Technical Memorandum

Date:	February 7, 2020
Project:	Fox Creek Hydraulic Evaluation
To:	Mrs. Sue Lawrence City of Rainier
From:	Preston Van Meter, PE, Project Manager Austin Rambin, PE, Project Engineer Patrick Davis, Staff Engineer Murraysmith
Re:	Fox Creek Culvert Hydraulic Modeling

REGISTERED PROFESSIONAL ENGINEER
51615PE
OREGON
JANUARY 2, 1999
PRESTON VAN METER
CERT. EXP. 6/30/2020
SIGNED 2/10/2020

Introduction

City of Rainier (City) private properties adjacent to Fox Creek were impacted by a significant flooding event between West C Street and US Highway 30 in February 2019. In December 2019, as part of our City Engineering contract, Murraysmith began a high-level evaluation of the Fox Creek culvert to develop design flows from the upstream basin, evaluate culvert hydraulics and provide recommendations to alleviate future flooding events along Fox Creek.

The following technical memorandum outlines the evaluation made by Murraysmith. It covers the existing conditions as modeled in Visual Hydraulics 4.2© software and provides recommendations for future improvements to the system to increase capacity and reduce potential flooding. See **Figure 1** for a Vicinity Map of the area. **Figure 2** shows an aerial view of the area.

Figure 1 – Vicinity Map

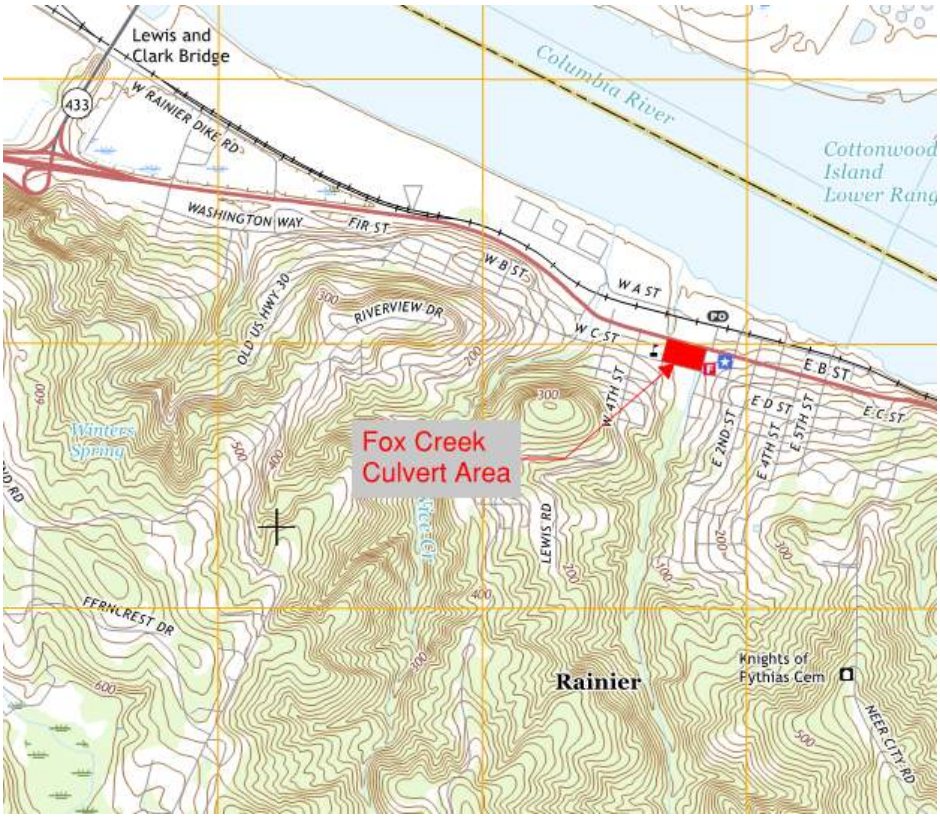


Figure 2 – Aerial View of Fox Creek Culvert Area

1. **Figure 2** shows the approximate location of the Fox Creek culvert, which is shown in red. The blue line at the bottom of the Figure illustrates where Fox Creek enters the culvert, and the blue line at the top shows the culvert exit.

Background

The Fox Creek watershed starts south of Rainier's City Limits, and the creek flows from south to north terminating at the confluence of the Columbia River. The creek is an open channel from its headwaters to West C Street. Here, it flows through a series of culverts before discharging on the north side of US Highway 30. These culverts are interconnected, and portions are owned by the City, private businesses, and ODOT. See **Attachment A** for culvert sizes and locations. The ground area between the culvert inlet and outlet is lower in elevation causing a low point on private property.

Records indicate that a sinkhole began forming in the area of the privately owned portion of the culvert that lead up to an investigation starting in 2014. This investigation included identifying the dimensions and extents of the culvert, plus identifying potential voids in the vicinity. See **Attachment B** for the Underwater Inspection Report. In 2017, a large portion of the culvert on private property was replaced and local area drains were connected to the culvert. **Attachment A** includes the extents of this work.

