East Fork Lewis River Thermal Study Meeting #2: Site List and Prioritization Strategy Review

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January 27, 2022

Lower Columbia Estuary Partnership

Project Goals Review

1. Mainstem, tributary and off-channel water temperature assessment for lower East Fork Lewis River (LEF). Includes identification & mapping of existing thermal refuge locations.

2. Identify areas to protect and restore - thermal refuges along the LEF and primary tributaries.
    - List of potential sites
    - Concept designs for top 3 sites

3. Revise habitat project recommendations in the LEF HRP as needed to incorporate these and other thermal actions.
    - Temp. listed as primary limiting factor Fall Chinook (SalonPORT)- all life histories
    - Also for coho and summer steelhead

Project Timeline

Year 1

Thermal-IR temperature data acquisition	summer '20
Thermal-IR field verification and habitat assessment of existing cold locations.	summer '21
Compile existing temperature info.	fall '21
Technical Oversight Group Meeting 1 – present temperature/site assessment results, primary focus areas.	Oct. 27, '21

Year 2

Identify strategies to protect, enhance and create thermal refuge opportunities.	Nov–Dec '21
Develop initial site list.	Dec '21
Develop site ranking methodology.	Jan '22
Rank initial sites (restoration opportunities)	Jan '22
Create map with temperature results, supporting data, sites.	Jan '22

Technical Oversight Group Meeting 2 – review site selection and ranking methodologies, initial site list, ranked sites.	Jan 27, '22
Develop alternatives for top three ranked restoration sites.	Feb '22
Technical Oversight Group Meeting 3 – review of restoration alternatives.	Late Feb '22
Finalize concept designs for top three ranked restoration sites.	March '22
Develop recommendations for landscape level strategies[1] and changes to LEF_HRP.	Feb-Mar '22
Technical Oversight Group Meeting 4 – review of final concept designs, additional recommendations.	March '22
Deliver final products (report, data, concept designs).	Apr '22

1. Includes broad-based prioritization of areas for improved riparian shading.

TOG Meeting 1 Re-cap

1) Reviewed temperature data, including thermal-IR and in-stream results.

2) Presented 4 focal areas for identifying potential opportunities to protect, restore, and create cold-water refuge zones:

   1) Downstream RM 4.5 – 5.5 (above La Center)
   2) Ridgefield Pits RM 7.5 – 9
   3) Below Lewisville Bridge RM 11.5 – 13
   4) Lucia Falls RM 20.5 – 21.5

3) Received input from TOG on focal areas and next steps for site selection and prioritization.

   a) Ranked focal areas 1 >> 3 >> 2 >> 4 (high >> low)

   b) Identified additional supporting data sources including:
      - Dept. of Ecology gaining/losing GW reaches
      - Clark County acquisition list and AOI

LEF Water Temperature Strategies (LCEP)

Site Scale

Strategy	Potential Actions	Notes
Preserve/Protect	- acquisition/easements	Applies primarily to existing thermal refuge locations on non-public lands
Enhance	- improve habitat (wood placement, shading, etc.) - increase connection to groundwater/tributary flow - flow diversions	Applies primarily to existing thermal refuge locations with no social constraints
Create	- flow diversions - connect to groundwater - pumping	

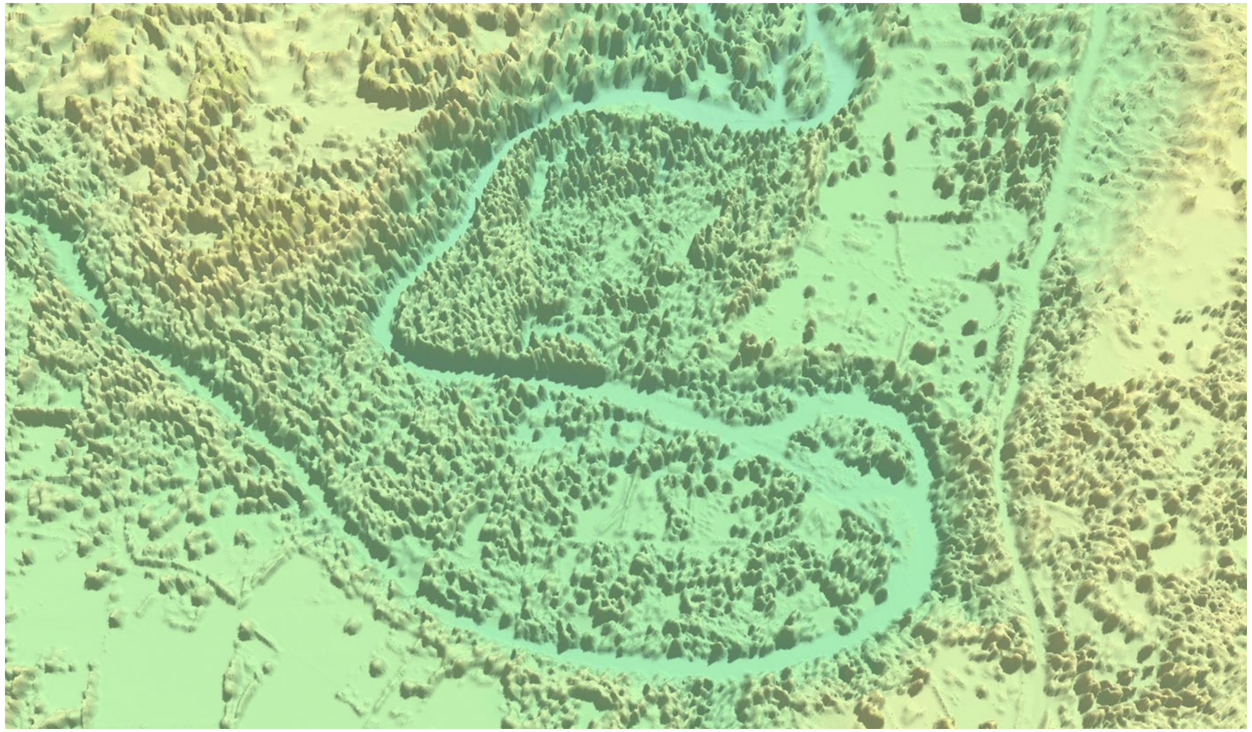
Landscape Scale

Strategy	Notes
▪ Large-scale reforestation	LCEP doing a basic GIS analysis based on canopy heights provided by recent LiDAR and available stream temperature data.
▪ Water withdrawal reduction	LCEP not assessing as part of this study.

