Date	August 22, 2014
To:	Craig Garric, Kate Akyuz, King County Department of Natural Resources and Parks
From :	Merri Martz, Mark Hopkinson, Cary Novotney, Tetra Tech
Project Name::	Willowmoor Floodplain Restoration Project
Subject:	Draft Addendum to Willowmoor Cold-Water Supplementation Concept Memo (June 2014)

INTRODUCTION

This memorandum is provided as an addendum to the Willowmoor Cold-Water Supplementation Concepts Memo finalized in June 2014 (King County 2014). Two additional cold-water supplementation concepts are evaluated herein:

7. Riffle-pool complex and hyporheic zone through Transition Zone; and
8. Hypolimnetic cooling of Lake Sammamish surface water (10 and 20 cfs).

The estimated conceptual level implementation and life-cycle costs of anticipated operation and maintenance (net present value over 50 years) of these two options added to the table in the original memo are summarized below in Table 1.

Table 1. Estimated conceptual level implementation and life cycle costs for six concept alternatives.

Concept Alternative	Implementation Cost ($)	Life-Cycle Cost (50 years; $)	Cfs Supplied[1]	$/cfs[2]
Concept 1-Hypolimnetic Withdrawal from Lake Sammamish	$6,959,000	$197,000	10, 20	$358,000[3]
Concept 2-Pumped Groundwater	$2,160,000	$145,000	3[4]	$768,000
Concept 3-Shallow Groundwater Trench	$752,000	$23,000	1	$775,000
Concept 4-Purchase Potable Water	$850,000	$4,457,000	1	$5,307,000
Concept 5-Pump Lake Water to Heat Exchange System	$2,603,000	$142,000	5, 10, 20	$549,000
Concept 6-Pump Lake Water to Hyporheic Discharge	$1,950,000	$62,000	5, 10, 20	$402,000
Concept 7-Riffle-Pool and Hyporheic Transition Zone	$4,338,000	$117,000	1	$4,455,000
Concept 8-Hypolimnetic Cooling of Lake Surface Water	$7,438,000	$197,000	10, 20	$382,000[3]

[1] – Concepts 5 and 6 only evaluated for 5 cfs in this memo. The potential for 10 or 20 cfs will be explored further in design.

[2] – Cost per cfs based on sum of implementation cost plus life-cycle cost.

[3] – Cost for 20 cfs

[4] – Estimate revised to three cfs based on input from City of Redmond that their water supply wells yield 3 cfs

DRAFT

TABLE 2. Alternative Matrix

TETRA TECH

	Hypolimnetic Withdrawal	Pump Deeper Groundwater	Shallow Groundwater Trench Consolidat	Purchase Potable Water	Heat Pump Exchange	Hyporheic Flow	Transition Zone Hyporheic	Hypolimnetic Cooling
Key Features	Withdraw water from 35 to 49 foot depth in Lake Sammamish	One or two 40-60 foot deep wells near transition zone	Pipe trench to intercept shallow groundwater	Connect to existing City water line at W Lake Sammamish Pkwy	Pump near rowing club to buried heat exchange mechanical system	Pump near rowing club to discharge to gravel trenches near Transition Zone	Replace existing Transition Zone channel with coarse gravel backfill for hyporheic exchange	Pump Lake Sammamish surface water through heat exchange piping on bottom of lake
	~16,000 LF submerged pipeline -- discharge at weir	~1,300 LF of pipeline -- discharge to Transition Zone or new channel	~3,000 LF of pipeline -- discharge to Transition Zone or new channel	~3,000 LF of pipeline -- discharge to Transition Zone or new channel	~1,100 LF of pipeline & ~1,500 LF heat exchanger-- discharge to Transition Zone or new channel	~2,800 LF of pipeline -- discharge to Transition Zone or new channel(s)	7 acres of excavation and backfill with new channel reconstruction	~16,000 LF of pipeline -- discharge at weir
Planning Level Construction Costs	$7.0 million total cost	$2.2 million total cost	$800k total cost	$900k total cost	$2.6 million total cost	$2.0 million total cost	$4.3 million total cost	$7.4 million total cost
Net Present Value, Operation and Maintenance Over 50 Years	$197k NPV for O&M (over 50 years)	$145k NPV for O&M (over 50 years)	$23k NPV for O&M (over 50 years)	$4.5 million NPV for O&M (over 50 years)	$142k NPV for O&M (over 50 years)	$62k NPV for O&M (over 50 years)	$117k NPV for O&M (over 50 years)	$197k NPV for O&M (over 50 years)
Water Quality of Source	Temperature average = 13C	Temperature average = 10C	Temperature average = 10C	Temperature average = 10C	Temperature average = 18C (after cooling)	Temperature average = 18C (after cooling)	Temperature average = existing river temps	Temperature typical = 13C (after cooling)
	DO average = 5 mg/l	DO average = <1 mg/l; requires aeration	DO average = <1 mg/l; requires aeration	DO average = <1 mg/l; requires aeration	DO average = 8 to 9 mg/l	DO average = <1 mg/l; requires aeration	DO average = <1 mg/l when upwelling	DO average = 8 to 9 mg/l
	Phosphorus = <0.01 mg/l; however may want to consider treatment for phosphorus	Phosphorus = no data	Phosphorus = no data	Phosphorus = no data	Phosphorus = <0.01 mg/l	Phosphorus = <0.01 mg/l	Phosphorus = <0.01 mg/l	Phosphorus = <0.01 mg/l
	Need to identify aeration options prior to discharge below weir in river.	Need to identify aeration options prior to discharge to pools	Need to identify aeration options prior to discharge to pools	Need to identify aeration and chlorine removal options prior to discharge to pools	Need to identify if further cooling is feasible, such as to 10C	Need to identify aeration options prior to discharge to pools and if further cooling is feasible		
Water Quantity	20 cfs (10 cfs also evaluated)	1-2 cfs based on estimated yield from City of Redmond wells	Less than 1 cfs; no data available	1 cfs assumed since City water supply would be limited	5 cfs (may be possible to scale up to 10, or 20 cfs)	5 cfs (may be possible to scale up to 10, or 20 cfs)	<1 cfs likely to exchange in hyporheic zone	10 or 20 cfs is feasible; 10 cfs is cooled more easily
	Costs assume 60 days of pumping (July 15-Sept 15)	Costs assume 60 days of pumping (July 15-Sept 15)	Need further information on water availability during summer	Costs assume 60 days of purchase (July 15-Sept 15)	Costs assume 60 days of pumping (July 15-Sept 15)	Costs assume 60 days of pumping (July 15-Sept 15)	No costs for water source	Costs assume 60 days of pumping (July 15-Sept15)
Temperature Cooling Effect and Distance Downstream	Cooling to 17.5C for 5,000 to 25,000 square feet when lake temperature is 24 or 20C (for 20 cfs)	Cooling by 0.5C or less within pool	Cooling by 0.5C or less within pool	Cooling by 0.5C or less within pool	Create thermal refuge(s) in Transition Zone at less than 21C lethal limit	Create thermal refuge(s) in Transition Zone at less than 21C lethal limit	Cooling by 0.5C or less within pools	Cooling to 21C when river temperature is 24C; cooling to 18C when river temperature is 21C
	Cooling of river to 17.5C for ~800 feet downstream of weir or 2000 feet remaining less than 21C (for 20 cfs)	Provides small area of refuge	Provides small area of refuge	Provides small area of refuge			Provides small area of refuge	
Change in Index of Thermal Stress	20 cfs reduces thermal stress by 88% and 100% for 16 and 21C thresholds; 10 cfs by 61% and 95%, respectively	Negligible	Negligible	Negligible	Reduces thermal stress by 12% and 85% for 16 and 21C thresholds, upper river only	Reduces thermal stress by 12% and 85% for 16 and 21C thresholds, upper river only	Negligible	tbd
Habitat and Water Quantity Effects of Construction Activities	Wetlands = less than 1/2 acre impact	Wetlands = 1 acre impact	Wetlands = 1 acre impact	Wetlands = 1 acre impact	Wetlands = 1 acre impact for trench-scale, could be 5-10 acres for larger area of exchange	Wetlands = 1 acre impact for short trench, could be 5-10 acres or more for larger channel system	Requires complete excavation of existing transition zone; wetlands = 5 acres impact and river channel	Wetlands = <1/2 acre impacts
	Tree Removal = ~16-20 (pump and discharge locations)	Tree Removal = ~6-8 (pipe trenching)	Tree Removal = ~25 (install pipe trench)	Tree Removal = ~6-8 (pipe trenching)	Tree Removal = ~6-8 (pipe trenching)	Tree Removal = ~6-8 (trenching)	Removal of existing willow buffer	Tree Removal = ~16-20 (pump and discharge locations)
	Fish screen required for intake	N/A	N/A	N/A	Fish screen required for intake	Fish screen required for intake		Fish screen required for intake
	No effects to groundwater table (replaces existing volume of surface outflow from lake)	Need to evaluate effects to groundwater table	Need to evaluate effects to wetlands from draining (up to 9 acres)	Need to evaluate effects on City water supply	Likely no effect to groundwater table	Need to evaluate potential effects (raising and/or lowering) on groundwater table and residence time	Need to evaluate potential loss of surface water to groundwater table and residence time	Avoids issues of potential effects on hypolimnion temperature and other constituents
Constructability	Easy to moderate -- sink pipeline to bed of lake/river	Easy to moderate -- trenching in wetland soils	Moderate -- large trench in wetland soils	Easy to moderate -- trenching in wetland soils	Moderate to difficult -- Much larger scale than normal heat pump systems; unproven to work at this scale	Moderate -- trenching in wetland soils	Moderate -- excvation in river channel, requires dewatering and removal of wet soils	Easy to moderate -- sink pipeline to bed of lake/river
Operation and Maintenance	Moderate -- annual pump maintenance and 60 days of electricity	Limited -- infrequent well pump maintenance and 60 days of electricity	Essentially none	Extensive -- high potable water purchase costs	Moderate to extensive -- Piping may need periodic clean-out; annual pump maintenance and electricity	Moderate -- annual pump maintenance and electricity; infrequent clean-out of gravel trenches	Low -- likely reduced annual maintenance to maintain channel capacity	Moderate -- annual pump maintenance and 60 days of electricity
Additional-Qualitative Disadvantages	Need for navigation buoys and signage	Water rights need review/approval	Likely not a reliable water source	Water rights or other City approval	Unproven as to feasibility on this large of a scale	Potentially too short residence time to cool water	Likely low volume of hyporheic flow does not appreciably cool the river	Need for navigation buoys and signage
Additional-Qualitative Advantages	Highest volume for maximum temperature reduction		Only "natural"-type solution, no mechanical/electrical required		Could potentially cool as low as 10C (similar to natural groundwater)	Gravel trenches will also passively convey cooler ambient groundwater to resting pools	Suitable for combination with any other restoration alternatives	Highest volume for maximum temperature reduction
	High reliability for source water	High reliability for source water		If confirmed with City, reliable water source	High reliability for source water	High reliability for source water	Limited engineering and limited O&M requirements	High reliability for source water
Bottom Line	Highly effective, high cost	Limited effectiveness, moderate cost	Limited effectiveness, low cost	Limited effectiveness, high cost	Moderate effectiveness, moderate cost	Moderate effectiveness, moderate cost	Limited effectiveness, moderate cost	Highly effective, high cost

