Agenda Report Reviewed by:
City Manager: [signature]

CITY OF SEBASTOPOL
CITY COUNCIL
AGENDA ITEM

Meeting Date:	September 6, 2022
To:	Honorable Mayor and City Councilmembers
From:	Kari Svanstrom, Planning Director
Subject:	Calder Creek Naturalization Final presentation, consideration of approval of concept and authorize work with California Urban Stream Preservation (CUSP) on grant applications
Recommendation:	Receive Report, Provide Direction to Staff, and Approval Ives Park Calder Creek Naturalization Concept (Phase 1) and Authorize Staff to Execute a Service Agreement with California Urban Stream Partnership (CUSP) and to submit a Grant to the Coastal Conservancy
Funding:	Currently Budgeted: _______ Yes _______ No ___X__ N/A Net General Fund Cost: $

Account Code/Costs authorized in City Approved Budget (if applicable) ___AK_____ (verified by Administrative Services Department)

INTRODUCTION/PURPOSE:

Review and consider approval of the final Calder Creek naturalization within Ives Park; review and provide feedback on potential future phases (Phase 2, east of downtown, and phase 3, downtown). Additionally, authorize continued work on the project with California Urban Stream Partnership (CUSP) and to pursue grant funding to further the project design and engineering. This will position the City for potential grants for implementation.

BACKGROUND:

The approved Ives Park Master Plan includes the concept of naturalizing Calder Creek as it runs through the Park. The City is working with WRI (Waterway Restoration Institute) and a Switzer Foundation Fellow, Jessica Hall, to help envision what the naturalization of Calder Creek could be, both within Ives Park, as part of the Master Plan, as well as up- and down- stream conditions. Conceptual approaches to restoring Calder Creek through downtown and east of downtown are also being explored as part of the project. Additionally, GHD is developed a hydrology report to test the feasibility of the concepts, as well as understand flooding issues along the creek, and test the potential scenarios for improving this (such as the flooding of Petaluma Avenue in October 2021 rain storm event).

On February 2, 2022, the City Council reviewed the potential options for Ives Park Calder Creek naturalization in Ives Park, and selected "Option 2" for further development. Since that time, staff, WRI, and GHD engineering have continued to develop and test this concept, as well as develop concepts for the eastern portions of Calder Creek as it travels to the Laguna de Santa Rosa. The team presented the developed concept for Calder Creek in Ives Park , as well as potential future phases, to the Planning Commission at its August 9, 2022 meeting. The Planning Commission unanimously recommended the Council review and approve the Phase 1 Calder Creek concept (within Ives Park) and review and provide input on the future phases. The Commission also recommend the City Council authorize continued work with Ann Riley, Jessica Hall, and Joshua Bradt, by authorizing a service agreement for this work (at zero cost to the City other than staff time, which will be greatly reduced given the work CUSP will be contributing).

DISCUSSION:

This project has several components. This includes refinement of the "Option B" alignment within Ives Park approved by Council on February 1, 2022, as well as later phase concepts for the creek within downtown and east of downtown. Jessica Hall has incorporated the input from the Commission as well as Council into the final concept for the Creek naturalization, maintaining the Little League fields.

Jessica Hall will present the Option 2 / selected concept to the Council as part of her final presentation. This concepts proposes a stream restoration concept that builds on the 2013 Ives Park Master Plan, maintaining the existing uses of the park while adding the necessary stream length and meander for a "dynamically stable" stream channel (one that erodes and deposits sediment in balance to maintain its channel form). It also widens and reconnects the stream to a functioning floodplain, creating more space for flooding or backwatering from extreme storms. Within the creek corridor, picnicking, trails, wading, informal nature exploration, and a sculpture garden are all accommodated.

Options for modifying the Jewell Street/Willow Street intersection were evaluated in terms of pedestrian and vehicular movement, and benefit to the creek and park. A proposed "T" intersection was included in the Ives Park Master Plan with Creek Restoration presented here. Jessica Hall/WRI developed different options for staff review (with Fire, Police, and Engineering). The chosen concept was then discussed with Steve Weinberger of W-Trans for initial review. While additional traffic engineering will be needed to further this component, the concept was is feasible. W-Trans had previously studied potential changes at this intersection, and while the Council at that time did not move forward with this option due to cost. This option will also require additional outreach to nearby residents, as their frontages may be impacted (no driveways will be closed or relocated, some parcels would potentially have larger front yards).

Beyond Ives Park (Phase 2 and 3), opportunities for Calder Creek were explored from High Street to Petaluma Avenue. In some cases, the culverted creek crosses through private property. Therefore, the Vision Plan shows possibilities to demonstrate to property owners that the buried creek as a potential attraction that adds value to developments, while also serving as a public asset for its flood management, stormwater and habitat benefits. With chronic flooding at Petaluma Avenue due to sedimentation in the stormdrain pipes and non-native trees obstructing flows in the open-channel reaches of Calder Creek in the Railroad Forest, this project also suggests increasing flood capacity within the Railroad Forest by removal of the railroad fill prism and replacement of the trail with a boardwalk, daylighting approximately three hundred feet of the creek that is currently culverted and allowing it to establish its own channel.

Hydrology

GHD has analyzed the new creek form, and found that it would reduce flooding within Ives Park. Additionally, the more natural creek form would reduce future sedimentation within the City's stormwater culverts, which as become a major issue and maintenance need. (GHD study also found that improvements east of downtown would further assist these issues).

Next Steps

The surrounding programmatic features within Ives Park and Ives Park Master Plan are illustrative of how the various elements might be configured. Formal revisions of the non-creek programmatic elements would be formally reviewed in a separate, subsequent process that would involve additional public participation from the community, and the Planning Commission has included these in it's future Workplan.

The downtown vision portion of the concept would require additional outreach to property owners, this portion represents a vision of what a naturalized creek in downtown could be, in support and coordination with private property owners and City property. The concept east of downtown, within the City's property to the Railroad

Forest parcel, includes areas controlled by Sonoma County Regional Parks, and would require outreach and a partnership with them. After review and input from the Planning Commission and Council, staff will pursue these in a future phase work.

City staff has been in discussion with Ann Riley and Joshua Bradt, Co-Directors of the California Urban Stream Preservation (CUSP), a non-profit organization related to WRI, to continue work on this project. CUSP has been preparing a pre-grant proposal prepared with Prunuske Chatham Inc., a local environmental consulting firm, to submit to the Calif Coastal Conservancy on behalf of the City. The pre-proposal will assist Coastal Commission staff in helping the city and CUSP understand which grant programs are appropriate for the project. in It is anticipated that the pre-grant proposal would fund additional design work for the Park, with an anticipation that the grant would cover costs to progress the Phase 1 (creek within Ives Park) to 65% design (890-85% is generally considered 'shovel ready' for most subsequent grants the City may pursue), and allow for further outreach, phase 2 east of Petaluma Avenue to Railroad Forest/Laguna) to 35% design, and phase 3 including potential design charrettes with local architects and landscape architects, to progress the concept in downtown (to 10% design)m to include outreach to property owners, downtown stakeholders, and Regional Parks).

The Planning Commission, which acts as the City's Parks Commission, has received this proposal, and unanimously recommended the Council approve the Calder Creek Phase 1 concept and authorize both a service agreement to work with CUSP and authorize CUSP to submit a grant application in conjunction with City staff. There is no financial commitment from the City to do this.

GOALS:

The Calder Creek Naturalization project relates to the following City Council Goals and General Plan Actions:

Council Goals:

Goal 2- Maintain, Improve, and invest in the City's Infrastructure, including parks;
Goal 4 -Maintain and Enhance the City of Sebastopol as a Walkable/Bike-able Community and Enhance the City's Commitment to Promotion of our public's health by Creating and Participating in City and Community Programs, Services and Policies;
Goal 4.1 – Create a Safe, Healthy, and attractive Environment for Residents and Visitors;
Goal 4.1.3 Implementation of the Ives Park Master Plan;
Goal 4.1.4 Evaluate public commons and land and identify opportunities to enhance benefits to the community.

PUBLIC COMMENT:

As of the writing of this staff report, the City has not received any public comment. However, staff anticipates receiving public comment from interested parties following the publication and distribution of this staff report. Such comments will be provided to the City Council as supplemental materials before or at the meeting. In addition, public comments may be offered during the public comment portion of the agenda item.

PUBLIC NOTICE:

This item was noticed in accordance with the Ralph M. Brown Act and was available for public viewing and review at least 72 hours prior to schedule meeting date.

FISCAL IMPACT:

No funding is required to approve the Concept. Implementation of the concept is anticipated to be included in grant applications and future Capital Improvement Plan budgets. There is no cost to enter the Service Agreement with CUSP, other than staff time (approximately 80-100 hours for the Fiscal Year, equivalent to $10,000-15,000).

The City has also approved $80,000 in the FY 22-23 Capital Improvement plan (CIP) for continued work on the Calder Creek naturalization project in Ives Park. The allocation of these funds are not being committed at this time, but likely will be needed for both additional traffic engineering work to develop the Willow/Jewell intersection, and hydrology work to develop the creek design. Allocation of those funds is not requested at this time.

RECOMMENDATIONS:

1) Receive Report and provide Direction to staff on the Calder Creek Naturalization project plans; and
2) Approve the Final Concept Ives Park Calder Creek Naturalization Concept (Phase 1) and;
3) Authorize staff to:
    a. execute a Service Agreement with California Urban Stream Partnership (CUSP) and,
    b. authorize staff to work with CUSP, and for CUSP to submit a Grant application on behalf of the City to the Coastal Conservancy

Attachments:
Calder Creek Restoration and Vision Concepts final report
Calder Creek Naturalization Final Presentation

Service Agreement with California Urban Stream Partnership
Coastal Conservancy pre-grant proposal

Technical Reports:
Basis of Design (Wilding Design Institute/WRI)
GHD Calder Creek Modifications Hydrologic and Hydraulic Modeling Assessment Report

Additional information:

The Ives Park Master Plan, can be found on the City's Parks Planning page:
https://www.ci.sebastopol.ca.us/City-Government/Departments-Services/Planning/Parks-Planning

California Urban Stream Partnership: https://www.californiaurbanstreamspartnership.com/

CALDER CREEK

RESTORATION & VISION CONCEPTS

Sebastopol, California

Waterways Restoration Institute

WILDLING DESIGN STUDIO

An ecological approach to recreation & stormwater management

CALDER CREEK VISION PLAN

Above: Overview of Calder Creek Restoration Concept and Vision Plan opportunity areas

Sebastopol is a small, charming city known for its agricultural history and environmental ethos. The restoration of Calder Creek builds on this sensibility, bringing back the invigorating experience of a living stream to public spaces, and providing an inviting backdrop that creative and thoughtful urban design can respond to. Moreover, creek restoration here reestablishes watershed processes that build resilience to climate change and promote a natural processes-infused approach to integrated water management.

This Summary explores of Calder Creek restoration opportunities from Jewell Avenue to the Laguna de Santa Rosa. This project was focused on Ives Park, the city's "central park", with consultations with individual upstream property owners as well as "vision" level concepts for daylighting the creek through downtown Sebastopol.

Background

Draining a one square mile watershed, the creek initially traverses low hills and low density residential properties. Through these properties, willow riparian habitat along the creek supports songbirds, hawks, waders, aquatic birds, frogs, minks and river otters. While an 1886 newspaper article noted salmon in the creek, it was better known for a water wheel and wood slate dam, the latter which created a seasonal swimming pond. When the creek was engineered into a channel and also culverted into underground stormdrain pipes, its footprint was reduced, and flood flows increased in velocity. Eventually operation of the seasonal pond ceased, and the remaining creek area at Ives Park, with steep channel walls and floodable areas, became a management concern. The creek remains in this straightened and hardened channel through Ives Park, and is otherwise forgotten through downtown. It outlets in the Railroad Forest, approximately three hundred feet downstream from the Joe Rodota Trail trailhead at Petaluma Avenue.

"The riparian canopy of the creek produces a zone of greater evapotranspiration, offsetting urban heat islands with shade and spaces for relaxation and respite…"

Forward-looking Creek Restoration

As climate change and population pressures increase, the need for more housing, preservation of biodiversity, and water resource management is becoming more acute. Restoration of Calder Creek, including daylighting of culverted reaches and reestablishing and reconnecting its floodplain, creates a lower-maintenance option for stormwater storage, groundwater recharge, habitat and recreation. The restored channel corridor provides greater capacity and increases storage for those times when the Laguna de Santa Rose backwaters. The riparian canopy of the creek produces a zone of greater evapotranspiration, offsetting urban heat islands with shade and spaces for relaxation and respite. This will be a benefit through Ives Park as well as through any daylighted urban areas.

At Ives Park, the proposed stream restoration concept builds on the 2013 Ives Park Master Plan, maintaining the existing uses of the park while adding the necessary stream length and meander for a "dynamically stable" stream channel (one that erodes and deposits sediment in balance to maintain its channel form). It also widens and reconnects the stream to a functioning floodplain, creating more space for flooding or backwatering from extreme storms. Within the creek corridor, picnicking, trails, wading, informal nature exploration, and a sculpture garden are all accommodated. Options for modifying the Jewell Street/Willow Street intersection were evaluated in terms of pedestrian and vehicular movement, and benefit to the creek and park. A proposed "T" intersection was included in the Ives Park Master Plan with Creek Restoration presented here.

Beyond Ives Park, opportunities for Calder Creek were explored from High Street to Petaluma Avenue. In some cases, the culverted creek crosses through private property. Therefore, the Vision Plan shows possibilities to demonstrate to property owners that the buried creek as a potential attraction that adds value to developments, while also serving as a public asset for its flood management, stormwater and habitat benefits.

With chronic flooding at Petaluma Avenue due to sedimentation in the stormdrain pipes and non-native trees obstructing flows in the open-channel reaches of Calder Creek in the Railroad Forest, this project also suggests increasing flood capacity within the Railroad Forest by removal of the railroad fill prism and replacement of the trail with a boardwalk, daylighting approximately three hundred feet of the creek that is currently culverted and allowing it to establish its own channel.

Acknowledgements

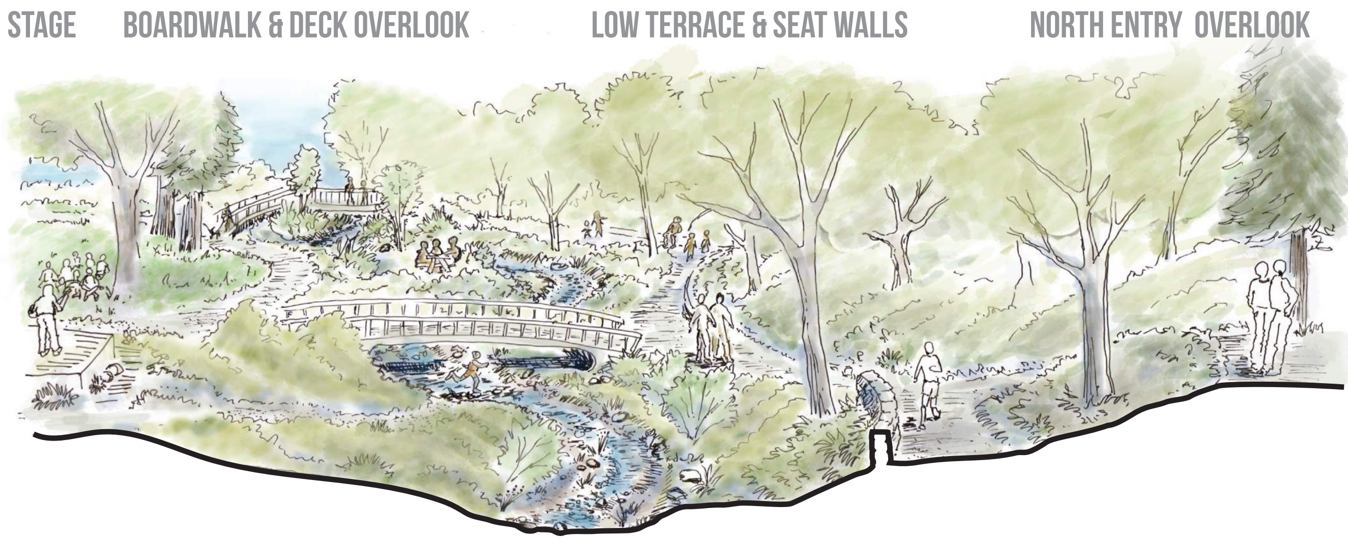
This project was made possible by a Switzer Foundation Leadership Grant to the Waterways Restoration Institute (WRI) with Wildling Design Studio (Wildling), and the cooperation of the City of Sebastopol.

IVES PARK MASTER PLAN UPDATE

OVERVIEW

CALDER CREEK RESTORATION INFORMS MASTER PLAN UPDATE

1 New T Intersection
2 New park entry
3 Rose garden
4 Preserved redwood trees
5 Boardwalk trail section
6 New stage
7 Restored Calder Creek
8 Central green 9 Picnic area
10 Pedestrian bridge
11 Vehicular access bridge
12 Baseball field
13 Pool
14 Playground
15 Sculpture Garden / High Entry
16 BBQ area



Restoration of Calder creek creates a safe and accessible interface to bring the public back to the water's edge, increases habitat, flood storage and groundwater infiltration.

A portion of the existing vertical channel wall is maintained to protect a stand of redwood trees. A deck is cantilevered over this wall, with an overlook crossing the creek at the current outlet location, marking a terminus of an accessible loop trail around the creek. A pedestrian bridge protects a city sewer main within its alignment, while another bridge is rated for vehicular access. The design modifies an existing sculpture garden and uses the riparian canopy as a backdrop for some of the artwork. The playground and a bbq area are shifted to accommodate the creek, while the stage is relocated along the creek to create a large central green with seating upslope from performances.

With a geomorphic approach to restoring the channel, wide floodplains also accommodate trails, relaxing, exploration, play and habitat. Preliminary grading focused on an equilibrium stream and accessible pathways, inviting all users to experience the creek. Terracing and some vertical walls area also used to achieve this. The increase in varied terrain creates new sightlines and points of interest within the park.

Facing Page: Master Plan Update with Creek Restoration

Above: Section through creek near upper Jewell entry looking upstream towards pedestrian bridge with protected sewer line, and in the distance, redwoods, boardwalk and overlook.

Right: View of park entry from High Street with sculpture garden in the foreground. Landscape terracing in the background balances an accessible walkway with the creek's geomorphic equilibrium channel design approach.

