8/14/2020

Ditch retrofits for improved stormwater management

A revised Proposal to the Stormwater Action Monitoring's 2020 Request for Proposals

Prepared by:

The Washington Stormwater Center- Washington State University, Herrera Environmental Consultants, and The City of Tacoma.

WASHINGTON STATE UNIVERSITY – PUYALLUP, CITY OF TACOMA, AND HERRERA ENVIRONMENAL CONSULTANTS

PROJECT PURPOSE

SUPPORT OF PRIORITY TOPICS

From SWG's 2019 list of priority topics, the following two topics will be addressed here:

1. Priority topic 14: Compare cleaned/uncleaned ditches to assess effectiveness of ditch cleaning at removing legacy pollutants. Include evaluation of likely release of pollutants.
2. Priority topic 15: Evaluate effectiveness of ditch enhancement techniques at removing pollutants.

We will work with the City of Tacoma to identify ditches in their jurisdiction for instrumentation and testing with alternative practices. The City of Kirkland, Kitsap County, City of Puyallup, City of Seattle have been identified as potential partners to serve on a technical advisory committee and share maintenance practices.

THE RELATIONSHIP BETWEEN DITCHES AND STORMWATER QUANTITY AND QUALITY

Road runoff is the primary contributor of runoff to most roadside ditches making roadside ditches and swales the first responders to road runoff. The sources of contamination are the road surface itself, vehicles (oil, fuel, tires, brakes), atmospheric deposition, surrounding land use, and road maintenance chemicals (Maestre and Pitt, 2006; Opher and Friedler, 2010). The contaminants in roadside runoff are sediment, many different types of metals, organic chemicals from deicing and agricultural chemicals, and a set of emerging pollutants yet to be identified (Bannerman et al., 1993; Peter et al. 2018). In addition, the ditch itself is a source of potential sediment from bank and bed erosion.

Ditches and swales offer a vital yet under-exploited potential to mitigate stormwater quality emanating from catchments of varying sizes. The standard trapezoidal ditch shape has been shown to be less than optimal in terms of ability to withstand erosion, requiring constant maintenance, and offering little in terms of water quality treatment. As sediments accumulate within a roadside ditch, a 'clean out' of the ditch is the common maintenance practice where the ditch is restored to its original trapezoidal shape. This form of ditch restoration/maintenance is done by simply regrading the system, removing sediments, and reestablishing the original trapezoidal cross-section with a backhoe bucket. Often no erosion control measures are installed when the ditch is cleaned-out, resulting in considerable releases of sediment and pollutants downstream.

Since ditches are the primary conveyance mechanism for roadside runoff to downstream receiving waters, they could be adding considerably to the impairment of the Puget Sound (Herrera 2011). They represent a largely untapped source of improvement for the Puget Sound water quality if they could be managed and maintained to more effectively manage stormwater quality and quantity.

THE IMPORTANCE OF DITCHES IN MANAGING STORMWATER

After multiple conversations with permittees, installing ditches that require the least maintenance over time was found to be the most important aspect of ditch management in the Puget Sound region. This is because ditches that require constant maintenance are a huge expense, and poorly maintained ditches (either neglected or maintained in a manner that promotes erosion) can themselves become pollutant sources.

Ditch maintenance in the region tends to be triggered by complaints from local residents (overgrown with invasive plants) or if the jurisdiction deems the ditch to have lost conveyance, either because the ditch is filled with sediments or choked by vegetation. Ultimately, the removal of vegetation and sediments tend to be the most common forms of ditch maintenance. With hundreds of miles of roadside ditches in western Washington, poor ditch maintenance methodologies could be contributing ecologically significant pollutant loads to our waterways. These systems should be managed and optimized as water treatment pathways, not reduced to pollutant generating surfaces. The overall goal of this work is to determine improved strategies to retrofit ditches through a tactical choice of ditch form and plant palettes, to promote pollutant removal, convey higher storm flows, and lower long-term maintenance effort.

