King County

1200 King County
Courthouse
516 Third Avenue
Seattle, WA 98104

Meeting Agenda

Regional Water Quality Committee

Councilmembers: Kathy Lambert, Chair; Claudia Balducci, Reagan Dunn

Sound Cities Association: Leanne Guier, Pacific, Vice Chair;
Penny Sweet, Kirkland; Yolanda Trout-Manuel, Auburn; Benson Wong, Mercer Island;
Alternates: Conrad Lee, Bellevue; Zandria Michaud, Kent

Sewer Districts: Pam Carter, Tom Harman
Alternate: Chuck Clarke

City of Seattle: Lisa Herbold, Alex Pedersen
Alternate: Kshama Sawant

Staff: Mike Reed, Lead Staff (206-477-0888)
Sharon Daly: Committee Clerk (206-477-0870)

3:00 PM | **Wednesday, September 2, 2020** | **Virtual Meeting**

PUBLIC NOTICE: The Regional Water Quality Committee's September 2, 2020 meeting will be held virtually. To help prevent the spread of the COVID 19 virus, the Chambers will be closed and all committee members and staff will be participating in the meeting remotely.

Pursuant to K.C.C. 1.24.035 A. and F., this meeting is also noticed as a meeting of the Metropolitan King County Council, whose agenda is limited to the committee business. In this meeting only the rules and procedures applicable to committees apply and not those applicable to full council meetings.

HOW TO PROVIDE PUBLIC COMMENT: The Regional Water Quality Committee values community input and looks forward to hearing from you on agenda items.

The Committee will only accept public comment on items on today's agenda in writing by submitting your written comments to kcccomitt@kingcounty.gov or by going to https://kingcounty.gov/council/committees/regional_water_quality.aspx and selecting "Click Here to Submit Written Public Comment". If your comments are submitted before 1:00 p.m. on the day of the meeting, your comments will be distributed to the committee members and appropriate staff prior to the meeting.

Sign language and communication material in alternate formats can be arranged given sufficient notice (296-1000).
TDD Number 296-1024.
ASSISTIVE LISTENING DEVICES AVAILABLE IN THE COUNCIL CHAMBERS.

HOW TO WATCH/LISTEN TO THE MEETING: There are three ways to watch or listen in to the meeting:

1) Stream online via this link https://livestream.com/accounts/15175343/events/4485487 or input the link web address into your web browser.

2) Watch King County TV Channel 22 (Comcast Channel 22 and 322(HD), Wave Broadband Channel 22)

3 Listen to the meeting by telephone.

Dial: 1 253 215 8782
Meeting ID: 918 2997 5752
Password: 388955

To help us manage the meeting, please use the Livestream or King County TV options, if possible, to watch or listen to the meeting.

To show a PDF of the written materials for an agenda item, click on the agenda item below.

1. Call to Order

2. Roll Call

3. Approval of Minutes

Minutes of the July 1, 2020 meeting pp. 5-8

4. Chair's Report

5. Metropolitan Water Pollution Abatement Advisory Committee

6. Director's Report-Mark Isaacson, Director, Wastewater Treatment Division

Discussion and Possible Action

7. **Proposed Motion No. 2020-0278** **pp. 9-186**

A MOTION acknowledging receipt of a report on the management of biosolids, including a description and evaluation of alternative options for the use of biosolids prepared in accordance with the 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, as amended by Ordinance 18930, Section 72, Proviso P3.

Sponsors: Ms. Lambert

Contingent upon referral to the Regional Water Quality Committee

Mike Reed, Committee Staff
Erika Kinno, Policy and Research Project Manager, Wastewater Treatment Division

8. **Proposed Motion No. 2020-0162** **pp. 187-354**

A MOTION acknowledging receipt of a report providing information and analysis regarding the design and placement of Section 2 of the Kenmore interceptor and the impacts thereof on sedimentation and fish populations as required by the 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, Proviso P2.

Sponsors: Mr. Dembowski

Mike Reed, Committee Staff
Katherine Fischer, Environmental Programs Managing Supervisor, Wastewater Treatment Division

Briefing

9. **Briefing No. 2020-B0070** **pp. 355-380**

Nutrient Discharges into Puget Sound-County Strategies for Responding to Anticipated Ecology Regulatory Action

Mike Reed, Committee Staff
Rebecca Singer, Resource Recovery Section Manager, Wastewater Treatment Division

10. **Briefing No. 2020-B0071** **pp. 381-398**

Asset Management Needs and Costs-Preliminary Discussion in Preparation for Rate Process

Mike Reed, Committee Staff
Bruce Kessler, Deputy Division Director, Wastewater Treatment Division

Other Business

Adjournment

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Meeting Minutes

Regional Water Quality Committee

Councilmembers: Kathy Lambert, Chair; Claudia Balducci, Reagan Dunn

Sound Cities Association: Leanne Guier, Pacific, Vice Chair; Penny Sweet, Kirkland; Yolanda Trout-Manuel, Auburn; Benson Wong, Mercer Island;
Alternates: Conrad Lee, Bellevue; Zandria Michaud, Kent

Sewer Districts: Pam Carter, Tom Harman
Alternate: Chuck Clarke

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Staff: Mike Reed, Lead Staff (206-477-0888)
Sharon Daly: Committee Clerk (206-477-0870)

3:00 PM | **Wednesday, July 1, 2020** | **Virtual Meeting**

DRAFT MINUTES

1. Call to Order

The Regional Water Quality Committee was called to order by Chair Kathy Lambert at 3:04 p.m.