DOWNTOWN VISION CONCEPTS

CALDER CREEK CAN INSPIRE NEW AMENITIES AND ATTRACTIONS

1 Daylighted Creek
2 Boardwalk
3 Overlook
4 Promenade
5 Seating area
6 Creek access
7. Walkway

Through downtown Sebastopol, public and private parking areas are shown converted back to a daylighted Calder Creek. Due to site constraints, there is a naturalized creek bed with vertical channel walls.

Between High and Main Street, these narrow constraints in one area result in cantilevered boardwalks along the edges, with one stretch of boardwalk crossing through the creek corridor. This is to provide support and protection for an existing city sewer main.

Top: Vision Concept for daylighting Calder Creek between High and S. Main Streets.

Above right: A daylighted Calder Creek can create an open space amenity for future urban design if desired by property owners.

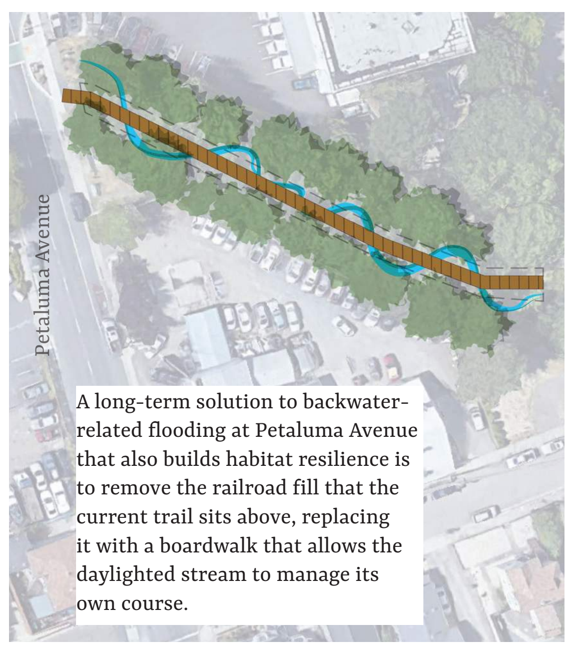
Opposite page, top: Vision Concept for daylighting Calder Creek between S. Main Street and Petaluma Avenue.

Opposite page, left: A promenade leverages the urban cooling and shade provided by the daylighted Calder Creek corridor, with outdoor dining and socializing.

S. MAIN STREET - PETALUMA AVENUE

Between Main Street and Petaluma Avenue, the creek creates a visual focus along a promenade that includes a side path gently sloping to the creek bottom. A narrower walkway completes a loop around the channel while maintaining some parking. This promenade includes extended terraces for seating ideal for future dining, from food truck "food courts" or restaurants associated with new development.

RAILROAD FOREST

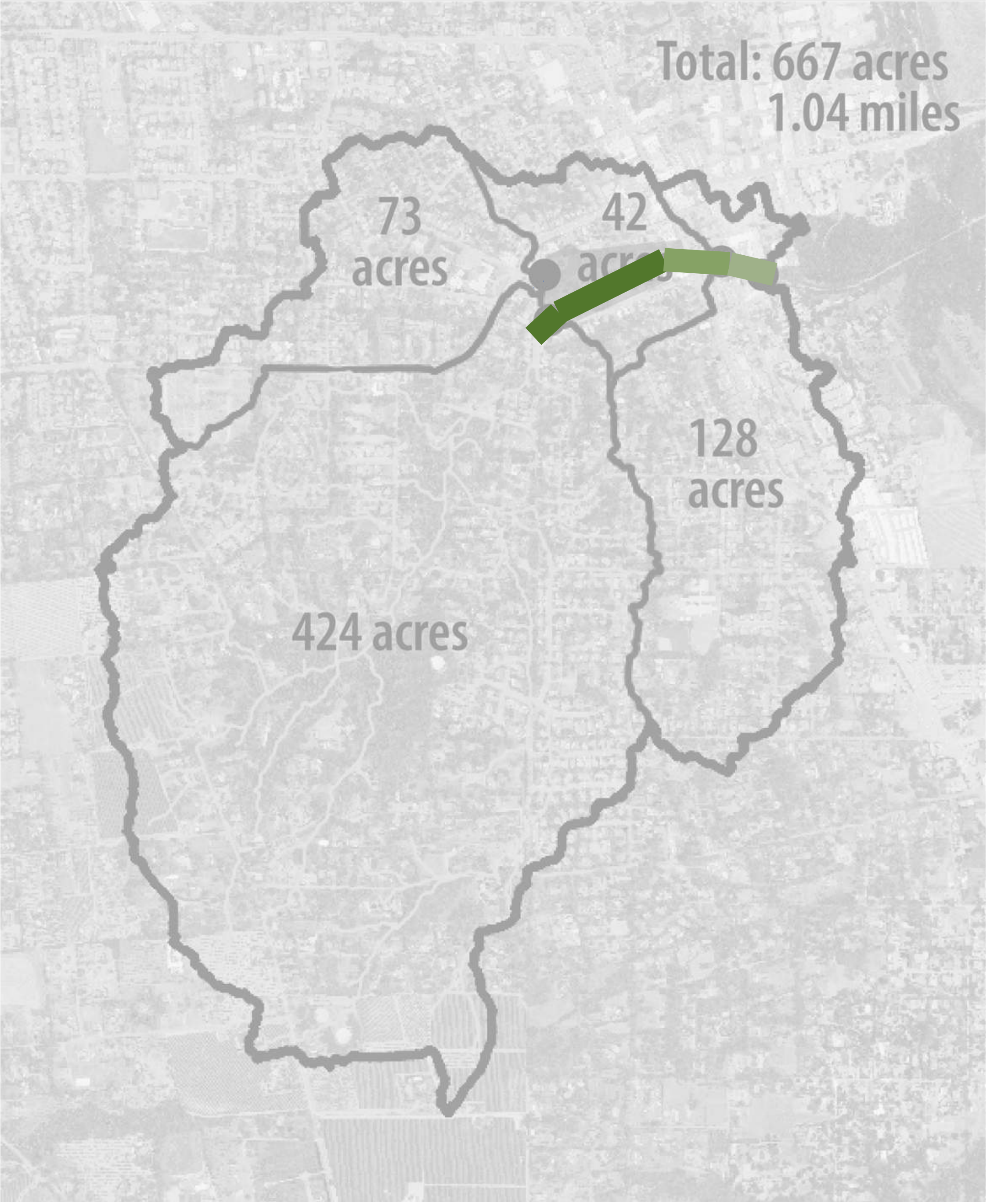


A long-term solution to backwater-related flooding at Petaluma Avenue that also builds habitat resilience is to remove the railroad fill that the current trail sits above, replacing it with a boardwalk that allows the daylighted stream to manage its own course.

WILDLING DESIGN STUDIO

Waterways Restoration Institute

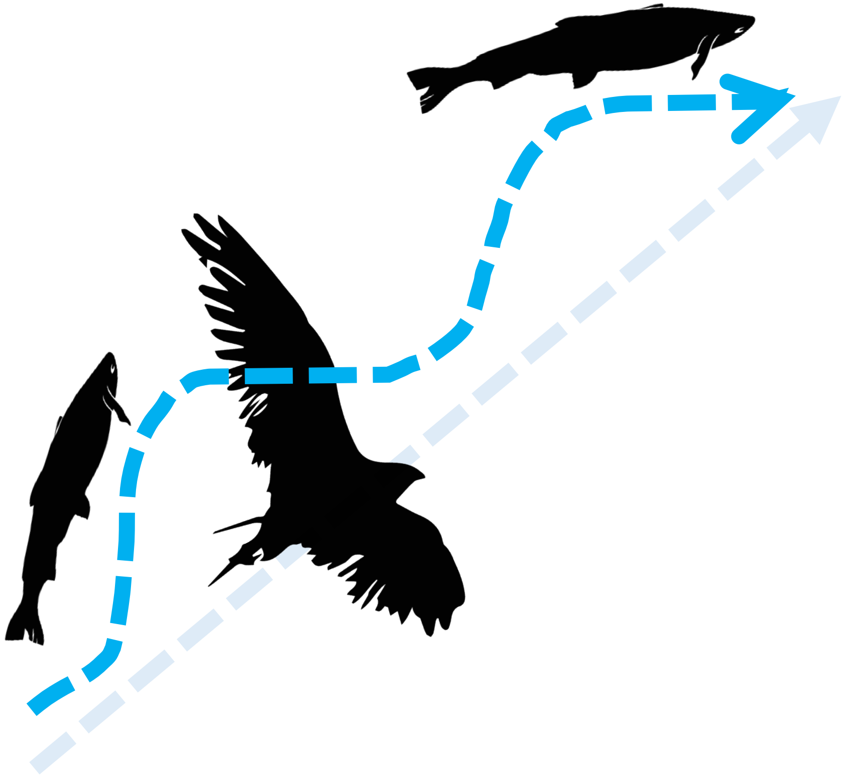
Today's focus: Ives Park (and a little of Downtown



Drainage Area & Design Parameters

	Drainage Area (Square Miles)	Bankfull Width (ft)	Bankfull Depth (ft)	Floodprone Width (ft)
The Intersection & Ives Park	0.77	8-10	1.5	20
Downtown	0.84	8	3	22
Railroad Forest	1.04	8	3	24

Stream Geometry: Relationship between Slope – Stream Length - Sinuosity

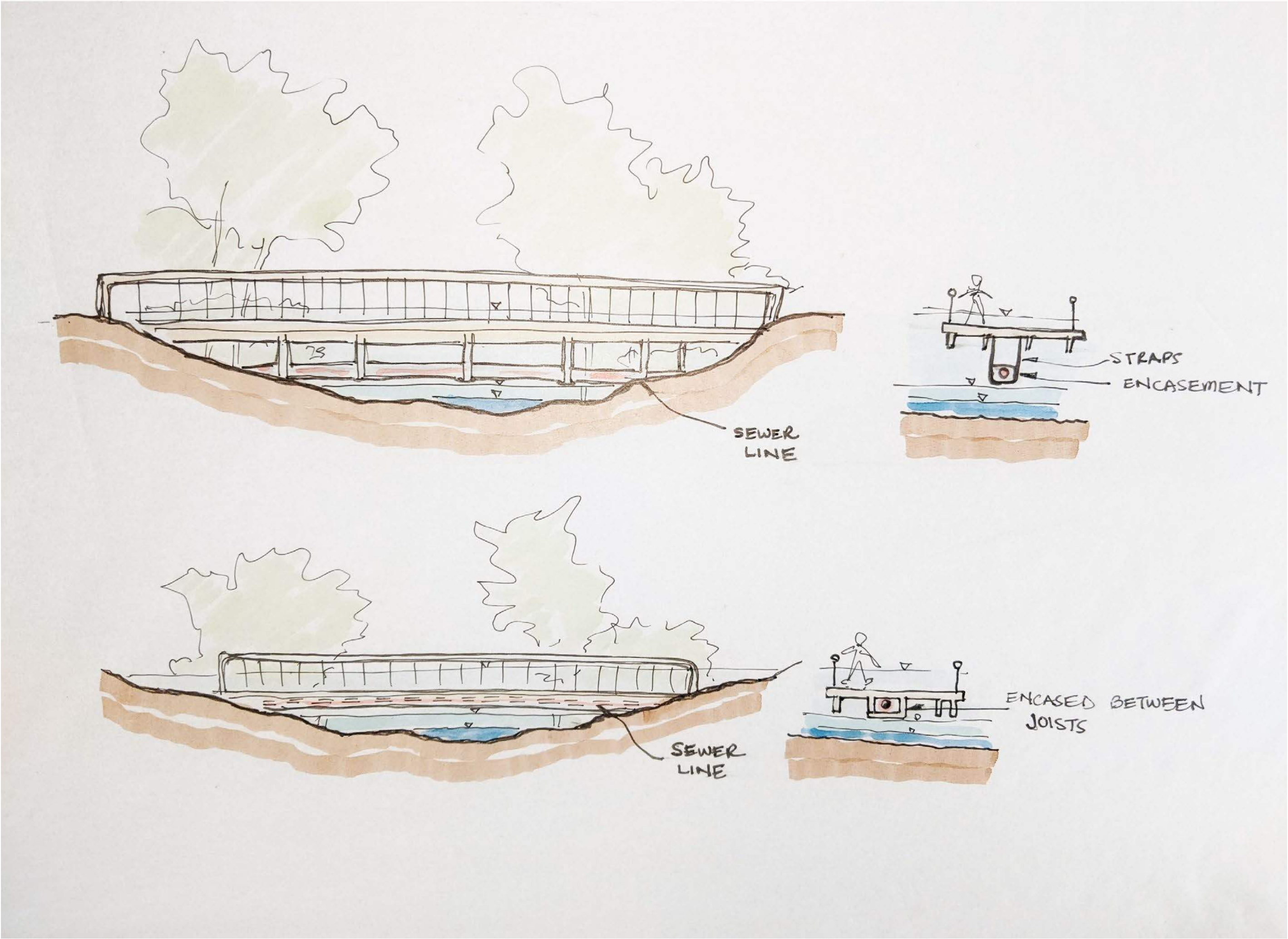


Stream Length
Ratio of Fish/Bird = 1.3

Sinuosity (Curviness)
Ratio related to channel width

Ideal stream channel geometry
for general stability

Utility Crossing Concepts



Preliminary estimates of channel depth relative to utility position suggest that it may be able to be encased or hung from a bridge for protection.

Ives Park (Includes Jewell Intersection)

Constrained

- Closest to current alignment
- Preserves some redwood trees
- Playground near BBQ and restroom
- Event area large lawn
- Rose garden centrally located
- Seating area by creek w/stepped access
- Stream length least stable

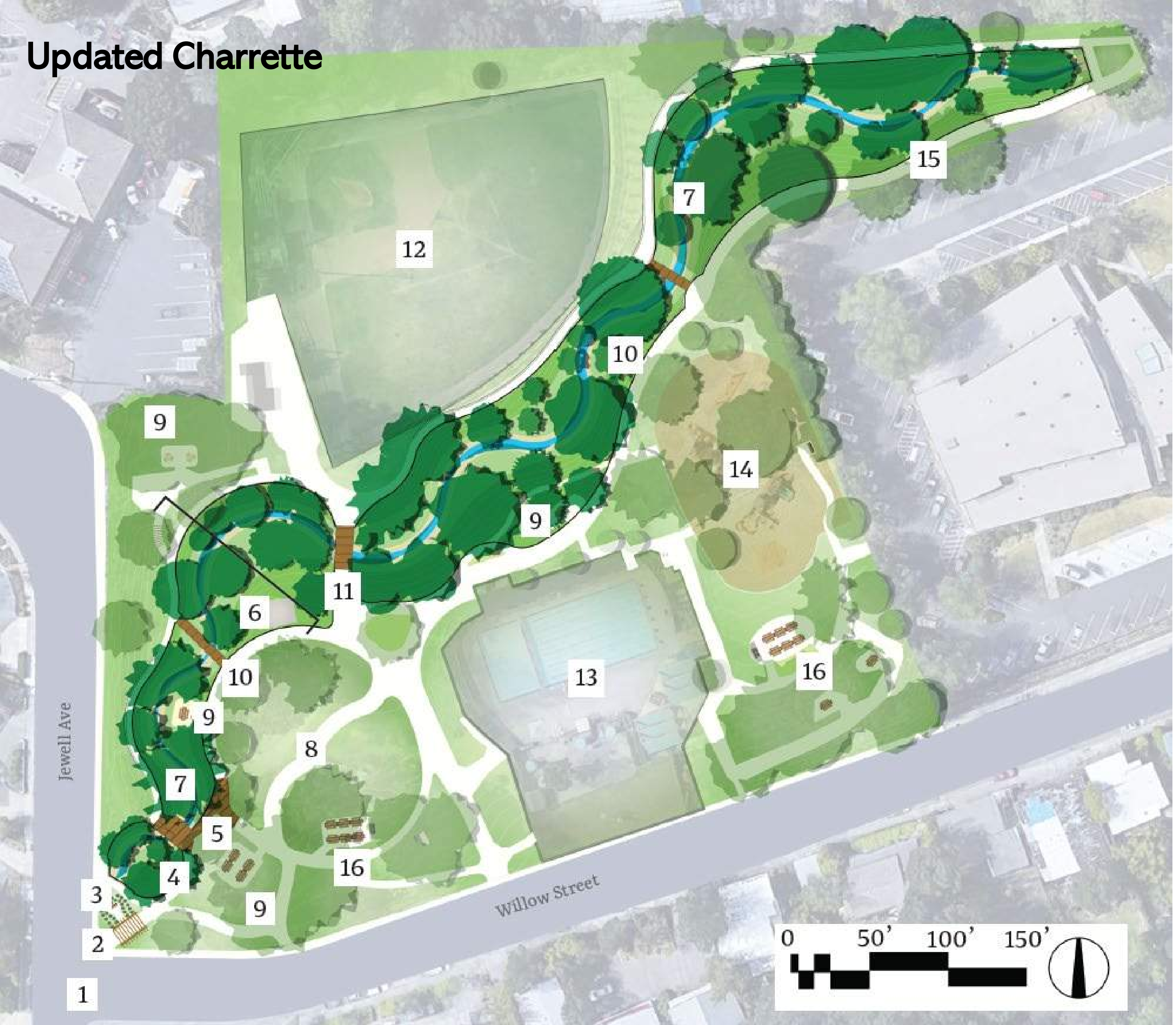
Updated Charrette

- New alignment winds through park
- Probably preserves more redwood trees
- Playground near Arts Bldg parking
- Event lawn includes preserved redwoods
- Rose garden at Jewell entry
- Stream length on target for stability

Stable Planform

- Creek defines the park
- Preserves some redwood trees
- Playground near Arts Bldg parking
- Largest event/great lawn
- New Fairy Tale Forest or other nature play area
- New dog park or other medium sized lawn activity area
- Small lawn area
- Stream length and planform most stable