After the sinkhole repair, a large rain event occurred on February 11th and 12th, 2019 and the private property between West C Street and US Highway 30 experienced severe flooding. Using historical data from local Weather Underground Station KORRAINI17, the 24-hour rainfall total over the heaviest rainfall period on these days was approximately 5.2-inches. By comparing this value to the *US Department of Commerce Weather Bureau Technical Paper No. 40 Rainfall Frequency Atlas of the Unites States*, this approximately equates to a 10-yr storm event. It should be noted that, according to City staff, flooding was not a regular occurrence prior to the sinkhole repair and culvert improvements.

Fox Creek Watershed Hydrologic Evaluation

As a first step in the evaluation, a hydrologic evaluation was completed to establish design flows under various rainfall events in the Fox Creek watershed. The analysis was used to estimate design flow rates on Fox Creek at the culvert inlet for 2-year through 500-year storm events. The analysis was completed using two publicly available online tools – the United States Geological Survey (USGS) *StreamStats* and the Oregon Water Resources Department (OWRD) *Peak Discharge Estimation Mapping Tool.* The tools automatically select specific parameters based on location, size, and elevation of the contributing watershed. Further information on the hydrologic analysis can be found in **Attachment C – Fox Creek Hydrological Analysis.**

The two streamflow calculation methods resulted in similar values, which were hand checked using USGS regression calculations. The more conservative estimates were chosen as the basis of the analysis. The resulting flow rates are listed in **Table 1.**

Table 1 – Fox Creek Peak Discharge Flow Rates

Storm Event	Fox Creek Flow Rate (cfs)
2 yr	155
5 yr	230
10 yr	281
25 yr	346
50 yr	394
100 yr	442
500 yr	554

1. See **Attachment C** for the Fox Creek Hydrological Analysis.

Fox Creek Culvert Hydraulics Evaluation

The next step in the evaluation was then to use the design flows developed as part of the hydrologic evaluation to evaluate the capacity of the Fox Creek Culvert between West C Street and Highway 30 where the flooding occurred in February 2019.

The Fox Creek culvert is approximately 650 feet long constructed with a series of corrugated metal pipes (CMP) and reinforced concrete box sections (BC). Starting from the upstream end, the CMP ranges in size from 66-inch to 84-inch, and the BC is 4-feet by 8-feet on the downstream end. Interspersed along the culvert are five manholes, one has a slotted top that serves as an area drain, and two other area drains are connected to the manholes. See **Attachment A** for an annotated map of the culvert system. Based on this information two scenarios were developed in Visual Hydraulics 4.2© software to model the hydraulics through the culvert:

1. Scenario A modeled the culvert as a standard pipe network with fittings, manholes, and the entrance and outlet. These conditions reflect the culvert properties after the sinkhole repair in 2017.
2. Scenario B modeled the culvert as a pressure pipe network with fittings, entrance, and outlet, but without manholes. These conditions reflect the culvert properties prior to the sinkhole repair in 2017.

The scenarios were calibrated using water surface elevation data determined during field surveying by DJ&A. After calibration both scenarios were modeled using flow rates representative of storms ranging from 2-year to 500-year events. These flow rates were determined by Kleinschmidt as reported in their Fox Creek Hydrological Analysis Memorandum. See **Attachment C**. The model results from the 2-year through 25-year storm events are shown in **Table 2** and **Table 3** below. The vertical datum used for the analysis is NAVD 88.

Table 2 – Scenario A: Standard Pipe Network Model Results

Storm Event	Flow Rate (cfs)	WS EL Upstream of Inlet (ft)[1]	WS EL Upstream of Outlet (ft)	Headloss Through Inlet (ft)[2]	Headloss Through Outlet (ft)[2]
2 yr	155	19.3	14.9	1.8	0.95
5 yr	230	25.6	16.1	4.0	2.1
10 yr	281	31.1	17.1	6.0	3.1
25 yr	346	39.8	18.7	9.2	4.7

1. The road surface elevation for West C Street is approximately 30-ft above MSL, therefore values above this represent flooding of this street.
2. Typical design headloss through an inlet or outlet is less than 2-ft.
3. These conditions reflect the culvert properties after the sinkhole repair in 2017.

Table 3 – Scenario B: Pressure Pipe Network Model Results

Storm Event	Flow Rate (cfs)	WS EL Upstream of Inlet (ft)[1]	WS EL Upstream of Outlet (ft)	Headloss Through Inlet (ft)[2]	Headloss Through Outlet (ft)[2]
2 yr	155	18.3	15.0	1.8	0.95
5 yr	230	23.3	16.2	4.0	2.1
10 yr	281	27.7	17.2	6.0	3.1
25 yr	346	34.6	18.8	9.2	4.7

1. The road surface elevation for West C Street is approximately 30-ft above MSL, therefore values above this represent flooding of this street.
2. Typical design headloss through an inlet or outlet is less than 2-ft.
3. These conditions reflect the culvert properties prior to the sinkhole repair in 2017.

The results of the model show two main issues:

- The existing culvert is undersized, and headloss through the inlet and the outlet is outside of typical design parameters beyond a 2-year storm event.
- The water surface elevations upstream of the inlet may cause flooding of West C Street during a 10-year or greater storm event.

