3.9 snʕaχ̌əlqaxʷiyaʔ - Vaseux Creek

Vaseux Creek flows from the east side of the Okanagan Basin into the Okanagan River just downstream of McIntyre Dam at the outlet of Vaseux Lake near Oliver, B.C. The Vaseux Creek watershed is approximately 296 km^2 (OBMEP 2019) and has one main tributary, Solco Creek (Associated 2016). The lower portion of Vaseux Creek was straightened and diked for flood control purposes in the 1950s. In response, extensive erosion and active channel migration upstream of the channelized section has been observed as the stream is trying to establish new equilibrium conditions (Agrodev 1996). A summary of creek characteristics is found in Table 3-27 and additional stream-specific data is provided in Appendix B9.

The lower reaches of Vaseux Creek have been subjected to rural and industrial encroachment and corresponding hydro-modification and riparian function impairment. From the mouth of the canyon downstream to the Highway 97 Bridge, the stream has a history of modifications around a large power station and significant water withdrawals. In this section, the stream is somewhat entrenched; however, there is a large complex of side channels and stream diversions that can be difficult to assess. During freshet flows, Vaseux Creek frequently floods these side channel areas, but in summer, flow is reduced to a very localized thalweg profile. Low summer flows are exacerbated by the significant water withdrawals and Vaseux Creek frequently runs dry somewhere between the canyon and the highway bridge. Much of the reach is devoid of any riparian vegetation with limited shading provided by rare large conifers. Industrial encroachment includes a gravel yard, the power station, and pipeline crossings. As well, a large concrete irrigation flume running from the mainstem Okanagan River down to Osoyoos crosses just upstream of the highway bridge. The flume is not hydraulically connected to the creek and a large boulder weir was built around it in 1996 because active erosion of the streambed around the flume was threatening its integrity and also blocking fish passage.

The lowest reach of Vaseux Creek, from the Highway 97 Bridge down to the mouth, has been subjected to intense urban encroachment and significant hydro-modification and riparian function impairment. In this section, the stream has been straightened with corresponding diking and complete bank armouring. Modifications to the streambanks eliminate the creek's ability to regularly interact with riparian areas, and riparian vegetation has been reduced to light tree cover. There is a subsequent deficiency of large woody debris. The width of the riparian areas is very thin, usually just a thin strip of trees, with houses, yards, and roads directly adjacent to the diking. Water losses are known to occur across most of the alluvial fan, though there is likely re-emergence somewhere downstream of the highway bridge as the bed elevation eventually intersects the water table (primarily the one that is connected to the river, with some possible groundwater mounding from the losses from Vaseux Creek). Losses across this fan are likely greater than for other streams because of the coarse fan material and the high elevation of the fan where it leaves the canyon (Neumann pers. comm. 2019).

A natural barrier to fish migration is located approximately 5 km from the mouth and this is the extent of available habitat to anadromous salmon populations (Associated 2016). The stream is known to currently support populations of adfluvial Rainbow, Steelhead, and Sockeye spawning (OBMEP 2019). As well, returns of spring Chinook from downstream hatchery programs have been observed to use the stream for spawning (OBMEP 2018). The stream is also available to Kokanee and Coho Salmon populations. Two riffle and 2 glide transects were installed in the lowest 1 km reach of Vaseux Creek between Highway 97 and the confluence with the Okanagan River.

At present there are 27 points of diversion within the watershed; however, the actual volume extracted is unknown (Associated 2019). There are no main water suppliers listed in the watershed

(Associated 2016) although there is a water licence for a Water Use Community (Associated 2019); water-use is largely for irrigation purposes. There is also no major developed water storage listed for the watershed (Associated 2016); one licence permits storage in a dugout in the Dutton Creek tributary (Associated 2019). Two large diversion channels have been noted on the Vaseux Creek alluvial fan; the water diverted appears substantial during some field visits though total volumes are unknown. One hydrometric station was previously installed by ONA upstream of Highway 97 through the OBMEP program. Naturally, Vaseux Creek is 'flow sensitive' during summer and winter as naturalized flows are below 20% LTMAD (Table 3-28).