Landscape Scale Shade Analysis - Example

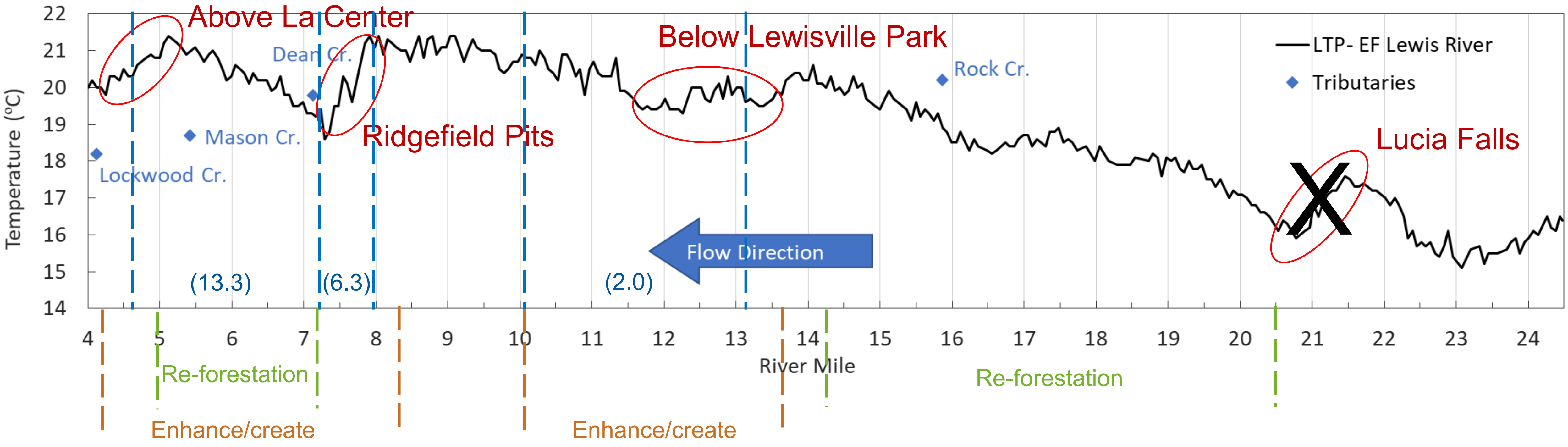
- ArcGIS shade prediction based on sun position and canopy height

Predicted shade extent @ 14:30, Jun 23, 2021



Predicted shade extent @ 16:30, Jun 23, 2021

Temperature Strategies By Reach



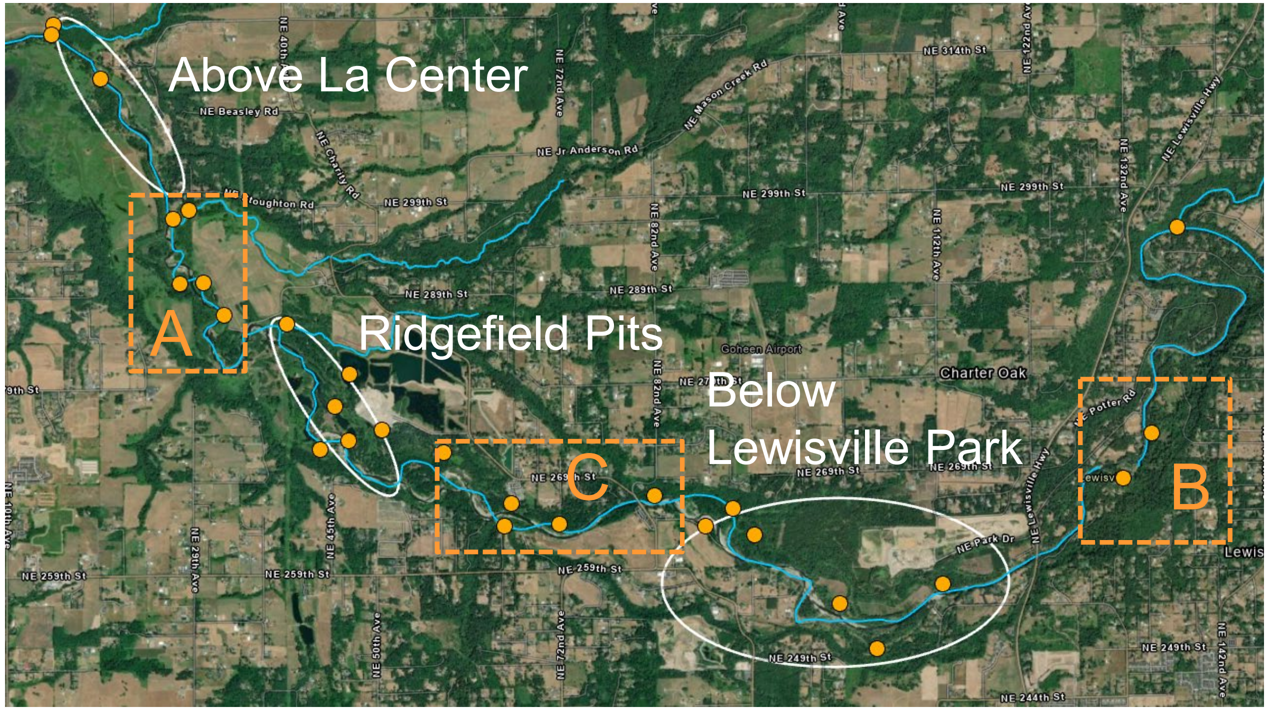
- Consider site enhancement/creation where DOE and LCEP reaches overlap (good GW potential)
- Consider reforestation 1) in reaches where temperature increases are seen, and 2) gains can be realized (suitable channel width/depth/current velocity, along a sufficient length of streambank lacking cover; large floodplain areas lacking cover)
- Apply additional supporting information: Ex.: sites identified in 2009 LEF HRP

