Crescent Harbor Creek Restoration
Final Design Report

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January 2021

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Final Design Drawings (bound separately)

1. Introduction and Background

Crescent Harbor Creek is a small perennial stream that drains about 3.9 square miles of land on Whidbey Island; the project site is within the Whidbey Island Naval Air Station boundary (Drawing 1). Substantial reaches of the mainstem creek have been channelized during previous decades, including the ¼-mile long reach proposed for stream restoration. Streams like Crescent Harbor Creek flowing into Puget Sound typically support communities of coho salmon, chum salmon, cutthroat trout, sculpin, and possibly other native fish species.

Restoration of the lower ¼-mile of Crescent Harbor Creek is outlined in this report (plus the drawings), with the overall objective to restore a natural meandering channel to replace the linear ditch alignment. Construction work will be completed between Crescent Harbor Road and the existing tidal estuary (Drawing 1). Major proposed project components are:

- ✓ Excavate a gradually meandering stream channel from the existing culvert under Crescent Harbor Road to the estuary, then place large wood and streambed substrate (cobbles, gravel & sand) to re-establish a stream channel with natural features (vs. ditched). Drawings 3 and 4 show overhead views of the proposed channel, with typical channel sections illustrated on Drawings 5, 6, and 7.

- ✓ At the upstream end of the stream restoration length, a 40'-long roughened channel (boulder channel) will be built just below the existing culvert (Drawings 12 and 13). The culvert appears moderately under-sized for peak flow events. An armored channel (roughened channel) below the culvert will prevent Crescent Harbor Creek from eroding downstream of the culvert, which could potentially form a barrier to upstream migration of fish (e.g. chum salmon).

- ✓ The existing culvert under Crescent Harbor Creek will be left as-is. The roughened channel bottom will be flush with the existing concrete invert within the culvert, and the channel downstream will have essentially the same cross-section dimensions and gradient as the existing channel. Therefore, the project will have no effect on streamflow or flood flows upstream of Crescent Harbor Road.

Stream restoration will provide unrestricted upstream access for all native fish (juveniles and adults) to all habitat in the lower ¼-mile of Crescent Harbor Creek, and will establish a near-natural creek alignment and character. Habitat complexity immediately after construction would be considered relatively uniform. However, over time, the creek's high flows, bedload from upstream reaches, wood debris, etc. will gradually increase habitat complexity per natural fluvial processes. The long-term result will be a stream channel with fisheries productivity matching its historic character, instead of the limited productivity dictated by confinement in a straight ditch.

This report is intended for review by the Skagit River System Cooperative (SRSC = project sponsor), United States Navy, Washington Department of Fish and Wildlife (WDFW), and other people or agencies interested in this project. Report text, combined with 13 design drawings (11x17 size) and the construction cost estimate, should provide a comprehensive understanding of the proposed stream restoration project.

2. Design Criteria and Considerations

Design of stream restoration and fish passage projects requires an interdisciplinary understanding of stream systems, application of fish passage criteria and experience, civil engineering knowledge and practice, requirements for permits, and common sense. It is impractical to list all criteria used for project design; however, some of the most important considerations are listed below for each category:

Stream Restoration

- A gradual meander pattern (Drawings 3 and 4) was developed with consideration of general formulas and relationships to describe natural meander patterns (Vanoni 1977). Sinuosity for the restored channel will be 1.4, which would be considered typical for a small stream in a similar physical setting.

- The existing excavated (ditched) channel passes through fine-grained and dense soils that do not appear to be alluvial deposits. It is likely that some reaches of the restored channel will meander through historic alluvial deposits from Crescent Harbor Creek, since the north half of the restored channel (Drawing 4) will be constructed in a shallow valley that is the likely historic channel alignment.

- Habitat complexity will be introduced to the new stream channel through placements of large wood (logs and rootwads), and a semi-natural mix of cobbles, gravel and sand (Drawings 5, 6 and 7). Also, channel widths, reach gradients, and bank slopes will be variable per data included on Drawing 10. Variations for these stream design parameters were determined somewhat randomly (within limits) with the intent to construct a non-uniform channel to mimic a stream channel created by natural processes.

