Indicator type: Stressor

Category: Physical Habitat

Risk level: Unresolved
(probably high)

ALTERED HYDROLOGY FLASHINESS

Flashiness reflects the frequency and rapidity of short term changes in stream flow in response to storm events. Streams that rise and fall quickly are considered flashy. This hydrologic change usually occurs in response to urbanization. One measure of flashiness, the R-B flashiness index, did not increase in the watershed over the past 11 years, although it is difficult to detect changes with such a limited dataset. However, there are many signs of altered hydrology that have been documented over the past 15 years. Due to the short period of record for flow data and the spotty nature of other observations, the risk to aquatic life in the watershed associated with flow changes remains unresolved, although it is likely that the risk is high.

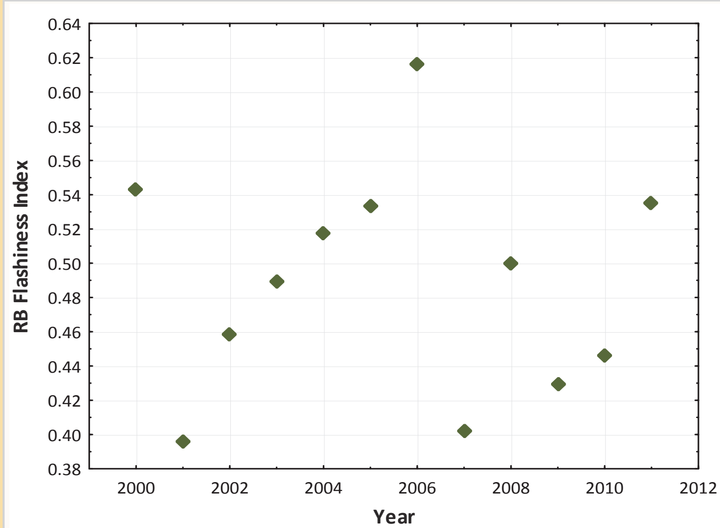

Figure 1. Dry Creek annual Richards-Baker Flashiness Index. Each data point represents the annual flashiness of Dry Creek, measured at the Vernon St. gauge in Roseville. Between 2000 and 2011, there was no consistent trend in flashiness in the watershed.

What is the graph showing?

The flashiness of a stream reflects how quickly flow in a river or stream increases and decreases during a storm. Flashy streams are common in urbanized areas because stormwater runoff reaches the waterways much more quickly than it would under natural conditions. The Richard-Baker Flashiness Index (R-B Index) reports changes in short term daily flows relative to average yearly flows. When stormwater flows into creeks at a higher volume and at a faster rate relative to natural conditions, the R-B flashiness index increases.

The flashiness of a stream will differ from year to year due to variation in precipitation. An increasing trend in flashiness is associated with watershed urbanization, which causes changes in the creeks' hydrologic regime. Due to year-to-year variation, a record of about 30 years is typically required to detect a trend in flashiness. The record of validated data from Vernon Street in Roseville extended back to 1999. This does not provide sufficient information to reveal a trend in stream flashiness. From 1980 to 2010, the population of Placer County nearly tripled. The Dry Creek watershed is located in the most heavily urbanized part of Placer County. Although the data in Figure 1 does not show an increasing level of flashiness, it is likely due to the relatively short period of record.

Reports on the consequences of altered hydrology

Although the R-B flashiness index does not show an increase in flashiness in recent years, numerous reports and studies in the Dry Creek watershed have identified many of the consequences of flashiness and altered hydrology. Holland (2000) reported that the banks of some of the lower reaches of Secret Ravine had eroded 5 to 15 feet in the previous few decades, linked to an increase in hardscape associated with urbanization. A pilot study evaluating erodibility of six of the ten established sampling sites in the watershed found the risk of bank and channel erosion was high (Wieland et al., 2010). Erodibility scores were also correlated with percentage of impervious cover at all spatial scales examined. Similarly, Swanson (2003) determined that the erosion potential of 85-90% of the banks in the study area along Dry Creek (south of the Miner's and Secret Ravines Confluence & Darling Way) was in the high to extremely high range. In this report, Swanson described "dramatic channel incision or increases in width, or both", as signs of altered hydrology and flashiness. A survey of 71 reaches in the Dry Creek and its tributaries documented extensive incision (Bishop, 1997). Finally, many of the indicators in this report, such as Percentage of Fine Particles in the Streambed and Turbidity, are consequences of altered hydrology and were ranked respectively as high and moderate stressors of aquatic life. Taken together, these reports and analyses clearly point to high likelihood that flashiness/hydromodification is the mediator of the changes that impact aquatic life. The linkages between hydrologic changes and aquatic life are illustrated in Figure 2.