DRAFT

Additional Conceptual Alternatives

Riffle-Pool Complex with Hyporheic Zone in Transition Zone

This concept would reconfigure the entire Transition Zone to create a meandering pool-riffle complex channel and a hyporheic zone. It may be possible to include riparian vegetation that does not reduce flood conveyance as well. The entire Transition Zone would be excavated and replaced with a coarse substrate to allow water to exchange freely between the channel and groundwater table to promote hyporheic flow and cooling. Based on literature values of hyporheic flow in natural rivers, the volume of hyporheic flow in the Transition Zone would likely be limited to less than 1% of the river flow, so less than 1 cfs would likely be cooled. However, the cooler water could upwell into the pools, providing localized cooler refugia for fish in the zone of critically high temperatures prior to passing over the weir.

The primary features of this concept alternative include:

- Excavate 6.5 acre area of the Transition Zone and install coarse sand/gravel infiltration backfill to a depth of 6 feet (averages 3 feet over length of Transition Zone).
- Create new meandering channel with constructed riffles and pools – lengthens channel from 1,432 feet to approximately 1,700 feet.
- Construct impermeable dikes at pools to force groundwater into pools for cool-water refuge

The potential temperature benefits of this alternative are likely to be minimal as only 1 cfs or less of water would likely be cooled. However, this concept could be incorporated easily into any reconfigured Transition Zone channel alternatives, and may also help to capture existing groundwater flow into the pools. Literature on hyporheic flows through gravel bars in natural rivers shows possible cooling of 2-3°C (3-5°F) just through a single localized bar feature (Burkholder 2007). Measurements of actual temperatures at the confluence of small tributaries to the Sammamish River in 2010 (R2 2010) with flows less than 1 cfs (tributary temperature approximately 17°C) indicated less than 0.5° C drop in temperature in the immediate vicinity of the tributary confluence. While a constructed pool could help to reduce the rate of mixing with river water, the potential cooling effect is still likely to be less than 1° C. While the temperature benefit is likely to be minimal, it could provide a small cooler water refuge for migrating fish.

All proposed features for this alternative would be located within King County-owned property (within the Transition Zone) and thus could easily be constructed and maintained. This concept could be implemented in conjunction with other restoration measures. A significant amount of excavation and backfill would be required (>30,000 CY), but would occur in the degraded and highly disturbed Transition Zone.