Table 3-27: Vaseux Creek description

Drainage Area	294 km^2
Median Elevation	1535 m
WSC station	08NM171 (active) Vaseux Cr above Solco Creek (1970-present) 08NM015 (historic) Vaseux Cr above Dutton Creek (1919-1982) 08NM246 (historic) Vaseux Cr near the Mouth (2006-2010)
ONA station	08NM246-HDS real-time station (2016-to present)
LTMAD	1.285 m^3/s (Associated 2019)
Fish species expected	Rainbow, Steelhead, Sockeye, Mountain Whitefish, Bridgelip Sucker, Longnose Dace, Prickly Sculpin (ESSA & Solander 2009), Chinook (Ernst & Vedan 2000)
Land use	Land use is predominately forestry in the upper watershed. The Bighorn National Wildlife Area is situated in the lower reaches (Associated 2016)

Okanagan Tennant EFNs for Vaseux Creek were developed in accordance with the methods outlined in Section 2.2. Naturalized, residual and maximum licensed flow data were provided by Associated (2019) with an estimated data quality rating of C (data error between 25% and 50%). The LTMAD estimate appeared relatively low; summer and fall naturalized low flow estimates were extremely low and highly uncertain. Estimated maximum licensed flows indicate relatively little licensed water use on Vaseux Creek. However, the creek frequently dries up abruptly in mid-July and the extent to which two large and unmonitored diversions on the alluvial fan contribute is unknown and warrants further investigation.

Fish periodicity and flow standards described in Table 2-2 to Table 2-6 were used. Weekly Okanagan Tennant EFNs were set to the lower of the naturalized flow or flow standard. WUW information from the study transects was then reviewed to determine whether EFNs needed adjustment from the Okanagan Tennant EFN. In some cases, recommended EFNs were adjusted upward due to the uncertainty in the extremely low naturalized summer low flow estimates, and an associated lack of suitable habitat. A summary of EFNs for Vaseux Creek is provided in Table 3-29 including the median EFN and the range of weekly EFNs, with weekly details in Figure 3-20, Figure 3-21 and Appendix B9, and flow sensitives in Table 3-28. Critical flows calculated as described in Section 2.4. Further information regarding EFN and critical flow setting in Vaseux Creek is provided at the end of this section.

Table 3-28: Flow sensitivities in Vaseux Creek

Species & life stage	1-in-2 yr 30-day summer low flow		1-in-2 yr 30-day winter low flow	
	Flow (m^3/s)	% LTMAD	Flow (m^3/s)	% LTMAD
O. mykiss & Chinook rearing	0.042	3%		
Insect production				
Chinook spawning				
O. mykiss & Chinook overwintering			0.002	0%
Sockeye & Chinook egg incubation				

Source: Associated (2019)

Table 3-29: EFN summary table for Vaseux Creek

Species & life stage	Time period	Okanagan Tennant EFN		WUW EFN (m^3/s)	Recommended EFN (m^3/s)				Critical flow	
		Median (m^3/s)	% LTMAD		Median	% LTMAD	Min	Max	Flow (m^3/s)	% LTMAD
O. Mykiss parr & Chinook Fry rearing, insect production [a]	April 1 – Oct 31	0.179	14%	0.15	0.150	12%	0.150	1.15	0.064	5%
Steelhead spawning	April 1 – Jun 25	1.74	135%	1.50	1.50	117%	0.191	6.61	0.477	37%
Rainbow spawning	May 20 – Jul 10	1.74	135%	1.50	1.50	117%	1.50	6.61	0.477	37%
Chinook migration	July 1 – Aug 26	0.313	24%	n/a	0.313	24%	0.200	1.50	0.257	20%
Chinook spawning	Aug 27 – Sep 30	0.107	8%	0.200	0.200	16%	0.200	0.200	0.129	10%
Sockeye spawning	Sep 16 – Oct 31	0.086	7%	0.150	0.150	12%	0.150	0.200	0.129	10%
Overwintering salmonids	Nov 1 - March 31	0.070	5%	n/a	0.070	5%	0.025	0.133	0.064	5%

a while EFNs apply to the entire period, median values are presented for the summer low flow period from Jul 15-Sept 30.