Scenario A has less capacity than Scenario B. This deviation is due to the pressure relief that occurs at the manholes in Scenario A. A pipe that is under pressure will have more capacity than one that is open to the atmosphere. Also, the modeled scenarios show that both the inlet and outlet become submerged during any storm events. These initial modelling results and observed conditions at the outlet suggest that the culvert is outlet controlled.

Alternatives

Based on the determination that Fox Creek Culvert is undersized to pass a 100-year flow event of 442 cfs from the upstream watershed, Murraysmith investigated two alternatives to increase culvert capacity. The first alternative reviews upsizing the portion of the culvert running beneath West C Street to improve hydraulic performance. The second alternative evaluates upgrades to the entire culvert to determine improvements required to pass the 100-year storm event.

Alternative 1 – Replace City-owned Culvert within West C Street R/W

The first alternative considers upsizing approximately 100 LF of culvert within City right-of-way underneath West C Street from 66-inch to 72-inch. It also assumes that the manholes are sealed, and the area drains were removed to create a pressurized network. These modifications were then made to the Scenario B model, as outlined above, to determine the overall effect of the improvements. See **Table 4** for results from the model using flows from the 2-year through the 25-year storm events.

Table 4 – Alternative 1: Replace City-owned Culvert within West C Street R/W

Storm Event	Flow Rate (cfs)	WS EL Upstream of Inlet (ft)[1]	WS EL Upstream of Outlet (ft)	Headloss Through Inlet (ft)[2]	Headloss Through Outlet (ft)[2]
2 yr	155	17.7	15.0	1.3	0.95
5 yr	230	22.0	16.2	2.9	2.1
10 yr	281	25.7	17.2	4.3	3.1
25 yr	346	31.6	18.8	6.5	4.7

1. The road surface elevation for West C Street is approximately 30-ft above MSL, therefore values above this represent flooding of this street.
2. Typical design headloss through an inlet or outlet is less than 2-ft.

The modelling results show that this modification would improve the hydraulics through the entrance of the culvert, and it would increase the capacity of the culvert to pass the 10-year storm event without overtopping the road. Despite these modifications, the culvert is still outlet controlled. Upsizing this portion of the culvert has little effect beyond the 10-year storm event.

Alternative 2 – Replace Under-Sized Portion of Culvert

The second alternative tests multiple culvert sizes to determine the minimum size required to convey the 100-year storm event. These various sizes were modeled in iterations using Scenario B as the baseline model and included replacing the inlet, outlet, and culvert.

Based on results of the model iterations, the minimum size culvert required to pass the 100-year storm event is 84-inches. As such, this would require approximately 400 LF of culvert replacement from the inlet to the connection to the 84-inch ODOT culvert, and approximately 80 LF of culvert replacement under US Highway 30.

See **Table 5** for results from the model using flows from the 10-year through the 100-year storm events.

Table 5 – Alternative 2: Replace Under-Sized Portion of Culvert

Storm Event	Flow Rate (cfs)	WS EL Upstream of Inlet (ft)[1]	WS EL Upstream of Outlet (ft)	Headloss Through Inlet (ft)[2]	Headloss Through Outlet (ft)[2]
10 yr	281	19.3	14.7	2.3	0.60
25 yr	346	21.9	15.3	3.5	0.92
50 yr	394	24.1	15.7	4.5	1.2
100 yr	442	26.6	15.6	5.7	1.7

1. The road surface elevation for West C Street is approximately 30-ft above MSL, therefore values above this represent flooding of this street.
2. Typical design headloss through an inlet or outlet is less than 2-ft.

Recommendations

Based on Murraysmith's evaluation, the existing culvert is undersized, and outlet controlled, which may cause flooding of the low area between West C Street and Highway 30 under any event above a 10-year flow event. In order to provide capacity for a 100-year flow event of 442 cfs, the culvert would need to be upsized to 84-inch diameter, including replacement of the 4'x8' box culvert under Highway 30 owned by the Oregon Department of Transportation.

In order to best improve the performance of the culvert, Murraysmith recommends a full replacement and upsizing of the Fox Creek culvert with a new 84-inch culvert to alleviate the potential for flooding under a 100-year flow event of 442 cfs. An alternate option that has not yet been evaluated would be to upsize the culverts under West C Street and Highway 30 and remove the culvert installed on private property between the rights-of-way to re-establish a fish-friendly stream channel through those parcels.