The 2019 Phase 1 Municipal Stormwater Permit has provided guidance for the Stormwater Management Action Planning (SMAP) program. SMAP is the first step in requiring stormwater retrofits in priority watersheds in permitted jurisdictions. With an increased focus on retrofitting existing MS4s there is a growing need for research on what retrofit methods will be most effective to implement. Phase 1 jurisdictions such as Pierce, Clark, King, and Snohomish Counties have hundreds of miles of roadside ditches that function as conduits for stormwater. If we can find ways to alter these conveyance systems so that they act as treatment systems, then a powerful new tool would become available for these permittees. This research will lay the foundation for improved ditch management techniques across the region.

PROJECT DESCRIPTION AND SCOPE OF WORK

There are two critical aspects of a roadside ditch that control the hydraulic and biogeochemical performance of the system – these are ditch form (slope and cross-section), and the plants growing in the ditch system. With this study, we seek to evaluate an alternative ditch form (the two-stage ditch), alternate plant palettes, and one form of alternative maintenance practice (skip-ditching). Our goal is to determine how we can design ditch systems so that over time, they are more stable, require less maintenance, and outperform standard trapezoidal ditches in terms of managing stormwater quantity and quality. Installing alternative ditch configurations could increase the conveyance of higher flows, dissipate excess in-ditch energy, lower average flow velocities, and increase contact times between water and the soil interface, thereby providing water quality benefits. Installing alternative plant palettes could improve erosion control within the ditch system by limiting erosive flow velocities, improve scour-resistance through root growth, and promote pollutant remediation at the soil/plant/water interface.

PROJECT OBJECTIVES

We believe the effective management of roadside ditches must include a combination of appropriate ditch shape form, vegetation, and maintenance protocol. Ditch configurations that increase the contact between water and the soils/plant interface for pollutant removal without compromising ditch conveyance is critical. The appropriate vegetation for planting in ditches must meet erosion control needs, not be invasive, must not impede high flows, and finally must not require much annual maintenance. Minimal annual maintenance of vegetation and ditch form is key. The overall goals of this work are, therefore, to evaluate two ditch retrofit strategies and identify appropriate vegetation palettes that promote erosion control without impacting the ability of the ditch to convey high flows. Specifically, the project objectives are to: A) quantify pollutant reduction or export across the various ditch configuration types; B) quantify potential flow control; and C) assesses alternative vegetation palettes.

PROJECT DESIGN

Through a careful selection of ditches based on TAC input, we will monitor the impacts of ditch retrofits and vegetation planting on flow and pollutant loads. We will evaluate two alternative ditch retrofit strategies as well as five vegetation planting palettes. The type of retrofit will be based on site constraints and TAC input, while vegetation palettes chosen based on TAC input. In all, three ditch sites will be selected in consultation with the TAC – one site for studying vegetation palettes, and one site each for the two ditch retrofit strategies. At all sites, flow, and water quality will be evaluated to see how these change under vegetation and ditch retrofit strategies (See Figure 1).

1. At the upstream-most location, every site will have a 100-ft section that has been cleaned out. Some minimal erosion control will be installed to prevent bedload from being transported downstream. This section will serve two purposes – to generate a pollutant load for downstream experimental reaches, AND to evaluate the impact of ditch cleanout on downstream reaches.

2. The second section is a 200-ft section comprising either alternative plant palettes **(Treatment 1)** or one of two ditch reshaping strategies **(Treatment 2)**. Selection of strategy will be based on site constraints and TAC recommendations - the two strategies considered are 2-stage channel (**Treatment 2a**) or skip-ditching (**Treatment 2b**).

All experimental reaches will have an upstream reach that will remain cleaned out for the duration of the study with some minimal erosion control. Treatment 1 will consist of an excavated ditch with standard erosion control practices (e.g., coir wattles, straw mulch, etc.) with 10 planted strips, each 20 feet wide. Each strip will consist of a different grass seed mix specially selected for western Washington's challenging ditch environments. Treatment 2 will include one of two retrofit strategies: a two-stage ditch or a skip-ditch. One of each of these strategies will be deployed at a site. The two-stage section will also be planted with the test vegetation palette. To reduce project scope, replication of these strategies across sites will not be attempted.

Figure 1 shows how the three strategies, plants, two-stage ditch, and skip-ditch, will be laid out across three sites. Road sections will be chosen such that there is little to no lateral sheet flow from the road surface with most of the flow generated from upstream sources.