Dept. of Ecology (DOE)
Gaining Reach

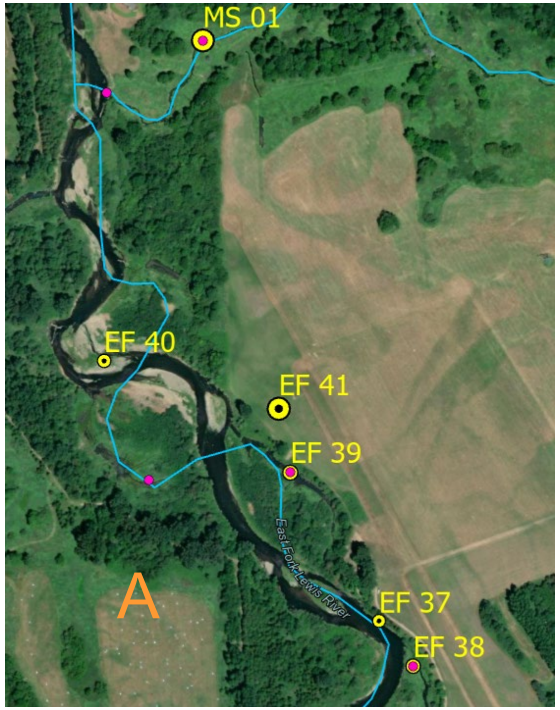
(est. GW input, cfs)

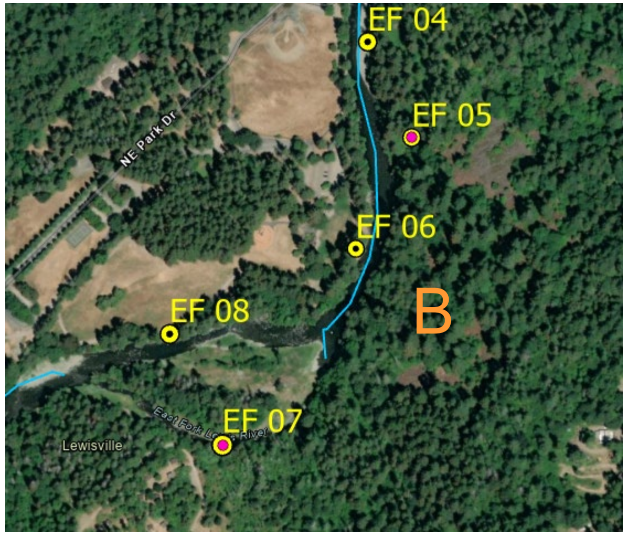
Preliminary Site List

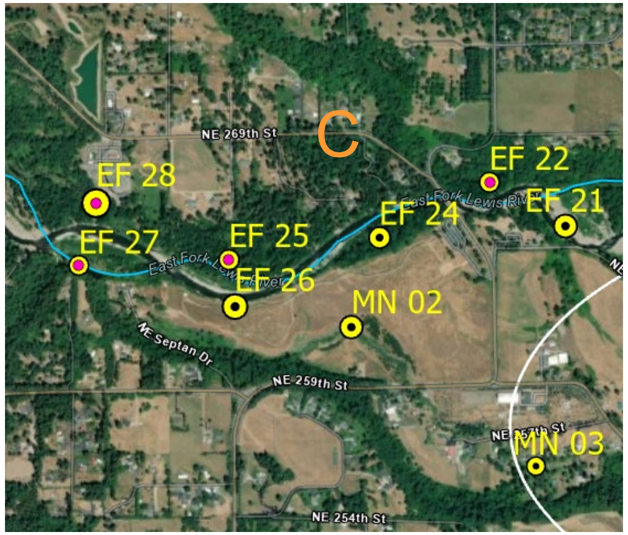
- Identified 28 initial locations through outlined strategy



- Projects outside reach priorities typically overlap with LEF HRP locations







Site Ranking Process and Criteria

- Protection of existing thermal refuge should be a top priority
- For enhancement/creation of sites we considered the following environmental (performance) and social (constructability) criteria:

Environmental

Criteria	Factors Considered	Weight (0–1)
Cooling source	quality/reliability of cooling source	1
Type and size	are we creating or enhancing a small or large feature	1
Connectivity	does the site fill a gap between existing features?	.5
Mainstem proximity	ease of access for rearing fish	1
Surrounding habitat quality	indicator of potential fish use	.4
Ecology gaining reach?	Indicator of good groundwater potential	.4
LEF HRP priority	indicator of site habitat potential	.5
Likelihood of success	Geomorphic persistence/stability	.7

Social

Criteria	Weight (0–1)
Ownership	1
Access	1
Likelihood of inclusion in another project	.5

Site Criteria Categories

Environmental Criteria

	Source		***Type/Size***		***Connectivity***		***Distance to Mainstem***		***Surrounding Hab. Quality***		***Ecology Reach***		***Likelihood of Success***		***LEF HRP Priority***	
	Trib	4	Created/Large	4	> 1 mi	4	On	4	Good	3	Gaining	1	High	2	High (110 - 140)	3
	GW	3	Created/Small	3	0.5 - 1 mi	3	Off/SC 0 - 200'	3	Fair	2	Losing	0	Med	1	Med (75 - 110)	2
	Other	2	Enhance/Large	2	0.25 - 0.5 mi	2	Off/SC 200 - 300'	2	Poor	1			Low	0	Low (45 - 75)	1
	Shade	1	Enhance/Small	1	< 0.25 mi	1	Off/SC > 300'	1							N/A	0
criteria weight (0-1)	1		1		0.5		1		0.4		0.4		0.7		0.5	

Social Criteria

	Ownership		***Access***		***Likelihood of Inclusion in other project***	
	Public	2	Road	1	No	1
	Potential Public	1	River	0	Yes	0
	Likely Private	0				
criteria weight (0-1)	1		0.5		1	