- Streambank slopes along the restored channel length will vary from 1.5:1 to 3:1 (horizontal:vertical). This range of slopes has proven to be stable for a broad range of soils in Washington, and the constructed banks are expected to remain stable long-term. Slopes along the new channel alignment will have erosion-control and vegetation elements including native plant seeding, native riparian trees and shrubs, and jute matting (Drawing 8).

Fish Passage (roughened channel)

- Although roughened channels are technically classified as fishways (WDFW 2013), the proposed channel's primary objective will be to prevent possible development of a fish passage barrier downstream of the under-sized existing culvert (via channel incision). The proposed channel would be considered a small roughened channel within the State of Washington, and the 3.0% slope would be considered low; the channel will easily be passable for all fish species and life-stages.

- Roughened channel design will generally comply with guidelines and/or criteria presented by WDFW (2013) and NMFS (2008). Also, the engineer's experience with about 80 roughened channel designs state-wide has been incorporated.

- Voids between boulders will be minimized with placement of finer-grained streambed materials (NMFS 2008, WDFW 2013).

Local Environment and Permits

- An existing wetland (Wetland A, see drawings) (Clifton, Hinton and Ritchie 2021) exists where water collects behind a soil berm constructed decades ago (Drawing 2); this wetland area is probably along the historic stream channel alignment. There are several great blue heron nests within this wetland, evidence the pond is used by beavers, and although man-made, this wetland area provides some habitat complexity for an otherwise uniform slope. All proposed channel restoration work will bypass Wetland A (Drawings 2 and 3).

- An on-site "Wetland B" (Clifton, Hinton and Ritchie 2021) coincides closely with the identified High Tide Line (see drawings). Construction of the new creek channel will stop at the upper edge of Wetland B, which is approximately High Tide Line.

- Clearing of vegetation at the project site will be limited to clearing necessary for channel construction. Narrow access routes will be cleared for heavy equipment, and for fish recovery when streamflow is switched to the new channel (Drawing 2).

- Most channel construction will be done well outside the ditch's Ordinary High Water (OHW). Channel construction at the downstream end will be completed during low to medium tides, so de-watering and/or water quality protection will not be required.

- Construction work for the roughened channel will be done within the existing ditch (stream), and a flow bypass system will be required. Sandbags and pumps will be used to bypass all streamflow around the work site (Drawing 11).

- When stream restoration construction is nearly complete, Crescent Harbor Creek will be gradually introduced to the new channel, and the existing ditch will gradually drain. Prior to flow diversion into the new channel (just before roughened channel construction), SRSC staff will isolate the project reach using block nets and will exclude fish from the project area using accepted protocols (USFWS 2012). After flow bypass starts, SRSC staff will walk the entire ditch length as it drains, to recover any fish observed. These fish will be released into Crescent Harbor Creek just downstream of the roughened channel location, to be the first fish inhabiting the restored channel.

- Project design will directly and indirectly incorporate normal requirements associated with a Hydraulic Project Approval (HPA) for a project of this type.

3. Stream Site and Hydraulic Data

Site Survey

Site surveys were completed in late 2015 and early 2016 by SRSC staff and the design engineer. Surveys collected information on site topography and features using a total station survey instrument (Leica TC800) and other survey equipment, including: natural slope contours and topography; alignment and grade for the existing creek channel (ditch); dimensions and elevations for the existing culvert; conifer tree locations; streambank and streambed characteristics; stream elevations and gradient; and streamflow conditions (width, depth, etc.). Survey data were used to draw a detailed base map of the Crescent Harbor Creek location to serve as a background for the project site plans (Drawings 2, 3 and 4).

Flow Estimates for Design

Flow estimates most useful for fish passage and stream restoration design include a "low fish passage flow", "high fish passage flow", and flood flows. All flows were estimated using equations based on regression analyses for western Washington streams. For Crescent Harbor Creek at the restoration project location, estimated flows are as follows (see Table 1):

- ♦ Low Fish Passage Flow — 2 cubic feet per second (cfs)
- ♦ High Fish Passage Flow — 15 cfs
- ♦ 100-year Flood — 90 cfs

Table 1. Design flow designation, method used to derive equations, and reference for flow estimation methods.