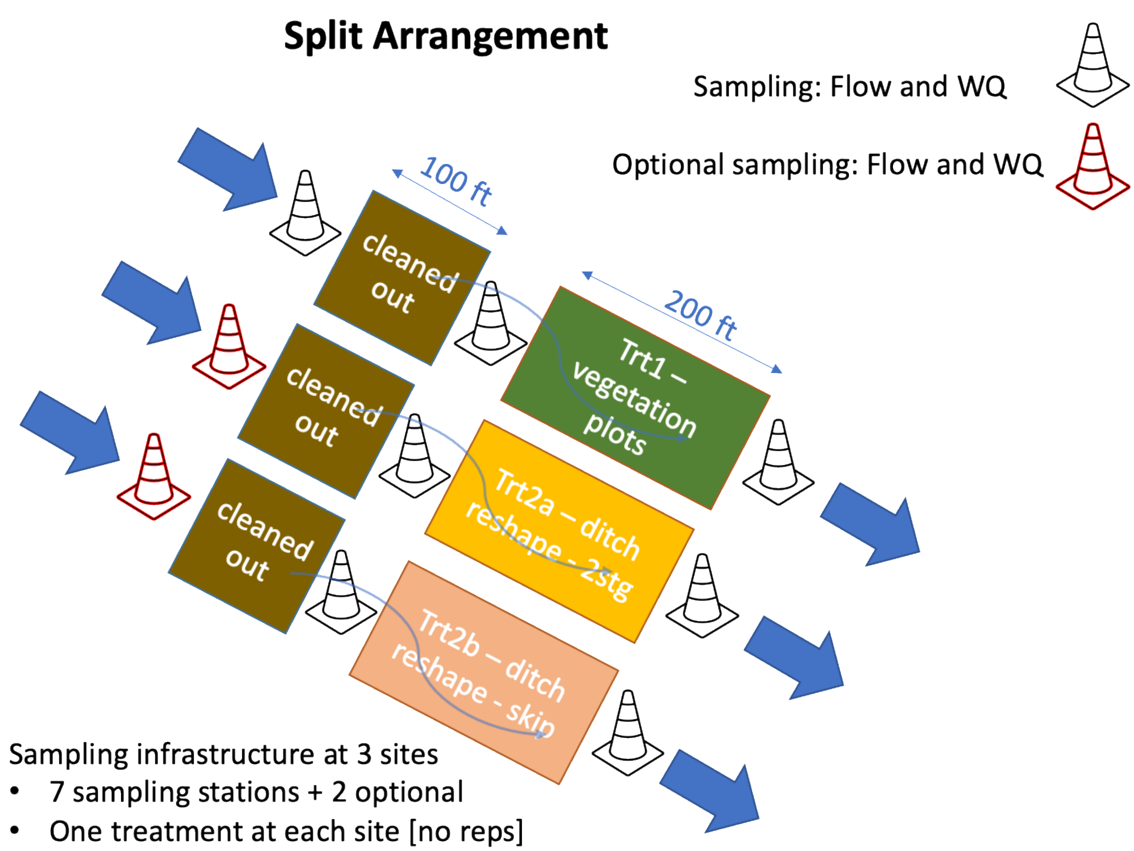

Figure 1: Split arrangement of three alternate vegetation and retrofit experimental setups. One of each experimental setup will be implemented at a site – with three sites total. Arrows denote flow direction.

PROJECT METHODS

Automated samplers and flow metering flumes will be installed at 3 locations at a site, bracketing each of the treatment reaches (Figure 1). Figure 1 shows this arrangement across all three ditch sites. Water level sensors associated with each flume will be interfaced with two dataloggers per site. The dataloggers will have integrated cellular modems and one rain gauge per site. Equipment will be housed in secure environmental enclosures and powered with solar. Eight events will be targeted for automated sampling over three years following the Washington State Department of Ecology's Technology Assessment Protocol – Ecology (TAPE) methods (Ecology 2018). Composite water quality samples will be analyzed for 11 analytes. Continuous flow data will be used to pace the automated samplers, and to assess variation in peak flow and volume reductions across each treatment.

To assess plant health, percent establishment (4-6 weeks post-planting) will show how fast the stand will provide complete ground cover. Additionally, stand quality (3 times per year: spring, summer, fall) will be rated in terms of ground cover, plant height, aesthetics, etc. Percent winter survival of a stand will be measured to determine if any component of the mix does not survive the winter. Lastly, percent ground cover (3 times per year: spring, summer, and fall) in terms of weed coverage as a percent of ground cover will be rated at establishment and at each stand quality rating date. Percent of each species that are dominant in a stand at the conclusion of the study will also be measured.