Example Site Sheet and Ranking

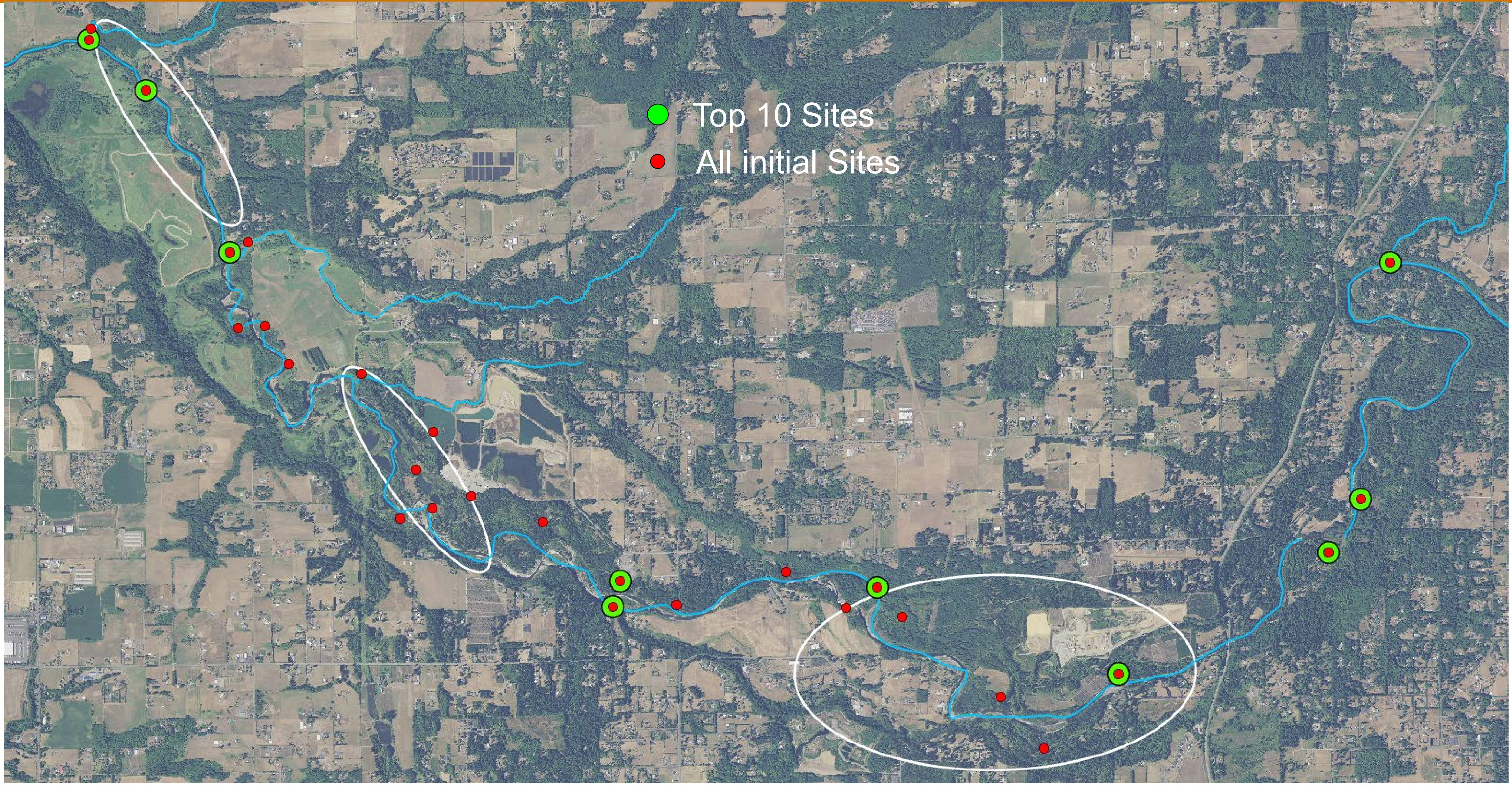
EFLR Thermal Refugia Site Evaluation

ID	Site	Short Description	Approx RM	Feature Type	Source	Type/Size	Stepping Stone	Mainstem Proximity	Surrounding Habitat Quality	Ecology Reach Type	Likelihoood of Success	East Fork Hab. Rest Plan	Normalized Env. Score (0 - 100)	Ownership	Construction Access	Already in an active project	Normalized Social Score (0-100)
	Site Characterization				Environmental Conditions Scoring									Social/Implementation Constraints Scoring			
1	East Fork, RM 4_5-5_5	mainstem, potentially enhance habitat in relatively cool reach (based on TIR). (BPA 43B project area)	4.5-5.5	mainstem	Other	Enhance/Large	> 1 mi	On	Fair	Gaining	High	N/A		Public	Road	No	
					2	2	2	4	0.8	0.8	1.4	0	58	2	0.5	1	100
2	Off-channel RM 6.3 L Bank (above 5A side chan project)	off channel enhancement - need to determine thermal potential.	6.3	off-chan	GW	Enhance/Small	0.25 - 0.5 mi	Off/sc 0 - 200'	Fair	Gaining	High	N/A		Public	Road	No	
					3	1	1	3	0.8	0.8	1.4	0	44	2	0.5	1	100
3	Off-channel RM 6.4 R bank (EF39)	We didn't confirm anything here, and there was discussion of some restoration previously occurring here- but are there addt.	6.4	off-chan	Shade	Enhance/Small	0.25 - 0.5 mi	Off/sc 0 - 200'	Fair	Gaining	Med	Med (75 - 110)		Likely Private	Road	No	
					1	1	1	3	0.8	0.8	0.7	1	32	0	0.5	1	43
4	Off-channel RM 6.6 R bank (EF38)	cold off channel area- chum channel? HRP observed cold water here. Has ISC/FOEF completed a project here since HRP?	6.6	off-chan	GW	Enhance/Small	0.5 - 1 mi	Off/sc 0 - 200'	Poor	Gaining	Med	Med (75 - 110)		Likely Private	Road	No	
					3	1	1.5	3	0.4	0.8	0.7	1	47	0	0.5	1	43
5	RM 7.5 Daybreak Pits	As Daybreak pits are phased out, could cold groundwater be pumped into off-channel or mainstem?	7.5	off-chan	GW	Created/Small	0.5 - 1 mi	Off/sc 0 - 200'	Poor	Gaining	Low	N/A		Likely Private	Road	No	
					3	3	1.5	3	0.4	0.8	0	0	49	0	0.5	1	43
6	RM 7.7 Ridgefield Pits 7/8	low priority..not even confirmed. Needs more study	7.7	off-chan	GW	Enhance/Large	0.5 - 1 mi	Off/sc 0 - 200'	Poor	Gaining	Med	N/A		Likely Private	River	Yes	
					3	2	1.5	3	0.4	0.8	0.7	0	47	0	0	0	0
7	Off-channel RM 7.8 - 7.9 L bank	Historic Channel- Stream R or Pits 2 & 4- Stream L	7.8-7.9	off-chan	GW	Enhance/Small	> 1 mi	Off/sc 0 - 200'	Poor	Gaining	Med	N/A		Likely Private	Road	Yes	
					3	1	2	3	0.4	0.8	0.7	0	43	0	0.5	0	14
8	Off-channel RM 7.95 R bank	small off-chan former pit area. Would also be addressed in RP design	7.95	off-chan	GW	Enhance/Small	> 1 mi	Off/sc 0 - 200'	Poor	Gaining	Low	N/A		Likely Private	River	Yes	
					3	1	2	3	0.4	0.8	0	0	38	0	0	0	0
9	Off-channel RM 8.9 - pits near Danger Park	pump cooler water from Pit near Danger Park into side chan or mainstem. This pit was cool when measured in July '21	8.9	off-chan	GW	Created/Small	0.5 - 1 mi	Off/sc > 300'	Fair	Losing	Low	N/A		Public	Road	Yes	
					3	3	1.5	1	0.8	0.4	0	0	35	2	0.5	0	71
10	Side channel RM 9 - 9.5 (R bank) (EF 28)	EF28 in HRP-confirmed cold in July 21	9-9.5	side-chan	GW	Enhance/Large	< 0.25 mi	Off/sc 0 - 200'	Fair	Losing	High	High (110 - 140)		Public	Road	Yes	
					3	2	0.5	3	0.8	0.4	1.4	1.5	55	2	0.5	0	71
11	Side channel along Storedahl	Cold water confirmed in this disconnected historic channel.	7.7	side-chan	GW	Enhance/Large	0.5 - 1 mi	Off/sc > 300'	Fair	Gaining	Med	N/A		Likely Private	Road	Yes	
					3	2	1.5	1	0.8	0.8	0.7	0	35	0	0.5	0	14
12	Off-channel RM 9.4, Mill/Manley confluence (EF27)	install wood in beaver ponds at Manley confluence for cover habitat. Possible re-grade to increase access but would need	9.4	off-chan	Trib	Enhance/Large	> 1 mi	Off/sc 0 - 200'	Good	Losing	Med	Med (75 - 110)		Likely Private	Road	No	
					4	2	2	3	1.2	0.4	0.7	1	67	0	0.5	1	43
13	Off-channel RM 9.7 R bank (EF25)	relic channel scar. Could grade in a downstream connection and tap groundwater potentially.	9.7	off-chan	GW	Enhance/Small	0.5 - 1 mi	Off/sc 0 - 200'	Good	Losing	Med	Med (75 - 110)		Likely Private	River	No	
					3	1	1.5	3	1.2	0.4	0.7	1	50	0	0	1	29