Updated Charrette



CALDER CREEK RESTORATION INFORMS MASTER PLAN UPDATE

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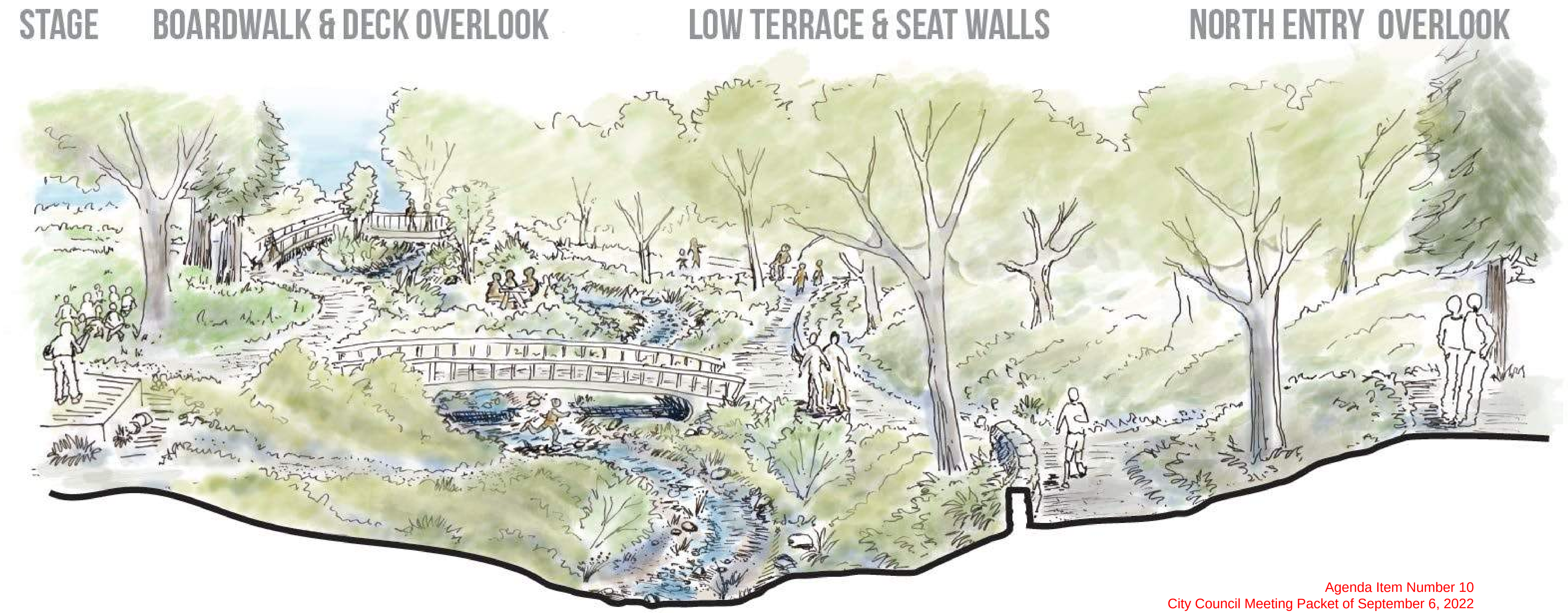
Sectional View

CALDER CREEK RESTORATION INFORMS MASTER PLAN UPDATE



CALDER CREEK RESTORATION INFORMS MASTER PLAN UPDATE

Art Walk Perspective

Downtown Preliminary Vision Concept

CALDER CREEK RESTORATION

DOWNTOWN VISION CONCEPTS

CALDER CREEK CAN INSPIRE NEW AMENITIES AND ATTRACTIONS

Agenda Item Number 10

CALDER CREEK RESTORATION

DOWNTOWN VISION CONCEPTS

CALDER CREEK CAN INSPIRE NEW AMENITIES AND ATTRACTIONS

HIGH STREET - S. MAIN STREET

Mixed Use/Downtown Commercial Development Concept Perspective

1 Daylighted Creek
2 Boardwalk
3 Overlook
4 Promenade
5 Seating area
6 Creek access
7. Walkway

CALDER CREEK RESTORATION

DOWNTOWN VISION CONCEPTS

CALDER CREEK CAN INSPIRE NEW AMENITIES AND ATTRACTIONS

S. MAIN STREET - PETALUMA AVENUE

Mixed Use/Downtown Commercial Development Concept Perspective

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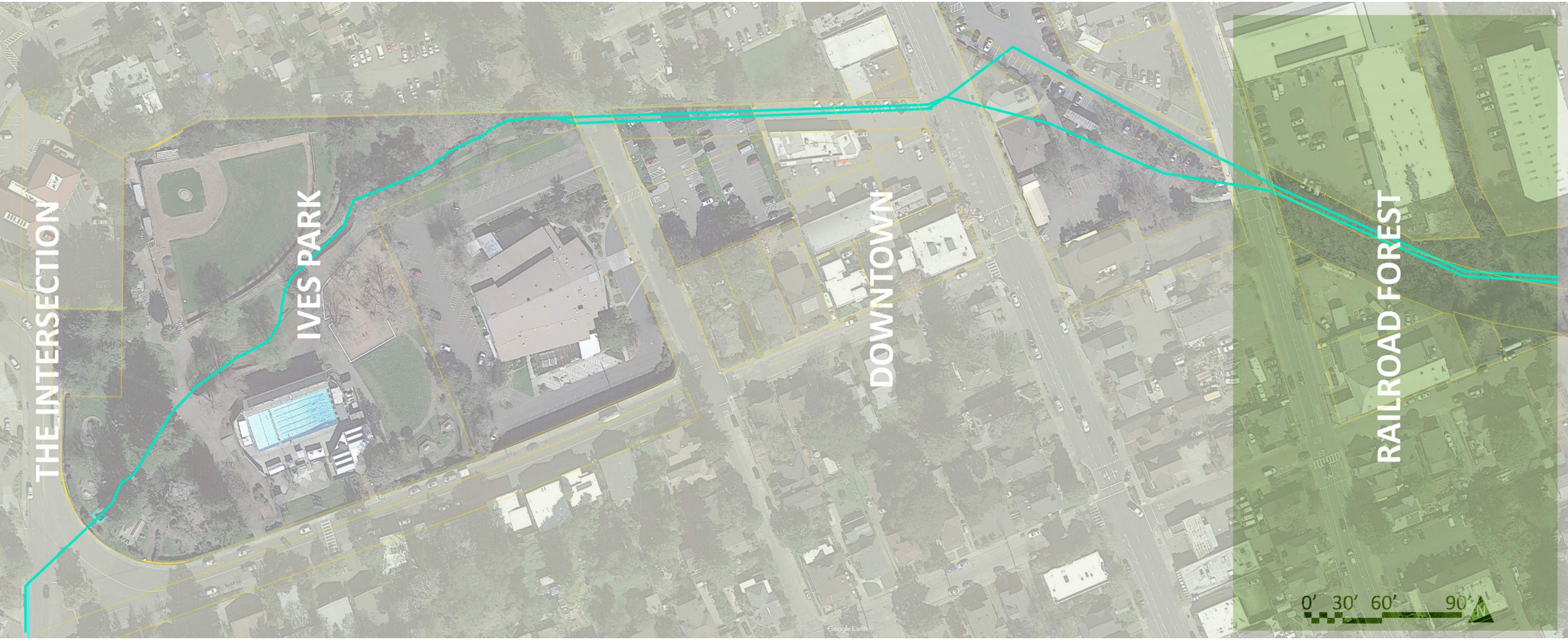
Railroad Forest Preliminary Vision Concept



Preliminary Daylighting Concept: Remove trail fill, use boardwalk to preserve existing trees

Service Agreement Between the City of Sebastopol and the Earth Island Institute on behalf of the California Urban Stream Partnership

Background

The service agreement describes the work plan that will be implemented by the California Urban Streams Partnership (CUSP), a program of the Earth Island Institute. Earth Island Institute is a 501)(c)3 non-profit corporation. CUSP personnel have designed and constructed urban stream restoration projects since 1994.

This is a Services Agreement ("Agreement") dated as of September 6, 2022 to, between **The City of Sebastopol** (City) and the **Earth Island Institute**, a California nonprofit corporation, for the **California Urban Stream Partnership** (CUSP) (referred to herein as "CUSP").

1. Services

1.1 Scope

CUSP will perform services ("Services") for the City as described in the Statement of Work ("SOW") attached as Exhibit A. If the City wishes to engage CUSP for additional services the City will notify CUSP, and if appropriate CUSP will prepare a separate SOW describing the specific assignment.

1.2 Personnel

The personnel engaged in the services are Ann L. Riley, PHD, and Joshua Bradt, Co-Director of the California Urban Stream Partnership and Jessica Hall, its Outreach and Restoration Director.

1.3 Cooperation

The City of Sebastopol acknowledges that the effectiveness of an engagement depends in large part on the information provided and the actions the City undertakes. To that end, the City will cooperate with CUSP in the performance of Services, including, without limitation, providing CUSP with timely access to information and ensuring the accuracy and completeness of the information the City provides to CUSP.

1.4 Scope Changes

If you request CUSP to do work relating to the project that is not included in the scope as described in the applicable SOW, CUSP will not perform any Service not authorized the SOW contained in this agreement, unless mutually agreed to by both the City and CUSP.

1.5 Compensation

No payment for the Services and reimbursements for expenses will be due as set forth in the applicable SOW.

2. Confidentiality and Work Product

2.1 Confidential Information

CUSP will use your Confidential Information (defined below) only in connection with our activities under this Agreement and will keep it confidential. CUSP may disclose Confidential Information only to contractors or other persons who need access to the information for the purposes contemplated by this Agreement, or as otherwise required by law. All Confidential Information furnished by the City is and shall remain the City's property. "Confidential Information" means all information furnished to CUSP by the city that is expressly marked or otherwise designated by the City as "Confidential." It does not include information that is generally available to the public, information already known by CUSP before entering into this Agreement, or information CUSP independently develop.

2.2 Work Product

CUSP in performing Services may furnish the city with reports specifically prepared for the City (the "Work Product"). Subject to the terms of this Agreement, the City will own all such tangible Work Product. The City acknowledge that CUSP own and retain all right, title, and interest in and to any and all proprietary know-how and methodologies CUSP use in creating the Work Product or in otherwise providing Services. The City may use the work products for use by its contractors or other entities for the purpose of advancing project designs, permits, fund raising, and other project implementation needs.

3. Relationship

3.1 Publicity

The City agrees that, subject to Section 2.1 of this Agreement, CUSP may, in our discretion, identify as a client in internal and external communications, including on our website and in our outreach materials.

3.2 Limitation of Liability

Neither the City or CUSP, or its partners performing the work will be liable to the other for any incidental, special, consequential, exemplary, punitive, or indirect damages arising out of or otherwise related to this Agreement, even if the other party has been apprised of the likelihood of such damages. CUSP's or the City's total liability in respect of an engagement will not exceed that which the City will pay to CUSP in fees under the applicable SOW, except that no such limitation will apply in respect of liabilities involving the gross negligence, willful misconduct, or fraud of organization.

4. Term and Termination

4.1 Term and Termination

This Agreement becomes effective on the date it is executed by the last to sign. An SOW or Change Order becomes effective on the date it is executed by the last to sign. The City may terminate this Agreement or any SOW or Change Order resulting from this Agreement at any time.

5. General Provisions

5.1 Entire Agreement; Amendment

This Agreement, together with all SOWs and Change Orders, expresses the final, complete, and exclusive agreement between the City and CUSP regarding our provision of Services to the City. Any additional Services that are the subject of separate SOWs and Change Orders will be covered by this Agreement. This Agreement may be changed only as described in a written document signed by the City and CUSP which refers specifically to this Agreement and says that it is changing this Agreement. Any modifications to an SOW must be made through a Change Order signed by CUSP and the City.

5.2 Severability; Waiver

If any provision of this Agreement is held illegal, invalid, or unenforceable, all other provisions of this Agreement will nevertheless be effective, and the illegal, invalid, or unenforceable provision will be considered modified such that it is valid to the maximum extent permitted by law. Any waiver of the provisions of this Agreement must be in writing and signed by the party granting the waiver. Waiver of any breach or provision of this Agreement will not be considered a waiver of any later breach or of the right to enforce any provision of this Agreement.

5.3 Governing Law

This Agreement is governed by California law. CUSP and the City consent to the exclusive jurisdiction of the state and federal courts for Sebastopol, California.

5.4 Counterparts

This Agreement may be executed in one or more counterparts, each of which shall be deemed an original and all of which shall be taken together and deemed to be one instrument.

* * * * * * * *

California Urban Stream Partnership

By: Josh Bradt______________________________

Title: Director______________________________

Date: ________________________________

City of Sebastopol

By: Lawrence McLaughlin______________________________

Title: City Manager_____________________________

Date: ________________________________

Earth Island Institute
By: David Phillips

Title: Executive Director______________________________

Date: ________________________________

Exhibit A Attached ***(Exhibit A – Scope of Work – to be finalized by City and CUSP)***

STATE COASTAL CONSERVANCY GRANT APPLICATION PRE-PROPOSAL

CONTACT INFORMATION

Organization: City of Sebastopol, California
Contact Person: Kari Svanstrom, Planning Director
Email: lowensvi@icloud.com
Phone: (707) 823-6167
Mailing Address: City of Sebastopol Planning Department; 7120 Bodega Avenue, Sebastopol, CA 95472

PROJECT INFORMATION

Project Name: Bringing Back Calder Creek

LOCATION INFORMATION

County: Sonoma
Latitude: 38.400241°
Longitude: -122.826283°
(center of Ives Park)

Organizations, agencies, and community-based partners involved with the project:
City of Sebastopol
California Urban Streams Partnership (community-based organization) (CUSP)
Waterways Restoration Institute (technical design assistance) (WRI)
Prunuske Chatham Inc. (civil engineers and community-based organization)
Sonoma County Open Space District; Laguna de Santa Rosa Foundation

Project Description: Bringing Back Calder Creek

Calder Creek is a perennial stream that drains one square mile, flowing from low hills in residential areas through the city of Sebastopol and ultimately into the Laguna de Santa Rosa to the east of the city. **Bringing Back Calder Creek** includes planning and design for restoring this long-neglected creek in three stretches: (1) Ives Park, a well-loved park in the heart of Sebastopol, where an 840-foot stretch has been encased in concrete since at least the 1960s), plus a 50- to 60-foot reach of the creek that currently flows beneath the streets just west of and connecting to the park; (2) a 620-foot stretch of creek that now flows downstream of the park beneath a commercial district parking lot and Petaluma Avenue before reaching the Railroad Forest in the Laguna; (3) a 300-foot stretch of buried creek downstream in Railroad Forest, part of the Laguna de Santa Rosa, a regionally significant wetlands preserve.

Bringing Back Calder Creek will increase and restore riparian habitat, help sequester carbon with the planting of new native vegetation (once the design is completed and the project is implemented), reestablish the creek's natural geomorphic processes, and provide a community asset and sense of place that is currently lacking in this part of town. With a $25,000 Switzer fellowship to the Waterways Restoration Institute (WRI), a conceptual restoration and feasibility plan to naturalize the creek in Ives Park has already been developed, including three potential alternatives that have been presented to the City Council and the public (please see attached). The City Council selected a preferred alternative which WRI developed and has been presented to the City's Planning Commission (which serves as the city's Park Commission).

Overarching Project Goal: Complete a Design for Calder Creek that will

- Reestablish the creek's geomorphic processes
- Add 1,900 feet of riparian habitat by restoring all three reaches
- Enhance Sebastopol's climate resilience by increasing carbon storage through new vegetation; promoting groundwater recharge and increased flood storage through reconnected and expanded floodplains and terraces.
- Increase biodiversity and nature experiences at Ives Park as well as in the other reaches of creek
- Connect the Calder Creek upper watershed to the Laguna Santa Rosa to increase habitat opportunities for anadromous fish and other aquatic life

Overarching Objectives (Measurable)

- Design (90% PS&E) restoration of approximately 1,000 feet of creek within Ives Park, including daylighting approximately 60 feet of culverted creek that is currently partially within Jewell Avenue (35 feet) and partially within Ives Park (25 feet)
- Design (10% Concept Plans) of buried reach of creek (620 feet) that flows through the downtown commercial district's parking lots.
- Design (30% Concept Plans) daylighting approximately 300 feet of Calder Creek within Railroad Forest (Laguna de Santa Rosa)
- Restore hydraulic geometry to creek's channel and reconnect the creek to functioning floodplains and terraces
- Increase riparian habitat in the Calder Creek watershed
- Create accessible opportunities for recreation and interaction along Calder Creek

Major Tasks

Feasibility Study (already completed with other funding):
Assessed watershed and stream conditions, studied stream profile, sedimentation patterns, relationship to the Laguna de Santa Rosa. Observed relationship to flood issues in downtown. Prepared feasibility design for integrating a naturalized Calder Creek into the Ives Park Master Plan. Assessed opportunities to expand length of natural stream through realignment of Jewell Avenue intersection. Developed a Basis of Design using geomorphic design principles to establish stream geometry including regional curves, reference sites, and hydrology to estimate bankfull and floodplain dimensions, stable stream length and meander belt, and channel widths and depths. The design feasibility and benefits were confirmed by 2-D hydraulic modeling. See attached.

Complete 90% PS&E (Plans, Specifications & Cost Estimates) to restore Calder Creek from Jewell Avenue to High Street through Ives Park and prepare and complete CEQA permitting. The City of Sebastopol will advance the feasibility plan to a construction ready plan. Final hydraulic modeling of the detailed plan will be completed. ***Conduct team reviews at 65%, and 80%, and 90% phases of design***, including hydrology and hydraulic modeling that iterates as design evolves; hold public meetings for design review; develop CEQA documents.

Conduct vision planning—10 percent concept design—for Reach 2 of the creek *(downtown parking lot),* which traverses public and private properties, many of which currently flood. Build public awareness and support for future daylighting actions that can be pursued by either individual property owners, a redevelopment group, or the City with property owner support. Outreach to local businesses, Tribal, disadvantaged community, environmental and agency stakeholders, and the general public; hold public and design professional design charrettes. The project team will work with a local agency or gallery to display charrette concepts for a month to invite ongoing dialogue.

Complete Railroad Forest 30 percent concept design and outreach. Outreach and coordination will initially focus on the agencies responsible for maintaining the Railroad Forest, including Sonoma County Open Space District and the Laguna de Santa Rosa Foundation. Tasks include topographic survey, restoration design alternatives and preliminary modeling for daylighting the creek, and preliminary trail and mitigation concepts. The concept of a trail connecting Ives Park to Downtown was raised in a community charette in 2012; incorporating a restored Calder Creek will connect trail users with a restored creek and add to their appreciation of this important local waterway and riparian habitat.