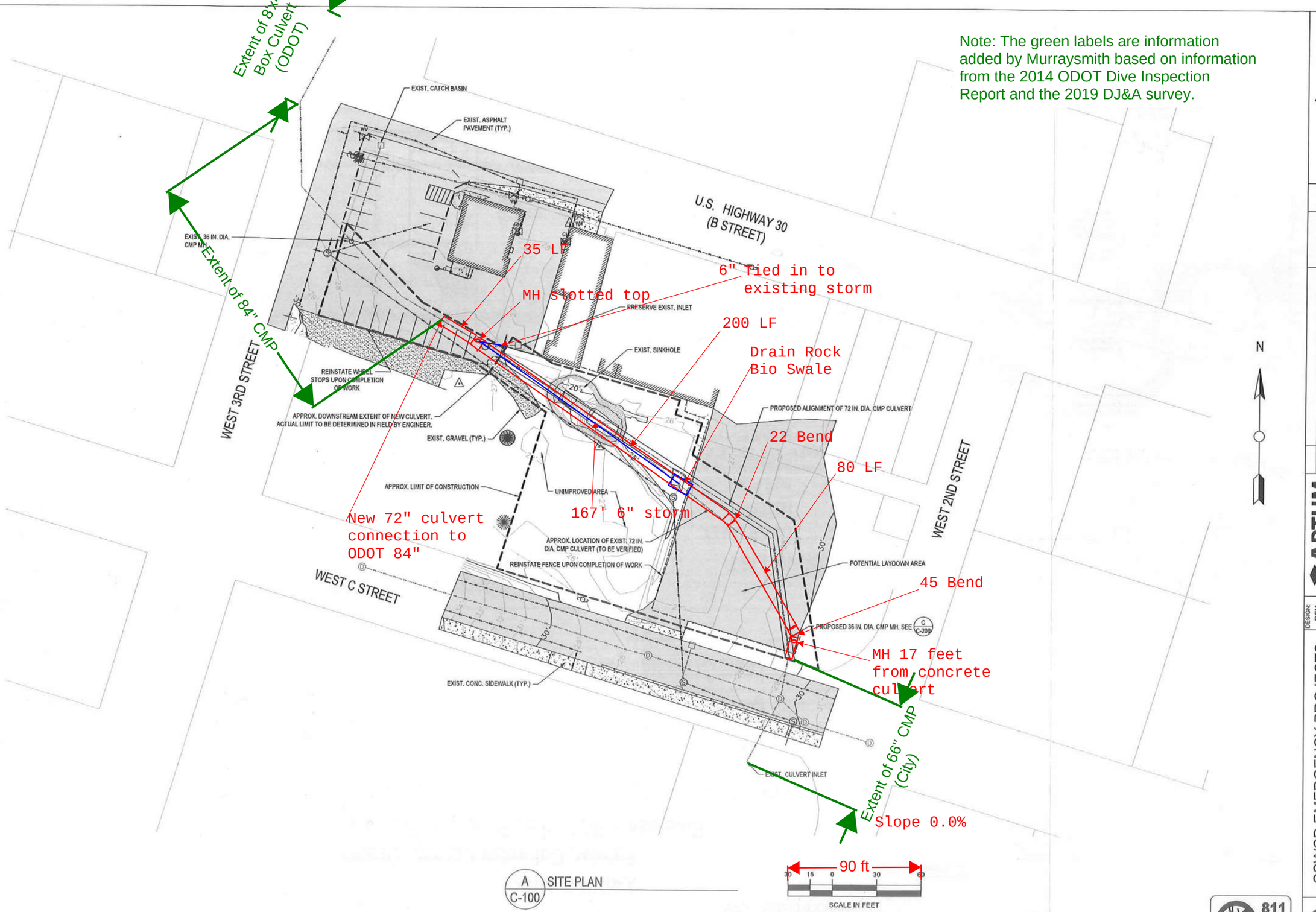
Next Steps

Moving forward the next steps needed to further analyze and improve the Fox Creek culvert hydraulic capacity include:

- Complete flow monitoring along Fox Creek and update flow estimates to better correlate creek flows with local rainfall;
- Complete additional culvert hydraulic analysis and design based on the preferred next steps of the City of Rainier and local property owners;
- Discuss permitting and other requirements with stakeholders and state agencies;
- Prepare a more detailed preliminary design based on the preferred path forward and begin pursuing project funding.

ATTACHMENT A

Note: The green labels are information added by Murraysmith based on information from the 2014 ODOT Dive Inspection Report and the 2019 DJ&A survey.



A C-100 SITE PLAN

811 CALL before you DIG

PRELIMINARY
REGISTERED PROFESSIONAL ENGINEER
OREGON
EXPIRES: 06/30/2017

REV.	DESCRIPTION	DATE	BY
0	DRAFT ISSUED FOR BID	02-20-2017	RFK

APTUM
APTUM INC.
411 NE 6TH AVENUE
SUITE D
CAMAS, WA 98607
TEL: (360) 216-4086

DESIGN: RFK
DRAWN: WKG
CHCKD: MBD
APPRVD: MBD
DATE SUBMITTED: 02-20-2017

CSWCD EMERGENCY PROJECTS
RAINIER SINKHOLE
FOX CREEK
SITE PLAN

SHEET NO. C-100
3 OF

UNDERWATER INSPECTION REPORT

BRIDGE NAME	RAINEER CREEK			REGION	1	BRIDGE NUMBER	3124
RIVER NAME	RAINEER CREEK	OWNER	STATE	DISTRICT	1	Construction	1913
STATE HWY #	2W	ROUTE NUMBER		MILE POINT	47.13	CURRENT	Low
COUNTY	Columbia	LEGAL NAME				VISIBILITY (ft)	1
FOUNDATION TYPE	Culvert			ACCESS	2	WATER TEMP	60
DIVERS	Shorb, J.Ottosen, Boothe			INS. INTERVAL	1	MAXIMUM DEPTH	3-ft.
Water Elevation	At the outlet 1.0-ft. down from top of culvert.						

GENERAL NOTES

This is a 520-ft. long culvert. 420-ft. is a CMP and 100-ft. is concrete box culvert.