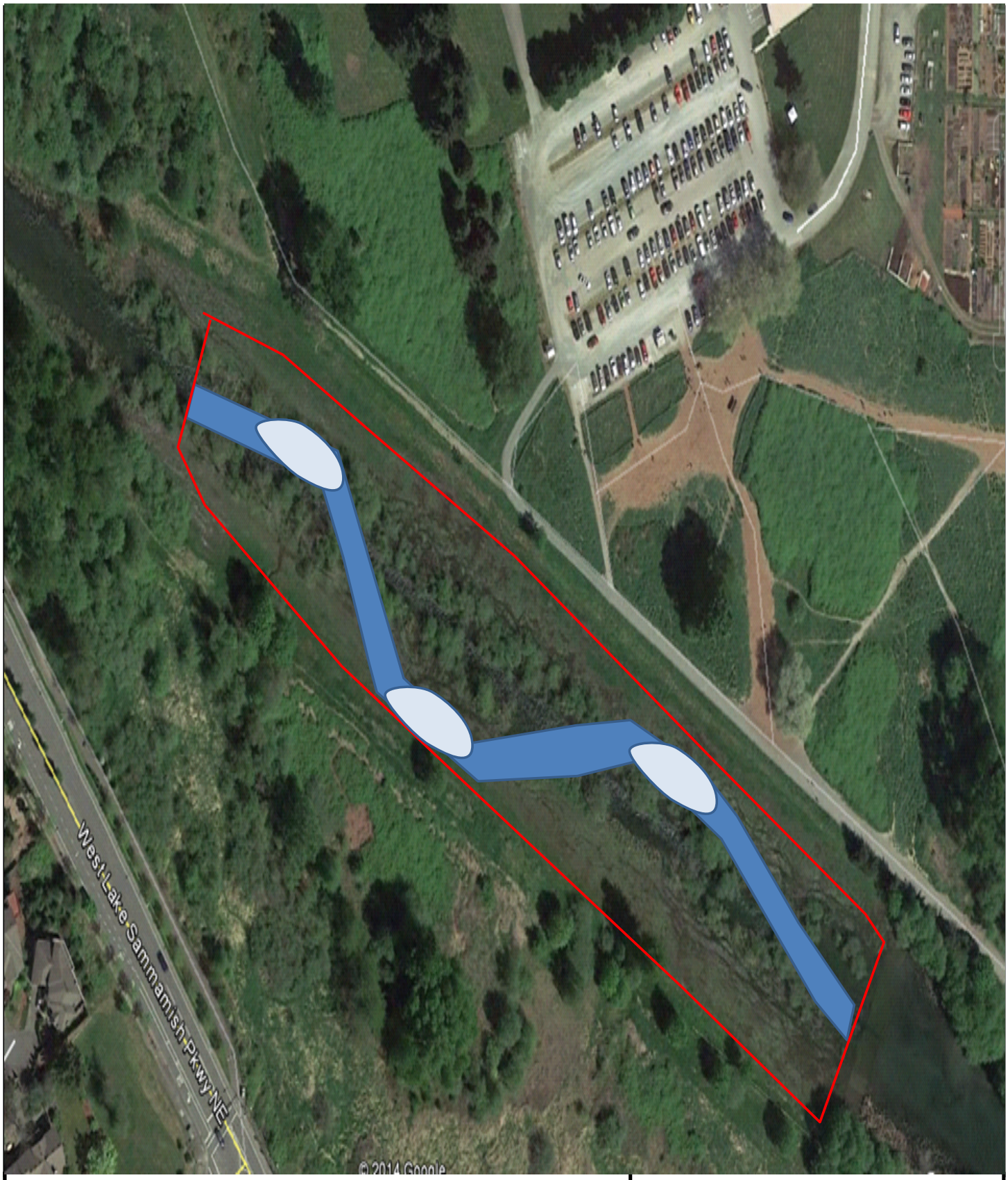
Potential risks or challenges of this concept include the possibility that more than a minor amount of the surface flow would infiltrate into the coarse substrate and return only over longer time periods into the river (days or weeks). Another concern is that the coarse material would become plugged up with fine material over time and thus have reduced flow volumes. However, the hyporheic zone would also likely

DRAFT

be recharged during winter flows and the groundwater table could become higher over time, providing good exchange. A feasibility analysis of residence time and infiltration rates is recommended.

The planning level cost estimate for this concept is approximately $4.3 million. Operation and maintenance needs would include vegetation maintenance at a likely reduced rate that is required for the existing channel. The estimated net present value of operation and maintenance activities is $117,000 over 50 years.

DRAFT

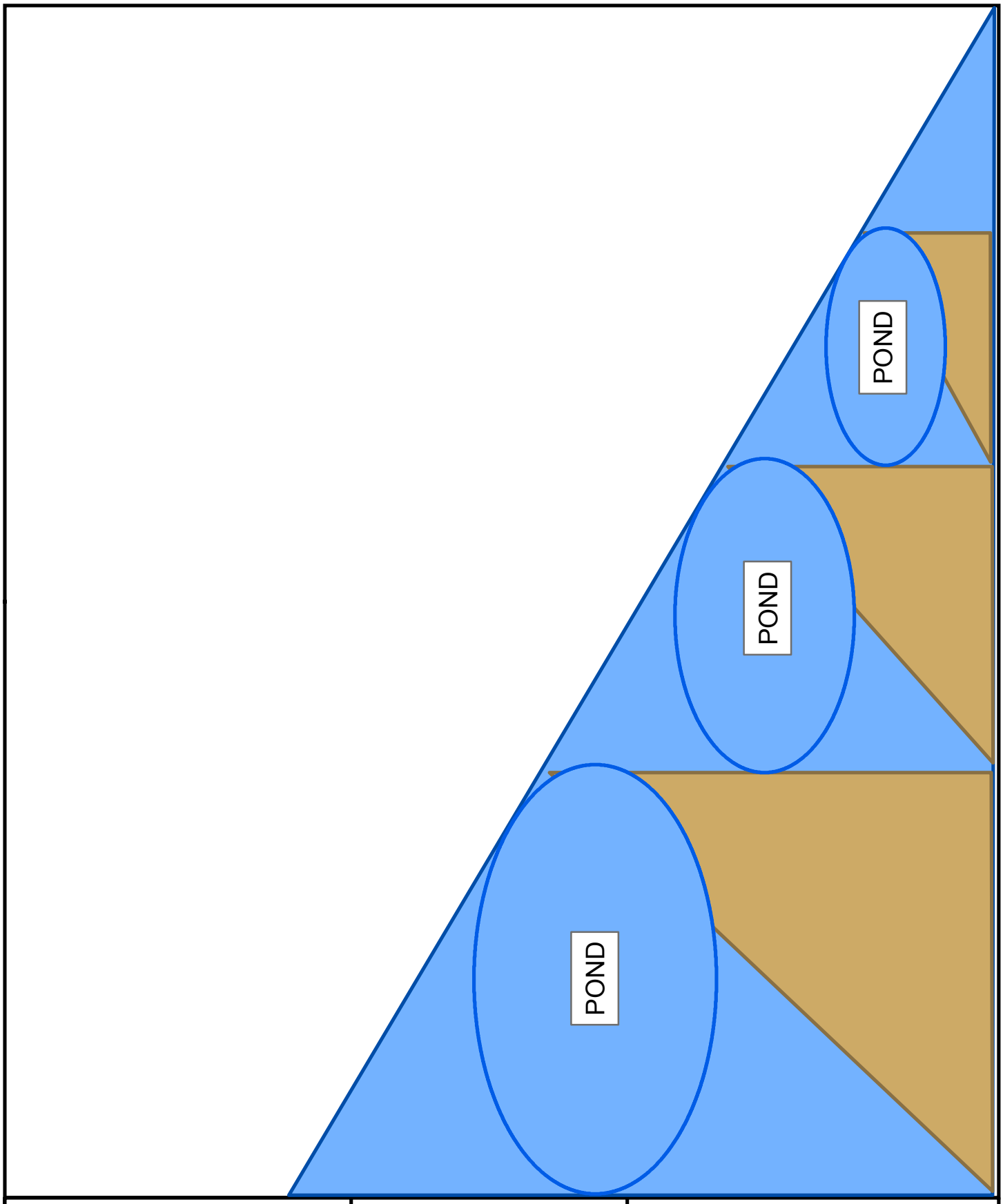


Excavate transition zone in a wedge from 6.75 feet near weir transitioning down to zero feet at downstream end and backfill with well-graded gravel/sand mixture to create hyporheic exchange throughout zone. Create new meandering channel on surface with clay dams arising at pool locations to force cold water to pools.