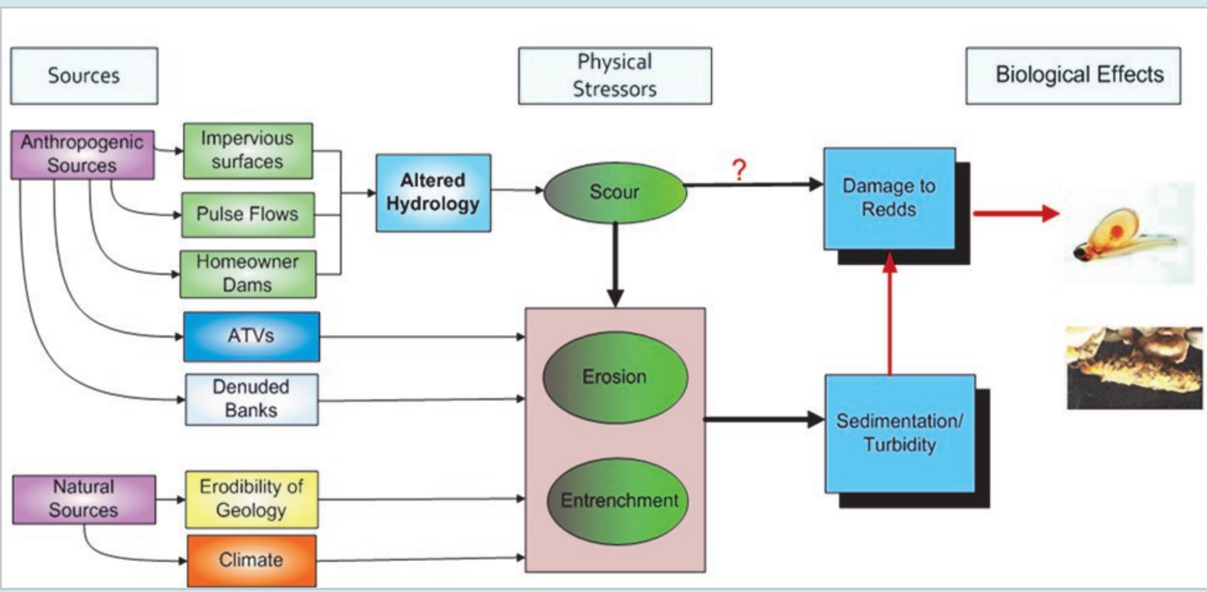

Figure 2. Conceptual model of the links between urbanization, altered hydrology, erosion and entrenchment, and harm to aquatic life. Entrenchment estimates of the long-term effects of erosion within the stream corridor while erosion reflects sloughing of the banking and downcutting into the streambed. Scour refers to the washing away of the stream bed/bank due to the force of water. Scour is known to damage redds or salmon egg nests (Montgomery et. al., 1994).

Why are flashiness and hydrologic changes in Dry Creek important?

One of the main effects of urbanization on the environment is an alteration in the water cycle. In a forest or grassland landscapes, only about 10 percent of rain ends up as runoff; the remainder percolates into the ground or evaporates. In an urban environment, greater than 50 percent of the rain ends up as runoff, producing large volumes of stormwater. This change takes on particular importance for the aquatic ecosystem because waterways have evolved over thousands of years to convey a certain range of flows. When more water enters the waterway at a faster rate, as occurs in urban areas, it causes erosion of the stream bed and bank, having a detrimental effect on aquatic habitat and changing the channel shape and size (Cappiella et al. 2012). The erosive force of water causes incision, forming steep banks, denuded of most vegetation. These changes mobilize large amounts of fine particulates which are carried away by the water, eventually settling in the streambed. The combination of alterations in flow and habitat adversely affects communities of aquatic organisms, especially benthic insects and salmon that prefer rocky stream bottoms. Further, many stream organisms rely on a stable range of flows to thrive. Sensitive benthic insects cannot survive while more disturbance-tolerant organisms move into this habitat, reducing biological diversity (DeGasperi et al. 2009; Richards et al., 2010). Salmonids cannot spawn successfully in streambed dominated by fine particles (Montgomery et. al., 1994), as is the case in many reaches of the Dry Creek watershed