The element description provided in the general notes will be used to establish the appropriate underwater bridge inspection procedures, as provided in Section 8 of the ODOT Underwater Bridge Inspection Manual.

Bridge Specific Safety Hazards (BHS)

Soft silt, Visibility, Bank access.

UNDERWATER ELEMENT CONDITION STATES

						CONDITION STATES			
Elem.	*Description:*	*Defects:*	*Environment*	*Qty*	*Units*	*1*	*2*	*3*	*4*
240	Steel Culvert		Moderate	420	LF	0	338	80	2
	1000	Corrosion		420	each	0	338	80	2
241	Reinforced Concrete Culvert		Moderate	100	LF	0	94	6	0
	1080	Delam/Spall/Patched		5	LF	0	0	5	0
	1130	Cracks		1	LF	0	0	1	0
	1190	Abrasion		94	LF	0	94	0	0

ELEMENT REMARKS

Elem. *Description:*

240 The first 20-ft. at the inlet is a 6-ft. x 4-ft. CMP, its 20-LF of C/2 corrosion.

241 From 20-ft to 40-ft. is a concrete box culvert 6-ft. x 4-ft. There is 1-LF of C/3 cracking in the East wall, and the rest of the concrete is in C/2 with abrasion.

240 From 40-ft the next 400-ft. is a CMP. It has C/2 corrosion full length, and 80-LF is in c/3 corrosion. There is 2 different 1-LF areas where the CMP is corroeded clear thru and is in c/4.

241 From 440-ft to the end, so the 80-LF at the outlet is Concrete box 8-ft. x 4-ft. There is 5-LF of C/3 spalling, and the rest of the concrete is in C/2 with abrasion.

NBI Ratings

Item	*Description:*	*Current Condition Rating*	*Underwater Portion Condition Rating*
61	Channel and Channel Protection Condition Assessment	6	6
62	Culvert	6	5
71	Waterway Adequacy	8	8
113	Scour	6	8

NBI Item 61, Some bank erosion.
NBI Item 62, Culvert has some deteriated areas, but no serious problems.
NBI Item 71, Sufficient flow area.
NBI Item 113, No scour noted