ANTICIPATED OUTCOMES

We anticipate three major outcomes: 1) The pollutant load generated by cleaned out ditches when erosion control is not placed; 2) the ability of alternative retrofit strategies to mitigate pollutant loads and peak flows; 3) the ability of alternative plant palettes to mitigate pollutant loads and peak flows.

PROJECT TASKS

TASK 1: PROJECT MANAGEMENT (TOTAL COST = $9,256)

Project administration will be led by Washington State University (WSU) staff. This includes initiating agreements, subcontracting with project partners, tracking progress of deliverables, and reimbursing partner project work based on detailed reports of deliverables. WSU will develop a Technical Advisory Committee (TAC) for this project. The TAC will comprise representatives from Ecology, other state agencies, and one permittee stormwater manager or coordinator from three or four jurisdictions. The TAC will advise the project team on site selection, planting palettes, and technical issues by meeting as needed throughout the project. Semi-annual reports will include status of the contract tasks and decisions related to the tasks made during the calls, meetings and coordination with the advisory committees and communication with Ecology as appropriate. The four semi-annual reports will include project updates, data quality assurance review, results, and findings to date.

Deliverable 1.1 to 1.5: Five semi-annual reports documenting activity, coordination, and communications with Ecology over the 35-month period of this study.

Cost = $1,851 each Target dates: End of month of months 6, 12, 18, 24, 30

TASK 2: QAPP DEVELOPMENT (TOTAL COST = $21,756)

A QAPP will be created before instruments are deployed or measurements are taken. The QAPP will list the ditch treatments to be investigated, the number of sensors that will be deployed, the plant species selection procedure, the type of data, how often data are collected, maintenance protocols for the system, how data will be managed, and lastly how data will be analyzed. Costs associated with QAPP development are related to time taken to write and revise the QAPP document.

For QAPP development, we will use the QAPP template provided by the SAM coordinator and follow the Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, July 2004 (Ecology Publication No. 04-03-030). The QAPP will be submitted to Ecology's SAM Coordinator for review and approval *before* the start of any fieldwork.

Deliverable 2.1: Draft QAPP
Cost = $10,878 Target date: End of Month 2
Deliverable 2.2: Final Approved QAPP
Cost = $10,878 Target date: End of Month 3

TASK 3: SITE SELECTION & INSTRUMENTATION (TOTAL COST = $137,792)

Sites will be selected in consultation with the TAC and permittees. Three study sites will be chosen (see Figure 1) at three locations. Prerequisites for sites will include the following:

1. Linear with no culverts and no tributary ditches
2. Dry between storm events
3. Approximately 200 feet per treatment
4. Low gradient (<2-3%)
5. The willingness of adjacent property owner to allow installation of sampling equipment

Instrumentation required for all 3 sites is presented below:

1. Seven flumes
2. Seven water level sensors
3. Seven ISCO automated samplers (6712 series)
4. Three dataloggers with cellular modems
5. Three rain gauges
6. Seven secure enclosures

To reduce costs, the samplers and sensors will be interfaced with only three dataloggers (one datalogger per site). A rain gauge will be interfaced with each datalogger. The selected equipment was chosen based on cost-effectiveness and instrument accuracy and reliability and is estimated to cost $70,000.
Deliverable 3.1: A memo with associated photos, to demonstrate the completed instrumentation of all sites. Appendices will include receipts of all equipment purchased. An inventory of all the equipment will be provided with the memo.
Cost = $137,792 (includes $70,000 equipment cost + installation costs) Target date: End of Month 5

TASK 4: - EVALUATING ALTERNATIVE PLANTING PALETTES (TOTAL COST = $124,354)

Plant palettes will be evaluated to determine the efficacy of current WSDOT roadside blends as well as the potential for new blends to be incorporated for use in Western Washington. Test plots will be established as an element of Treatment 1 (see detail below).