Flow	Method	Reference
Low fish passage flow	60-day low flow	WDFW 1994
High fish passage flow	Monthly 10% exceedance flow	Powers and Saunders 1998
100-year flood	Log-Pearson Type III	Sumioka et. al. 1998

Consideration of Flow Estimates

The only direct and quantitative application of flow estimates (above) was an assumption that the roughened channel boulders should be stable at flood flows up to (and above) the estimated 100-year flood. Boulders were sized with the same methods the engineer has used for 65+ constructed roughened channels, and all of these channels have remained stable since construction; some channels have been through flood flows substantially larger than the estimated 100-year floods, without damage.

A flow rating curve (Figure 1) for the proposed roughened channel was developed with Manning's equation (Chow 1959). These calculations showed that the 100-year flood flow depth would be about 2.5', and average water velocity would be relatively low for a peak flood (5 feet per second = fps). Mild hydraulic conditions even during a 100-year flood event are related to the 1.3% overall stream slope, which is low compared with many streams in western Washington.

Roughened channel gradient (3.0%) will be slightly higher than the overall channel slope downstream (1.3%), which indicate that hydraulic conditions in the downstream restored channel would be more placid than in the roughened channel. However, the slightly higher slope of the roughened channel (would increase flow velocity) will be counter-balanced by the relatively rough streambed (would decrease flow velocity). Overall, it is expected that hydraulic conditions through the roughened channel will be comparable to hydraulic conditions within riffle reaches of the downstream channel. Hence, Figure 1 could be used to get an overall impression of how flow rates would correspond to hydraulic conditions within the restored stream channel.

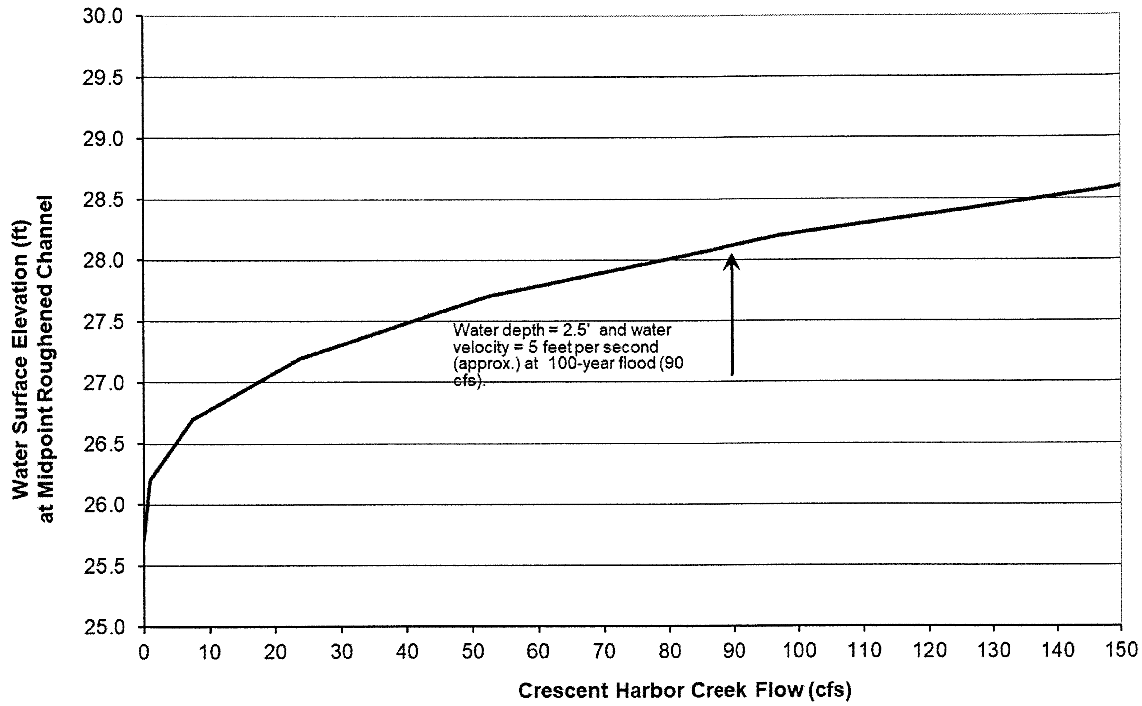

Figure 1. Rating curve for proposed roughened channel for Crescent Harbor Creek, to be just downstream of culvert under Crescent Harbor Road.