Top 10 Prioritized Sites

ID	Site	Short Description	Approx RM	Feature Type	Env. Score (0 - 100)	Social Score (0-100)
25	Mason Cr/EF confluence	Potential deflector structure but is there enough summer flow?	5.9	confluence	70	43
15	Side channel above Daybreak Bridge (R bank)	Historic mainstem now complex off-channel habitat with trib input, beaver dams, deep pools. Actions could include protect, improve fish access, add LWD/complexity	10.5	side-chan	68	57
12	Off-channel RM 9.4, Mill/Manley confluence (EF27)	install wood in beaver ponds at Manley confluence for cover habitat. Possible re-grade to increase access but would need more eval.	9.4	off-chan	67.4	43
27	Rock Cr/EF confluence	potential deflector structure but is there enough summer flow?	16	confluence	66.7	29
26	Lockwood Cr/EF confluence	potential deflector structure but is there enough summer flow?	4.5	confluence	64	43
21	Off-channel RM 14.1 L bank (EF05)	HRP observed cold water here. Has ISC/FOEF completed a project here since HRP?	14.1	off-chan	60	29
1	East Fork, RM 4_5-5_5	mainstem, potentially enhance habitat in relatively cool reach (based on TIR). (BPA 43B project area)	4.5-5.5	mainstem	58	100
10	Side channel RM 9 - 9.5 (R bank) (EF 28)	EF28 in HRP-confirmed cold in July 21	9-9.5	side-chan	55	71
28	RM 12.5 - 12.6, both banks (EF11)	EF 11 Could be off-chan opportunity to create, or mainstem opportunity to preserve/enhance. Need to verify TIR results.	12.5-12.6	off-chan	53	100
20	Off-channel RM 13.7 L bank (EF07)	Did not observe cold water here, but could a hyporheic zone be created by limiting upstream flow entering? HRP lists as high priority but does not ID temp potential. Could it include this?	13.7	off-chan	53	86

Map of Top Sites (Env. Score Only)



Technical Resources – Project Concepts

- Extensive literature related to characterization and use of thermal refuge.
- Limited literature related to creation and enhancement of thermal refuge.

Kurylyk et al. 2015, Ecohydrology

Preserving, augmenting and creating cold-water thermal refugia in rivers: Concepts derived from research on the Miramichi River, New Brunswick (Canada)

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Note: This is a post-print of this 2015 *Ecohydrology* article. If you wish to have the final, type-set version, please send me an email at barret.kurylyk@dal.ca or go to: http://onlinelibrary.wiley.com/doi/10.1002/eco.1566/abstract

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From Kurylyk et al. 2015, Ecohydrology