Preliminary Budget

Task	**Milestone**	**Estimated completion date**	**In-kind Funding**	**Total requested from Conservancy**
Feasibility study for Ives Park	**Completed August 2022**		$25,000 Switzer Fellowship/WRI; WRI $25,000.$15,000 City staff support (**received**)	
Project management	Project mgmt. $25,840 Coord./permitting $172,659	Ongoing	$10,000 from city (**to date**)	$198,499
90% design for Ives Park reach	Refine concept $167,448 65% design: $174,199 Public outreach: $5,200 90% design: $54,247 Agency coord. $3,900 O&M manual $3,900	12/2024	$29,567 (H&H Modeling **completed**); $12,000 traffic study (**completed**) $50,000 from city for other consultants (**received**)	$408,894
10% design for downtown reach	Vision planning $62,995 Public outreach $5,200 Agency coord. $6,900	12/2024		$70,795
30% design for Railroad Forest reach	30% design $52,530 Public outreach $33,250 Agency coord. $6,990	12/2024		$92,770
Contingency (10%)		n/a		$77,096
Other in-kind		n/a	$25,000 WRI for all phases of design	
Total project cost		18-24 months after start		$848,054

TECHNICAL REPORTS

STREAM RESTORATION BASIS OF DESIGN

For Calder Creek in Sebastopol, CA

Waterways Restoration Institute

WILDLING DESIGN STUDIO

Basis of Design for Calder Creek Restoration

I. Introduction

Calder Creek historically was the site of a widely celebrated water wheel feature, documented on old post cards which the Sonoma County Historical Society has in its records. Ives Park contained a wood slate dam that allowed the development and operation of a popular swimming hole in the central park. Today's park users have told us of parents who have memories of enjoying this swimming hole. Calder Creek was channelized (straightened) in the 1960s and lined in concrete made to look like stone. The channel was designed as a high velocity flood control channel, became viewed as a safety hazard, and was subsequently fenced off from the park.

That spurred some in the community to advocate "hiding" part of the creek. The 2013 Master Plan for Ives Park proposed covering a portion of the stream channel. BKF, an engineering firm, noted that the City would need to install new 53" x 84" culvert to contain the flood flows to make that work, which would be a substantial cost.

Nationally as well as locally since that time, a dramatic evolution has occurred in public awareness of the benefits of naturally functioning creeks for aesthetics, recreation and tourism potential. Likewise engineering practice has changed dramatically, instructed by the repeat experience that channelized streams are not safe because of high velocities and entrapping children in spaces they can't easily escape. Concrete lining and sacrete failures are now common performance legacies.

The project design for Calder Creek embraces a new design method that is now well described in modern day engineering manuals, guidance and reports published by federal agencies. The lesson overtime has been that trying to control streams in concrete channels has led to unexpected flood hazards and channel unraveling. The new methodology creates more predictable "stable "channels by paying attention to providing stable channel widths and depths and planform lengths. Our concept of "stable " is that the channels will not excessively deposit sediment or excessively erode. This means the high maintenance needs and costs of the older engineering model are avoided, such as continual channel repairs and sediment removal for channel capacity.

The design steps used in this Calder Creek naturalization first employ learning as much as possible from existing reaches of creek in reasonably stable (or equilibrium condition) to get an initial understanding of the channel shapes and planforms that should inform the restoration design. This involved locating upstream reference reaches of Calder Creek and surveying cross-sections and profiles. This information is combined with regional information collected on correlations with existing watershed drainage areas and stable channel shapes. Some of the best information that can inform design are historic records. The Sonoma County Historical Society tried its best to help find pre-flood control photos and maps but little information has so far been available. A newspaper record does record sighting of salmon in Calder Creek in the late 1800s (Sonoma County West Times and News, 1886). The city also provided an old photo and map of a portion of Ives park.

This information is then combined with what is referred to as the river science field of "hydraulic geometry." This science was able to correlate natural channel widths with the shapes of meanders. Another benefit of this new science has been the development of what are called "regional restoration curves" in which measured watershed areas (measured in square miles) can inform how wide and deep the stream channel should be.

The stream channel WRI designs for is referred to as the "active' or "bankfull channel". This is the channel which over a period of time carries the most sediment and is typically associated with the 1.5 to 2-year flood. By designing this channel correctly, we can avoid excessive erosion and deposition, lower maintenance, and also return the functions of a living stream and provide for habitat.

The hydrology contained in this report uses existing rational method calculations performed by BKF Engineering, with the calculations dating back to 2005. This report supplements this information with US Geological Survey multiple regression equations which have been developed for this region to estimate the different magnitude floods and how often they occur on average. Regional data collected from North Coast streams that equate the 2 and 5 year flood with bankfull discharges was also used.

Finally, vegetation is becoming a central tool in stabilizing the planform of a creek, creating shade and habitat for the native amphibians, reptiles, birds and fish. Shear stress tables published by the US Army Corps of Engineers that indicate the effectiveness of soil bioengineering systems to hold streambanks has been applied to this design. Soil bioengineering manuals and books began being published in the 1980s and the use of these bundled plant materials has become a mainstream method of erosion control and habitat creation.

I.1. Project Design Objectives

The overarching project goal is to naturalize Calder Creek through Ives Park, to develop a vision for daylighting Calder Creek through downtown Sebastopol, and to address backwatering and flooding at Petaluma Ave, as well as the constriction of flows within the Joe Rodota Trail.

Existing flooding in downtown Sebastopol is indicative of future flood risks under climate change, and a driver for increasing upstream flood storage when the Russian River backs up. This underscores the importance of the related project goal: to align with the State's water resources and climate change resiliency policies, by leveraging the passive benefits of natural stream functions and processes, including increased flood storage, groundwater recharge, evapotranspiration-derived urban cooling. By enhancing the groundwater table, vegetation moisture is retained, dampening likelihood of ignition and thereby reducing the likelihood of wildfire. These outcomes of restoring streams help to prepare Sebastopol for an uncertain climate future.

As scientists with the Russian River Salmon and Steelhead Monitoring Program and Redwood Chapter of Trout Unlimited are now pit-tag monitoring the migration of hatchery Coho salmon through the Santa Rosa Laguna, the potential for return of salmonids to Calder Creek is now being considered.

Criteria that serve as project objectives include developing a design that:

- is lower maintenance;

- updates the 2013 Ives Park Master Plan concept to fully incorporate the stream into the proposed suite of park uses, creating a more aesthetic park experience that serves park users;
- reconnects Calder Creek to its floodplain, increases flood storage and promotes groundwater recharge;
- provides suitable fisheries habitat that would encourage fish migration if downstream conditions are also restored to provide access;
- addresses a public safety issue at the intersection of Jewell Ave and Willow St.

The restoration design for Calder Creek references existing estimates for stormwater runoff, local flood management standards, reference creeks, and geomorphic relationships. The information presents design criteria for channel geometry (shapes) and function, however it is also expected that the channel will adjust and evolve, especially as upstream and downstream conditions or other inputs change.

The recommended parameters are provided to establish a dynamically stable stream: a natural stream with earthen bed and banks, that erodes and deposits sediment in a balanced way to maintain its channel form. Because of the role that stream length and geometry plays in maintaining this stability, these parameters may require adjustment in restoration reaches where the ideal stream length, radius of curvature, or other criteria can not be attained. This is expected in the proposed downtown daylighting reaches.

This Basis of Design approaches the design of a better functioning creek channel at the Joe Rodota Trail. By proposing that the hydraulic constriction caused by the culvert connection between the downstream channel flowing to the Laguna be addressed by daylighting the creek under the trail and constructing a boardwalk over the creek. This approach allows for a channel to self- form in the daylighted reach and evolve to a flat gradient channel type which corrects for dammed up flows and backwater issues. The approach advocated for this reach is to create adequate space for the channel to build and form on its own.

I.2. Watershed Description

The Calder Creek watershed was analyzed by converting LiDAR to a DEM and 1’ contour topography in QGIS. An operation for determining flowlines and watershed boundaries was then applied. The resulting map indicates that the Calder Creek watershed is a small, semi-developed watershed, totaling 1.04 square miles (667 acres) in size. It is characterized by rural-suburban lots in the upper reaches, and denser urbanization in the lower reach (below Jewell Avenue).

Drainage Area ID	Drainage Area (Acres)	Drainage Area (Sq Mi)	Description	Outlet
DA 1	424	0.66	Southern extent of watershed, mostly rural-suburban large lots. Partially sewered.	Southwest end of Ives Park
DA 2	73	0.11	Northwestern extent of watershed; a few rural-suburban lots, mostly smaller	Within Ives Park

			residential lots. Mostly sewered.	
DA 3	42	0.07	Flanks mainstem alignment of Calder Creek through small lot neighborhoods and Main Street development. Mostly sewered.	Main Street
DA 4	128	0.2	Small lot residential, commercial and industrial development. Mostly sewered.	Petaluma Ave
	727	1.04		

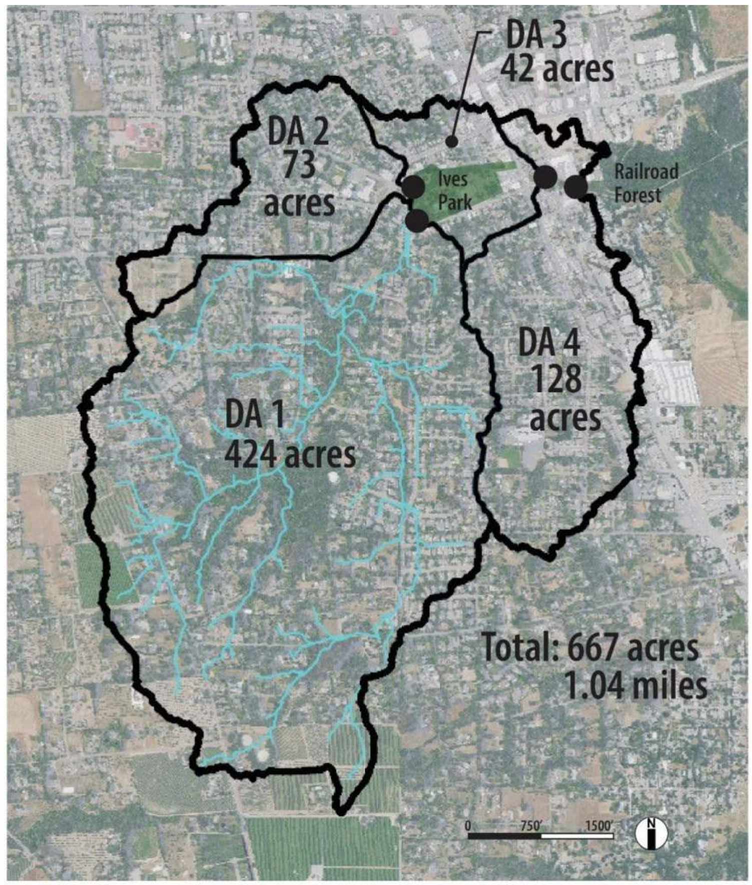


Figure 1 (right): GIS analysis of watershed drainage area and drainage pathways based on LiDAR data. Note that these drainage paths may not be surface flowing streams, but rather show the direction of waterflow by topography. Ives Park is the area highlighted

The City's 2005 Stormwater Utility Master Plan, which was visually summarized by GHD in the preliminary Hydraulic Model Domain Figure (2022), provides descriptions of the routing of watershed flows through these drainage areas. Much of the lower watershed has been sewered, and much upstream surface flow is also captured and delivered to the creek via culverts and ditches. At Ives Park, the main drainage, DA1, coming from the southwest, is carried by a 60" RCP stormdrain, and two additional pipes (36" RCP and 42" RCP) carry flows from the northwest (DA2). Downstream of Ives Park, the flows are routed through two stormdrains, a 66" RCP and a 48" RCP through a mix of public and private property from High Street to Main Street, with additional inflow coming from the north and south ends of Main Street (DA 3, with an 18" RCP and a 36" RCP). Between Main Street and Petaluma, the stormdrain pipes take divergent paths, with one carrying flows through a public parking lot, and the other beneath the Chamber of Commerce building and then through a parking lot. At Petaluma Ave DA4 is delivered to these pipes via a 42” RCP/CPFP. These flows outlet into a ditched wetland area of the Railroad Forest adjacent to the Joe Rodota Trail via a 66” RCP and a 6’ x 3’ concrete arch culvert.

II. Hydrology

A review of existing hydrologic data for the region, as well as for the Calder Creek watershed included:

- The 2005 City of Sebastopol Stormwater Utility Master Plan by BKF. This report estimates that discharge from the stormdrain that outlets into Ives Park, Pipe 487 60”Dia, delivers Q_{10} of 174 CFS. The Rational Method was used for computing this with an assumption of 35” annual rainfall. Estimated Q_{10} at Petaluma Ave from all stormdrains is 322.99 CFS;
- Regional Curves of Hydraulic Geometry for Wadeable Streams in Marin and Sonoma Counties, San Francisco Bay Area. Draft Summary Report. (Collins-Leventhal, 2012);
- The Regional Leopold data contained in A View of the River (1994)which uses data from 42 gage stations in coastal northern California that estimate the Q5 and Q2 in relation to bankfull discharges;
- To calculate hydrology and obtain average annual rainfall assumptions, we were directed by the City of Sebastopol Public Works Director to the Sonoma County Water Agency Flood Control Design Manual. This manual refers planners to Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006, by USGS Scientific Investigation Report 2012-5113 to calculate recurrence interval discharges. This report’s updated isohyetal map from the USGS document places Sebastopol within the 43” annual average rainfall zone. Note that the WRI hydrology calculated for Calder Creek project design uses this updated 43 inches average annual rainfall as opposed to the previous rational method estimates using an assumption of 35 average annual precipitation .

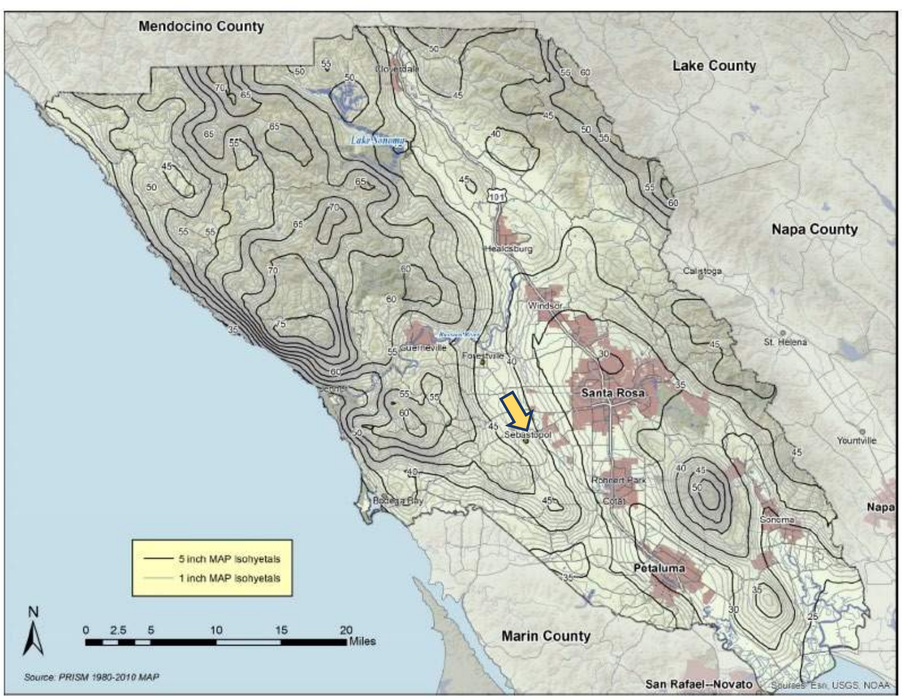


Figure 2: Isohyetal map with arrow indicating Sebastopol. Source: Sonoma Valley Water Agency.

II.1. Discharge estimates for DA 1, at Ives Park

The regional flood frequency equations for rural ungaged streams in California (USGS 2012) were used to calculate 5- to 100-year discharge for Calder Creek above Jewell Avenue (watershed area of 424 acres). Assumptions used include:

- Drainage area 0.7 sq mi (rounded up from 0.66 sq mi)
- 43" average annual rainfall
- 20 % culverted watershed
- 30% developed watershed

The USGS references Rantz (1971) for urbanization factors in their regional flood frequency equations. At the outfall of DA1(Pipe 487) in Ives Park, this yielded an estimated 2-year recurrence interval (RI) flow of 79 CFS, a five year RI of 135 cfs, a 10-year RI of 185 cfs, a 25 year RI of 252 CFS, a 50 year RI of 305 CFS, and a 100 year RI of 360 CFS.

The Regional Curves of Hydraulic Geometry for Wadeable Streams in Marin and Sonoma Counties(Collins and Leventhal, 2013) estimated active channel discharge as 30 CFS for $Q_{1.3}$ recurrence interval.

The Leopold ratio for North Coast stations of Q_2 to bankfull calculates bankfull discharge of about 50 cfs (Leopold, 1994).

The following table summarizes calculated discharge alongside discharge estimates from these previously referenced sources.

Table 1: Discharge Estimates for Ives Park from Different Sources

Recurrence Interval	**Calculated Discharge (CFS)** USGS Method	**Discharge** (CFS) per Royston Hanamoto and Abey 2013 (Ives Park MP Appendix)	**Bankfull Discharge Estimate** (CFS) (Leventhal/Collins, 2013)	**Leopold North Coast Stations*** (CFS) (Leopold, 1994)
1.3 hr*	-	-	30	-
2 yr	79	-	-	1.9 x 30cfs (bf) = 57
5 yr	135	-	-	4.5x 30 cfs (bf) = 135
10 yr	185	174	-	-
25 yr	252	-	-	-
50 yr	305	-	-	-
100 yr	360	-	-	-

*Leopold used data from 42 stations in the coast range of California to develop ratios between bankfull and other discharges. These ratios include Q_2= 1.9x bankfull; Q_5 = 4.5x bankfull (Leopold, 1994.