King County

N

WILLOWMOOR PARK
CONCEPT 7
RIFFLE-POOL WITH HYPORHEIC ZONE TRANSITION ZONE



King County

WILLOWMOOR PARK
CONCEPT 7
RIFFLE-POOL WITH HYPORHEIC
ZONE TRANSITION ZONE

T31746 King County - Willowmoor
Task 6 Cold Water Supplementation
Concept Alternative Cost Estimate Details
Concept 7 - Riffle-Pool Complex with Hyporheic Zone Transition Zone
Date : 22-Aug-14

TETRA TECH

Item	Description	Quantity	Unit	Unit cost, $		Cost, $
1	**Mobilization/Demobilization/Testing**					
	Assume 8% of subtotal for items 2-5	1	ls	$155,200	**$**	**155,200**
2	**Sitework**					
	Transition Zone Riffle-Pool Construction					
	Archaeological monitoring (SHPO standards) allowance	1	ls	$20,000	$	20,000
	Erosion control & turbidity curtains	1	ls	$10,000	$	10,000
	Clear & grub	6.5	ac	$6,800	$	44,200
	Salvage Topsoil in existing Transition Zone	6,000	cy	$12	$	72,000
	Wet excavation in existing Transition Zone	31,900	cy	$25	$	797,500
	Haul waste to disposal	1,900	ton	$10	$	19,000
	Impermeable fill zone downstream of pools	1,000	cy	$20	$	20,000
	Light rip rap protection of impervious zone	1,000	tn	$40	$	40,000
	Course gravel fill in reconstructed Transition Zone	57,300	tn	$16	$	916,800
	Transition Zone Resting Pools - sitework by others during channel reconfiguration project				$	-
	Subtotal, Sitework				**$**	**1,939,500**
3	**Piping**					
	not applicable				$	-
	Subtotal, Piping				**$**	**-**
4	**Structural and Architectural**					
	not applicable				$	-
	Subtotal, Structural and Architectural				**$**	**-**
5	**Mechanical**					
	not applicable				$	-
	Subtotal, Structural and Architectural				**$**	**-**

DRAFT

6	**Electrical**					
	not applicable				$	-
	Subtotal, Structural and Architectural				**$**	**-**
7	**Intrumentation and Control**					
	not applicable				$	-
	Subtotal, Structural and Architectural				**$**	**-**
8	**Site Restoration**					
	Transition Zone Riffle-Pool Construction					
	Fine grading and slope dressing	1	ls	$25,000	$	25,000
	Transition Zone Resting Pools - restoration by others during channel reconfiguration project				$	-
	Subtotal, Structural and Architectural				**$**	**25,000**

Total Estimated Direct Costs (Rounded)		$	2,120,000
General Contractor Overhead and Profit	15.0%	$	318,000
Subtotal		**$**	**2,438,000**
Contingency	30.0%	$	731,000
Sales Tax (City of Redmond)	9.5%	$	301,000
Subtotal			**$3,470,000**
Engineering (Design and Construction)	15.0%	$	521,000
Administration	10.0%	$	347,000
Alternative 7 - Total Estimated Project Costs			**$4,338,000**

DRAFT

Hypolimnetic Cooling of Lake Sammamish Surface Water

This concept is generally the opposite idea to the hypolimnetic withdrawal system concept (Concept #1). This concept would withdraw 10 or 20 cfs of surface water from Lake Sammamish and pump it through a pipe system at the bottom of the lake to cool the water via heat exchange. The water would then be piped to discharge immediately downstream of the Sammamish Weir. The water temperature at 20 meters (66 feet) in the lake averages less than 10°C (50°F) during the July to September time period (Figure 1). This concept avoids potential water quality and fish concerns regarding withdrawing water from the hypolimnion by using surface water that is the current natural source of discharge over the weir and uses the heat exchange possibilities of the cold water at the bottom of the lake. The cooled water discharge would replace 10 or 20 cfs of passive outflow from the Lake during a 60-day critical time period (generally July 15 to September 15).

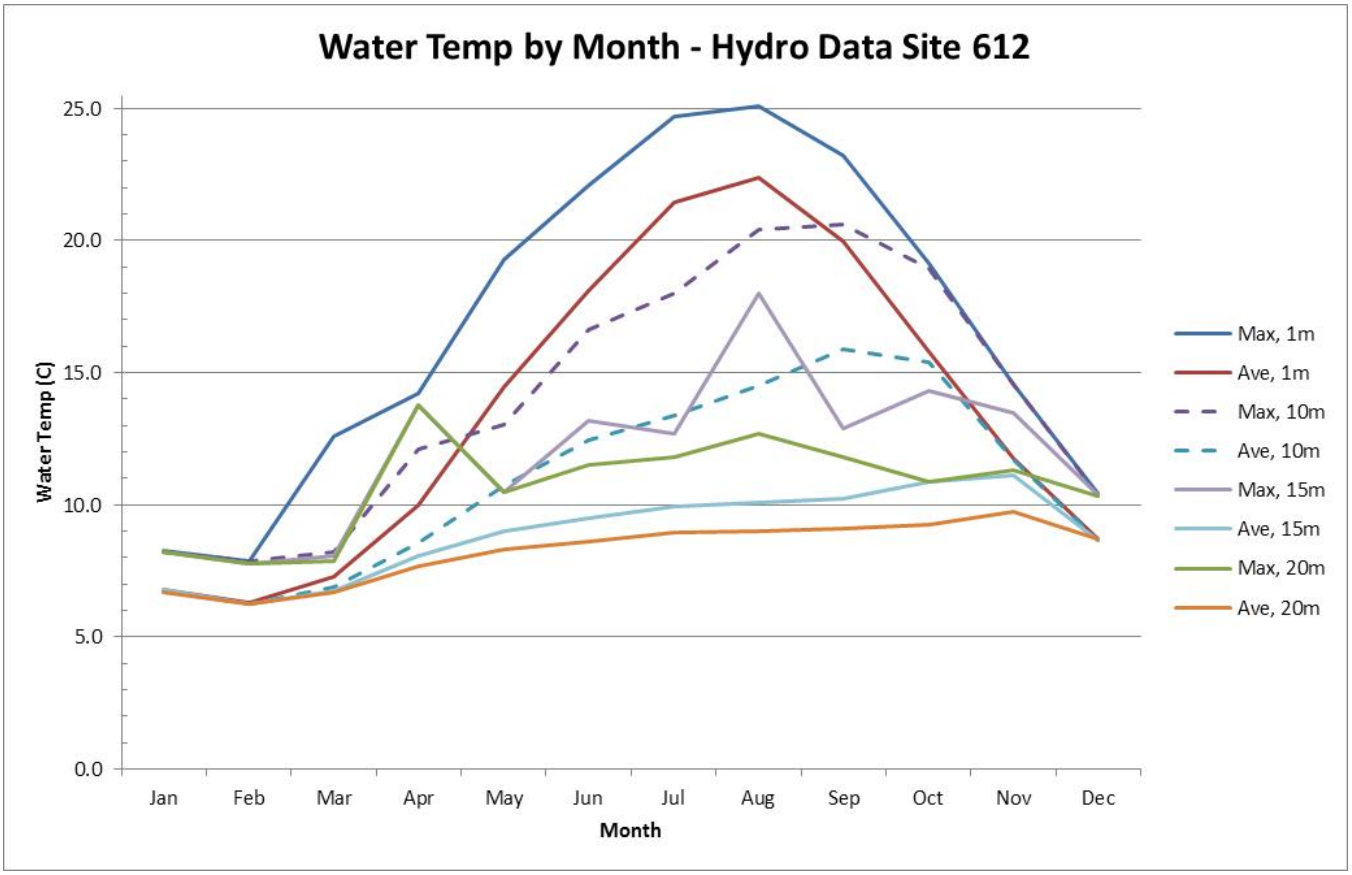


Figure 1. Monthly maximum and mean water temperatures at Lake Sammamish Hydro Data Site 612 at 1, 10, 15, and 20 meter depths

In order to conduct the heat exchange where the lake is sufficiently deep (20 meters or greater depth), the surface withdrawal would be located in a similar location as proposed for the hypolimnetic withdrawal (Concept #1), see Figure 2.