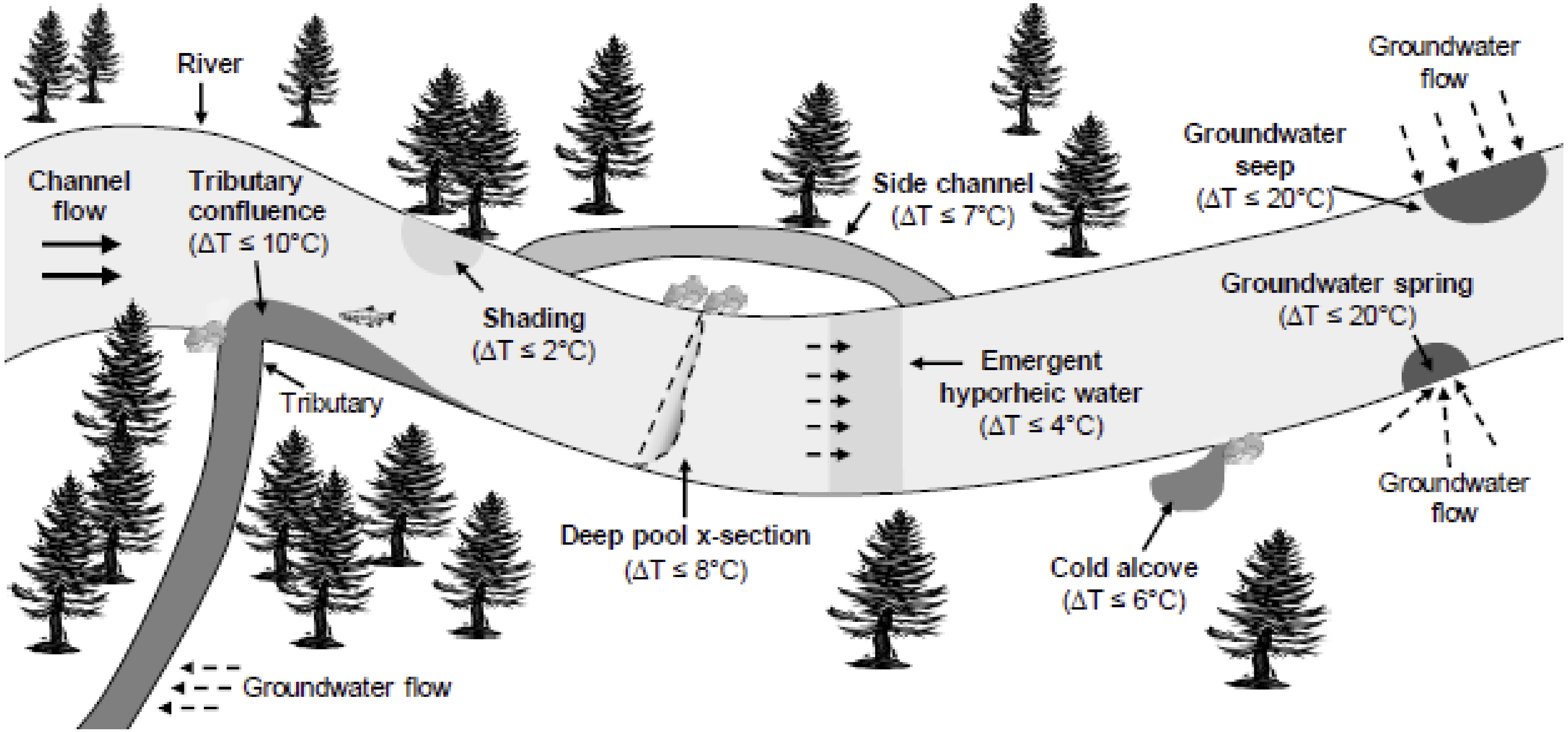

Figure 1. A conceptual overview of mechanisms that induce thermal diversity in rivers and create suitable thermal refugia. The estimated maximum temperature differences between a particular thermal anomaly and the ambient river temperature given in brackets are derived from other literature sources (Ebersole *et al.*, 2003b; Nielsen *et al.*, 1994) and extensive aerial infrared images and in-stream thermal surveys of the Little Southwest Miramichi River and other branches of the Miramichi River (*e.g.*, Wilbur, 2012). Darker colors indicate colder water.

Technical Resources – Project Concepts

From Kurylyk et al. 2015, Ecohydrology

climate change may influence surface/subsurface thermal dynamics and to develop effective thermal refugia management strategies (Kanno *et al*., 2013).

5. Augmenting existing thermal anomalies

In certain locations where thermal anomalies are not functioning as refugia, their conditions may be improved through application of ecological and hydraulic principles.

5.1 Enhancing the spatial extent or preserving the temperature of cold-water plumes

The potential for an existing thermal anomaly to provide thermal refuge may be potentially increased by enhancing the thermal difference between the cold-water plume and the river mainstem. The spatial extent and temperature of cold-water plumes are primarily controlled by thermal mixing due to the mainstem channel flow (Fischer *et al*., 1979; Tanaka, 2007). Advective thermal mixing is limited along the river bank due to increased shear stress (Fischer *et al*., 1979). The influence of shear stress on the spatial extent of thermal anomalies is evidenced by the fact that cold-water plumes can extend along river banks for significant distances downstream of the point of cold-water input (*e.g*., cold-water tributary plume, Figure 2c). Thus, the spatial extent can be increased and the temperature of cold-water refugia may be preserved by limiting hydraulic and thermal mixing between the cold-water plume and the river mainstem. A channel deflector constructed of boulders or other material is presented in Figure 4 as one option for physical manipulation and control of flow. However, fluvial geomorphological principles should be employed to design any such channel modifications, because the installation of channel deflectors can lead to scouring problems and bank erosion, particularly when the deflector is submerged at high flow (Biron *et al*., 2004; Rodrigue-Gervais *et al*. 2011). In addition, river ice may damage the designed deflectors in seasonal latitudes (Biron *et al*., 2005), and thus it may be beneficial to design easily removable, temporary deflectors. Hydrodynamic thermal mixing models, such as CORMIX3 (Jones *et al*., 1996) can be employed to model the

Technical Resources – Project Concepts

From Kurylyk et al. 2015, Ecohydrology

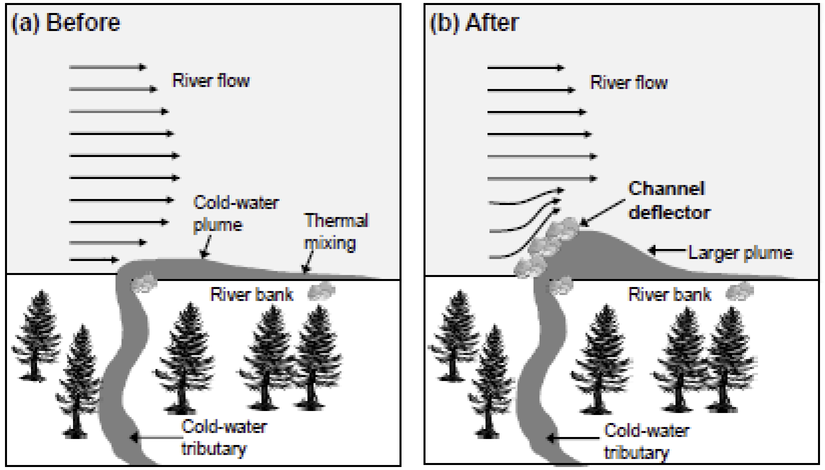

Figure 4. A cold-water plume at the mouth of a tributary before (a) and after (b) installation of a channel deflector to limit advective thermal mixing (adapted from Bilby, 1984).

further decrease the temperature of existing thermal anomalies. For example, Ebersole *et al.* (2003b) installed experimental shade covers and observed a subsequent 2-4°C decrease in the daily maximum temperature of cold-water plumes. The effectiveness of installing artificial shading will, of course, depend on the ability of shade to influence a specific in-stream temperature regime (Ebersole *et al.*, 2003b).