Low and high fish passage flows estimated above (2 to 15 cfs) are typically calculated to provide a range of streamflows that would occur most of the time; this range is conventionally used to evaluate fish passage conditions with an assumption that fish passage should be provided most of the time. This is a convenient range of flows to review with Figure 1, since the flow rating curve and hydraulic data would be similar for the roughened channel and proposed stream restoration reaches (not including the proposed pools). At the estimated low flow = 2 cfs, water depths would be 0.5' to 1.0' deep in riffle reaches, with average water velocity = 1 to 2 fps. The high flow (15 cfs) would result in water depths 1.0' to 1.5' deep, with average water velocity 2 to 3 fps. These hydraulic characteristics would be well within the ranges that native fish are adapted to in many small, low-gradient streams in western Washington.

<u>Evaluation of Potential for Backwater of Existing Culvert (Or Upstream Property)</u>

The project engineer completed a detailed survey near the existing culvert and prepared rating curves to quantitatively show the relationship between creek flow in cubic feet per second (cfs) and estimated water surface elevations at the downstream end existing culvert. The specific interest was whether or not the proposed channel would result in additional backwater of the existing culvert. Flow rating curves are shown in Figure 2, with all rating curves adjusted per creek alignment to hydraulically coincide with the downstream end of the existing culvert. Conclusions from the analysis of rating curves:

- On the chart (Figure 2), rating curves to the right represent channels that have higher flow capacity than curves to the left.

- For flows 0 to 40 cfs, the existing culvert and downstream channel would both have slightly more flow capacity than a roughened channel at 3% slope; see the thick solid line (proposed channel) to the left of dashed lines (existing conditions) in Figure 2. Within this flow range, the proposed roughened channel would create a minor backwater within the existing culvert, up to about 0.3' deep. Slightly higher water elevations (up to 0.3' higher) upstream within this flow range were not considered any concern.

- Above 40 cfs flow in Crescent Harbor Creek to the estimated 100-year flood flow and above, the proposed roughened channel would have increasingly high flow conveyance capacity compared with existing conditions. On-site, beginning at about 60 cfs flow, there would be a small water level drop from the existing culvert into the roughened channel. This water level drop would be about 0.5'-high at the estimated 100-year flood flow; there would not be any upstream backwaters at high creek levels, or during floods.