Primary features of this alternative include:

- Floating surface intake and 16,000 linear feet (LF) 36-inch HDPE pipeline on Lake Sammamish bottom.
- Heat exchange manifold and six 18-inch or 24-inch cast aluminum pipes for 1,000 or 2,000 LF on Lake Sammamish bottom.
- Submerged 2,000 LF 36-inch pipeline on Sammamish River bottom from lake outlet to pump station.
- Upland pump station proposed near Sammamish Rowing Association river access for existing power and access purposes.
- Submerged 2,000 LF 24-inch pipeline on Sammamish River bottom from pump station to discharge at existing weir.
- Discharge to mix with weir outflow and cool overall river temperatures. The 20 cfs would be approximately half the discharge, since current mean monthly weir discharge during July, August and September is typically 50 cfs.

The calculation of the potential cooling provided by a heat exchanger is based on fundamental heat transfer equations (ASHRAE 2009) for three types of heat exchange that will occur in the pipe: 1) forced-convection through the pipe; 2) thermal conduction at the pipe wall per unit length; and 3) natural-convection as the heat is dissipated away from the pipe where the lake serves as a heat sink. The forced convection component is a function of the Nusselt number derived from correlations based on empirical data that are a function of the thermal conductivity of water and the diameter of the pipe for fully developed turbulent flow. The thermal conduction through the pipe wall is a function of the thermal conductivity of the pipe material (aluminum) and the pipe wall thickness. Aluminum is a good conductor of heat, whereas HDPE is a very low conductor. Natural convection of heat from the pipe to the lake, acting as a heat sink, is similarly derived from the Nusselt number.

Assuming a lake surface temperature of 24°C (75°F) flowing through the heat exchanger piping array on the bottom of the lake, the output cooled water can be as low as 13°C (55°F) and has the potential to cool the river temperature by as much as 3°C (5°F) downstream of the weir. The 10 cfs volume is more efficiently cooled to 13°C (55°F), whereas the 20 cfs volume can only reasonably be cooled to 18°C (65°F).

Head losses on the suction side of the pump determine the maximum reasonable length of the heat exchanger piping array. For a flow rate of 20 cfs, the total length of the heat exchanger is limited to approximately 1,000 feet. A flow rate of 10 cfs allows a total length of 3,000 feet. However, only 2,000 feet is required to provide more substantial cooling. The pump energy requirements are also lower for the 10 cfs option.

Similar to the hypolimnetic withdrawal concept (Concept #1), this alternative requires very little construction work on land or in wetlands; the pipelines and concrete anchors would be assembled on land, floated into the lake as it is assembled, positioned via barge or work boats, and then sunk to the bottom. The only land elements are the pump station and the discharge. Consideration should be given

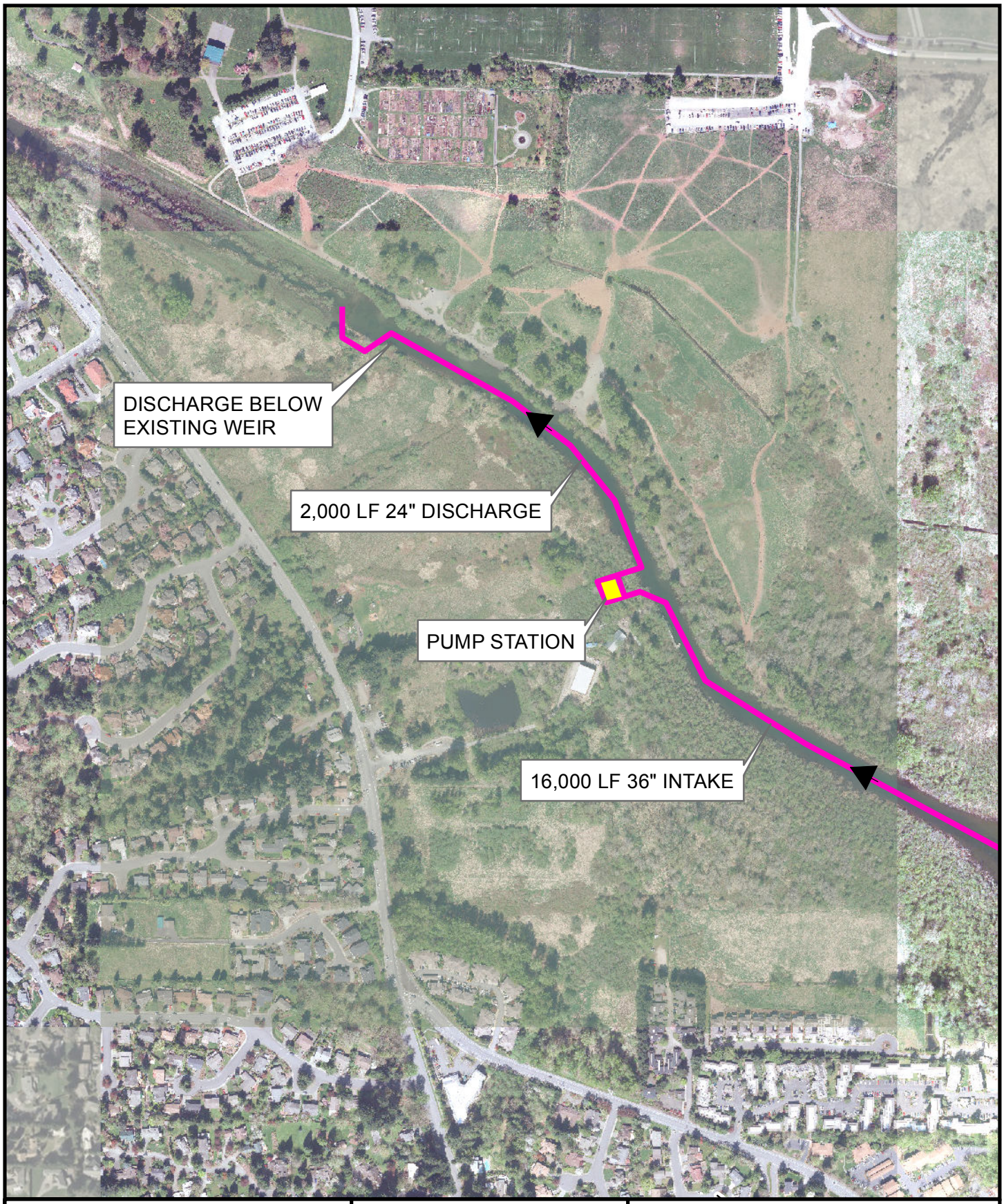
DRAFT

to a variable speed pump system, as compared to delivering a 20 cfs or 10 cfs discharge presented here. Variable speed systems have advantages, but are typically more expensive and pump selection can be more difficult, given head losses for the different flow rates using the larger pipe diameters sized for the higher flows.