5.2 Enhancing the cover of cold-water plumes

Salmonids may be threatened by avian predators when aggregating in refugia (Keefer *et al.*, 2009). The enhanced shading described previously is one potential method for decreasing

From Sullivan et al. 2021, Ecohydrology

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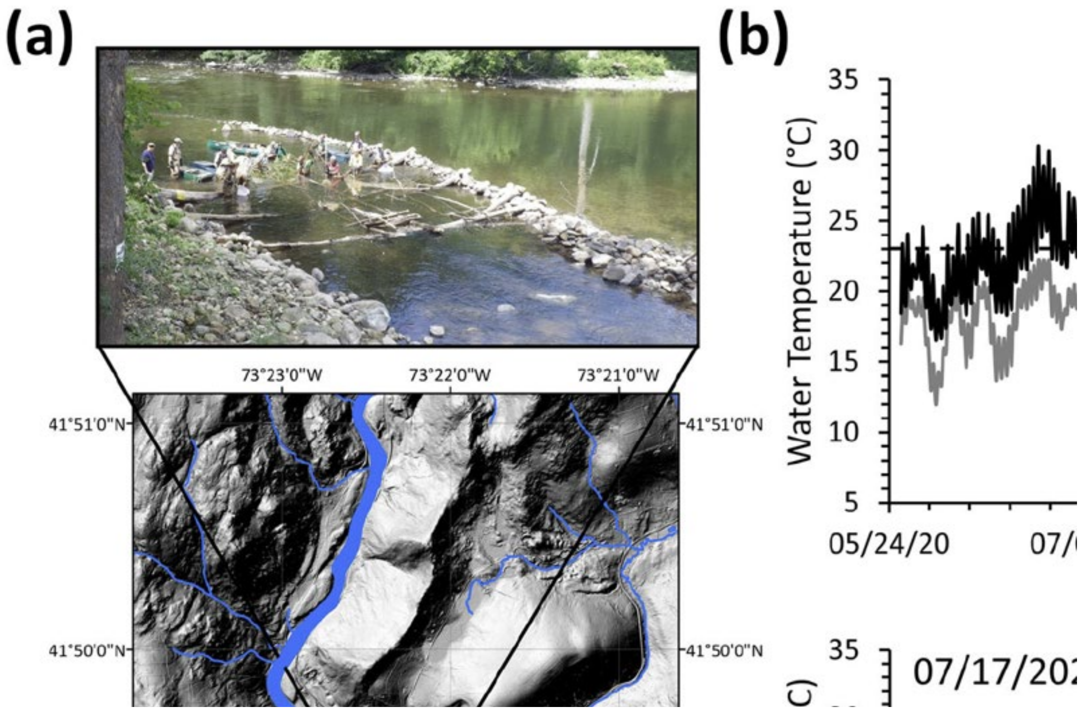

Technical Resources – Project Concepts

From Kurylyk et al. 2015, Ecohydrology

floodplain thermal refugia where flow may have a lesser impact on the structure itself. In this case, the stakes and wires would be protected from minor increases in river stage, and it would be difficult for swimming birds or mammals to dive under the array.

6. Creating new thermal refugia

Many river reaches lack thermal diversity and thus cannot provide suitable thermal refugia for cold-water fish species. One example is the lower reach of the Fraser River (British Columbia), where significant mortalities of sockeye salmon were reported as a result of thermal stress (Martins *et al.*, 2011). In some situations, it may be feasible to create the thermal diversity necessary to produce useful thermal refugia to limit stress-induced mortalities. A critical unknown to be determined prior to utilizing these, possible costly, solutions is the spatial frequency at which thermal refugia are needed for different target species, *e.g.*, a linear distance which various fish species are capable of moving under physiologically stressful conditions to seek cold-water refugia.

6.1 Inducing thermal anomalies via groundwater pumping

Natural groundwater discharge is a source of cool water during the summer period when surface waters are at their annual temperature maxima (Figure 1). Inducing points of focused groundwater discharge may be a viable mechanism by which to create new thermal refugia. This could be achieved by pumping groundwater from upslope locations in adjacent aquifers to a discharge point along the river (Figure 5). Pumping and immediately discharging the cold, intercepted groundwater to the river will not significantly change the total groundwater input to the river. Rather, it will transform groundwater discharge from a diffusive input that slightly cools the ambient river temperature to a focused input that significantly cools a smaller plume and thus creates a cold-water refuge (Figures 5b, 5c). A proposed design for an automated system is presented in Figure 5 in which a solar panel provides energy to power the pump, and the pumping is triggered by a signal from a water temperature sensor programmed to a species-specific temperature threshold, *i.e.*, the refuge is created only when it is most urgently needed. In