What factors in Dry Creek influence flashiness and hydrologic changes?

Anthropogenic

Urbanization is the primary cause of flashiness and hydrologic alterations. Increased stream flashiness in urban areas is typically a result of increased hardscape, soil compaction, and the increased hydraulic efficiency of traditional stormwater and flood management practices that are designed to quickly drain urban areas. Managed flow releases could be another factor that could affect stream flashiness. Some of the tributaries in the Dry Creek watershed receive releases from the Yuba and Bear rivers through a system of canals (Placer County Water Agency, 2008). These releases occur in the summer, to provide water for irrigation. Periodically, large amounts of water are released into the canals to flush out accumulated sediment. There flushing flows are relatively infrequent and limited in scope so that their impact is likely minimal.

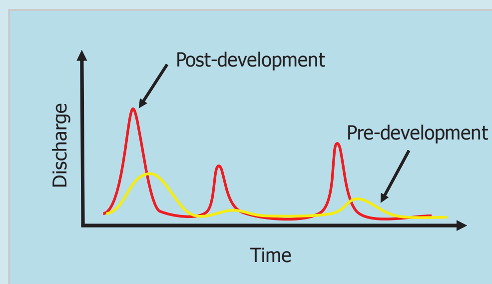

Figure 3. Pre and post-development stream hydrograph. Difference in the flow in an urban stream (red line) and an undeveloped watershed stream (yellow line) with respect to flow and time (hydrograph). The urban hydrograph reflects more drastic spikes and changes in flow patterns due to increased flow rates, runoff volumes/events, and long-term-flow durations as a result of urban development and more impervious surfaces.

Natural

Natural conditions may also contribute to stream flashiness. For example, regions with little attenuation of runoff, such as an area with clay soils or rock layers, typically have higher base flashiness than areas with more permeable soils. The impact on flow typically intensifies during winter months

Figure 4. Examples of bank incision in the Dry Creek Watershed, resulting from hydrologic changes that eroded sediment from the creek banks. This type of incision is common in urban waterways and is associated with hydromodification or changes in the hydrologic cycle (Trimble, 1997).

and the beginning of spring, as there is a smaller degree of absorption and evaporation due to a lack of vegetation and cooler temperatures (Schoonover et al., 2006).

Eco-region and watershed size also influences the R-B Index. There is a greater degree of variability in flow (i.e., higher flashiness) in smaller watersheds. The slope surrounding creeks can also increase flashiness. Many of the creeks found in Roseville, Rocklin, and further up in the foothills are confined within ravines with steep banks, which make this watershed a more flashy system independent of urbanization. Many of the smaller sub-watersheds such as Secret and Miner's Ravine tend to be flashier since the energy of increased flows cannot be dissipated on large, low floodplains (Baker, 2004) such as found at lower elevations. Dry Creek is a relatively small watershed of about 100 square miles. The smaller size, numerous ravines, and varying gradients and slopes found within the Dry Creek watershed all contribute to some degree to the natural flashiness of this watershed.