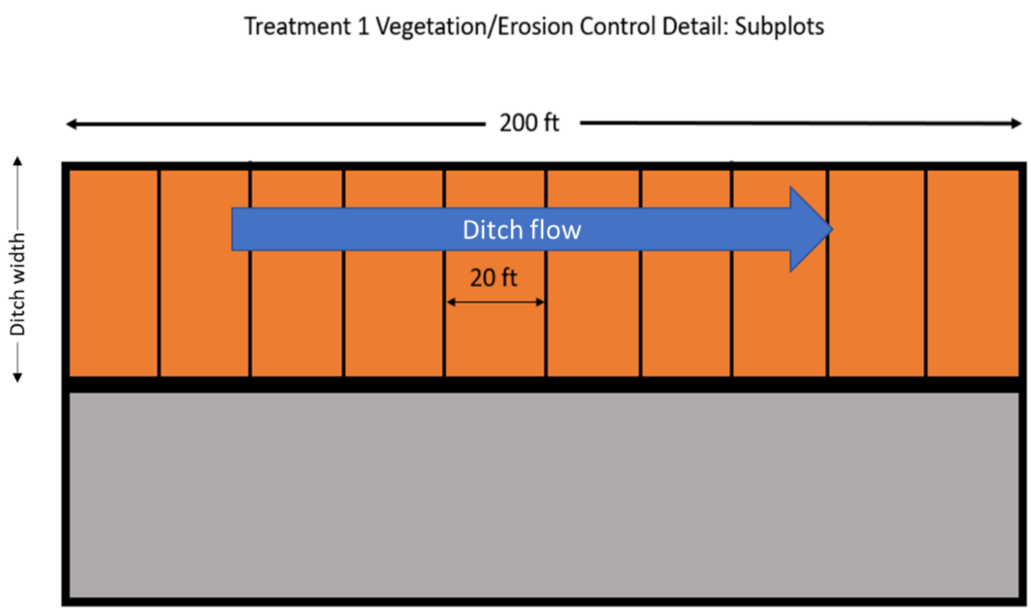

Figure 2: Arrangement of 20-feet wide vegetation plots in treatment section 1

Vegetation plots will be 20 ft wide with lengths dependent on the ditch width. Palette evaluation will comprise of 10 vegetation plots at each ditch site. Plots will include many current WSDOT blends used in Western Washington as well as a few designed by WSU. Palettes will be replicated at each site and arranged in a random complete block design. Below are a few options for potential palette compositions. Actual palettes may differ slightly depending on seed availability at the time of planting.

WSDOT Blends:

1. 50% Perennial Ryegrass, 40% Creeping Red Fescue, 10% White Clover
2. 50% Perennial Ryegrass, 30% Hard Fescue or Sheep Fescue, 20% Sherman Big Bluestem
3. 70% Creeping Red Fescue, 15% Meadow Foxtail, 15% White Clover
4. 40% Tall Fescue, 30% Perennial Ryegrass, 25% Creeping Red Fescue, 5% Highland Bent
5. 80% Tall Fescue, 10% Seaside Bent, 10% Redtop
6. 40% Creeping Red Fescue, 40% Perennial Ryegrass, 10% White Clover, 10% Highland Bent

WSU Blends:

1. 50% Creeping Red Fescue, 40% Chewings Fescue, 10% Highland Bent
2. 50% Hard/Sheep Fescue, 35% Strawberry Clover, 15% Yarrow
3. 35% Idaho Fescue, 35% Tufted Hairgrass, 30% Strawberry Clover
4. 55% Creeping Red Fescue, 15% Yarrow, 15% Meadow Foxtail, 15% Sweet Vernal Grass
5. 50% Redtop, 50% Highland Bent
6. 50% Slender Creeping Red Fescue, 40% Chewings Fescue, 10% Redtop

Data Measurements include:

1. Establishment percentage (4-6 weeks post seeding)
2. 6 stand quality ratings (3 ratings per year: spring, summer, and fall on a 1-9 scale; 1 =dead 9 =ideal)
3. Winter survival percentage (at each spring stand quality rating date)

4. Percent invasive cover (at establishment and each stand quality rating date)
5. Ground cover percentage (3 ratings per year: spring, summer, and fall)
6. Species dominant (at conclusion of study)

Successful palettes will have a high percent establishment, quality rating >5, low invasive percentage, high winter survival percentage and species dominant as a component of the seed blend. Planting of sites will occur in Fall 2021, and monitoring will continue through to the end of the project in early 2024.