II.2. Discharge estimates for DA's 1-4, at Petaluma Blvd

At Petaluma Blvd, discharge was calculated using the USGS 2012 regional flood frequency equations. The assumed drainage area used was 1 square mile, average annual precipitation remained 43", and urbanization factors were 30% culverted, and 60% developed. Data from the 2013 Ives Park Master Plan, Collins-Leventhal report, and Leopold North Coast Stations for this drainage area:

Table 2: Discharge Estimates for Petaluma Ave (Downtown Reaches) from Different Sources

At Petaluma Blvd				
Recurrence Interval	**Calculated Discharge** (CFS) USGS Method	**Combined estimated** (CFS) Discharge from P-578,P-508, P-576,P-516 (BKF et al)	**Bankfull Discharge Estimate** (CFS) (Leventhal/Collins)	**Leopold North Coast Stations*** (CFS) (Leopold, 1994)
1.3 hr*	-	-	50	-
2 yr	146	-	-	1.9 x50cfs (bf) = 95
5 yr	259	-	-	4.5 x 50cfs (bf) =225
10 yr	304	323	-	-
25 yr	386	-	-	-
50 yr	466	-	-	-
100 yr	530	-	-	-

*Leopold used data from 42 stations in the coast range of California to develop ratios between bankfull and other discharges. These ratios include Q_2= 1.9x bankfull; Q_5 = 4.5x bankfull (Leopold, 1994.

The USGS doesn't provide data for calculating a $Q_{1.3}$ discharge. The two year recurrence interval discharge is frequently used as a high end estimate for bankfull discharge. It is expected that bankfull discharge will be similar for both DA1 (approximately 0.7 sq mi) and DAs 1-4 (approximately 1 square mile).

Leopold's research of 1994 showed that Q50 flood elevation can be estimated to be about 2x bankfull depth.

II.3. Hydrology Conclusions

We computed bankfull discharge to be able to size a dynamically stable bankfull channel. At Ives Park, the channel forming discharge estimates include Collins-Leventhal at 30 CFS, Leopold at 50 CFS. The $Q_2$from the USGS is 80 CFS. These values are all remarkably similar adding confidence to use a design assumption of30-50 cfs for the bankfull or active channel. Given the small change in drainage area from Jewell Ave to Petaluma Blvd area we are assuming that the 30-50 CFS range is a good assumption for bankfull discharge design throughout.

We computed discharge for low frequency high magnitude storms for two reasons:

- to understand capacity or lack of capacity of these culverts for bigger storms

- to design enough floodplain in the event that the stormwater system changes.
- to accommodate future flooding predicted by climate change models.

Given the general concurrence between calculated discharges for Q10 storms, we feel confident in using these numbers for planning floodprone areas of the stream corridor.

The culverts are sized with efficient hydraulics that should be able to convey the 25-year flood. However, flooding at Petaluma Ave has raised questions about the capacity of these pipes. They have been observed to be blocked with sediment, likely caused by backwatering from the Laguna. Upstream sediment supply is likely also exacerbating the problem, which has been noted by the City Engineer. If these issues were addressed, the capacity of the pipes would likely be adequate.

A watershed approach stabilizing Calder Creek by working with upstream landowners can over time reduce sediment from these sources. This should be viewed as a long term more labor-intensive effort. Backwatering of the Laguna however seems to be the primary driver of hydraulics. Therefore our design looks at the option of opening up the channel downstream of Petaluma Ave to remove hydraulic constrictions and allow flow to spread, with the additional benefit of lowering of water surface elevations in Calder Creek above Petaluma Ave.

III. Stream Restoration Design

Designing a restoration channel shape for an urban stream is a particular discipline within stream restoration. It requires detective work to pull as much information from different sources together to arrive at a reasonable width, depth, and cross-sectional area for the channel.

Our design objective is to mimic natural channel dynamics so that we have some erosion and deposition forming of pools and riffles, so that the creek is alive. Designing in this manner avoids excessive erosion and deposition thereby typically preventing any channel maintenance needs.

III.1. Hydraulic Geometry: Channel Shape

Regional hydraulic geometry is explored using regional curves, and further informed by reference stream explorations. Each sub-section covers both restoration for Calder Creek in Ives Park and downstream Downtown reaches where the channel shape and slope are expected to change.

Regional Hydraulic Geometry and Regional Curves

One of the first things we do is look at regional hydraulic geometry. Active or bankfull channel discharges form the bankfull channel dimensions. We are fortunate that Roger Leventhal, a flood control engineer at Marin County FCD, with geomorphologist Laurel Collins, completed a study creating regional curves of hydraulic geometry of equilibrium channels in 2013. Regional curves of hydraulic geometry collect information from a large number of stream sites, correlating the drainage areas with channel widths, depths, discharges, and cross-sectional areas of equilibrium (stable) streams. This means they don't excessively erode or deposit, which is one of our design objectives. The Collins-Leventhal report, using multiple data stations through Sonoma and Marin County, determined that most urbanized streams were formed by the 1.3 recurrence interval discharge. Their report references 45 sites of "hydraulic geometry dimensions of cross-sectional area, width, and depth at what was identified from field surveys as the possible channel stage associated with the discharge the tends to maintain stable channel geometry."

Jewell Avenue/Ives Park Drainage Area

For a watershed of about 0.7 square miles, which represents Jewell Avenue, the regional averages show a cross sectional area of 10 square feet, or 1 foot wide by 10 feet deep.

Downtown Area

For 1 square mile, which represents Petaluma Blvd, the cross-sectional area is about 15 square feet. We use the regional information to guide our field reference explorations.

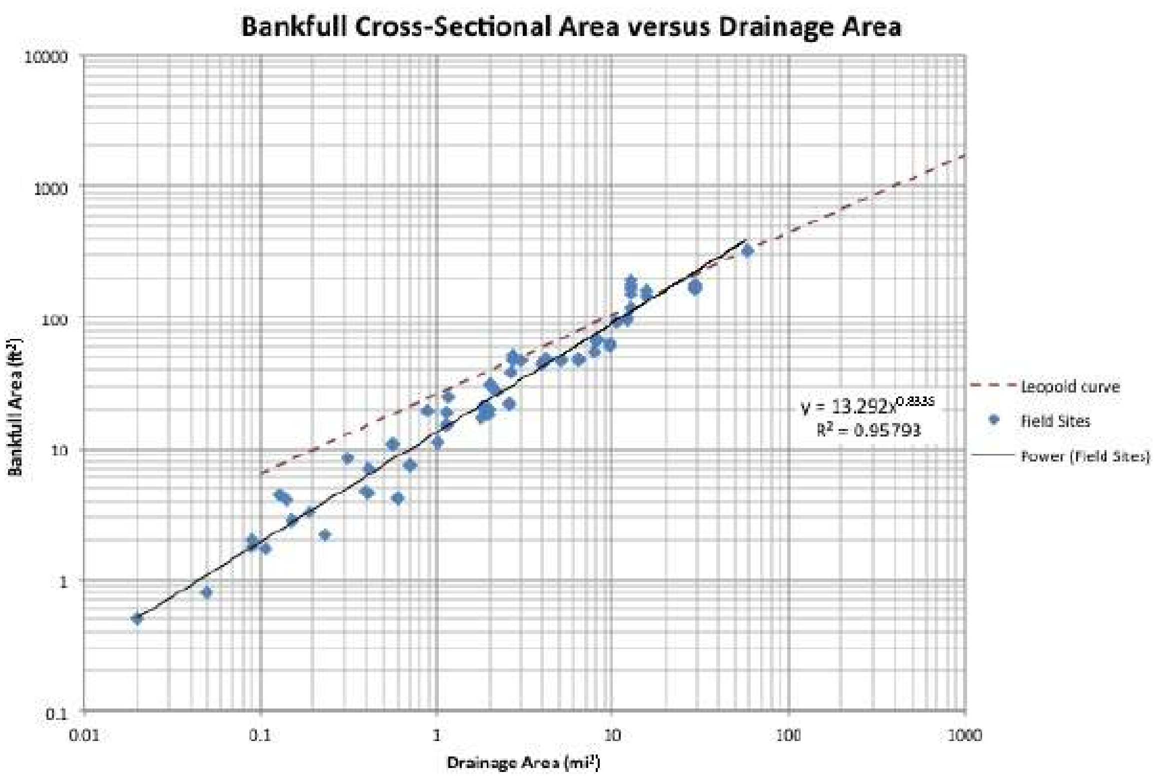


Figure 3 Regional Curve for Cross Sectional Area vs Watershed Drainage Area. Collins and Leventhal, 2013.

Reference Sites

Reference sites provide real-world context for regional curve and modeled data. In stream restoration design, this is referred to an analog for informing design. Ideal reference sites are undisturbed equilibrium reaches of either the same stream nearby, or from neighboring watersheds with similar levels of rainfall, development, and profile slope.

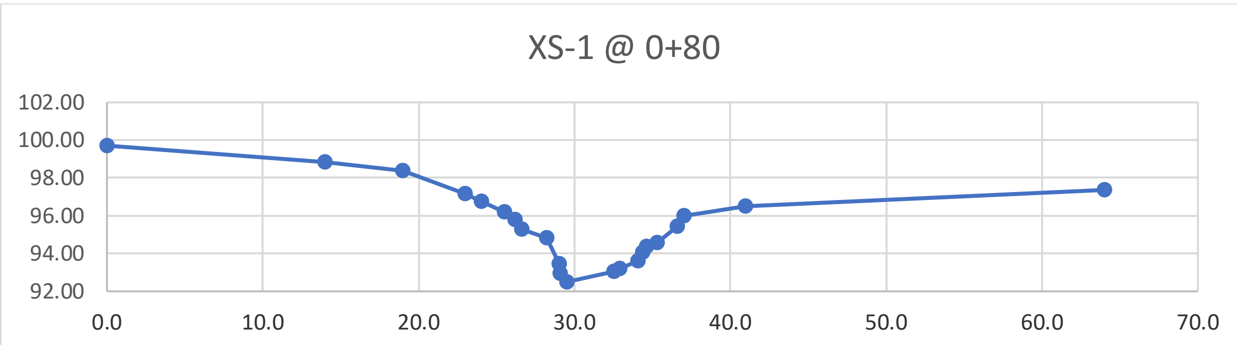
Jewell Ave Upstream Reference Sites

We visited six properties upstream, to look at reaches in equilibrium. Out of the six properties that we visited, three could provide reference conditions. In the interest of maintaining the privacy of these property owners, they are referred to as Residence 1, 2 and 3.

Residence 1: Channel dimensions were similar to those found at Residence 2.

Residence 2: Three cross sections were surveyed. The cross sections indicated that the upper two were impacted by culverts and debris in the channel, so the most downstream cross section was ultimately used as a reference. Bankfull channel form presents a channel width of about 6' and a depth of about 2'.

Table 3: Reference Channel observed at Residence 2



Residence 3: The channel at Residence 3 tended to be 8-10' channel widths.

Railroad Forest Reference Site

We observe that the slope associated with the channel configuration in Railroad Forest actually begins between High Street and Petaluma Ave. For this reason, we recommend using the observed channel in Railroad Forest as the reference for that reach, which we are calling the Downtown reach.

The natural channel within Railroad Forest was visited and observed. Measurements at reference sites here indicate a channel that is 6 feet wide and up to 4 feet deep, or a cross-sectional area of 24 sq ft. The cross sectional area in square feet is slightly larger than the upstream creek and the dimensions between width and depth are distributed differently.

Restoration Channel Shape Discussion and Summary

The reference channel cross sectional areas were close to estimates provided by the Regional Curves, but the width and depth dimensions were distributed differently. Reference streams on Calder Creek had deeper and narrower channels than the regional average.

It is expected that after the channels are graded at the recommended dimensions they will act on their own to attain their final dimensions. Our design objective is to estimate as closely as possible what the final shapes will evolve towards. The level of adjustments made by Calder Creek will not impact the basic site design parameters.

Channel shape parameters for Ives Park

Generally, the natural stream type observed upstream of Ives Park was a typical pool and riffle stream. This is also consistent with the stream gradient observed. We consider a more optimum channel width for design is 8 feet wide and 1.5 feet deep as a starting point for channel design at Ives Park.

Channel shape parameters for Downtown Reaches

The stream channel downstream of Petaluma Avenue represents a different stream type than the more typical pool riffle channel upstream of Ives Park. This channel is heavily influenced by the flat gradient and backwater dynamics of the Laguna. As a result, the width to depth ratio is going to adjust to a narrower and deeper channel. For the purposes of design in the downtown area we are selecting a channel 8 feet wide by 3 feet deep which represents a transition channel type between upstream and below Petaluma Avenue.

III.2. Sinuosity

There are two main methods used to estimate the design sinuosity of the channel through Ives Park. Sinuosity refers to the meandering length of stream over a given valley distance.

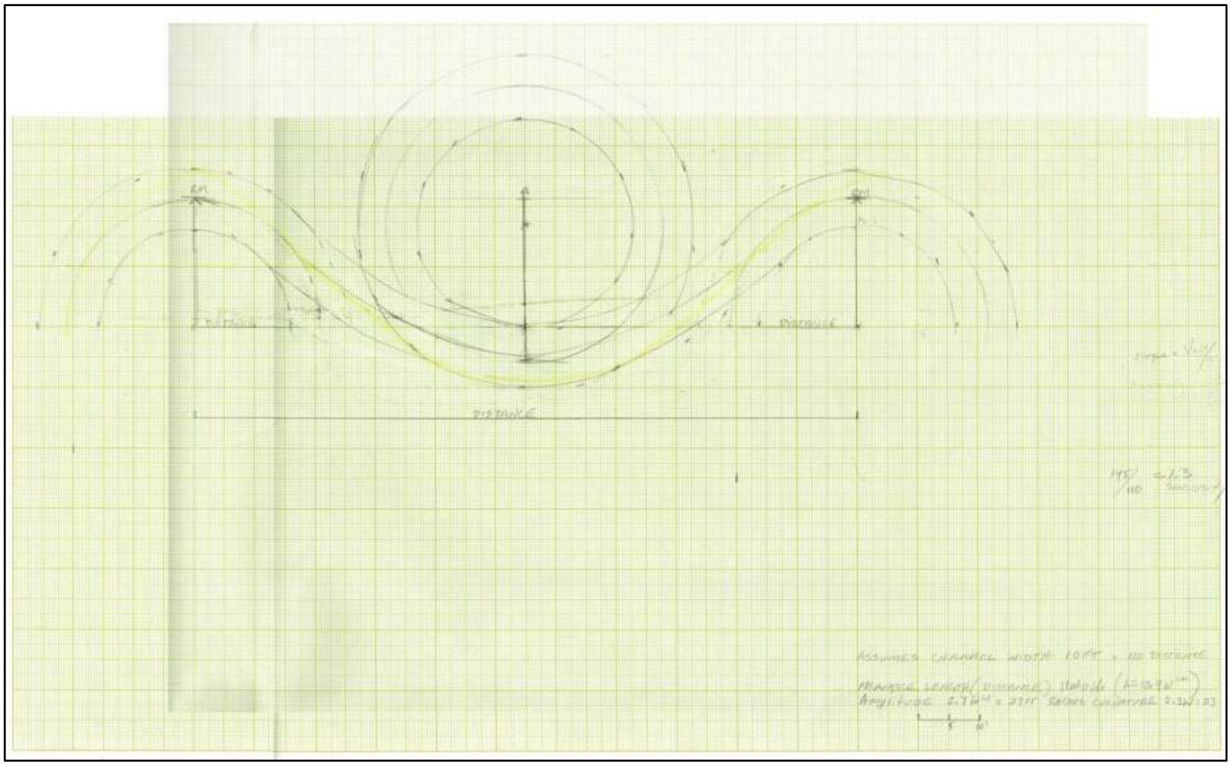
The first method was to observe upstream reaches on Calder Creek that have achieved near stable conditions. The second method uses stream science dated to the 1950s-1960s which calculated correlations between the lengths of streams and the shapes of channels with channel widths (Leopold, Wolman, and Miller, 1964). Historic information provided by the city informs the previous shape of the stream meander in Ives Park which correlates well with the other two sources of information.

The reference site surveys provided data for estimating the stream lengths and shapes. The survey at Residence 2 was used to create a ratio of the meandering stream length to its straight-line distance. The bridge to the downstream fence was 121 feet. The actual channel length from the bridge to that same point was 168 feet. The sinuosity was 1.38. The sinuosity we derived from the correlation method of estimation was 1.3. At this property, we also measured valley length from vehicle entry road to south end of property. Valley slope is similar at 0.017 (Residence 2) to the park's 0.013.

Observing properties upstream, the stream has frequently outflanked bank stabilization works put in by property owners. This indicates that one of primary means of channel adjustment to watershed hydrology and conditions to establish an equilibrium slope is channel lengthening. The upstream stream reaches indicate that efforts to straighten Calder Creek have been met with failure with the channel eroding around hard points built on outside bends.

The correlation method of estimating sinuosity assumed that the channel length for a mid-watershed pool- riffle channel would be approximately 11 times the width. A ratio of 2.7 times the channel width was used to determine the meander amplitude. Assuming a channel width between 8 and10 feet, the amplitude would be between 21.6 and 27 feet. The radius of curvature is estimated at 2.3 times the channel width, or 18.4 to 23 feet. These dimensions were used to draw a design meander.

Agenda Item Number 10



It is not intended that the graphic of an idealized meander should be the literal design channel appearance. This drawing is applied to inform sinuosity.

Sinuosity and Stream Length for Stream Reaches

For purposes of design, we selected a design sinuosity of 1.3. Applying this factor resulted in target restored stream lengths for each reach:

- Within Ives Park: 749 x 1.3 = 973 ft
- Between High Street and Main Street: 392 x 1.3 = 510 ft
- Between Main Street and Petaluma: 276 x 1.3 = 359 ft

Applying the hydraulic geometry relationships between channel width, radius of curvature and amplitude (Leopold, Miller and Wolman 1964), we estimated the channel width and meander length ranges between 9 to 11 x the channel width. Considering the stream's mid-watershed location, pool-riffle reach, and Bay Area experience, this range was narrowed down to a factor of 11.

Meander Belt and Floodplain Design

Combining the design channel width of approximately 8 - 10 feet and the meander amplitude of 21.6 to 27 feet provides design floodplain width of 30 to 37 feet for purposes of achieving channel planform stability. The floodplain cross slope was assumed to be 2%.