TECHNICAL CONSIDERATIONS

Stressor Identification Analysis

The flashiness indicator was not evaluated using the Stressor ID methodology due to the nature of the available data. This was due, in part, to the fact that data was available only from a single site, the USGS gauge at Vernon Street in Roseville. However, there was extensive evidence of the consequences of an altered hydrologic regime and increased flashiness. Stream incision and other alterations in stream morphology are widespread but this data comes from one-time studies or surveys performed in different parts of the watershed. Some of the indicators in this report that ranked as high-risk stressors were reviewed, using the Stressor ID methods, are also consequences of hydrologic changes. The weight of this evidence is significant. Unfortunately, the information in these reports is not readily adaptable to review using two of the three key Stressor ID criteria: spatial co-occurrence and stressor-response relationship, which are reviewed in detail in the Causal Assessment Methodology chapter. Analysis of the causal pathway in a stepwise fashion, as performed for other indicators, was not possible with flow data due to the limitations of available data. However, a conceptual model illustrating the linkages between land use, altered hydrology, changes in aquatic habitat, and the effects on aquatic life are illustrated in figure 2. These relationships have been extensively documented in peer-reviewed literature (See Urbanization Indicator). Taken together, this information suggests changes in flashiness have likely occurred over a period of decades and its consequences have been widely reported. Because of these challenges, altered hydrology and flashiness remain an unresolved stressor. The parenthetical "probably high" reflects that the professional judgment of the scientific team was that with additional information, it is likely that altered hydrology could be identified as a high risk stressor.

Calculations of Flashiness

Fifteen-minute flow data from the Vernon Street gauge was obtained from the United States Geological Survey (USGS). It was converted to average daily flows to calculate the R-B Index. This index was calculated over each water year from October 1, 1999 to May 1, 2011. The R-B Index uses daily flow data to determine the frequency and rapidity of changes in flow. The R-B Index is calculated with Equation 1. This equation measures oscillations in daily flow measured compared to total flow. The sum of the differences between flows on two consecutive days is divided by the total daily average flow. Larger fluctuations in flow will result in a higher R-B Index value, while a stable stream flow will have a value closer to zero. Since the R-B Index is based on differences in flow, it is more sensitive to changing trends than flow rate data (Baker, 2004).

$$\boldsymbol{R - B\ Index = \frac{\sum_{i=1}^{n} |q_i - q_{i-1}|}{\sum_{i=1}^{n} q_i}}$$

To identify trends in the Dry Creek data, the R-B index values were evaluated using the Mann-Kendall test, a non-parametric test useful for small datasets. The analysis of the Dry Creek data suggested it was unlikely (a 2-sided probability value of 0.95) that there was an increase in flashiness over the 11 year period of record.

The lack of a change in flashiness during a period of significant urbanization is likely explained by the short period of record. DeGasperi et al (2009) applied eight hydrologic metrics to an urbanizing watershed with 47 years of data. They found significant correlations between the R-B Index and B-IBI scores as well as between the R-B Index and the total impervious area. They concluded that the R-B Index is the most sensitive of the eight metrics they tested to detect trends in urbanization (Figure 5).

Data in Figure 5 confirms the need for long-term data record. For example, in the years between 1980 and 1990, it appears that the R-B Index values might have actually declined. However, over the entire 50+ period of record, there is a significant positive relationship. Subsequent communication with hydrologists using this and other metrics of hydrologic alteration (B. Bledsoe, Colorado State, March 20, 2013 and C. Konrad, USGS, April 30, 3013, personal communications) suggest that a minimum of 30 years of flow data is needed to identify trends. A valid dataset of covering this length of time was unavailable for Dry Creek.

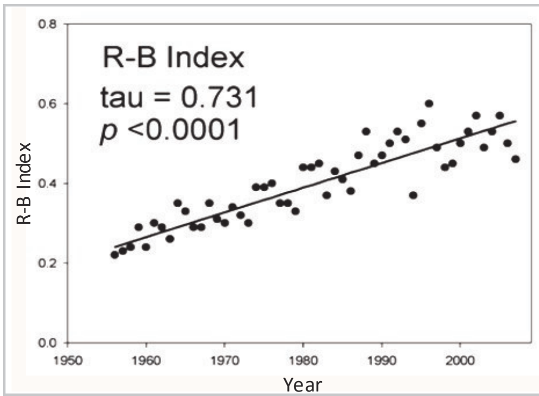

Figure 5. Time series plot showing the trend in flashiness for an urbanizing watershed in the state of Washington (DeGasperi et. al., 2009). The R-B Index had the highest Mann-Kendall tau value of any hydrologic metrics evaluated, suggesting it was a sensitive indicator of change.

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