Deliverable 4.1: Draft report of analysis with a presentation shared at TAC meeting # 4 that outlines the total effort associated with the successes and failures of the vegetation plantings.
Cost = $62,177 Target date: End of Month 30
Deliverable 4.2: Revised analysis and revised report shared with TAC meeting # 5
Cost = $62,177 Target date: End of Month 32

TASK 5: QUANTIFYING EFFECTS OF DITCH MAINTENANCE & RETROFIT ON WATER QUALITY AND QUANTITY (TOTAL COST = $175,954)

Maintenance activity will be quantified by tallying all human plus machine hours over the duration of the study. A metric for maintenance that weights automated, and manual time differently will be developed to quantify maintenance effort. Maintenance effort for the three ditch treatments will be compared to controls (no maintenance). Alterations to peak flow rates of inflow and outflow will be used to characterize the effect of the ditch reconfiguration for each of the four sections.

We will test 11 physico-chemical pollutants during every qualifying storm event[1] over two wet seasons. Samples will be collected from both the influent and effluent from each ditch section. We will attempt to sample at least 4 storms a wet season, or 8 over the three-year period of study. Pollutants that will be analyzed for are: dissolved organic carbon, total suspended solids, total phosphorus, ortho-phosphorous, total and dissolved copper, total and dissolved zinc, total petroleum hydrocarbons, total Kjeldahl nitrogen, and nitrate-nitrite.

Pollutant removal efficiencies of each ditch reshaping treatment will be evaluated by quantifying inlet and outlet contaminant concentrations and mass loading rates at each ditch station.

Deliverable 5.1: Draft analysis and presentation shared at TAC meeting # 2 that outlines the total effort associated with water quality remediation by ditch treatment a total of 12 ditch sections.
Cost = $87,977 Target date: End of Month 26
Deliverable 5.2: Revised analysis and revised report shared with TAC meeting # 3
Cost = $87,977 Target date: End of Month 28

TASK 6: COMMUNICATION (TOTAL COST = $12,342)

Deliverable 6.1: Draft report of the whole study that integrates ditch treatment effects on water quantity and quality for the four ditch treatments tested. The draft will also include a data quality review and usability statement.
Cost = $3,086 Target date: End of Month 32

[1] See TAPE guidelines for qualifying storms criteria

Deliverable 6.2: Final report with complete appendices and Excel file of all QA/QC'd data collected over the project period
Cost = $3,086 Target date: End of Month 33
Deliverable 6.3: Two presentations – one for the Stormwater Work Group and another for regional stormwater related conference or workshop.
Cost = $3,086 Target date: End of Month 34
Deliverable 6.4: Draft fact sheet per SAM format for stormwater managers who seek information.
Cost = $3,086 Target date: End of Month 35

PROJECT TEAM AND PROJECT MANAGEMENT

Task	Lead	Support
1 - Project Management	Jayakaran	
2 – QAPP Development	Jayakaran	Ahearn
3 – Site Selection & instrumentation	Ahearn, Gallardo	Jayakaran
4 - Evaluating alternative planting palettes	Neff	Schnore, Golob
5 – Quantifying effects of maintenance & retrofit	Jayakaran	Ahearn
6 – Communication	Jayakaran	Ahearn

A doctoral student (Schnore) with the help of a field technician (Golob), both from the Neff lab, will assist with Task 4. A masters student and a hydrologic technician will assist with Task 5. The project will be managed by WSU with support from Herrera Environmental Consultants. The team will meet on a quarterly basis to discuss project status, share preliminary data analyses, and assess and strategize solutions around potential pitfalls.

WASHINGTON STATE UNIVERSITY TEAM

ANI JAYAKARAN, PHD, PE – will serve as the project lead and will be responsible for meeting project deliverables and communications between the project team and SAM. Ani will assist with QAPP development and site selection. He will manage a graduate student, two technicians, and will be responsible for all data analyses. He serves as an Associate Professor with WSU Extension and holds graduate degrees in Civil Engineering (MS), Agricultural & Biological Engineering (PhD), and is a licensed Civil Engineer in the states of Washington and South Carolina.