Table 4: Minimum estimated channel and floodplain at Ives Park

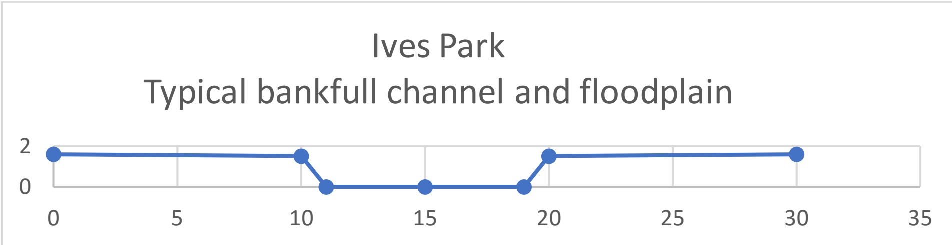
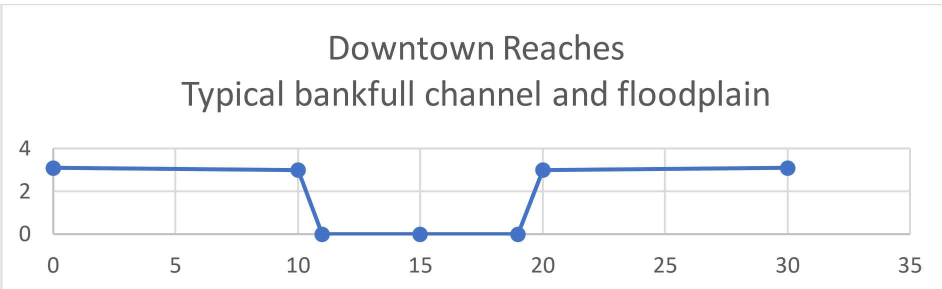


Table 5: Minimum estimated channel and floodplain for downtown reaches



Minimum Corridor at Ives Park

The banks from the floodplain to top of the stream corridor have been designed ranging from a 2H:1V slope to shallower slopes for access. Note that 1.5H:1V is likely acceptable given the soils at reference sites. In several places, constraints with meeting grades results in short (<30") vertical walls at the top of banks. In general, the difference in grade between the channel thalweg and top of the stream channel corridor was approximately 4 to 5 feet. The steepest change in grade from the top of banks to the channel thalweg was 8.28 feet. The resulting minimum corridor width ranges from 52 to 68 feet with 2H:1V sides slopes. The proposed project actually varies from 23 to 130 feet, responding to constraints, and accounting for more variety, access, and other project goals (such as recharge) within the stream corridor.

Minimum Corridor at Downtown Reaches

Based on stormdrain invert elevations and available survey data for surface elevations through downtown, we estimate an average of 7' difference between a restored channel bottom and existing grade through downtown. This leads to a minimum corridor width of 58 feet.

Discussion

Our initial estimation is that these rights- of -way contain the one in 50-year flood discharge. However, ultimately the hydraulic model should take into account backwater conditions from the Laguna and particularly the culvert located at the downstream end of Ives Park.

III.3. Channel Slope

The sinuosity of the Ives Park channel returns a thalweg slope of 0.0128.

The existing slope between High and Main Street appears to be 0.005. It is not clear if available survey was to actual inverts or to top of sediment deposits, given the acknowledged issue of sedimentation in the stormdrains. Between MainStreet and Railroad Forest the slope is estimated at 0.004, which we do not see reason to change for preliminary planning. Subsequent work including more detailed survey and reference site analysis in the Laguna may indicate that a shallower slope is appropriate.

III.4. Channel Roughness

The "n value" is a factor describing the effect of frictional forces on the flow of water in a stream. Sediment in the channel, including pebbles, cobble, and boulders on the bed and banks, as well as vegetation or other material lining the banks of streams all contribute to the n value. We reference the USGS publication, "Roughness Characteristics of Natural Channels" (Barnes, 1967) along with experience, to derive recommended n values. Barnes obtained gage data with known discharges at multiple streams and calculated n values. Some examples are provided below for context.

Figure 5: Computed n value of 0.030 for recorded discharge 1,860 cfs and mean depth of 7.4 ft

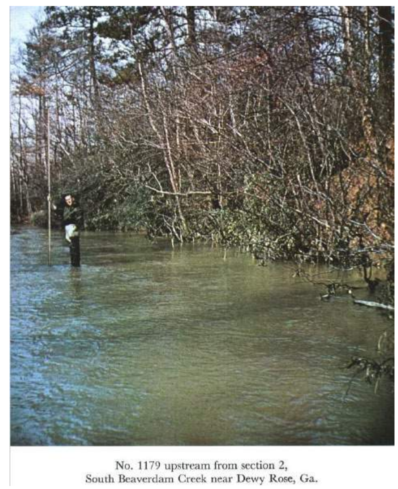


Figure 6: Computed n value of 0.052 for recorded discharge 820 cfs and mean depth of 5.1; computed n value of 0.047 for recorded discharge of 221 cfs and mean depth of 2.8 ft

Figure 7: Computed n value of 0.059 for recorded discharge of 1,000 cfs and mean depth of 4.9 ft

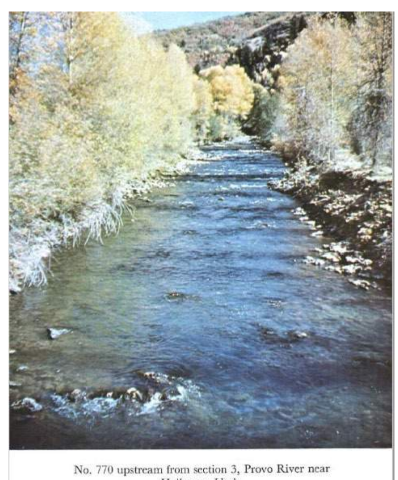


Figure 8: Computed n value of 0.045 for recorded discharge of 1,200 cfs and a mean depth of 3.5; and computed n value of 0.073 for recorded discharge of 64.8 cfs and a mean depth of 1.1 ft

It should be noted that as floodwaters rise, assuming that the forested area of the channel has not changed, the roughness decreases. This should be reflected in flood modeling. We therefore recommend one n value for the Q_2 through Q_{25} floods, and to assume a different n value in modeling for larger magnitude floods.

Roughness for Jewell Ave/Ives Park

To account for the likely density of willow and alders, with groundcover vegetation on the floodplains, an n value of 0.065 is selected for lower magnitude floods Q_2 to Q_{25} between Jewell Avenue and High Street. For larger discharges, with the same level of vegetation, the n value should go down to 0.05.

Roughness for Downtown Reaches

Given the stream between High Street and Petaluma will have a steeper bankfull channel and a composite of vegetation and concrete flood walls, an n value of 0.060 is selected for use for Q2 to Q25. At higher flow, an n value of 0.055 is recommended.

III.5. Streambank Stabilization

Streambank stabilization applies tables containing calculations of expected channel velocities and shear stress to inform channel design. Shear stress calculations are considered the most relevant measures for bank stabilization design to avoid erosion problems. The U.S. Army Corps of Engineers Stability Thresholds for Stream Restoration Materials provides stream restoration designers with a table of “permissible shear and velocity for selected lining materials” which presents quantitative guidance on the selection of biodegradable fabrics and soil bioengineering systems capable of holding banks. (Fischenich, 2001). The Natural Resources Conservation Services provides similar guidance in its National Engineering Handbook (2007).

Bankfull Velocity and Shear Stress

For Ives Park and between High Street and Main Street

The initial velocities for bankfull discharges estimated with the Mannings Equation is 3.4 fps. The estimated shear stress in pounds per square foot is 1.19 lbs/sq ft, where:

Manning’s equation for estimated velocities:

V= velocity, R = hydraulic radius, S = channel longitudinal slope or profile, n = channel roughness

$V = 1.49\ (R)^{2/3}\ (S)^{1/2}/n$

$V= 1.49(1.5)^{2/3}\ (0.128)^{1/2}/0.65$

$V = 3.4$ fps

Shear stress equation (Leopold, Wolman and Miller, 1964):

$\tau = \gamma Rs$ (lbs./sq.ft.), where

Γ – specific density of water (62.42 lbs/cu ft)

R – Hydraulic radius (Mean Depth)

S - slope

(62.42 lbs/cu ft) (1.5) (0.128) = 1.19 lbs/sq ft

WRI calculated a high or more conservative value for shear stress acting on the channel using Corps guidance for channels with wide meander bends. The shear stress value acting on the channel therefore is multiplied by 1.15 to represent meander bend areas of the channel:

1.19 lbs/sq ft x 1.15 = 1.37 lbs/sq ft for meander bends.

Between High Street and Petaluma Avenue

The initial velocities for bankfull discharges estimated with the Mannings Equation is 3.9 fps The estimated shear stress in pounds per square foot is 1.2lbs/sq ft, where:

Manning's equation for estimated velocities:

V= velocity, R = hydraulic radius, S = channel longitudinal slope or profile, n = channel roughness

$V = 1.49 (R)^{2/3} (S)^{1/2}/n$

$V= 1.49(3)^{2/3} (0.004)^{1/2} /0.6$

V = 3.2 fps

Shear stress equation (Leopold, Wolman and Miller, 1964):

$\tau = \gamma Rs$ (lbs./sq.ft.), where

γ – specific density of water (62.42 lbs/cu ft)

R – Hydraulic radius (Mean Depth)

S - slope

(62.42 lbs/cu ft) (3) (0.004) = 0.75lbs/sq ft

The conservative/meander bend shear stress value acting on the channel represented by multiplying by 1.15 is:

0.75lbs/sq ft x 1.15 = 0.86lbs/sq ft for meander bends.

Higher Magnitude Flood Shear Stresses

Although most erosion and deposition occurs during bankfull flows, we thought it was important to generally consider shear stresses for greater depths. With expected higher discharges depth could reasonably achieve three or four feet, the related shear stresses could increase to somewhere between 2.76 and 3.68 psf through Ives Park, and 1.72 to 2.01 psf through downtown. These values are within the realm of soil bioengineering for bank protection.

Backwatering can have differing effects on shear stress, which is not discussed here.

Discussion

Following the design guidance in the USACE Stability Thresholds for Stream Restoration, we need to note that given the high suspended sediment loads in Calder Creek, that the stabilization thresholds for soil bioengineering systems presented in their table increases by 1.5 to 3 times. This is due to the way in which "sediments in suspension have the effect of dampening turbulence within the flow. Using erosion control fabric such as coir (made from coconut fibers) can perform erosion protection at 3-5 pounds per square foot shear stresses and increases to 4.5 pounds per sq ft with the sediment loading factor. This fabric alone most likely addresses much of the potential erosion control along the restored channel given the equilibrium active channel design. The Army Corps table indicates that a vegetated coir mat increases the shear stress performance to 4-8 pounds per square foot before adding in a sediment factor. WRI recommends combining vegetation with coir to protect streambanks. WRI experience indicates that securing the fabric with 6-to-9-inch staples provides at least the level of protection shown in government tables. The NRCS table indicates a combination of coir used with vegetated reinforced soil slopes (VRSS) provides an immediate bank protection for 3 to 5 lbs/sq ft with a protection level of 10+ lbs/sq ft once growth is established.

The WRI recommends the use of coir fabric along the active channel and jute netting for the side slopes of the floodplain. This adds an attractive component to the just graded channel and functions for weed control. The soil bioengineering systems can be applied to the meander bends and live willow or dogwood stakes should be adequate for cross-over sections of the channel.

Table 6:Excerpt from USACE (Fischenich, 2001) table: Permissible Shear and Velocity for Selected Living Materials

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

IV. Design Summary

The table below summarizes the design criteria discussed above by the two main design reaches considered, between Jewell Avenue - (Ives Park, and from High Street to Petaluma Avenue and into the Railroad Forest.

Design Criteria	Reach	
	Jewell Ave-Ives Park	**High Street-Petaluma/Railroad Forest**
Bankfull Cross Sectional Area	12-15 sf	24 sf
Bankfull Mean Width/ Mean Depth	8 - 10' x 1.5'	s8' x 3'
Sinuosity	1.3	1.3
Meander Length	88-110'	88'
Meander Amplitude	21.6-27'	21.6'
Meander Radius of Curvature	18.4 - 23'	18.4'
Floodplain and Bankfull Channel Combined Minimum Width	30-37'	30'
Minimum Estimated Stream Corridor Width	52-68'	58'
Thalweg (Profile) Slope	0.0128	0.004
Channel Roughness (n value)	0.065/ 0.05	0.06/ 0.055
Bankfull velocity	3.4 fps	3.2 fps
Bankfull shear stress	1.19 psf	0.75 psf
Bankfull outside meander shear stress	1.38 psf	0.86 psf

V. Community Review

Restoration design unfolded through a process of online meetings hosted by the Planning Commission, including:

- August 24, 2021: WRI presented examples of successful stream restoration in other small communities.
- October 26,2021: WRI presented examples of failed stream protection strategies, in order to build understanding for the role restoration plays in creating lower maintenance, more aesthetically desirable environments.

- November 16,2021: WRI met with the Planning Commissioners Evert Fernandez and Kathy Oetinger, who compose the Ives Park Subcommittee, to charrette park design options with proposed stream restoration alignments. The group reviewed potential alignments and then focused on a park layout that worked with an increased stream length along the baseball field.
- December 14, 2021: WRI presented three stream restoration alternatives following the input from participants of the November charrette session. The alternatives included: "Constrained Creek" that fit the alignment into a shortened stream length following its existing path; the "Updated Charrette" alignment based the concept that was the focus of the Nov 16 charrette, and at the Ives Park Subcommittee's request, a "Stable Planform Creek" that explores the potential for restoration without the ballfield. At this meeting Planning Commissioners voted to recommend two alternatives to the City Council for adoption. This included an alternative that removed a baseball field to provide for greater stream length and new park experiences, and an alternative that worked the stream alignment around the existing baseball field.
- February 1, 2022: City Council reviewed preferred alternatives and selected Alternative 2, restoration with baseball field.

WRI also conferred with the City's consulting arborist, Becky Duckles, and Wendy Trowbridge, the Director of Restoration and Conservation Science Programs with the Laguna de Santa Rosa Foundation. Ms Duckles provided information to help with planning around existing trees, and offered some insights into the health of specific trees. Ms Trowbridge provided a range of perspectives including regional soil characteristics, recharge potential, local priorities for the Laguna and habitat restoration, and climate change concerns.

There were also in-person visits with various property owners for both reference site surveys and to provide advice for managing their stream.

VI. Notes on Preliminary Conceptual Grading

Development of the preferred design concept included preliminary conceptual grading, based upon survey from the 2013 Master Plan that had been adjusted by GHD Inc, with additional survey points taken by GHD Inc. Grading design also considered planned ADA improvements to existing paths, and included a coordination meeting with the City. Preliminary grading focused on the following design objectives:

- A consistent grade for stream thalweg along its entire length in Ives Park. WRI expects the thalweg to develop pools and riffles over time, which would result in variation of the channel thalweg.
- A consistent initial bankfull channel cross-section through Ives Park.
- Variable width floodplains and terraces to increase flood storage and groundwater recharge, provide for gentler grades for park user access, and increase riparian corridor habitat. A minimum floodplain width of 5 feet on each side of the bankfull channel is assumed. The floodplain cross-slope is assumed to be 2% or less.
- Path grades of less than 5% in order to maximize ADA accessibility, reduce handrail infrastructure, and promote greater ease of park use.

- Low vertical retaining walls are used where site constraints would create a steeper than 2:1 slope on channel banks. The distance from top of bank to paths is less than 30” when these walls are used, in order to minimize the need for guardrails. Design refinements in future phases may include consideration of stepped or terraced banks for increased access in these areas.

VII. References

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DRAFT Technical Memorandum

July 21, 2022

To	Kari Svanstrom & Dante Del Prete (City of Sebastopol)	**MSA No.**	2010-01-36
From	Corey Hayes & Jeremy Svehla, PE (GHD)	**Task Order No.**	27
Reviewed By	Toni Bertolero, PE (GHD)	**GHD Project No.**	12566276
Project Name	Calder Creek Modifications at Ives Park – Hydrologic and Hydraulic Modeling Assessment		

1. Introduction

This technical memorandum (TM) summarizes methods and results for development and analysis of flood reduction alternatives and improvements for Calder Creek in the vicinity of Ives Park in the City of Sebastopol, California. The purpose of this TM is to support technical findings and discussion for project alternatives to better understand the system hydraulic response and inform future maintenance and project improvements.

1.1 Structure of Technical Memorandum

This TM presents the hydrologic and hydraulic analyses that were performed to evaluate the existing condition and a range of proposed, project conditions within the study area. Some of the proposed improvements described below were developed and presented in the Waterways Restoration Institute (WRI) Stream Restoration Basis of Design Report for Calder Creek (WRI, 2022). A summary of the existing condition, along with the existing hydrologic condition for Calder Creek within the study area, is described in Sections 2 and 4, respectively. Hydraulic analysis methodology and results are later summarized in sections 5, 5 and 6, respectively. The final section of this TM summarizes the opinion of probable costs to implement the various improvements.

1.2 Study Area

The study area for this analysis encompasses the region between the 60-inch Calder Creek Outfall at Ives Park and the Joe Rodota trail footbridge, approximately 350 feet downstream of the Calder Creek storm drain outfall at the Laguna de Santa Rosa floodplain. For this analysis, Calder Creek was separated into four (4) discrete, numbered reaches within the study area. Reach 1 encompasses the Calder Creek channel from the 60-inch CMP concrete storm drain pipe at the upstream end of the park nearest Jewell Ave. to the Ives Park outfall nearest S. High St. flow from Ives Park then splits into two underground storm drain pipes until the pipes converge at a single junction structure at S. Main St. This reach was assigned as Reach 2. Reach 3 begins after the flow splits again from the S. Main St. junction structure end ends at the Calder Creek storm drain outfall at the Laguna de Santa Rosa floodplain. Reach 4 consists of the Calder Creek length between the Calder Creek storm drain outfall to the downstream model boundary condition near the Joe Rodota Trail footbridge (See Figure 1).