2. Roll Call

Present: 10 - Ms. Balducci, Ms. Carter, Ms. Guier, Mr. Harman, Ms. Lambert, Ms. Sweet, Mr. Wong, Mr. Lee, Ms. Michaud and Mr. Clarke

Excused: 4 - Mr. Dunn, Ms. Herbold, Ms. Trout-Manuel and Mr. Pedersen

3. Approval of Minutes

Mayor Guier moved approval of the minutes of the November 6, 2019 meeting. Seeing no objections, the minutes were approved.

4. Chair's Report

Chair Lambert welcomed all to the meeting and extended a special welcome to new members, members in new roles and the new committee clerk.

The Chair turned the meeting over to Vice Chair Guier for election of a new Vice Chair. Councilmember Wong moved to nominate Mayor Sweet for the position of Vice Chair. The motion passed unanimously.

5. Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC)

Pam Carter, Chair, Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC), reported on MWPAAC activities which included an update on the Nutrient Management discussion, activities around the Clean Water Plan, and cancellation of a planned tour of the Georgetown wet weather treatment plant. A workshop on the Asset Management program will be held on July 22, 2020. The next regular meeting will be August 26, 2020. MWPAAC activities and thoughts related to the capacity charge rate structure were also provided.

6. Director's Report-Mark Isaacson, Director, Wastewater Treatment Division

Mark Isaacson, Director, Wastewater Treatment Division (WTD), reported on staff protection measures for the COVID-19 crisis, testing for COVID in the wastewater stream, extension of comment period for the Clean Water Plan, affirmation from two bond rating agencies of WTD's AA+ bond rating, disruptions in service and work with the Seattle Department of Transportation and Office of Emergency Services on contingency plans pending a West Seattle Bridge failure that impacts WTD facilities.

Discussion and Possible Action

7. RWQC Resolution No. RWQC2020-01

A RESOLUTION concerning the regional water quality committee work program.

Mike Reed, Committee staff, briefed the committee on the resolution and answered questions from the members. Mayor Sweet asked if time might be better utilized by hearing the Clean Water Plan update and then come back to the work plan. It was noted the work plan can be amended. The Chair has requested that updates be sent to the committee as each section is completed of the Clean Water Plan. Mike Reed outlined meeting opportunities for the rest of the year.

Due to the design of the legislative tracking software used to produce the proceedings, the vote on this item is misreported. The correct vote is:

Votes: Yes: 8 Ms. Balducci, Ms. Carter, Ms. Guier, Mr. Harman, Ms. Lambert, Ms. Sweet, Mr. Wong and Mr. Lee voting as alternate for Ms. Trout-Manuel, who was excused.
No: 0
Excused: 4 Mr. Dunn, Ms. Herbold, Mr. Pedersen and Ms. Trout-Manuel

A motion was made by Mayor Sweet that this RWQC Resolution be Passed subject to amendment. The motion carried by the following vote:

Yes: 7.5 - Ms. Balducci, Ms. Carter, Ms. Guier, Mr. Harman, Ms. Lambert, Ms. Sweet, Mr. Wong and Mr. Lee

Excused: 7 - Mr. Dunn, Ms. Herbold, Ms. Trout-Manuel, Mr. Pedersen, Ms. Michaud and Mr. Clarke

8. Proposed Ordinance No. 2020-0102

AN ORDINANCE revising a financial policy of the Regional Wastewater Services Plan addressing the capacity charge; and amending Ordinance 13680, Section 16, as amended, and K.C.C. 28.86.160.

Mike Reed, Committee staff, briefed the committee and answered questions from the members. Hiedi Popochock, Financial Services Manager, Wastewater Treatment Division (WTD), and David Clark, Project Manager, WTD, addressed the committee and answered questions from the members.

Due to the design of the legislative tracking software used to produce the proceedings, the vote on this item is misreported. The correct vote is:

Votes: Yes: 8 Ms. Balducci, Ms. Carter, Ms. Guier, Mr. Harman, Ms. Lambert, Ms. Sweet, Mr. Wong and Mr. Lee voting as alternate for Ms. Trout-Manuel, who was excused.
No: 0
Excused: 4 Mr. Dunn, Ms. Herbold, Mr. Pedersen and Ms. Trout-Manuel

A motion was made by Mayor Sweet that this Ordinance be Recommended Do Pass. The motion carried by the following vote:

Yes: 7.5 - Ms. Balducci, