately 18 percent of the basal area of the Deadhorse watershed has been harvested with no detectable impact on flow (peak or volume) at the gage (Troendle and King, 1987). Analysis of the sediment data does not indicate any significant change occurred; supporting the observation on the North Fork that there is no increase in introduced material due to disturbance alone. In the case of Main Deadhorse Creek there is no detectable flow change so one would not expect a flow driven sediment increase.

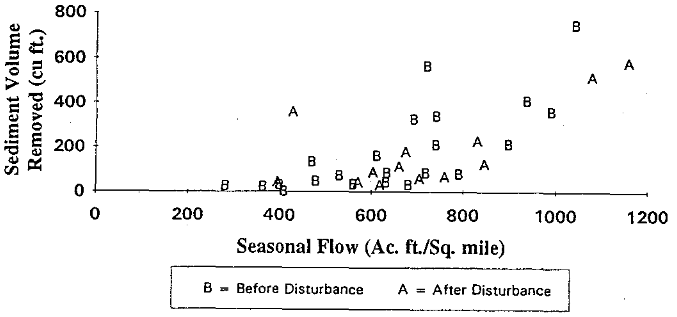

Figure 7. — Sediment volume removed vs. seasonal flow at Main Deadhorse Creek.

Water Management

Because 70-80 percent of the water supply in the Western United States is generated from 15-20 percent of the land base, a significant portion of that water is diverted, transferred from one basin to another, stored on or off site, and in effect manipulated so it can be delivered when and where it is needed for other purposes.

The net effect in either the diversion or augmentation process is to alter the natural flow regime. The watersheds on the Fraser Experimental Forest also lend themselves well as an example of the effect of diversion on the flow regime. The U.S.G.S. maintains a gage on Main St. Louis Creek, the 9300 ha drainage containing East St. Louis Creek, that dates to the mid-1930's. In 1956, the Water Department of the City of Denver, CO started diverting a significant portion of the flow from various tributaries on St. Louis Creek. For the period 1943-1955 the flow from both East St. Louis Creek (the control watershed, described earlier) and Main St. Louis Creek was unaltered. Both drainage's have similar aspect, relief, and vegetative cover with East St. Louis Creek being a small tributary of St. Louis Creek; and one-tenth its size. The flow from Main St. Louis is highly correlated with that from East St. Louis such that East St. Louis Creek can be used to estimate "expected" flow for Main St. Louis Creek for the period of diversion (1956 to present).

A fairly significant proportion of the expected seasonal flow on Main St. Louis Creek (approximately 50 percent) is diverted (fig. 8). The consistent pattern has been to take a high percentage of the flow in average and drier years and little flow in the wetter years. (Please note that the scale on Figure 8 does not clearly reflect the fact that there is a significant bypass of at least 280 to 480 l.s base flow at all times.)

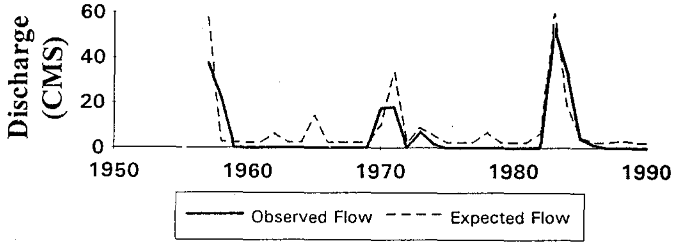

Figure 8. — Comparison of observed and expected flow equal to or exceeding bankfull at St. Louis Creek for the post diversion period 1957 - 1990.

In a manner similar to the one used for Fool Creek, we estimated the expected frequency of occurrence of flow near bankfull discharge (1.5 year return interval) and compared it with observed occurrence (fig. 9). The greatest impact of diversion appears to be at flow levels less than bankfull. Although there is significant reduction in the duration of flows at 80 to 100 percent of bankfull, the greatest impact is on the duration of lower flows.

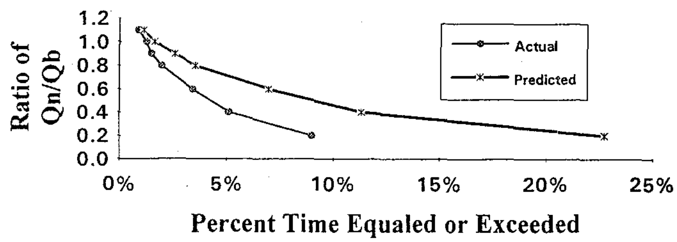

Figure 9. — Flow duration curve for St. Louis Creek (1957-1990) comparing the mean duration predicted from East St. Louis Creek vs. the actual mean.

The climatic regime at Fraser is such that there is an 11 year cycle from wet to dry to wet, as is evident in figure 8. In the wettest years, most of the high flows are by-passed, but in the near average and lower years (perhaps when bankfull does not occur) nearly all flow is taken. As noted earlier, the degree to which diversion alters flow depends on many factors. St. Louis Creek is used only as an example of the nature of the change in flow resulting from diversion.

DISCUSSION AND SUMMARY

It has been well demonstrated that forest disturbance alters the flow regime (see fig. 4). Most reports on response to disturbance have dealt primarily with impact on total yield, some with effect on peak, and few with effect on flow duration (see Troendle and Leaf, 1980, Troendle and King, 1985). However, forest disturbance, particularly timber harvest, has the potential to increase total flow, increase peak discharge, and lengthen the duration of the larger flows apparently also critical to sediment (bedload) movement. Flow augmentation has the same potential. The analysis of flow parameters associated with sediment transport implies increasing any of the three expressions of flow increases sediment transport. In the case of the North Fork of Deadhorse Creek the significant increase in sediment, demonstrated to occur following harvest, appears to be largely a reflection of increased export associated with prolonged duration of higher flows.

Flow diversion, on the other hand, reduces energy as demonstrated by St. Louis Creek. In most years, the critical occurrence and duration of sediment- transporting flows (be it total, peak, or effective flow) are less available. Given the sediment transport relations demonstrated in figures 2, 3, 6, and 7, less of the sediment carried by what would be the "expected" flow would be carried by the "observed" flow. The difference would be deposited in the channel, in bars, spawning beds, etc. Although figure 5 depicts an example of the effect of forest disturbance on flow duration while figure 9 depicts an example of the effect of flow diversion, a direct comparison of the two figures or impacts is not necessarily valid. The forest harvest effects are monitored "on-site" or at the mouth of the first order watershed in which the treatment was imposed. The flow diversion effect is monitored "off-site", or some distance downstream from where diversion is occurring, thus allowing for some recovery. At some of the diversion points, the on-site impact is to totally dry the surface stream. In evaluating these impacts, one has to consider temporal and spacial differences.

Overall, one can conclude that the duration of the higher levels of flow or "bankfull" and above, are needed to ensure sediment movement. Forest disturbance can increase the occurrence of those flows significantly (at least on-site). Lower flows resulting from diversion, reduce the frequency of sediment transporting flows, and may result in aggradation. It is not the purpose of this paper to judge the significance of any possible changes, only that they can occur.

Aquatic systems can best be preserved under natural, pristine conditions. However, competing uses of water and other terrestrial resources almost dictate some modification in flow will occur. The need is to preserve a base flow capable of keeping the thalweg free of vegetation and sustaining the flora and fauna through various life stages. Adequate high flows are needed to transport sediment, keep the channel open, maintain spawning gravels, and prevent undue aggradation. Overbank flows are needed to preserve the riparian environment and for the energy the deeper stage adds to the channel transport processes. Both forest disturbance and water management have the opportunity to adversely alter the needed regime.

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