O. mykiss parr and Chinook Fry rearing

The recommended EFN for Steelhead and Rainbow (*O. mykiss*) parr and Chinook Fry rearing is 0.150 m^3/s (12% LTMAD), which is slightly lower than the Okanagan Tennant EFN and median naturalized flow for the summer period (0.179 m^3/s, 14% LTMAD). The EFN maintains approximately 45% of maximum WUW for *O. mykiss* parr rearing (Figure B9-5, Appendix B9) and 60% for Chinook fry rearing (Figure B9-6, Appendix B9), as well as 25% of maximum insect production WUW (Figure B9-7, Appendix B9). Riffles decline below 60% of maximum wetted width at 9% LTMAD (Table B9-1, Appendix B9). The recommended critical flow for *O. mykiss* parr and Chinook fry rearing is 0.064 m^3/s (5% LTMAD; Table B9-2, Appendix B9) based on the LTMAD criterion (Table 2-7) due to naturally low flows. Photos of habitat conditions in Vaseux Creek at the recommended EFN flows are provided in Plate 3-19. ESSA & Solander (2009) previously suggested an EFN of 0.4-0.8 m^3/s for *O. mykiss* rearing.

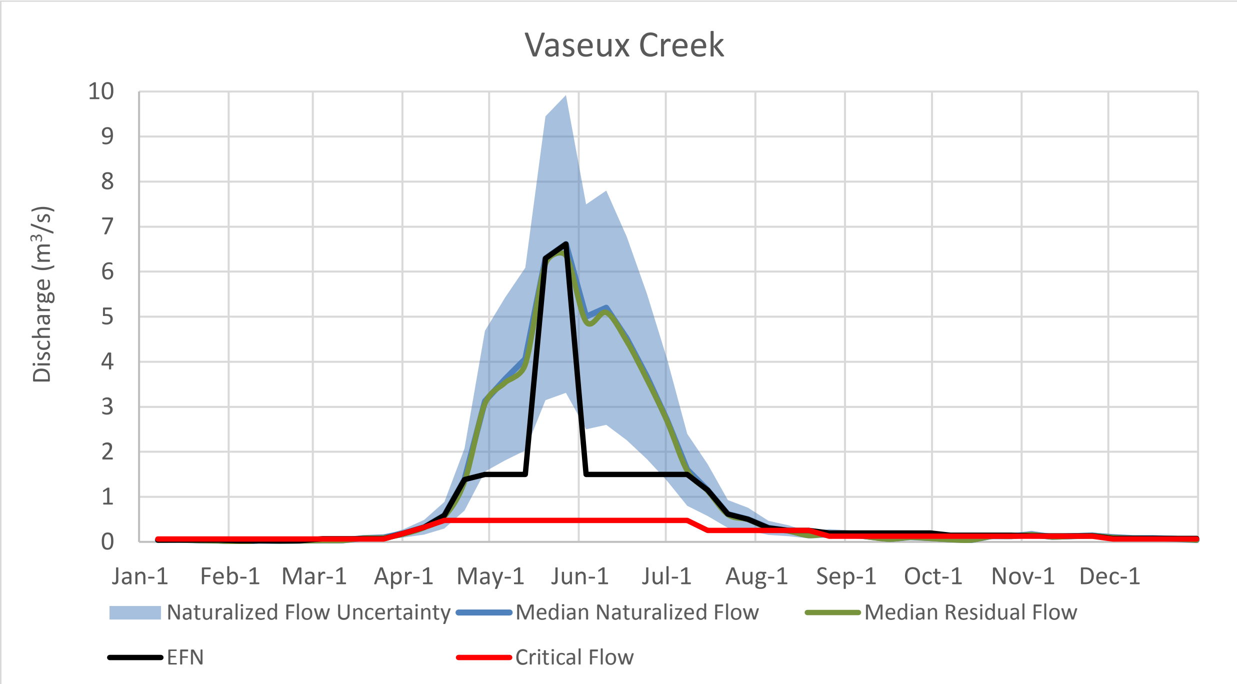

Figure 3-20: Weekly EFNs, critical flow and streamflows in Vaseux Creek

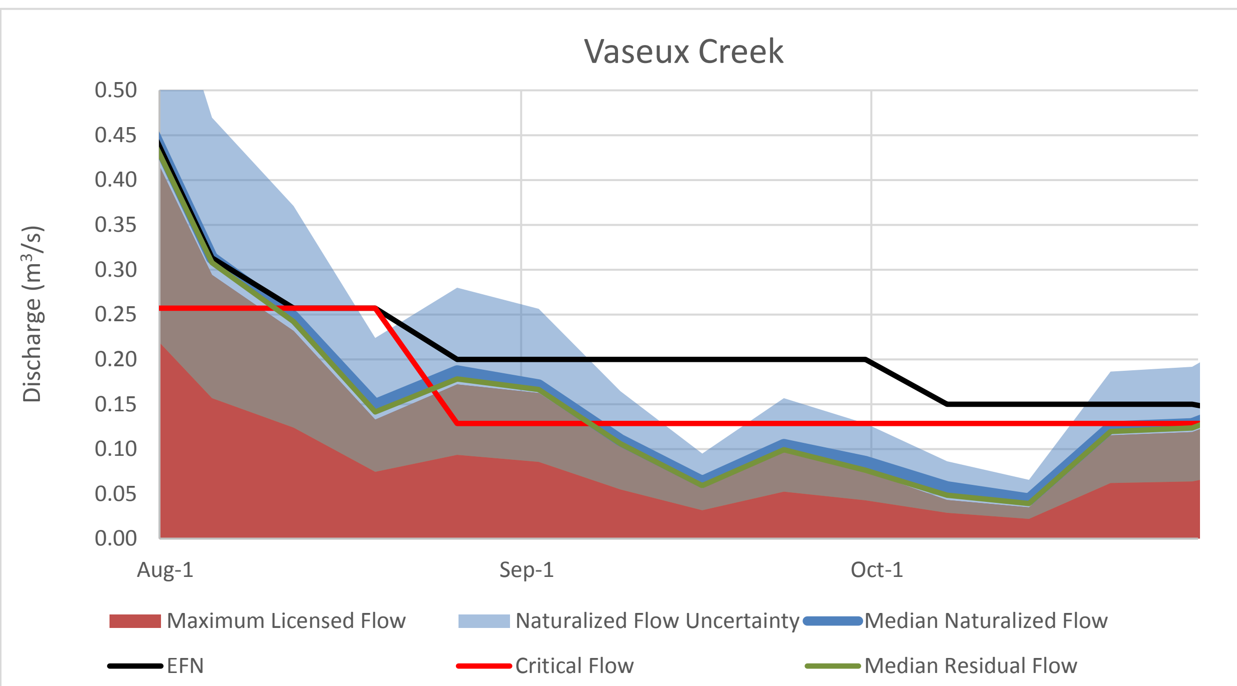

Figure 3-21: Weekly EFNs, critical flow and streamflows during the summer and fall period in Vaseux Creek

Naturalized summer flows estimated by Associated (2019) are generally above the recommended EFN except a period from early September to late October when they decrease to 0.05-0.1 m^3/s. Flows at the WSC hydrometric station 08NM171, which is located much further upstream in the watershed, as well as the historic WSC station 08NM015, located above the alluvial fan and most points of diversion, are adequate for meeting the recommended EFNs year-round (Figures B9-3, Appendix B9). However, flow naturalization on the Vaseux Creek alluvial fan is difficult and highly uncertain given relatively large unmonitored irrigation diversions as well as unknown but likely significant losses to groundwater on the fan. It is unknown what influence straightening and channelization of the streambed (Agordev 1994), had on historic groundwater-surface water interactions on the fan. The limited available flow records from the mouth, in addition to field observations, indicate that the creek frequently goes dry in late summer, fall and winter (Figures B9-2 and B9-3, Appendix B9), rendering it unusable for rearing fish.