Potential concerns or risks of this alternative include the potential effects to navigation from having a 36 or 30-inch diameter pipeline running along the bed of the lake outlet channel upstream of the weir. The bathymetry of the existing Sammamish River is assumed to be in the range of 6-10 feet, so a submerged pipe is considered feasible and also reduces wetland disturbance of an upland trench alignment. Another constraint to this alternative is the fish screen at the intake that would need detailed sizing / design, along with a cleaning mechanism. Maintenance at the intake would be easier for a surface intake than for a submerged intake.

The planning level cost estimate for the 20 cfs alternative is $7.4 million, for the 10 cfs alternative would be approximately $6.5 million. Operation and maintenance (life-cycle) requirements would include electricity for pumping and annual start-up/maintenance/shut-down labor and equipment costs for the pump. An estimated net present value of operation and maintenance is $197,000 over fifty years. The following table provides the planning level cost estimate for this alternative.

DRAFT



Proposed System

King County

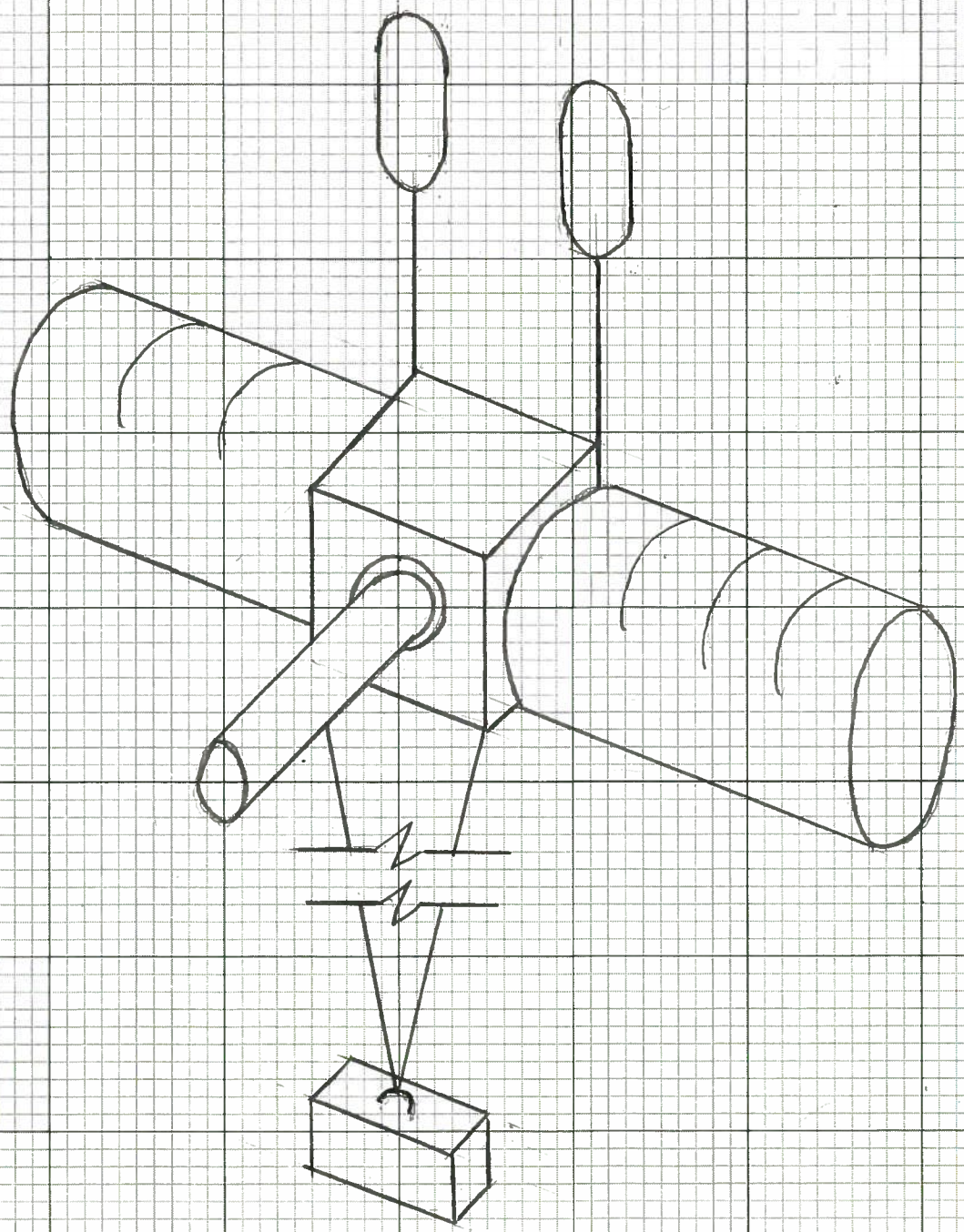
N

0 500 Feet

WILLOWMOOR PARK
CONCEPT 8
HYPOLIMNETIC COOLING
OF LAKE SURFACE WATER

CLIENT: KING COUNTY WLRD	PROJECT: WILLOWMOOR

SUBJECT: CONCEPT 8 – CYLINDER STYLE FISH SCREEN



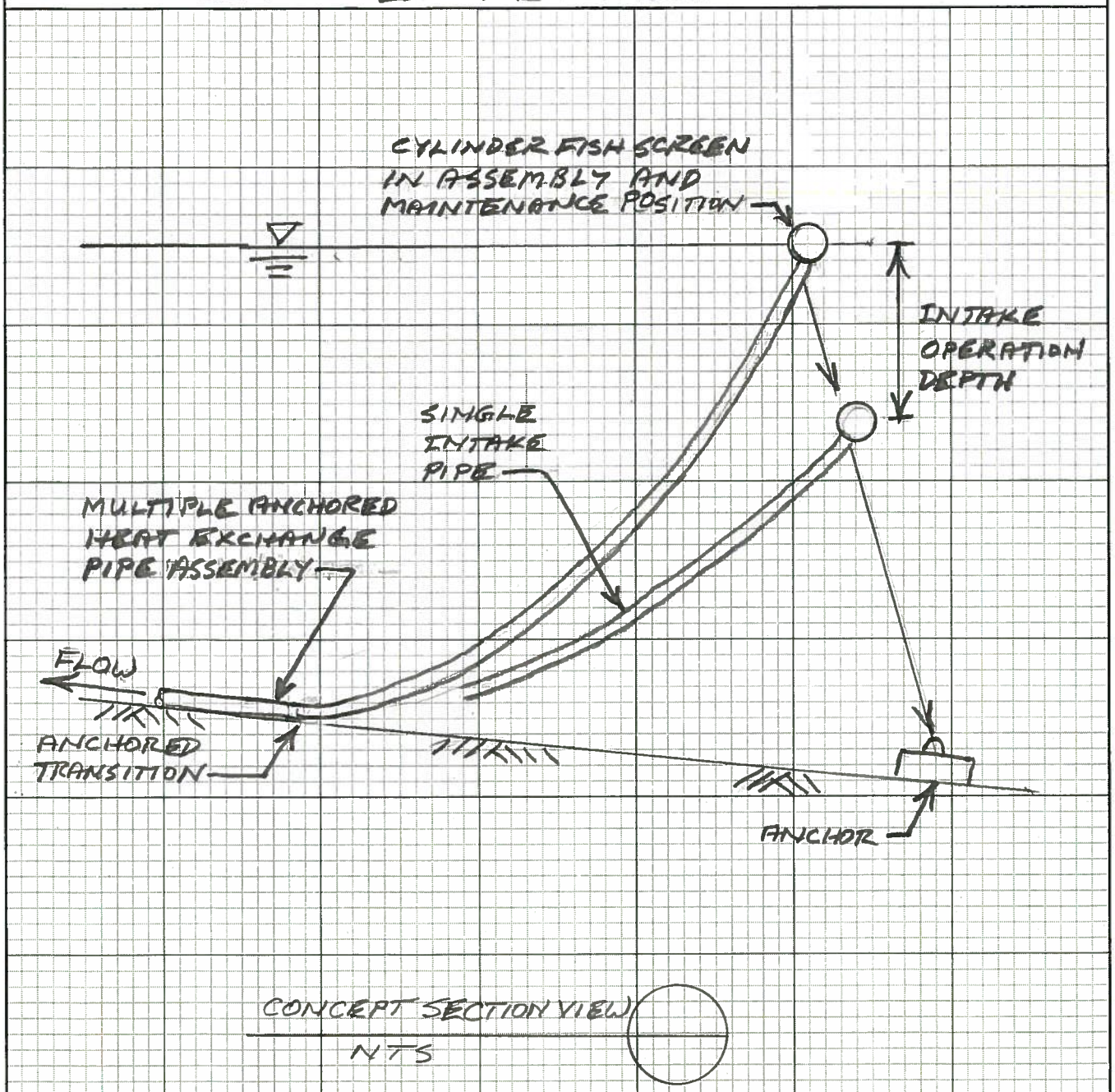
CONCEPT FISH SCREEN

NTS

TETRA TECH		HOPKINSON	8/22/14	
	JOB NO.	BY	DATE	SHEET NO.

CLIENT: KING COUNTY WLRD | PROJECT: WILLOWMOOR

SUBJECT: CONCEPT 8 - INTAKE SYSTEM



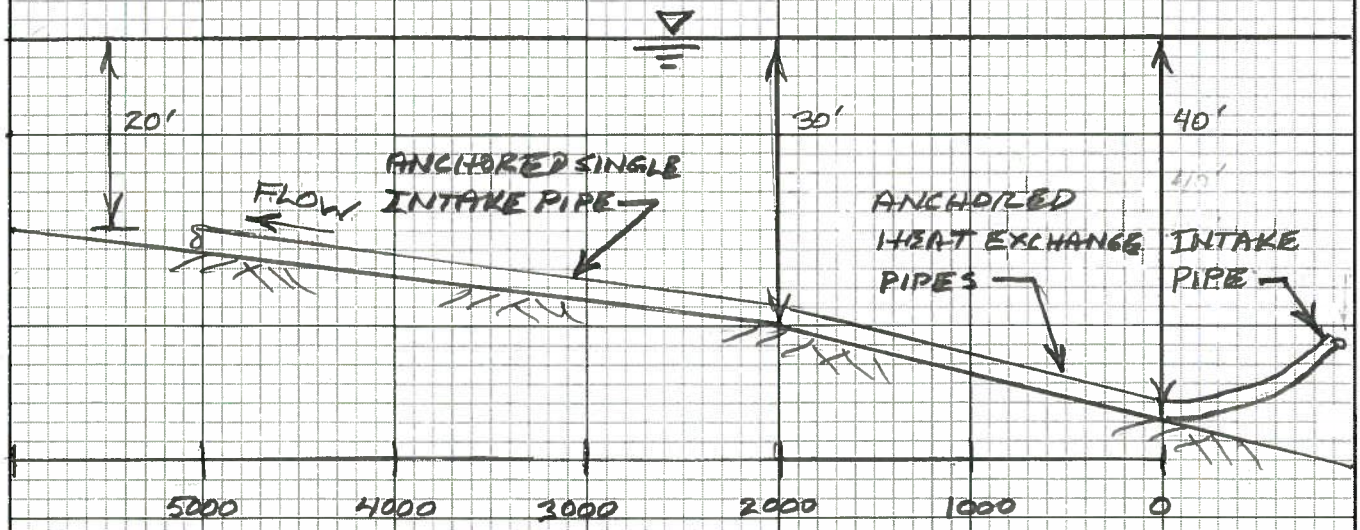
CONCEPT SECTION VIEW

NTS

TETRA TECH		HOPKINSON	8/1/14	
	JOB NO.	BY	DATE	SHEET NO.

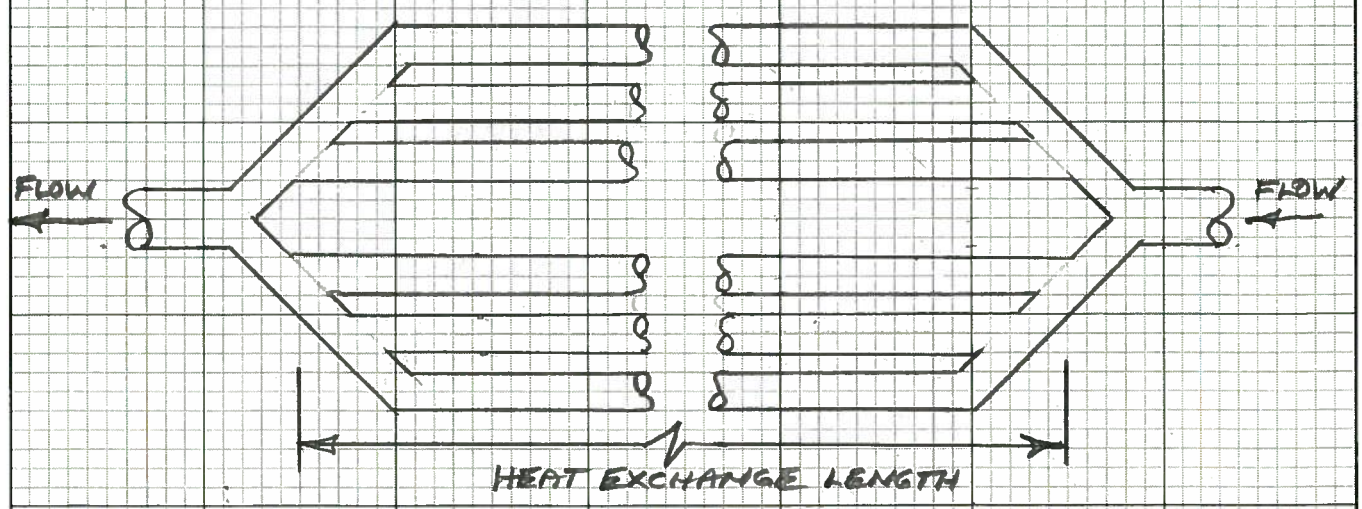
CLIENT: KING COUNTY WLRD	PROJECT: WILLOWMOOR

SUBJECT: CONCEPT 8 – LAKE BOTTOM HEAT EXCHANGE PIPE



LAKE BOTTOM PIPE PROFILE

SCALE: AS SHOWN



LAKE BOTTOM HEAT EXCHANGE PIPES

NTS

TETRA TECH		HOPKINSON	8/5/14	
	JOB NO.	BY	DATE	SHEET NO.