MICHAEL NEFF, PHD – will lead Task 4 and will support presentation and report writing associated with other deliverables. He will manage a Ph.D. student (Jon Schnore M.S.) and a field technician (Charles Golob M.S.). Jon Schnore will be responsible for the bulk of this task with the support of the field technician, when needed. Michael serves as a Professor in the Department of Crop and Soil Sciences at WSU where he also holds the position of Assistant Department Chair. Dr. Neff is also the director of the Molecular Plant Sciences Ph.D. program and the Principal Investigator for WSU's newly built, 5-acre, Grass Breeding and Ecology Farm. Dr. Neff has a Ph.D. in Botany and Plant Physiology from the University of Washington in Seattle, WA.

HERRERA ENVIRONMENTAL INC

DYLAN AHEARN, PHD - will be responsible for site selection, QAPP development, instrumentation of all sites, and data analysis and reporting support. He is an Environmental Scientist with a focus on hydrologic and meteorological data collection, management, and analysis. Dylan is currently an Associate Scientist with

Herrera Environmental Consultants and he has over 15 years of experience in hydrology and stormwater. Dylan specializes in experimental design, statistical analysis, low impact development, telemetry systems, automated sampling, nonparametric statistics, and stormwater BMPs. He holds a doctorate in Hydrology from the University of California, Davis.

CITY OF TACOMA

ANGELA GALLARDO –a will provide oversight of the project from a permittee perspective. Angela has over 15 years of experience in analysis, design and project/program management in the public sector focused on stormwater management, application of LID techniques in capital projects, operations & maintenance, and policy. Angela will bring a critical municipality-perspective and administrative expertise to this project.

PROJECT BUDGET AND SCHEDULE

BUDGET TABLE

	WSU					Herrera Subcontract			
Task	**Salaries**	**Benefits**	**Supplies**	**Travel**	**Indirect**	**Equip.**	**Labor**	**Travel**	**Total**
1-Mgmt.	$5,655	$1,465	$0	$0	$2,136	$0	$0	$0	**$9,256**
2-QAPP	$5,655	$1,465	$0	$0	$2,136	$0	$12,500	$0	**$21,756**
3-instrmnt.	$8,568	$5,850	$0	$0	$4,325	$70,000	$48,779	$270	**$137,792**
4–Veg. study	$54,383	$34,735	$1,000	$7,500	$26,735	$0	$0	$0	**$124,354**
5-Water qty. & qual.	$54,383	$34,735	$47,600	$0	$26,735	$0	$12,500	$0	**$175,954**
6-Comm.	$7,540	$1,954	$0	$0	$2,848	$0	$0	$0	**$12,342**
Total by Object	**$136,185**	**$80,204**	**$48,600**	**$7,500**	**$64,916**	**$70,000**	**$73,779**	**$270**	**$481,454**

BUDGET DESCRIPTION

Overall funds requested to support this work is **$481,454**

Washington State University ($337,406): Support requested for 2 months of Dr. Jayakaran's time, two graduate students, and a temporary worker. Details of salary & benefits rates are outlined in the budget table above. WSU requires an annual 4% inflation for faculty and technician salary that has been included. Travel funds are requested for Dr. Neff's team to travel from Pullman to Tacoma, as outlined in Task 4. Each trip will require a vehicle rented from WSU motor pool, gas, food, and four nights stay in a hotel in Tacoma for two people. Funds are requested for the purchase of seeds and other supplies necessary for planting the palettes. For analyses of pollutant inflow and outflow samples, we are requesting funds to cover sample analyses costs. Each storm will comprise 9 composite samples for water quality analyses- 3 samples per site, at 3 sites. Water quality analysis costs are estimated at $561 per composite sample. For 8 storm events, the total cost of water quality analyses is $39,600. Indirect costs are calculated at 30% on salaries and benefits.

Herrera ($144,409): Support is requested for $70,000 in equipment costs to instrument three sites, $48,799 in labor costs for 374 person-hours, and $270 in travel to and from the sampling sites.

DETAILED SCHEDULE

A timeline for the 6 principal tasks and deliverables is presented below over the 35-month period of this work is shown below. Wet seasons are marked in dark blue.