Water temperatures in Vaseux Creek recorded at the hydrometric station were unsuitable for *O. mykiss* and Chinook rearing (>20°C) from early July to early September reaching up to 24°C (Figure B9-4, Appendix B9). High water temperatures are likely exacerbated by the very low flows typically observed in the lower reaches and the lack of riparian vegetation. Given the presence of a species of concern (spring Chinook), maintaining sufficient flows is vital to maintain favorable thermal conditions in this creek though flow thresholds for temperature maintenance were not formally studied under this project.

<u>Steelhead and Rainbow spawning</u>

The recommended EFN for Steelhead and Rainbow spawning is 1.50 m^3/s (167% LTMAD), which is slightly lower than the Okanagan Tennant EFN. This EFN maintains spawning WUW near 100% for both species (Figure B9-8 and B9-9, Appendix B9). It is well below median naturalized flows during the Steelhead and Rainbow spawning periods and it is therefore likely that spawning in Vaseux Creek naturally occurs at the beginning (Steelhead) or end (Rainbow) of freshet. The recommended EFN also maintains near maximum WUW for *O. mykiss* parr and Chinook fry rearing as well as very high insect production from riffles. ESSA & Solander (2009) previously suggested an EFN of 2.1-3.6 m^3/s for Steelhead spawning and 2.6-3.6 m^3/s for Rainbow spawning. Photos of habitat conditions in Vaseux Creek at the recommended EFN flows are provided in Plate 3-20. Recent and historical residual flows were greater than the EFN from mid-April to late June (Figure B9-2 and B9-3, Appendix B9).

The recommended critical flow for the Steelhead spawning period is defaulted to the naturalized median weekly flows for the last week of March (0.191 m^3/s; 15% LTMAD) and the first week of April (0.327 m^3/s; 25% LTMAD). For the remainder of the Steelhead spawning period and the entirety of the Rainbow spawning period, the recommended critical flow is 0.477 m^3/s (37% LTMAD, Table B9-2, Appendix B9), based on the minimum passage depth criterion (Table 2-7).

<u>Spring Chinook spawning</u>

Spring Chinook spawn in Vaseux Creek and have been detected at the Vaseux Creek PIT array in early July in recent years (OBMEP 2018). Spawning may be naturally constrained by low streamflows in the August/September spawning period although, historically, spawning may have occurred slightly earlier starting in late July and peaking in August (Fish and Hanavan 1948) prior to the lowest streamflows in late August/early September. Naturalized streamflow estimates (Associated 2019) for the Chinook spawning season are very low, particularly in comparison to WSC hydrometric station 08NM171 (Figure B9-3, Appendix B9), which is much further upstream in the watershed and not affected by irrigation withdrawals and losses to groundwater to the same extent as the lower reaches of the stream. This complicates EFN setting according to the methods outlined in the Phase I report (Associated 2016) considerably. There are concerns that the naturalized flow estimates during the spawning period are lower than expected for a stream of this size; thus, EFNs were set to weekly naturalized flows for the migration period and based on WUW information for the spawning period, resulting in EFNs higher than naturalized flow estimates for spawning. No historical long-term streamflow data for Chinook spawning reaches near the mouth exists for comparison.