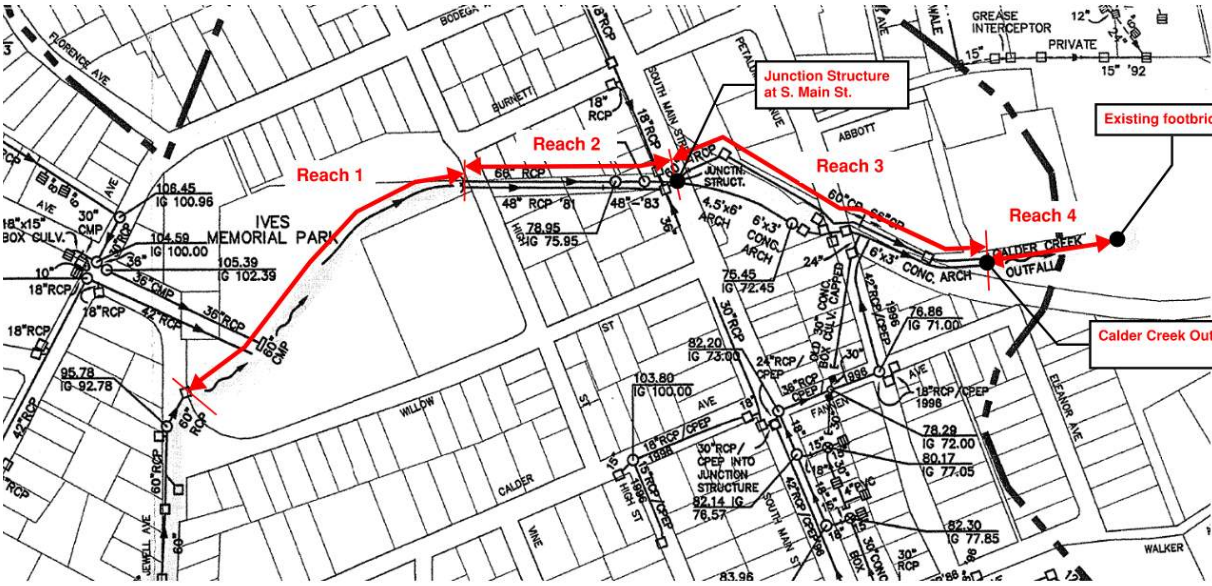

Figure 1 Reaches at Calder Creek within study area (Background image provided by City of Sebastopol storm drain mapping, 2022)

2. Existing Conditions

The Calder Creek drainage area consists of an approximate 667-acre watershed draining both rural-suburban and denser urban areas (WRI, 2022). Drainage enters the study area from the upstream Calder Creek subdrainages at various input locations. These discrete locations are discussed in Section 5.2, Boundary Conditions. The portion of Calder Creek within the study area consists of a highly urbanized and modified network of channels and storm water conveyance conduits that drain water from surrounding neighbourhoods and lands, conveying stormwater toward the Laguna de Santa Rosa to the east. Based on site and geomorphic assessment conducted by WRI (2022) and GHD, sediment sources from the upper watershed in combination with the release of stored sediment from the former Ives Park pond has caused the lower reaches (Reaches 2-4) to aggrade with sediment and effectively clog the lower Calder Creek storm drain system resulting in significant flooding near S. Main St and Petaluma Ave from surcharged drain inlets and manholes. Additionally, a single rootwad obstruction exists approximately 350 feet downstream from the Calder Creek storm drain outfall where Calder Creek drains into the Laguna de Santa Rosa floodplain. This rootwad and the resultant sediment accumulation within the lower reaches has caused the bed elevation to increase reducing the overall capacity of the storm drain system.

A significant storm event occurred on October 24, 2021 and caused Calder Creek to flow overbank and flood portions of Petaluma Ave. and adjacent private properties. According to the National Weather Service (NWS, 2022) total precipitation accumulation for that event was 6.09 inches over a 24-hour time period (NWS, 2022 from the Sonoma County Airport Rain Gauge). According to the intensity, duration, frequency data provided by the National Oceanic and Atmospheric Association (NOAA) this event was approximately a 10-year recurrence interval storm event (NOAA, 2022), or an event that has a 10% chance of occurrence in any given year. An image taken near the peak flooding event is provided below (Figure 2).

Figure 2 Calder Creek flooding at Petaluma Avenue during the October 24th, 2021 10-year recurrence interval storm event.

2.1 Site Topographic Survey and Geomorphic Assessment

As presented in Section 2, a topographic survey and geomorphic assessment was conducted during a series of site visits by GHD staff between October 19, 2021 and January 7, 2022. This assessment also references findings contained in the Calder Creek Stream Restoration Basis of Design Report by WRI (2022). The primary focus of the assessment was to capture channel conditions such as change in channel slope, form or geometry, identify breakpoints in the channel such as placed rock, root structures, infrastructure or any feature that would affect flow regimes within Calder Creek. Exhibit 1.1 attached to this Technical Memo provides locations for each of the observed channel conditions described in this section.

2.1.1 Ives Park (Reach 1)

Calder Creek drains into Ives Park through an existing 60-inch diameter concrete storm drain pipe where flow immediately becomes channelized (Figure 3, left) into a trapezoidal, concrete lined channel with stone surface texturing that extends through Ives Park. Central to Ives Park is a widened, naturalized, earthen portion of the channel with Inset floodplains (also known as in-channel benches consisting of narrow floodplain “benches” which lie 1-2 feet above the existing low flow channel thalweg but below the bankfull width. A single weir and flashboard system downstream to this widened channel was constructed to create a pond feature (Figure 3, right). Overtime, this backwater effect has slowed velocities, which has allowed sediment to accumulate behind the weir structure and collect along the streambed and inset floodplain areas. The flashboard weir was later removed which caused geomorphic response along Reach 1, effectiv ely dropping the thalweg profile, re-mobilizing the stored sediment to downstream reaches during large flow events.

Figure 3 Left: Calder Creek at upstream end of Ives Park (looking toward the southwest); Right: Calder Creek at the central flashboard weir system within the heart of Ives Park.

2.1.2 Storm Drain System Downstream of Ives Park (Reaches 2 and 3)

Reaches 2 and 3 consist of underground storm drain pipes extending from the east end of Ives Park to the outfall at the Laguna de Santa Rosa floodplain. Portions of these pipes lie directly under S High St., S. Main St., and Petaluma Ave. Reach 2 consists of the portion of underground, parallel, reinforced concrete pipe (RCP) between Ives Park and the Junction Structure at S. Main St. Reach 3 consists of the portion of underground pipe that splits once again from the Junction Structure at S. Main St. and runs parallel to the storm drain outfall in the Laguna de Santa Rosa floodplain.

Figure 4: Left: Calder Creek at downstream end of Ives Park at the inlet of the parallel, underground pipes. Right: Calder Creek outfalls at the Laguna De Santa Rosa floodplain.

Sediment has accumulated within the Reach 2 and 3 storm drain system as a result of a) upstream sediment loads, b) the removal of the flashboard weir system at Ives Park and c) a single Willow "rootwad" that has grown within the channel, downstream of the Calder Creek outfall at the Laguna de Santa Rosa floodplain, which has created a backwater effect, slowing water velocities and accelerating sediment accumulation. These contributing factors have resulted in sediment accumulation where, in some cases pipes are 75 – 90% clogged. Underground storm drain pipes at the upstream end of Reach 2, near the Ives Park outfall are generally free of sediment due to the steep slopes where velocities are high enough to maintain sediment transport to downstream reaches. These observations were made during onsite surveys by a GHD surveyor where nearly all manholes between Ives Park and the storm drain outfall at the Laguna de Santa Rosa were uncovered and surveyed.

According to the hydrology study performed by Coastland Civil Engineering (2005), under a sediment-free (unplugged) condition, the Reach 2 storm drainage system has sufficient capacity to convey the 10-year storm. However, because of the large sediment accumulation within Reaches 2 and 3, hydraulic capacity in the system has been significantly reduced resulting in flooding during the 10-year event, especially near the area where Calder Creek crosses Petaluma Ave. (see Figure 2 and Figure 5).

Figure 5 GHD staff at a manhole upstream from Petaluma Ave. with sediment accumulation at the manhole rim along the southern run of Reach 3 along a run of 6'x3' arched concrete conduit.

2.1.3 Reach Between Calder Outfall and Joe Rodota Trail Footbridge

An existing channel rootwad consisting of a large non-native Mayten tree (*Maytenus boaria*) has grown directly in the creek channel, approximately 125-feet downstream of the storm drain outfall (Figure 6). This rootwad has created an obstruction in the conveyance channel and has caused considerable backwater in the storm drain system, slowing water velocities thus allowing sediment to deposit and collect, upstream of the rootwad. Based on on-site investigation by GHD field crew, a considerable quantity of sediment was observed at a manhole along the southern leg of Reach 3, just upstream of the Calder / Petaluma Ave. crossing (Figure 5).

The rootwad creates an approximate 1.7-foot drop in creek bed elevation. Calder Creek then flows toward the Laguna de Santa Rosa through a series of shallow channels. For this report, geomorphic and hydraulic conditions were characterized to the footbridge at the Joe Rodota Trail.

Figure 6 Non-native Mayten trees in Calder Creek channel approximately 125 ft downstream of the storm drain outfall. Rootwad obstruction causes approximate 1.7' drop in the bed elevation.

2.2 FEMA Flood Analysis

The downstream end of the study area lies within the10-year FEMA flood elevation of 70.2 feet (NAVD88-ft). A larger portion of the study area (up to Petaluma Ave) lies within the 100-year FEMA flood zone (Zone AE). The area between Petaluma Ave. and S. Main St. lies within the 500-year FEMA flood zone (Zone X). The 100-year FEMA flood elevation is 77.8 feet within the study area (FEMA, 2017).

3. Conceptual Design and Phasing Scenarios

A total of seven (7) separate scenarios (Existing Condition and Proposed Scenarios A-F) were modelled within the study area (Reaches 1 – 4). These scenarios are discussed in further detail below. Each of the seven scenarios were developed to better understand the hydraulic response of varying proposed conditions compared to the system's existing condition. Three (3) additional scenarios presented by WRI, Inc. (2022) are further described at the end of this section (Section 3.8). These scenarios were not modelled in this analysis, however the City of Sebastopol may consider these in future planning. The additional three scenarios were beyond the scope of this preliminary modelling effort and the results of the seven modelled scenarios demonstrate significant flood reduction. The scenarios below are present in the potential sequence they could be implemented; however additional planning and design are necessary as some scenarios could be combined for funding, design and regulatory permitting efficiencies.

3.1 Existing Condition Scenario

This scenario assesses the existing hydraulic conditions within the study area. This option represents existing channel conditions in Reach 1 through Ives Park, partially clogged storm drain pipes within Reaches 2 and 3, and the existing rootwad and channel conditions within Reach 4.

3.2 Proposed Scenario A – Removal of Tree Rootwad at Calder Outfall

Proposed Condition A removes the single rootwad obstruction and lowers the bed elevation 1.7 feet between the storm drain outfall and rootwad (see Figure 6). The rootwad occurs approximately 100 feet downstream of the Calder Creek storm drain outfall. Given the backwater condition created by the rootwad, removal of rootwad and lowering of the channel could allow some accumulated sediment in the upstream storm drain pipes to remobilize and therefore, an additional assumption was made for this scenario that accounted for approximately 1 vertical foot of stored sediment remobilizing during the first high winter flow, slightly increasing the storm drain capacity. This model condition assumed the remobilized sediment would transport out of the system and redistribute throughout the Laguna.

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3.3 Proposed Scenario B – Deepen and Widen Calder Creek Outfall

This scenario extends the deepening and widening within Reach 4 by expanding 375 feet of Calder Creek downstream from the storm drain outfall from the Calder Creek storm drain outfall to the Joe Rodota trail footbridge. The Reach 4 channel thalweg was lowered to match the storm drain outfall inverts while maintaining the existing channel slope through this reach. The modified Reach 4 was graded into the LiDAR surface and used in the PCSWMM 2D modelling using the channel geometry proposed by WRI (2022). The channel geometry included a trapezoidal channel with 8-ft bottom width, 3-ft channel depth and 1.5H:1V side slopes (WRI, 2022).

3.4 Proposed Scenario C – Unplug Storm Drains and Deepen / Widen Calder Creek Outfall

This scenario includes Condition B described above in addition to complete removal of all debris and sediment that has collected in the storm drain system. This option would fully restore the storm drain infrastructure to its full capacity.

3.5 Proposed Scenario D –Ives Park Improvements Only

The Calder Creek Improvement concept was incorporated and analysed in Proposed Conditions, D-F. This concept through Ives Park was designed and generated by WRI, Inc. and was provided to GHD as a 3D surface model. This design incorporates a new creek realignment of Calder Creek through the Ives Park Reach (Reach 1), new pedestrian pathways, bridges and other facilities. Further description of how this model was developed is described in the Calder Creek Restoration Basis of Design Memo by WRI (2022).

Proposed Condition D includes the WRI improvements to Calder Creek through Ives Park based on the proposed Calder Creek realignment preferred by the City (the “Updated Charrette” alignment). Proposed Condition D does not incorporate any improvements to Reaches 2–4 described in Condition A and B above.

3.6 Proposed Scenario E –Ives Park Improvements, Unplug Storm Drains and Deepen / Widen Calder Outfall

This scenario includes Condition C and D described above.

3.7 Proposed Scenario F - With Ives Park Improvements, Unplug Storm Drains and Deepen / Widen Calder Outfall – During 10-year Backwater Elevation

This scenario includes Condition E and applies a 10-year FEMA water level to the downstream model boundary condition to simulate a coincident flood occurrence in the Laguna de Santa Rosa.

3.8 S. High St. to S. Petaluma Ave. Improvements

This option would remove the parallel underground storm drain pipes and daylight Calder Creek east of Calder Creek in downtown (between S. High St. to Petaluma Ave). This design option was explored by WRI, Inc. as an option to consider in future studies however was not modelled in this study as the results from Scenario C described below will reduce the flooding during a 10-year event if implemented.

4. Hydrologic Model Development

Peak runoff was estimated at the project boundary locations from data provided by the 2005 City of Sebastopol Storm Drain System Utility Master Plan (SSUMP) by Coastland Civil Engineering, Inc. This study utilized a hydraulic model that analysed the City's stormwater infrastructure during a 10-year storm event. This study was generated according to Sonoma County Water Agency (SCWA) Flood Control Design Criteria Manual for Waterways, Channels and Closed Conduits (1983) using the Rational Method and computer aided software StormCAD v5.5 (Coastland Civil Engineering, 2005). Comparisons of these data were made in the WRI Basis of Design Report (2022) which compared peak runoff values by Coastland Civil to other estimates obtained with regional regression equations. The 2005 Storm Drain System Utility Master Plan included the most up-to-date information available to GHD at the time of this study. Should the City conduct future hydrologic studies, use of the Flood Management Design Manual (2020) should be considered however given the watershed size and methods, the results are not anticipated to vary from those described above.

4.1 Coastland Civil Engineering Inc. 2005 Storm Drain System Utility Master Plan

GHD obtained model data from the 2005 SSUMP by Coastland Civil Engineering, Inc. from City of Sebastopol staff which included 10-year recurrence interval peak flow values, estimated time of concentration at each location in the system along with pipe sizes and geometries. All of this data was utilized in this modelling effort. Table 1 summarizes peak flow rate estimates at each of the seven (7) boundary condition locations within the study area.

Table 1: Peak runoff estimates from the 2005 City of Sebastopol Storm Drain System Utility Master Plan by Coastland Civil Engineering, Inc. (See Exhibit 4.1 for boundary locations)

Boundary Location ID (See Exhibit 4.1)	10-year Peak Flow (cfs) (Coastland Civil, 2005)	Storm Drain Size (inches)	Location Description
BC1	175	60" CMP	Upstream end of Ives Park
BC2	83	42" RCP	Northern Drainage from Bodega Ave
BC3	31	36" RCP	Northern Drainage from Bodega Ave
BC4	17	18" RCP	Northern Drainage from S. Main St.
BC5	61	42" RCP	Southern Drainage from Fannen Ave.
BC6	117	66" RCP	Downstream end of Ives Park (Ives Park Outfall)
BC7	128	60" RCP	Downstream end of Ives Park (Ives Park Outfall)

The 10-year peak runoff values, along with the corresponding time of concentration to that discrete location were used to generate synthetic, triangular hydrographs for inputs into each hydraulic model. Exhibit 4.1 in the Attachments provides locations of each boundary condition, along with other inputs that were assumed in each hydraulic model. Triangular synthetic hydrographs were developed at each boundary location from the data contained in the SSUMP study data by Coastland Engineering, Inc. (2005). Each hydrograph assumed that the time of concentration (tc) is equal to the time to peak (tp) (tc = tp). A 10-minute peaking period was applied to each hydrograph. The duration of the receding limb of each hydrograph was assumed to be 1.67*tp. Plots showing each of the boundary condition synthetic hydrographs are provided in Exhibits 3.1 through 3.7.

4.2 FEMA Flood Studies

The 10-year water surface elevation was obtained from the FEMA Flood Insurance Study (FIS) report for Sonoma County and Incorporated Areas (See Exhibit). This study determined the 10-year water surface elevation (WSE) to be at 70.2 feet (NAVD88). The 100-year WSE was much higher at 77.8 feet NAVD88 (Table 2, FEMA, 2017). Exhibit 6.1 presents the project reach within the Laguna de Santa Rosa FEMA FIS report showing the model results from the FEMA flood study.

Table 2: Storm event and corresponding boundary condition for Calder Creek (FEMA, 2017)

Calder Creek Storm Event	Downstream Boundary Condition	WSE (ft)
10-year	Calder Creek 10-year Backwater	70.2 ft (NAVD88)
100-year	Calder Creek 100-year Backwater	77.8 ft (NAVD88)

5. Hydraulic Model Development

Given the combination of both open channel and storm drain pipes, two separate 2D hydraulic modelling software platforms were utilized to analyse hydraulics through the study area. Model runs analysed the system under the 10-year recurrence interval storm event.

Version 6.1 of the US Army Corp of Engineers HEC-RAS 2D model was utilized to assess hydraulics through Ives Park. PCSWMM hydraulic modeling software was utilized downstream of Ives Park because of its capabilities to model flow in closed conduits, and route overland flow from surcharged inlets using a 3D DEM surface model. Each of these models are further described below.

The HEC-RAS model domain encompassed the Ives Park area (Reach 1) from the upstream 60-inch RCP Pipe outfall, to the lower Ives Park dual headwall condition which flows into two, parallel, underground pipes towards Reach 2 – 4. Existing and proposed surface models were compiled and formatted in AutoCAD Civil 3D from onsite survey data conducted by BKF, Inc. dated June 2011 and data provided to GHD by WRI, Inc for the proposed Ives Park condition. Each data source was used to generate a 2D mesh within HEC-RAS 2D. boundary conditions were inserted at each boundary location (See Section 5.2). Inline structures were used at existing bridges. A single rectangular weir inline structure was used within HEC-RAS at the central weir structure, to model hydraulics through this streambed stabilizing structure. Roughness coefficients presented in the WRI (2022) report were utilized in the model to simulate ground cover characteristics.