T31746 King County - Willowmoor
Task 6 Cold Water Supplementation
Concept Alternative Cost Estimate Details

Concept 8 - Hypoliminetic Cooling of Lake Sammamish Surface Water (20 cfs)

Date : **22-Aug-14**

Item	Description	Quantity	Unit	Unit cost, $		Cost, $
1	**Mobilization/Demobilization/Testing**					
	Assume 8% of subtotal for items 2-5	1	ls	$259,600	**$**	**259,600**
2	**Sitework**					
	Pump Site					
	Archaeological monitoring (SHPO standards) allowance	1	ls	$10,000	$	10,000
	Erosion control	1	ls	$5,000	$	5,000
	Clear & grub	1	ls	$5,000	$	5,000
	Excavation - Pipelines	640	cy	$15	$	9,600
	Excavation - Pump station	40	cy	$20	$	800
	Turbidity Curtain	200	lf	$15	$	3,000
	Haul waste to disposal	1,300	ton	$10	$	13,000
	Imported fill - Pipeline & Pump Station	1,300	ton	$15	$	19,500
	Trench shoring	1	ls	$5,000	$	5,000
	Dewatering for pipeline and pump station	5	days	$200	$	1,000
	Crushed Surfacing Base Course	100	cy	$30	$	3,000
	Discharge Site At Weir					
	Archaeological monitoring (SHPO standards) allowance	1	ls	$10,000	$	10,000
	Erosion control	1	ls	$2,000	$	2,000
	Clear & grub	1	ls	$2,000	$	2,000
	Excavation - Pipelines	210	cy	$15	$	3,200
	Turbidity Curtain	200	lf	$15	$	3,000
	Haul waste to disposal	400	ton	$10	$	4,000
	Imported fill - Pipeline	400	ton	$20	$	8,000
	Trench shoring	1	ls	$2,000	$	2,000
	Dewatering for pipeline construction	2	days	$200	$	400
	Rip Rap Energy Dissipation	30	ton	$40	$	1,200
	Weir retrofit contingency allowance	1	ls	$5,000	$	5,000
	Subtotal, Sitework				**$**	**115,700**

DRAFT

3	**Piping**					
	Intake To Pump Station					
	Cylinder Style Fish Screen	1	allow	$50,000	$	50,000
	36" HDPE Intake to Heat Exchange System	100	lf	$141	$	14,100
	24" Alum Heat Exhange Pipe with Fittings	1,000	lf	$240	$	240,200
	36" HDPE DIPS DR 21 Intake Pipe	16,000	lf	$141	$	2,256,000
	36" Precast Pipe Anchors	640	ea	$300	$	192,000
	Large work boat for fish screen & heat exchange	1	allow	$12,000	$	12,000
	4 - small work boats for pipe positioning	1	ls	$10,000	$	10,000
	30" HDPE DIPS DR 21 PS Transition Pipe	150	lf	$105	$	15,800
	30" Valve	1	ea	$25,000	$	25,000
	30" 45 Deg Bend	4	ea	$732	$	2,900
	36x30 Reducer	1	ea	$1,000	$	1,000
	Discharge From Pump Station					
	18" HDPE DIPS DR 21 PS Transition Pipe	150	lf	$42	$	6,300
	18" Valve	1	ea	$20,000	$	20,000
	18" 45 Deg Bend	8	ea	$224	$	1,800
	24x18 Reducer	1	ea	$500	$	500
	24" HDPE DIPS DR 21 Discharge Pipe	2,000	lf	$69	$	138,000
	24" Precast Pipe Anchors	80	ea	$300	$	24,000
	Discharge Site At Weir					
	24" HDPE DIPS DR 21 PS Transition Pipe	150	lf	$69	$	10,400
	24" 45 Deg Bend	5	ea	$371	$	1,900
	Subtotal, Piping				**$**	**2,971,900**
4	**Structural and Architectural**					
	Pump Station					
	Slab on grade (10'x20'x8")	5	cy	$250	$	1,200
	Pump building (timber frame, 8'x16')	128	sf	$200	$	25,600
	Subtotal, Structural and Architectural				**$**	**26,800**
5	**Mechanical**					
	Pump Station					
	Vertical Turbine Pump (single pump, with no backup pum	1	ea	$126,000	$	126,000
	Building space heater and passive ventilation	1	ls	$5,000	$	5,000
	Subtotal, Mechanical				**$**	**131,000**

DRAFT

6	**Electrical**					
	Pump Station					
	Pump station power and control panel	1	allow	$100,000	$	100,000
	2-3" PVC direct bury conduit	500	lf	$20	$	10,000
	Power extension to pump station	500	lf	$20	$	10,000
	Meter & shutoff	1	ls	$500	$	500
	Electrical contingency allowance	1	ls	$2,500	$	2,500
	Subtotal, Electrical and Control				**$**	**123,000**
7	**Intrumentation and Control**					
	Included in electrical in section 6				**$**	**-**
	Subtotal, Intrumentation and Control				**$**	**-**
8	**Site Restoration**					
	Pump Station					
	Site landscaping	1	ls	$2,000	$	2,000
	Discharge Below Existing Weir					
	Key Logs	3	ea	$500	$	1,500
	Imported topsoil	100	cy	$15	$	1,500
	Wetland landscaping	1	ls	$2,000	$	2,000
	Subtotal, Site Restoration				**$**	**7,000**

Total Estimated Direct Costs (Rounded)		$	3,635,000
General Contractor Overhead and Profit	15.0%	$	545,000
Subtotal		**$**	**4,180,000**
Contingency	30.0%	$	1,254,000
Sales Tax (City of Redmond)	9.5%	$	516,000
Subtotal			**$5,950,000**
Engineering (Design and Construction)	15.0%	$	893,000
Administration	10.0%	$	595,000
Alternative 8 - Total Estimated Project Costs			**$7,438,000**

DRAFT

Summary

Concept 8 should be considered for further evaluation as it does result in substantial cooling, while avoiding some of the concerns about potential effects to the Lake Sammamish hypolimnion and water quality. It costs slightly more than Concept 1 due to the heat exchange piping added to the overall piping length, and the 10 cfs option may be more feasible as it results in better cooling.

Concept 7 would not likely result in any substantial water quality and temperature benefits. However, any reconfiguration of the channel could include backfill with coarse material to promote better hyporheic exchange than would likely occur in the existing silty soils.

Concept 2, Pumped Groundwater, could yield better water temperature benefits than initially considered in the June 2014 memo. Feedback from the City of Redmond indicates that up to 3 cfs could be pumped from a new groundwater well, as that is the typical yield from the City's groundwater wells located to the north of the study area. This would reduce the costs/cfs and potentially yield fairly good localized cooling, such as in pools.

DRAFT

References

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. 2009. Fundamentals. 880 pages. On the web at: https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals

Burkholder, B. 2007. Influence of hyporheic flow and geomorphology on temperature of a large, gravel-bed river, Clackamas River, Oregon, USA. Master's thesis, Oregon State University.

King County. 2014. Willowmoor Cold-Water Supplementation Concepts. Prepared by Tetra Tech, Inc. Seattle, WA. Final June 2014.

R2 Resource Consultants. 2010. Assessment of summer temperatures and feasibility and design of improved adult Chinook salmon thermal refuge habitat in the Sammamish River. Prepared for the Muckleshoot Indian Tribe, Auburn, WA.

DRAFT