The recommended median EFN for Chinook migration is 0.313 m^3/s (24% LTMAD), which is the median naturalized flow during the migration period. Critical migration flows for Chinook are 0.257 m^3/s (20% LTMAD) based on the LTMAD criterion typically used by FLNRORD (Table 2-7). However, safe riffle passage (0.24 m depth over $\geq$25% of riffle width) would be maintained at 1.17 m^3/s (91% LTMAD), which is much greater than naturalized flows during the latter part of the migration period in late July and August.

A preliminary Chinook spawning EFN of 0.200 m^3/s (16% LTMAD) is recommended as it provides a reasonable amount of spawning WUW (30%, Figure B9-10, Appendix B9). Significant increases in WUW can be achieved at flows greater than the EFN with >90% WUW available at flows of 1 m^3/s. Naturalized flow estimates for the spawning period are lower than the EFN at 0.063 - 0.187 m^3/s (5-15% LTMAD), which provides virtually no suitable spawning conditions. However, the accuracy of the naturalized flows is uncertain due to unknown losses on the alluvial fan and unknown volumes of water diversion. Recorded residual flows near the mouth are well below the EFN and frequently approach zero (Figure B9-2, Appendix B9), which is likely a combination of streamflow losses to groundwater and irrigation withdrawals. As such, spring Chinook spawning in Vaseux Creek will only be possible if sufficient flows can be re-established and maintained on a consistent annual basis. The recommended critical flow for Chinook spawning is 0.129 m^3/s (10% LTMAD, Table B9-2, Appendix B9) based on the LTMAD criterion of 10% LTMAD typically employed by FLNRORD (Table 2-7). Photos of habitat conditions in Vaseux Creek at the recommended EFN flows are provided in Plate 3-19.

When Chinook are known to have entered the creek under higher flow conditions in July, sudden decreases in flow, as observed in the hydrometric records from the mouth (Figure B9, Appendix B9), may lead to stranding and mortality. Thus, if suitable conditions are to be maintained for spring Chinook spawning, any water diversion between early July and late September would have to be severely limited for survival and spawning success. High water temperatures observed during July and August would also be problematic for Chinook spawners. However, maintaining sufficient flows for spawning may also serve to lower temperatures.

<u>Sockeye spawning</u>

The recommended EFN for Sockeye spawning is 0.150 m^3/s (12% LTMAD). This flow maintains approximately 30% of maximum WUW for Sockeye spawners (Figure B9-11, Appendix B9). The recommended EFN is near average flows from the hydrometric station above Solco Creek (08NM171) (Figure B9-3, Appendix B9) but greater than naturalized flows near the mouth estimated by Associated (2019). The recommended critical flow for Sockeye spawning is 0.129 m^3/s (10% LTMAD, Table B9-2, Appendix B9) based on the LTMAD criterion (Table 2-7). Safe riffle passage is achieved at flows of 0.477 m^3/s (37% LTMAD, Table B9-1, Appendix B9), but naturalized flows are well below that during the Sockeye spawning period. Photos of habitat conditions in Vaseux Creek at the recommended EFN flows are provided in Plate 3-19. ESSA & Solander (2009) previously suggested an EFN of 0.8 m^3/s for Sockeye spawning.

If Sockeye and Chinook spawning takes place, maintenance of flows throughout the winter incubation period is critical to ensure egg survival. Any water diversion during this period should therefore be discouraged.

Plate 3-19: Vaseux Creek habitat conditions at flows near the recommended *O. mykiss* parr and Chinook rearing and Sockeye spawning EFNs (0.150 m^3/s), and Chinook spawning EFN (0.200 m^3/s)

VAS40GL at 0.126 m^3/s (10% LTMAD)

VAS40GL at 0.224 m^3/s (17% LTMAD)

VAS30SCR at 0.126 m^3/s (10% LTMAD)

VAS30SCR at 0.224 m^3/s (17% LTMAD)

Plate 3-20: Vaseux Creek habitat conditions at flows near the recommended Steelhead and Rainbow spawning EFNs (1.50 m^3/s)

VAS40GL at 1.37 m^3/s (106% LTMAD)

VAS40GL at 1.81 m^3/s (141% LTMAD)