5.1 PCSWMM

The PCSWMM Model domain started at the Ives Park outfall where the double, parallel RCP pipes begin. The downstream model domain limit ended at the footbridge along the Joe Rodota Trail near the Laguna de Santa Rosa floodplain. PCSWMM is ideal for this application due to its capability to perform full dynamic modelling of natural rivers, culverts, bridges, storm water utilities and much more. The 1D and 2D connectivity allows water to be routed overland over a 2D mesh. The model is also ideal for analysing systems that are partially or fully clogged with sediment.

Topographic survey data was used to estimate the size and horizontal geometry of the storm drain system as well as estimated depth of accumulated sediment. These data were used in the geometry inputs of the PCSWMM model.

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5.2 Boundary Conditions

Flow input locations into the HEC-RAS 2D model domain existed at three discrete locations. BC1, BC2 and BC3 were all assigned as boundary condition inputs into the HEC-RAS 2D model (See Exhibit 4.1). Boundary conditions BC6 and BC7 were located where the two hydraulic models converged. Flow hydrographs were shared at these locations between the two models.

The outflow hydrograph from the HEC-RAS 2D model were used as inputs into the upstream boundary condition for the PCSWMM model. Two additional boundary conditions were applied to the PCSWMM model. One near the Junction Structure at S. Main St. from the northern drainage (BC-4) and the second from southern drainage from flow originating from Fannen Ave. and entering the system near Petaluma Ave. (BC5).

The downstream boundary condition was set as a normal depth for all model runs except Scenario F (described below). The computed 10-year normal depth elevation at the model downstream boundary condition is similar to that of the 10-year Laguna de Santa Rosa backwater elevation (FEMA) and therefore use of the normal depth boundary condition appears appropriate. Additionally, due to the size of the Laguna de Santa Rosa watershed in comparison to the Calder Creek watershed, it is assumed for this study that the time to peak in the Laguna is much longer than the time to peak within the Calder Creek watershed, and thus coincident 10-year events is unlikely.

6. Hydraulic Modelling Results

For each of the seven scenarios described above, hydraulic modelling results showing both inundation extents along with longitudinal hydraulic grade line (water surface elevation) for each modelling scenario are presented the attached Exhibits 2.1 through 2.7 and 5.1 – 5.13, respectively.

6.1 Model Verification

The October 24, 2021 storm event and resulting flooding extent was the only available verification of model accuracy and used to calibrate the model (see Figure 1). Inundation extent during the time of peak runoff was observed for this 10-year recurrence interval storm event. Sediment depth in the existing pipe network was adjusted between the topographic surveyed elevations to match the observed water levels as a calibration variable for the model.

6.2 Existing Condition Scenario

The combined hydraulic models were successful in modelling the existing conditions through the study area (Reaches 1-4). The existing condition within the study area resulted in flooding in both Ives Park (Reach 1) and the downstream storm drain system (Reaches 2 and 3) for the 10-year recurrence interval design storm events. Exhibit 2.1 provides flood inundation extents for this scenario. Exhibit 5.2, 5.3 and 5.7 present longitudinal profiles and velocity information through each reach.

6.2.1 Channel and Storm Drain Capacity

Portions of the Ives Park channel through Reach 1 overtopped during the 10-year storm event. The HEC-RAS 2D analysis showed water overtopping on river right (looking downstream) near the 60-inch RCP culvert near the area where the Jewel Ave. drainage enters the park. Additional overtopping occurred near the existing playground on river right, along the right hand side, inset floodplain, just upstream of the flashboard weir structure. According to the model, stormwater re-enters the Calder Creek channel downstream of the overtopping location. The concrete, trapezoidal channel downstream of the flashboard weir structure did not overtop during the 10-year storm. The model predicted higher velocities (5-10 ft/s) within this reach which corroborates the absence of observed sediment in the channel through this reach (See Exhibit 5.2 for velocity profile). Lower velocities (1-5 ft/s) were observed through the reach upstream of the flashboard weir system where the channel slope is not as steep, structures exist which act to slow velocities and cause flow to back up behind each structure.

Correspondence with City of Sebastopol staff confirm that flooding occurs during large storm events at the playground. This serves as an additional verification point for model accuracy through Ives Park.

While the existing condition exhibited some overtopping, the system's ability to transport sediment through and maintain a stable channel exists due to the quantity of grade control structures within earthen portions of the Ives Park reach and the stable, concrete lined channel that make up approximately 74% of Reach 1. Historically sediment would accumulate behind the flashboard weir system when the flashboard was installed and bed elevations were approximately 4-ft higher upstream of the weir system. Since the removal of the flashboard weir, the bed has mobilized to the invert of the existing concrete below the flashboard. The bed profile has since stabilized to its current elevation after the release of sediment and post-removal of the flashboard weir.

Storm drain capacity was exceeded within Reaches 2 and 3 resulting in overtopping of storm water at manhole structures and flooding within the lower area near Petaluma Ave. This was due to the sediment accumulation within the existing storm drain system and the rootwad obstruction within Reach 4. Exhibits 2.1 and 5.7 provide both inundation extents for flooding within Reaches 2 and 3 along with velocity and hydraulic grade line information through the storm drain system. Conduit C1 and C23 (60" and 66" RCP pipes, Exhibit 5.7) show velocities at 7.96 ft/s and 5.47 ft/s, respectively. These velocities will be used as a comparison for later scenarios and a gauge for understanding sediment re-entrainment from higher velocities.

6.2.2 Flood Inundation

Exhibit 2.1 presents flood inundation for the Existing Condition Scenario. Under this scenario portions of Ives Park become inundated from channel overtopping. Further extensive inundation occurs near S. Main St. and Petaluma Ave. due to surcharging at manholes and drain inlets within the existing storm drain system. The area most impacted by flood inundation is the Post Office parking area adjacent to where the Calder Creek storm drains cross Petaluma Ave. Flood inundation is also observed at the S. Main St. manholes and drain inlets. This flood inundation extent is similar to peak flooding conditions observed during the 10-year storm that occurred on October 24, 2021 (Figure 1).

6.3 Scenario A – Removal of Tree Rootwad at Calder Outfall

The modelling results for this scenario are described below and Exhibits 2.2, 5.2, 5.3 and 5.8 provide inundation mapping, velocity and water surface elevation profiles.

6.3.1 Channel and Storm Drain Capacity

This scenario did not increase channel capacity through Ives Park (Reach 1) but did provide minor additional flow capacity and resultant flood reduction through the Reach 2 and 3 storm drain system. This additional capacity was cased by a lower bed elevation at the outlet and a slightly reduced quantity of sediment within the storm drain system. Conduit C1 and C23 (60-inch and 66-inch RCP pipes, Exhibit 5.8) show velocities at 7.96 ft/s and 7.1 ft/s, respectively which is an observed higher velocity compared to existing conditions. This increase in velocity and additional capacity through the lower reaches could promote remobilization of deposited sediment in the storm drain system during high flow events.

6.3.2 Flood Inundation

Exhibit 2.2 provides inundation mapping for this scenario which shows a light reduction of flooding compared to the Existing Condition especially in the vicinity of Petaluma Ave. where an approximate ~0.25' depth flood reduction was observed.

6.4 Scenario B – Deepen and Widen Calder Outfall

The modelling results for this scenario are described below and Exhibits 2.3, 5.2, 5.3 and 5.9 provide inundation mapping, velocity and water surface elevation profiles.

6.4.1 Channel and Storm Drain Capacity

Similar to Proposed Condition A, this scenario did not increase channel capacity through Ives Park but did generate additional capacity and resultant flood reduction through the Reach 2 and 3 storm drain system. This option resulted an approximate additional 0.5' depth reduction in flooding compared to Proposed Condition A and a 1.0-foot depth reduction in flooding compared to the Existing Condition. Conduit C1 and C23 (60-inch and 66-inch RCP pipes, Exhibit 5.9) show velocities at 8.01 ft/s and 8.25 ft/s, respectively which is an observed higher velocity compared to both Proposed Condition A and the Existing Condition. This increase in velocity and additional capacity through the lower reaches will assist in transporting sediment through the system and reducing flooding.

6.4.2 Flood Inundation

A significant reduction in flooding was observed under this scenario. Manholes and drain inlets remain surcharged near the S. Main St. and Petaluma Ave. but depths of surcharges are significantly reduced. Exhibit 2.3 provides inundation mapping for this scenario which shows a reduction of flooding compared to the Existing Condition where an approximate ~0.73' depth flood reduction was observed in the vicinity of Petaluma Ave.

6.5 Scenario C – Unplug Storm Drains and Deepen / Widen Calder Creek Outfall

The modelling results for this scenario are described below and Exhibits 2.4, 5.2, 5.3 and 5.10 provide inundation mapping, velocity and water surface elevation profiles.

6.5.1 Channel and Storm Drain Capacity

Removal of the deposited sediment within the storm drain system and deepening/widening the channel downstream of the storm drain outfall results in full recovery of the system's conveyance capacity and elimination of flooding during the 10-year storm event. A slight reduction in water surface elevation was observed near the Ives Park outfall due to the increase in system capacity through Reaches 2 and 3 (Exhibit 5.3). Conduit C1 and C23 (60" and 66" RCP pipes, Exhibit 5.10) show velocities at 7.78 ft/s and 9.19 ft/s, respectively which is an observed higher velocity compared to both Proposed Condition B and the Existing Condition.

6.5.2 Flood Inundation

This scenario eliminated the 10-year flooding in Reaches 2 and 3. While the downstream reach near the Ives Park dual headwall outfall resulted in slightly lower water surface elevations locally, inundation and overbank flow still occurred at the same locations as scenarios A and B (Exhibit 5.3). This shows flooding at Ives Park is independent of sediment removal within the storm drain system in Reach 2 and 3 due to the inlet controlled condition of the culvert entrance at the eastern end of Ives Park at High Street.

6.6 Scenario D – Ives Park Improvements Only

The modelling results for this scenario are described below and Exhibits 2.5, 5.4, 5.5 and 5.11 provide inundation mapping, velocity and water surface elevation profiles.

6.6.1 Channel and Storm Drain Capacity

The WRI concept improvements through Ives Park included widening the channel corridor, and which effectively provided increased flow capacity through Reach 1 which removed overtopping of the channel compared to the Existing Condition Scenario. This option provides sufficient capacity to convey the 10-year storm event. While the low flow channel overtops within the channel corridor as it is designed to do - it is sized for lower recurrence interval storm events, the 10-year event remains within the inset floodplains. Additionally, due to the gentle meander of the channel, constant slope along the channel thalweg and relatively uniform cross section through the modified Reach 1, velocities also remain relatively constant (5.0-8.0 ft/s) (Exhibit 5.4 and 5.11 show velocity information within Reaches 1-4).

6.6.2 Flood Inundation

Flood inundation within Ives Park (Reach 1) with the WRI improvement plan incorporated results in flood inundation beyond the designed low flow channel which activates the inset floodplains (the"inset floodplain" is the lower 'shelf' of the bank designed to flood to prevent overflow of the upper edge of bank). No inundation was observed outside of the Calder Creek channel area (Exhibit 2.5). Flood inundation for Reaches 2 and 3 under this scenario remain similar to Existing Conditions.

6.7 Scenario E – With Ives Park Improvements, Unplug Storm Drains and Deepen / Widen Calder Outfall

The modelling results for this scenario are described below and Exhibits 2.6, 5.4, 5.5 and 5.12 provide inundation mapping, velocity and water surface elevation profiles.

6.7.1 Channel and Storm Drain Capacity

This scenario results providing Reach 1 through 4 with the highest level of storm water conveyance capacity due to the incorporation of the Ives Park improvements by WRI, the clearing of sediment through the Reach 2 through 4 storm drain and channel systems and the deepening / widening of the Calder Creek outfall at the Laguna de Santa Rosa floodplain area. No surcharging or overtopping of channels are observed within the study area under this scenario.

Exhibits 5.4 and 5.5 show a decrease in water surface elevation compared to the Existing Condition was observed near the Ives Park outfall due to the clearing of sediment within Reaches 2 – 4. Consequently, an increase in velocity is observed at the downstream end of Reach 1.

6.7.2 Flood Inundation

No flood inundation was observed outside of the Calder Creek corridor for this Scenario in a 10-year (10% chance annualy) event Similar flood inundation was observed within Ives Park compared to the Proposed Condition D with a slight reduction near the Ives Park outfall. Water surface remained within the Calder Creek channel for this option. A similar observation was made to Scenarios A – C where inundation at Ives Park were largely independent of sediment removal within the storm drain system in Reach 2 and 3 due to the inlet controlled condition of the culvert entrance at the Ives Park outfall. No flood inundation was observed with this scenario within Reaches 2 or 3.

6.8 Scenario F - With Ives Park Improvements, Unplug Storm Drains and Deepen / Widen Calder Outfall – During 10-year Backwater Elevation

This scenario was incorporated into the analyses to assess what (if any) backwater effects of incorporating the 10-year FEMA flood elevation of 70.2 feet (NAVD88) to the downstream boundary as a "fixed boundary". Exhibits 2.7, 5.4, 5.5 and 5.13 provide inundation mapping, velocity and water surface elevation profiles for Scenario F.

6.8.1 Channel and Storm Drain Capacity

Channel and storm drain capacity with Reaches 1 through 3 were similar to results from Proposed Condition E. slightly deeper depths were observed in Reach 4 under this scenario due to the lower outfalls being partially submerged (inundated) throughout the model run. This created slightly increased backwater into the Reach 2 and 3 storm drain system but did not result in surcharging or flooding at any area within Reaches 1 though 3.

6.8.2 Flood Inundation

No flood inundation was observed outside of the Calder Creek drainage way for this Scenario. Slightly deeper channel depth was observed near the Calder Creek outfall within Reach 4 but the channel did not overtop.

6.9 Flood Reduction Results Summary

Based on the summaries above, Table 3 represents the percent reduction in flooding relative to existing conditions within the study area (Reaches 1 through 4) for a10% annual chance (10-year event). Additionally, the percent reduction of maximum flooded depth at Petaluma Ave. is reported as an additional metric of project benefit for each scenario. This information is also provided in Section 7 which compares the percent reduction in flooded area to the project cost (Table 4).

Table 3: Flood Reduction Summary from modelled results A – E within study area (Reaches 1 – 4)

Flood Reduction Summary - Model Results - Scenarios A through E				
	Area of Flood Inundation (ac)	Percent Reduction in Flooding Depth at Petaluma Ave.*	Max Depth Flooding at Petaluma Ave. (ft)*	Percent Reduction in Flooded Area from Existing Conditions
Existing Condition (No Action)	4.09	-	0.73	-
Scenario A	3.24	14%	0.63	21%
Scenario B	2.32	30%	0.51	43%
Scenario C	1.10	100%	0.00	73%
Scenario D	3.10	1%	0.72	24%
Scenario E	0.00	100%	0.00	100%

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7. Opinion of Probable Construction Cost

Class 4 rough order of magnitude construction costs (ROM) were developed for the scenarios (Table 4). The opinion of construction cost range consists of a combination of estimated labor, equipment and materials necessary to implement the alternatives. Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side. The scenario costs reflect an estimating contingency of +50% to account for material and construction cost volatility and uncertainties given the early planning phases of this study. Scenario costs are based on recent bid results of similar projects and professional judgement. Construction costs associated with instream projects are difficult to estimate given the unique nature of work and lack of applicable industry standard construction estimating resources such as R.S. Means data. Site conditions such as a high groundwater, presence of sensitive species and seasonal work windows increase construction costs. The risks associated with working in these environments are much higher relative to typical public works construction projects. Construction costs are subject to variations in contractor bidding, labor rates, material costs, availability, permitting conditions, site accessibility, general economic pressures and other unforeseen costs associated with a project in the current planning level. Given these potential variations, GHD makes no warranty, express or implied, that actual scenario costs will not vary from the provided cost. Remaining planning, engineering, regulatory compliance and construction management services were not included in the cost estimate, however these costs can be included in future project planning and budgeting.

Table 4: Class 4 rough order of magnitude construction costs (ROM) for Proposed Conditions A - E.

Condition	Cost	Cost +50% Contingency	Percent Reduction in Flooded Area from Existing Conditions
A - Removal of Tree Rootwad at Calder Creek Storm Drain Outfall	$134,000	$201,000	21%
B - Deepen and Widen Calder Creek Below Storm Drain Outfall	$460,000	$690,000	43%
C - Unplug Storm Drains and Deepen / Widen Calder Creek Outfall	$1,815,000	$2,722,500	73%
D - Ives Park Improvements	$5,249,000	$7,873,500	24%
E - Ives Park Improvements with Unplugged Storm Drains / Deepened & Widened Calder Creek Outfall	$6,689,000	$10,033,500	100%

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8. Conclusions and Next Steps

The conclusions from this study are summarized below and can be used to support future restoration and maintenance activities on Calder Creek.

1. The existing storm drain capacity in Reaches 2-4 are highly sensitive to both the quantity of sediment within the system and the outfall condition. Removal of the deposited sediment from the storm drain system in combination with deepening/widening the channel downstream of the storm drain outfall (Scenario C) will reduce flood risk and eliminate flooding throughout the Petaluma Ave. area during the 10-year event. While Scenario A and B provide some flood reduction benefits in the Petaluma Ave., these Scenarios could result in some remobilization of sediment from the storm drain pipes and re-deposition into Reach 4. Alternatively, daylighting the storm drain system in Reach 2 through 4 which was conceptualized by WRI however not modeled in this study, could be assessed comparatively and would require additional feasibility assessments beyond the scope of this study. The remaining planning, design and implementation for the daylighting concepts could take 3-10 years and would be subject to available grant funding.
2. Ives Park improvements (Scenario D) will reduce flood inundation locally within Ives Park, however it had little effect on flood impacts within Reaches 2 through 4. The modelling results indicate removal of sediment from Reaches 2 and 3 have a minor effect on the water surface elevations at the eastern end Ives Park and therefore Scenario C could be implemented independent of Scenario D.
3. Obtaining grant funding to conduct maintenance activities is often challenging and therefore securing funds to only remove sediment from the storm drain pipes in Reaches 2 and 3 may be difficult. Including the widening/deepening of Reach 4 which would include invasive species removal, instream habitat features and re-vegetation of natives would improve the competitiveness of a grant application by demonstrating multi-benefits of flood reduction and habitat enhancements.

9. References

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Exhibits