Maintenance Recommendations

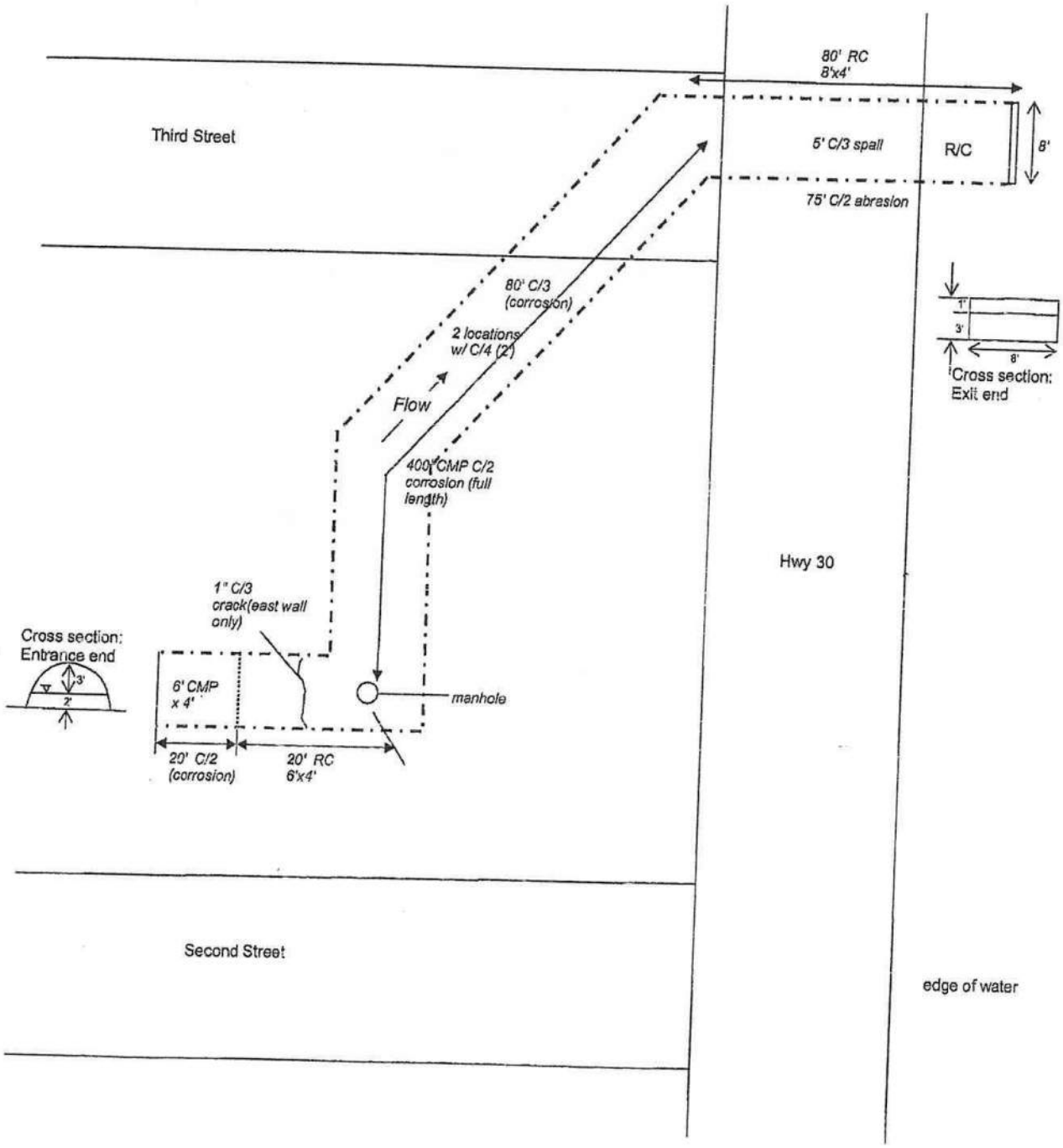
Elem. *Description:*

No underwater maintenance is recommended at this time.

Rick Shorb, P.E.
Underwater Operations Engineer
(503) 986-2979

cc: District 12
Region 5 Bridge Inspector
Bridge Operations

Br. #03124 Rainier Creek (STATE Hwy 2W, Region 1)



MEMORANDUM

TO: Mr. Austin Rambin, P.E.
MurraySmith

FROM: Ben Cary, P.E. and Isha Deo, Kleinschmidt Associates

CC: Jason Kent, P.E.

DATE: December 20, 2019 **DOCUMENT NO.:** 4688003.01_ME

RE: Fox Creek Hydrological Analysis

Dear Mr. Rambin:

Kleinschmidt Associates (Kleinschmidt) presents this memorandum to summarize the hydrological analysis conducted for Fox Creek in Rainier, OR. Fox Creek flows through Rainier, OR before discharging into the Columbia River. Fox Creek enters a culvert approximately 1,400 ft upstream of the confluence with the Columbia River, at the State Highway 30 crossing. This culvert does not adequately pass high water flows, causing flooding to adjacent areas. As part of the effort to analyze the performance of the culvert, Kleinschmidt was asked to complete a hydrologic analysis of Fox Creek and provide the resulting 1% exceedance probability (100-year) flow and the 4% exceedance probability (25-year) peak flow.

Kleinschmidt used the United States Geological Survey (USGS) *StreamStats* and the Oregon Water Resources Department (OWRD) *Peak Discharge Estimation Mapping Tool* to calculate the peak flows within Fox Creek. The USGS *StreamStats* and OWRD *Peak Discharge Estimation Mapping Tool* are two online hydrologic programs that estimate peak discharges of streams at specific locations based on regression equations from the USGS Report *Estimation of Peak Discharges for Rural and Unregulated Streams in Western Oregon*. These regression equations require hydrologic parameters of the contributing watershed area that are automatically generated within the programs based on the location, extent, and elevation of the contributing areas upstream of a specified location.

For this analysis the location of interest was directly upstream of the State Highway 30 culvert in question. Based on the specified location, the two programs automatically generated hydrologic parameters of the contributing watershed (Table 1).

TABLE 1- GENERATED WATERSHED PARAMETERS

Program	Drainage Area	Mean Basin Slope	24-Hr 2-Yr Precip
	(sq miles)	(degrees)	(in)
USGS	3.13	11.6	2.09
OWRD	3.16	12	2.1

As noted in Table 1 the two programs calculated slightly different watershed parameters. These slightly different parameters lead to slightly different resulting peak flows from the regression equations. The resulting peak flows from the regression equations are listed in Table 2. Kleinschmidt verified the peak discharge calculations based on the basin parameters from each

tool using the same USGS regression equations calculated by hand. The 1% and 4% exceedance probabilities (corresponding to 100-yr and 25-yr flows) are in **bold**.

TABLE 2 FOX CREEK RETURN INTERVAL FLOWS

Return Period, yr	Peak Discharge (cfs)	Peak Discharge (cfs)	Peak Discharge (cfs)
(sq miles)	USGS	OWRD	Recommended
2	151	155	155
5	224	230	230
10	274	281	281
25	**337**	**346**	**346**
50	384	394	394
100	**431**	**442**	**442**
500	539	554	554

Given the similarity of the two solutions Kleinschmidt recommends using the more conservative flow values calculated using the OWRD *Peak Discharge Estimation Mapping Tool* software. The results from the USGS StreamStats application and the OWRD Peak Discharge Estimation tool are given in Appendix A and B, respectively.

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Appendix A
USGS StreamStats Results

Fox Creek Hydrologic Analysis StreamStats Report

Region ID: OR
Workspace ID: OR20191216181751205000
Clicked Point (Latitude, Longitude): 46.08846, -122.93785
Time: 2019-12-16 10:18:09 -0800

Conducted by IPD 12/16/2019

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	3.13	square miles
I24H2Y	Maximum 24-hour precipitation that occurs on average once in 2 years - Equivalent to precipitation intensity index	2.09	inches
SOILPERM	Average Soil Permeability	0.76	inches per hour