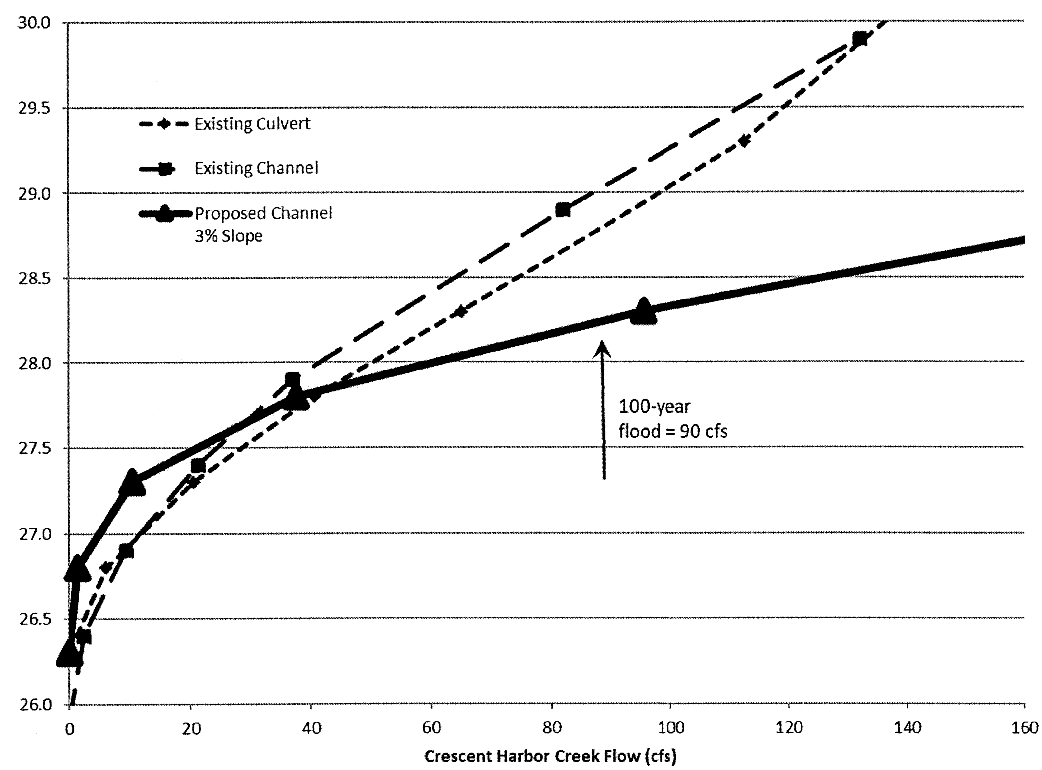

Figure 2. Rating curves for Crescent Harbor Creek, with channel data adjusted to estimated water surface elevations at the downstream end existing culvert. Rating curves to the right on this chart represent channels with higher flow capacity than curves to the left, per water surface elevations on the vertical axis.

4. Design for Restored Stream Channel

Stream channel design started with site survey measurements and observations, and determination of overall slope and length for the restored channel:

- The existing ditch below Crescent Harbor Road is about 1,000'-long and spans a vertical range = 14' +/- before it spreads out through dense vegetation near the estuary. Overall ditch slope = 1.4%.

- For channel restoration, the historic estuary is readily identifiable on-site, and this location was selected for the mouth of Crescent Harbor Creek. The gradually meandering channel between Crescent Harbor Road and estuary location would have a length = 1,420' and would span 19' vertical; overall slope = 1.3%.

Once the overall length, alignment, and slope for the restored channel was determined, the design incorporated the following measures and metrics to describe a non-uniform channel that would somewhat mimic what a stream may create through channel jumping (avulsion) and/or other natural fluvial processes.

- Riffles and pools were included in the design, with riffle slopes varying 1% to 4%, and pool depths varying 2' to 4' (Drawings 7 and 10). Each of the 13 pools would be excavated to be 20'-long (+/-), with an understanding that natural bedload transport and/or deposition may change the constructed pool dimensions.

- Streambanks slopes 1.5:1 to 3:1 were included in the design to add variability to the restored channel (vs. uniform excavation = ditch).

- Riffle reach lengths, slopes, pool locations, cross-section dimensions, and streambank slopes were determined randomly, and entered into spreadsheet form (Drawing 10).

- Rootwad and log placements were included in the design to increase in-stream habitat diversity and complexity (Drawings 3 to 7).

- Scissor log weirs or log constrictions were included just upstream of each proposed pool; these logs will result in relatively high water velocities during high flows which will increase the likelihood that constructed pools will maintain depth (like natural pools).

- The paramount requirement was to design a semi-natural channel between the existing estuary and existing culvert outlet, with a variety of habitat types, moderate stream complexity, and channel variables within the ranges listed above.

It is recognized that many different assumptions, opinions, approximations, etc. could be made with varying results for channel restoration, and that the channel restoration design is inherently subjective. The design engineer commonly sees constructed channels (designed by others) with straight alignments, uniform cross-sections, large wood anchored with chains and cables, pools with armored walls, washed gravel substrate entirely 1” to 2”-diameter, and other results obtained by stricter application of engineering design criteria. Crescent Harbor Creek restoration design respects that natural streams form by somewhat random processes during peak flow events, natural channels are not uniform for any metric, and in fact natural stream channels could be considered somewhat chaotic compared to the man-made order sometimes applied to natural systems. Random variations within the subject design (Drawing 10) are intended to result in a semi-natural stream channel.

5. Design for Roughened Channel

Roughened channels are an excellent technique for modifying stream channels to provide fish passage, for example downstream of a moderately under-sized culvert where a water level drop has been created (so-called shotgun culvert). Although the existing culvert under Crescent Harbor Road has not developed any fish passage barrier, the scour pool downstream of the road indicates that the culvert is moderately under-sized for Crescent Harbor Creek’s peak flow events. It was considered worthwhile to design an armored channel (roughened channel) downstream of the existing culvert to safeguard against possible future development of a fish passage barrier.

