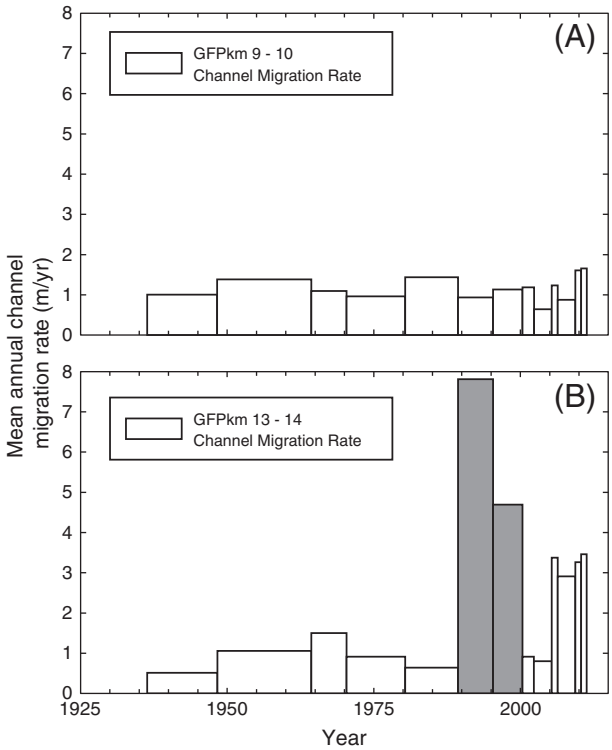

Fig. 8. Mean annual channel migration rate (A) between GFPkm 9 and 10 and (B) GFPkm 13 and 14. Migration rates greater than the total error from orthorectification and digitization are shaded gray.

frequency and magnitude during the twentieth century. Most revetments were built between 1960 and 1970 (Edmondson and Abella, 1988). The active channel mapped by the GLO between 1865 and 1880 was wider than the contemporary river and included multiple anastomosing channels (Fig. 10D). The GLO mapped large sections of anastomosing channels in several areas of the geomorphic floodplain including GFPkm 7–8, 12–18, and 20–21; in other areas, the river was mapped as a single channel suggesting relative channel stability prior to anthropogenic alteration of the Cedar River and its floodplain. The LiDAR-based HAWS maps showed the topographic remnants of anastomosing channels throughout much of the floodplain including anastomosing channels mapped during the GLO surveys (Fig. 10E). Scroll bars, oxbow lakes, and other topographic features indicative of a meandering channel are largely absent suggesting the channel form of the predevelopment river was anastomosing and not a single-threaded meandering channel. In these reaches, the Cedar River was variously confined by valley walls, alluvial terraces, and alluvial fans built by small tributary streams entering the geomorphic floodplain from adjacent plateaus.

5. Discussion

The interaction between sediment supply, discharge, and large wood in determining a river's channel form and processes is complex and occurs over timescales ranging from decades to centuries (e.g., O'Connor et al., 2003; Konrad et al., 2011). Anthropogenic changes to the Cedar River and its floodplain, including flow regulation and bank stabilization, have contributed to decreases in sediment supply, reduced wood, lower peak discharges, and lower frequency of peak discharge events. Collectively, these changes have contributed to channel narrowing, lower channel migration rates, and the predominance of a single-threaded channel on the Cedar River.

5.1. Alteration of Cedar River channel dynamics and processes

Prior to anthropogenic alterations, the Cedar River had a wider and predominantly anastomosing channel (Perkins, 1994) similar to other western Washington rivers like the nearby Nisqually River (Collins et al., 2012), which serves as a control site for analysis of anthropogenic changes to the Cedar River. Along the lower Nisqually River, where federal and tribal land ownership has preserved much of the riparian corridor, large wood recruited from the floodplain acts as 'key' stabilization points upon which log jams and forested islands form helping to maintain an anastomosing channel pattern (Collins et al., 2012). In addition to promoting multiple channels, wood assemblages in the low-flow channel of a river increase pool depth and frequency, which is beneficial to fish. On the Cedar River, much of the wood in the riparian corridor was removed with development. Also, revetments have mostly isolated the river from its floodplain, reducing the recruitment of new wood. Revetments and a marked decrease in wood availability changed the Cedar River's anastomosed channel pattern to its present single-threaded character.

Revetments along the Cedar River also prevented the recruitment of gravel from the floodplain to the river by limiting channel migration and avulsions. Sediment sources to the lower Cedar River for gravel include alluvium from eroding banks, landslides of unconsolidated Pleistocene sediment of glacial and glaciofluvial origin, and minor tributary inputs (Perkins, 1994). In recent years, removal of revetments in the vicinity of Cedar Rapids (Rkm 11.5–12.5) has facilitated local channel migration and the formation of side channels resulting in sediment recruitment from the floodplain.

Landslides along the valley walls of the Cedar River are evident throughout much of the twentieth century orthoimagery. The largest and most geomorphically significant landslide occurred in 2001 at Rkm 7.5–8.5. Subsequent high-flow events transported and reworked this landslide sediment, but much of the Pleistocene glacial sediment released by the landslide was smaller than existing gravel in the river, and the landslide provided little additional sediment available for salmonid spawning. The significant accumulation of sediment from the landslide and its subsequent reworking resulted locally in a wide, braided channel at Rkm 7.5–8.5 that migrated into the adjacent floodplain.

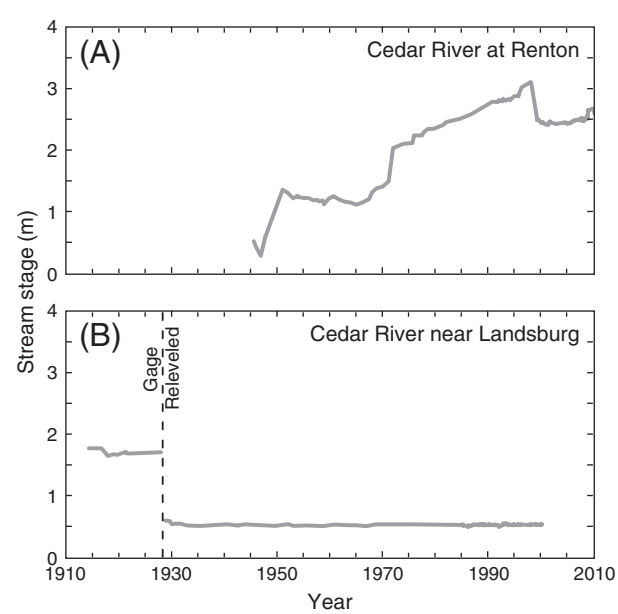

Fig. 9. Temporal variations in stream stage for the median streamflow at USGS streamflow gaging stations at (A) Renton (12119000) and near (B) Landsburg (12117500) on the Cedar River.