Parameter Code	Parameter Description	Value	Unit
JANMAXT2K	Mean Maximum January Temperature from 2K resolution PRISM 1961-1990 data	44.3	degrees F
WATCAPORC	Available water capacity from STATSGO data using methods from SIR 2005-5116	0.14	inches
ORREG2	Oregon Region Number	10001	dimensionless
BSLOPD	Mean basin slope measured in degrees	11.6	degrees
JANMINT2K	Mean Minimum January Temperature from 2K resolution PRISM PRISM 1961-1990 data	31.2	degrees F
ELEV	Mean Basin Elevation	646	feet

Peak-Flow Statistics Parameters[Reg 2B Western Interior LT 3000 ft Cooper]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.13	square miles	0.37	7270
BSLOPD	Mean Basin Slope degrees	11.6	degrees	5.62	28.3
I24H2Y	24 Hour 2 Year Precipitation	2.09	inches	1.53	4.48
ELEV	Mean Basin Elevation	646	feet		
ORREG2	Oregon Region Number	10001	dimensionless		

Peak-Flow Statistics Flow Report[Reg 2B Western Interior LT 3000 ft Cooper]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SE	SEp	Equiv. Yrs.
2 Year Peak Flood	151	ft^3/s	89	255	32.6	32.6	2
5 Year Peak Flood	224	ft^3/s	133	378	32.4	32.4	2.8
10 Year Peak Flood	274	ft^3/s	161	466	33	33	3.6
25 Year Peak Flood	337	ft^3/s	195	583	34.1	34.1	4.8
50 Year Peak Flood	384	ft^3/s	218	675	35.1	35.1	5.5
100 Year Peak Flood	431	ft^3/s	241	770	36.2	36.2	6.2
500 Year Peak Flood	539	ft^3/s	289	1010	39.1	39.1	7.5

Peak-Flow Statistics Citations

Cooper, R.M.,2005, Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon: U.S. Geological Survey Scientific Investigations Report 2005-5116, 76 p. (http://pubs.usgs.gov/sir/2005/5116/pdf/sir2005-5116.pdf)

Application Version: 4.3.11

Appendix B
OWRD Peak Flow Estimation Results

PEAK DISCHARGES FOR SELECTED FREQUENCIES

Report prepared for: auto-delineation
Time: 9:51 AM Date: 12/16/2019
Watershed Name: FOX CR

PEAK DISCHARGE CALCULATION BY PREDICTION EQUATION

Peak discharges for the ungaged watershed have been determined from a set of hydrologic prediction equations derived using generalized least squares. The models relate peak discharges to physical watershed characteristics such as area and precipitation. The equations take this form:

```
--------------------------------------------------
Q(T)=(10.0^C0(T))*(CHR1^C1(T))* . . . (CHRn^Cn(T))
--------------------------------------------------
   Q(T)  =  Peak Discharge for Return Period T
   Cx(T) =  Coefficient x for Return Period T
   CHR1  =  The First Watershed Characteristic
   CHRn  =  The nth Watershed Characteristic
--------------------------------------------------
   Note: * = multiplication, ^ = exponentiation
```

For this ungaged watershed, peak discharges were estimated using prediction equations for this flood region:

WESTERN INTERIOR WATERSHEDS - < 2875 FEET

WATERSHED ELEVATION = 648 FEET

For western interior watersheds with mean elevations below 2875 feet, peaks are estimated using the prediction equations for western interior watersheds below 3000 feet.

Prediction Equation for Interior Watersheds < 3000 Feet

```
-------------------------------------------------------------------------
Q(T)=(10.0^C0(T))*(X1^C1(T))*(X2^C2(T)*(X3^C3(T))*(X4^C4(T))*(X5^C5(T))
-------------------------------------------------------------------------
    Q(T)   =  Peak Discharge for Return Period T
    Cx(T)  =  Coefficient x for Return Period T
    X1     =  Drainage Area                    (square miles       )
    X2     =  Mean Slope                       (degrees            )
    X3     =  Precip Intensity 2-yr 1-day      (inches             )
    X4     =
    X5     =
-------------------------------------------------------------------------
   Note: * = multiplication, ^ = exponentiation
```

Prediction Equation Coefficients

Return Period T	C0(T)	C1(T)	C2(T)	C3(T)	C4(T)	C5(T)
	Coefficients					
2	9.607e-01	9.004e-01	4.695e-01	8.481e-01		
5	1.162e+00	9.042e-01	4.735e-01	7.355e-01		
10	1.267e+00	9.064e-01	4.688e-01	6.937e-01		
20	1.351e+00	9.081e-01	4.634e-01	6.651e-01		
25	1.375e+00	9.086e-01	4.616e-01	6.578e-01		
50	1.443e+00	9.101e-01	4.559e-01	6.390e-01		
100	1.503e+00	9.114e-01	4.501e-01	6.252e-01		
500	1.620e+00	9.141e-01	4.365e-01	6.059e-01		

Required Watershed Characteristics

Drainage Area	(square miles)	3.160
Mean Slope	(degrees)	12.000
Precip Intensity 2-yr 1-day	(inches)	2.100