The engineer has designed (and had built) multiple roughened channels state-wide for 25+ years; all have been successful for fish passage and other stream functions (e.g. bedload transport, substrate for benthos production, wood and debris passage). Previous designs have had gradients from 2% to 12%, and channel lengths have been up to 400’. This experience has been included in the subject design, with an overall observation that the proposed 40’-long boulder channel at 3% slope will be a short riffle downstream of the existing culvert, with an armored streambed and banks to be stable at least up to the 100-year flood flow event. Design details are shown on Drawings 12 and 13, and are not repeated in this text.

6. Design for Other Project Elements

Miscellaneous and relatively minor project elements are briefly described below; these elements have all been incorporated into the 13 final design drawings referenced in this report.

- The existing ditch (Drawing 2) will be completely filled with native soils excavated for the new creek channel alignment (Drawing 9), after completion of the project and establishment of perennial flow into the restored creek channel. On-site agricultural ditches abandoned long ago will also be filled with excavated soils (Drawing 9). These linear fill areas will be seeded (native plants), then weed-free straw will be spread for mulch (Drawing 8).

- Stream channel restoration will bypass the existing (man-made) wetland area, as shown on Drawings 2 and 3. There would be advantages for channel restoration construction through the wetland, because the soil berm to construct the wetland appears to span across the historic creek alignment. However, the advantages of building the restored channel through the wetland were more than overcome by the disadvantages, including adverse impacts to herons, beavers, and other native flora and fauna that have colonized the man-made berm and pond. The wetland does not appear to receive any streamflow from the ditch, and the proposed channel would not discharge into the existing wetland; environmental features would remain as-is with holistic benefits to native plants and animals.

- Detailed project requirements for switching creek flow from the existing channel (ditch) to restored channel, including SRSC recovery and relocation of native fish, are shown and described on Drawing 11.

7. Construction Quantities and Cost Estimate

Project drawings and design notes, etc. were used to develop the list of construction items and material quantities, which cumulatively were used for estimation of the construction cost for the stream restoration project. The quantity take-off and construction cost estimate for the project is summarized in Figure 3. The quantity take-off format (Bid Form) is similar to the information that would be provided to general contractors to bid the construction project. The estimated costs for unit prices listed on the Bid Form (Figure 3) are comparable to similar and recent project construction experience in western Washington. Total estimated construction cost would be $223,000 for the project.

Figure 3: Bid Form
Crescent Harbor Creek Restoration

Contractor: **Engineer's Estimate** Date: **1/26/2021**

Item No.	Spec.	Refer to Drawing	Item	Qty	Unit	Unit Cost	Total Cost
1	1-09	1	Mobilization	1	LS	$15,000	$15,000
2	1-50	2, 3, 4, 10	Surveying (most will be done by engineer)	1	LS	800	800
3	2-01	2	Clearing (on-site disposal)	1.5	Acre	7,600	11,400
4	2-03	5, 6, 9, 13	Excavation (includes haul & place on-site)	4,800	CY	16	76,800
5	2-03	5, 6, 7	Excavate & Backfill (install large wood)	800	CY	20	16,000
6	2-15	11	Water Control (flow bypass near culvert)	1	LS	2,400	2,400
7	8-30	2, 5, 6	Large Wood Retrieve & Place (includes weirs)	74	EA	150	11,100
8	8-30	2, 8	Erosion-Control Seed	60	LB	20	1,200
9	8-30	8	Jute Matting	24,000	SF	0.25	6,000
10	8-30	2, 8	Weed-Free Straw	120	Bale	40	4,800
11	8-30	8	Native Conifer Trees	250	EA	40	10,000
12	8-30	8	Native Shrubs (Pacific willow)	130	EA	30	3,900
13	9-20	5, 6, 7	Streambed Mix (cobbles, gravel, washed sand)	780	TN	40	31,200
14	9-25	12, 13	Boulders (12" to 24"-size)	140	TN	80	11,200
15	9-30	12, 13	Gravel & Sand for Roughened Channel (sluice)	60	TN	50	3,000
Construction Subtotal (without sales tax):							$204,800
Washington State Sales Tax (@ 8.7%):							$17,818
Total Construction Cost (rounded):							$223,000

CY = cubic yard	LB = pound	SF = square foot
EA = each	LS = lump sum	TN = ton

8. References

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