	2021 Q2	2021 Q3	2021 Q4	2022 Q1	2022 Q2	2022 Q3	2022 Q4	2023 Q1	2023 Q2	2023 Q3	2023 Q4	2024 Q1
1 -Project Mgmt.			1		2		3		4		5	
2- QAPP	1	2										
3 -Site Instrumentation		1										
4 -plants											1 2	
5- water qty. & qual.									1	2		
6 - Comm.											1	2 3 4

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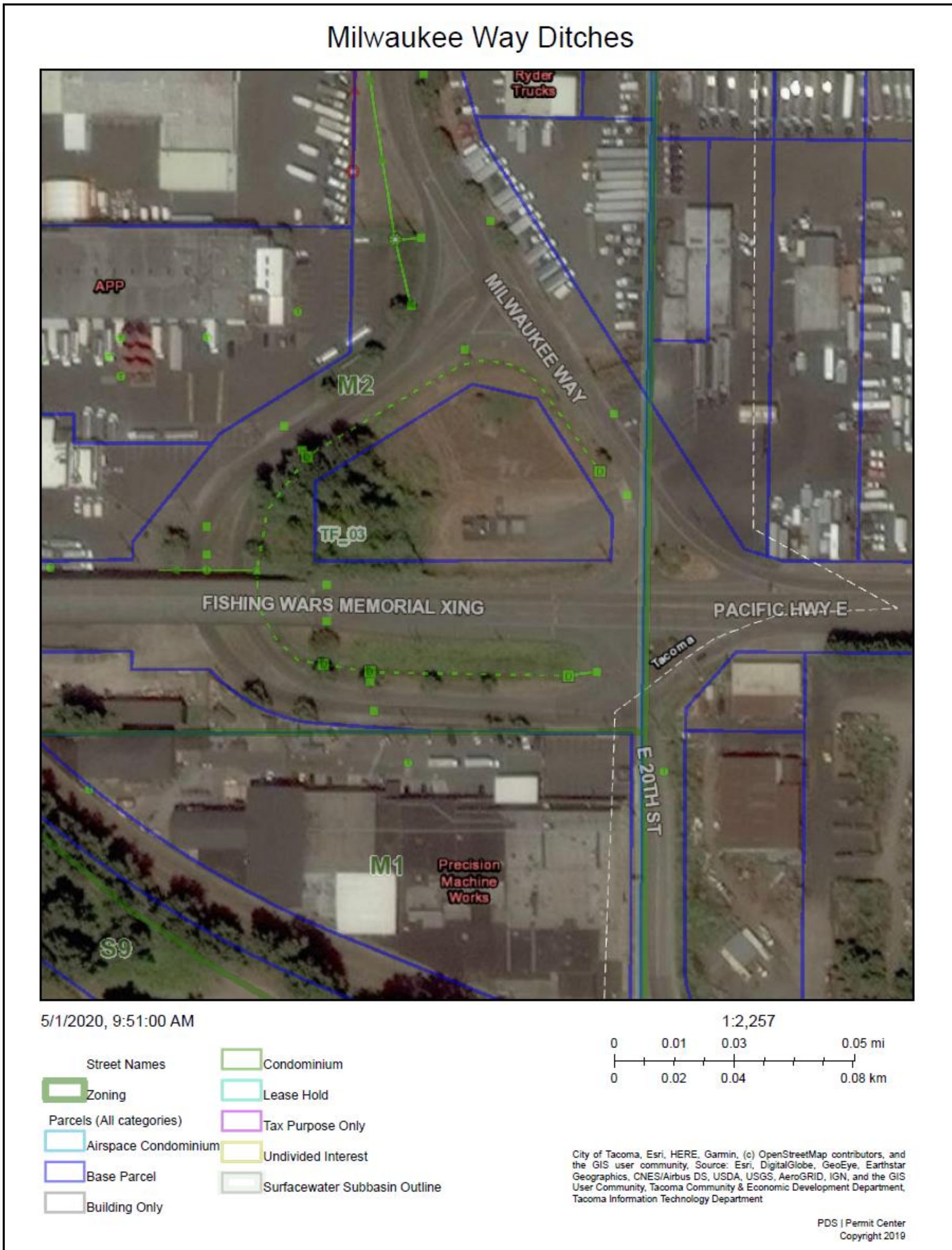

Figure 3: Potential sites for ditch study in Tacoma

Figure 4: Potential ditch sites in Tacoma