Selected Watershed Characteristics

Drainage Area	(square miles)	3.160
Maximum Relief	(feet)	1170.000
Mean Slope	(degrees)	12.000
Average Aspect	(degrees)	189.000
Mean Elevation	(feet)	648.000
Precip Intensity 2-yr 1-day	(inches)	2.100
Mean January Precip	(inches)	8.960
Mean July Precip	(inches)	0.778
Mean Annual Snow Fall	(inches)	9.140
Mean January Min Temp	(degrees Fahrenheit)	31.500
Mean July Min Temp	(degrees Fahrenheit)	50.100
Mean January Max Temp	(degrees Fahrenheit)	44.400
Mean July Max Temp	(degrees Fahrenheit)	75.800
Soils Storage Capacity	(inches)	0.140
Soils Mean Permeability	(inches per hour)	0.760
Soils Depth to Bedrock	(inches)	58.500

PEAK DISCHARGE ESTIMATES BASED ON PREDICTION EQUATIONS

Return Period years	Peak Flow cfs	95% Confidence Lower Limit cfs	Upper Limit cfs
2	155	82.7	291
5	230	123	430
10	281	149	531
20	331	173	633
25	346	180	666
50	394	201	773
100	442	221	886
500	554	263	1170

REFERENCES

Cooper, R.M., Estimation of peak discharges for rural, unregulated streams in western Oregon: U.S. Geological Survey Scientific Investigations Report 2005-5116, 134 p.

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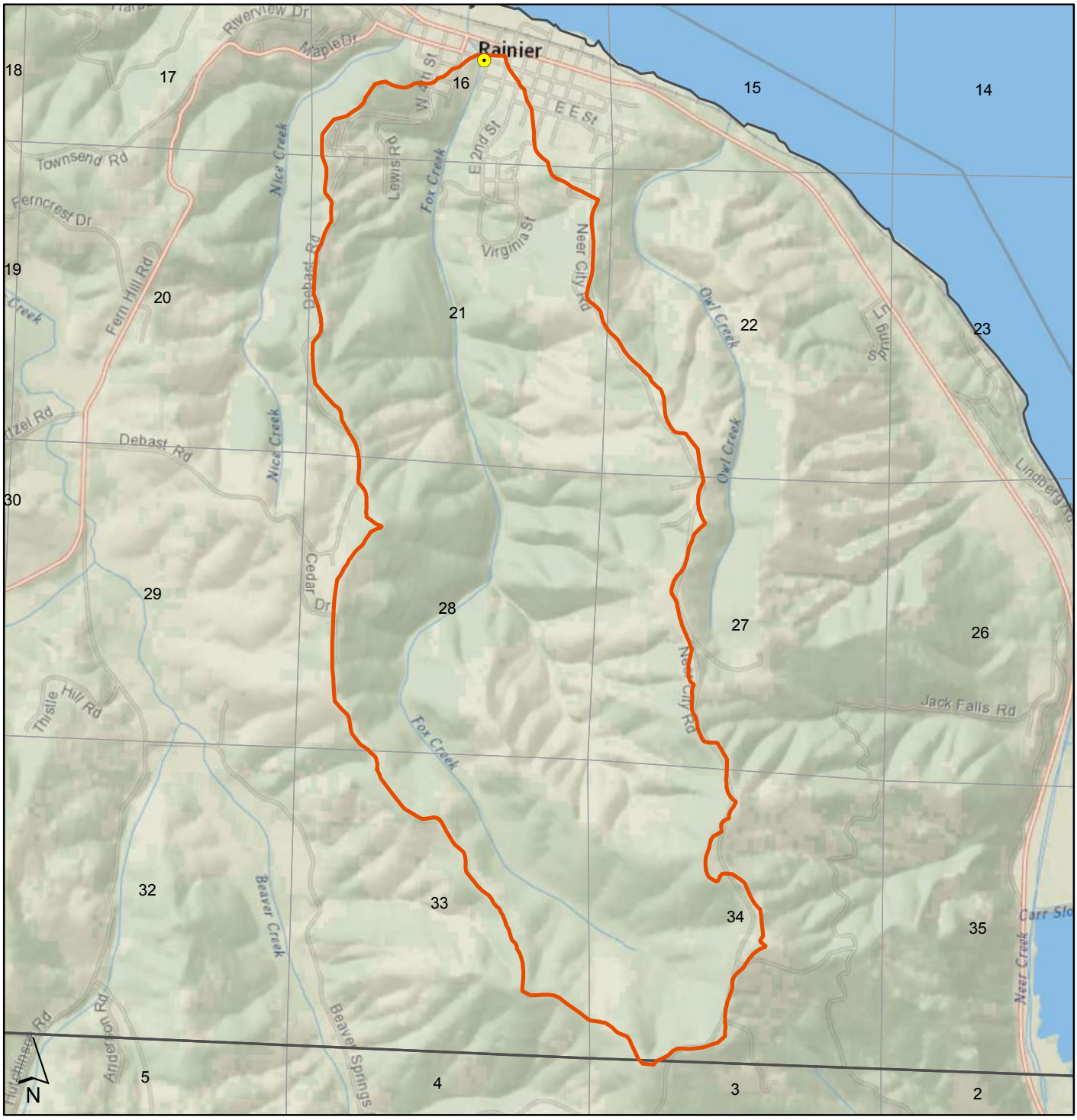
Peak Discharge Estimation

Oregon Water Resources Department

Date: December 16, 2019



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Legend

- Pour Point
- Peak Discharge Gaging Stations
- Watershed

0 0.125 0.25 0.5 0.75 1 Miles