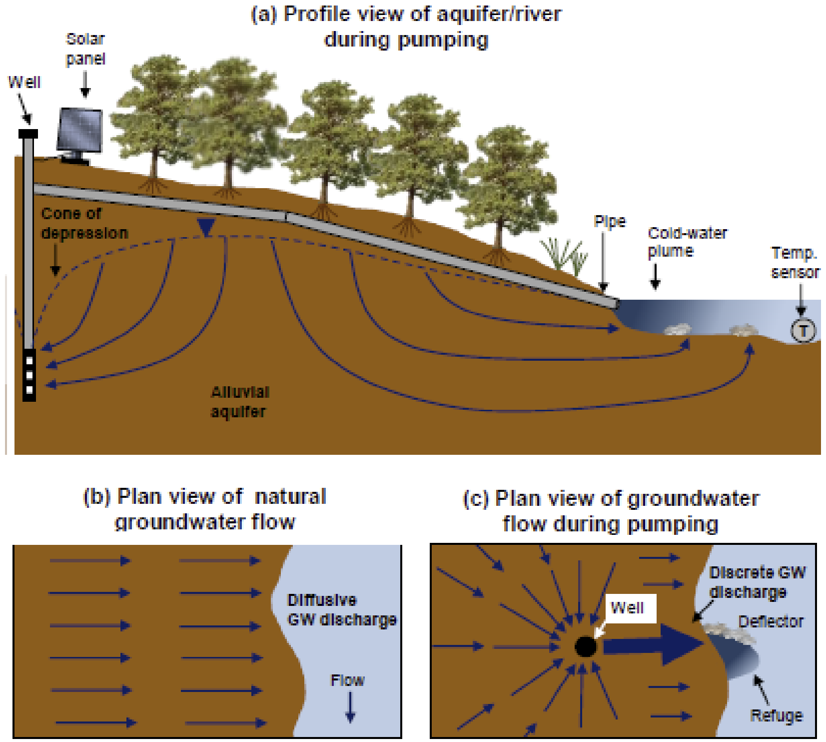

Figure 5. (a) Conceptual model for creating a temporary thermal refuge by pumping water from alluvial aquifers and discharging the groundwater at a discrete point. The groundwater pumping and redirection to the river transforms the groundwater discharge to the river from a (b) diffusive input to a (c) discrete input.

Technical Resources – Project Concepts

From Kurylyk et al. 2015, Ecohydrology

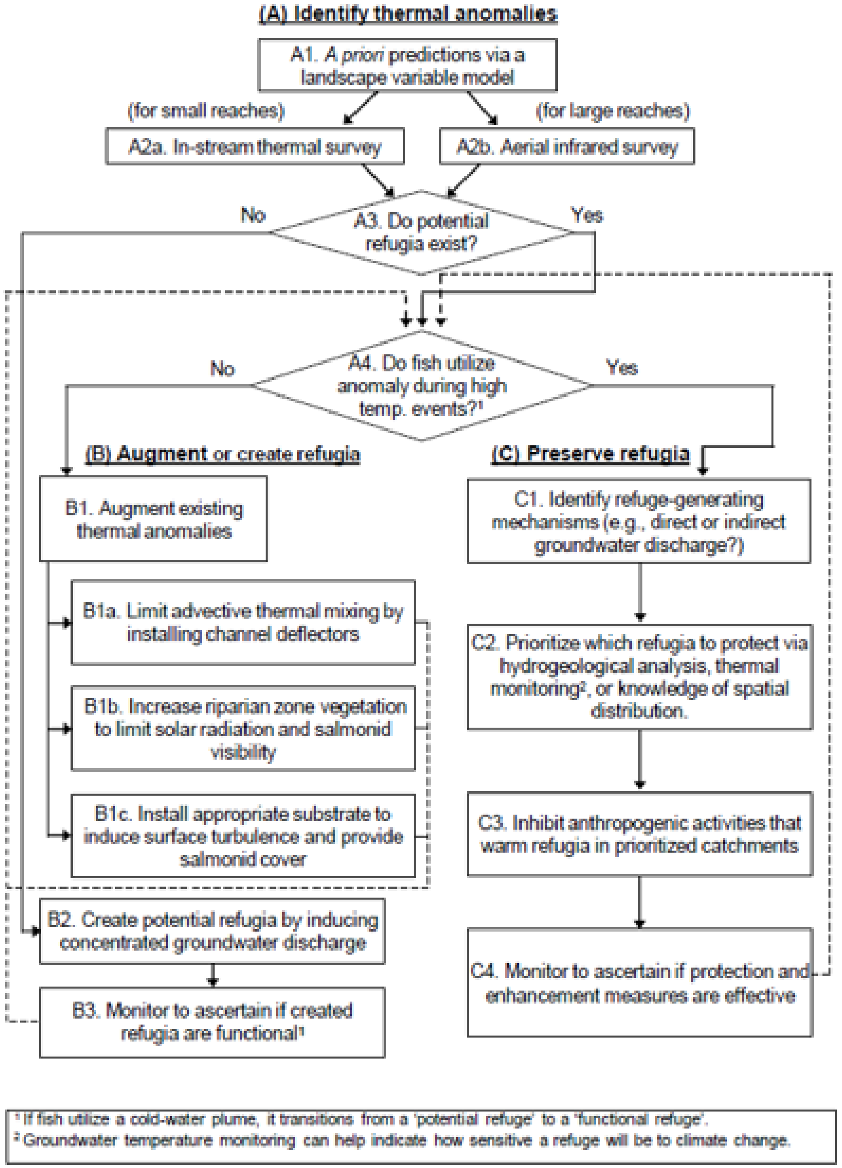

Figure 7. Comprehensive thermal refugia management strategy that includes (a) identifying, (b) augmenting/creating, and (c) preserving (natural and engineered) thermal refugia.

Technical Resources – Project Concepts

Hester et al. 2009, Limnology & Oceanography

Wang et al. 2020, River Res. Applications

Limnol. Oceanogr., 54(1), 2009, 355–367

The influence of in-stream structures on summer water temperatures via induced hyporheic exchange

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Abstract

Temperature is an important controlling factor for ecological functions. In-stream geomorphic structures affect stream thermal regimes by facilitating hyporheic exchange of water and heat between stream channels and underlying sediments. We varied the height of an experimental weir (representing debris dams, log dams, and boulder weirs) in a small stream during the summer and monitored the hydraulic and thermal response of surface

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RESEARCH ARTICLE

WILEY

Tributary confluences are dynamic thermal refuges for a juvenile salmonid in a warming river network

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Abstract

As rivers warm, cold-water fish species may alleviate thermal stress by moving into localized thermal refuges such as cold-water plumes created by cool tributary inflows. We quantified use of two tributary confluence plumes by juvenile steelhead, *Oncorhynchus mykiss*, throughout the summer, including how trout positioned themselves in relation to temperature within confluence plumes. At two confluences, Cedar and Elder creeks, along the South Fork Eel River, California, USA, we moni-

Next Steps

Technical Oversight Group to review site selection and ranking process. LCEP will create online map with supporting data which accepts review comments and questions.

LCEP to add any additional sites, revise scoring process as needed, and re-rank sites.

LCEP to generate alternatives for top three sites.

Technical Oversight Group Meeting # 3 to review project alternatives. Late February 2022

Upcoming Meetings:
- February: Review restoration alternatives for three priority sites.
- March/April: Review concept designs for restoration alternatives.

Questions?

Lower Columbia Estuary Partnership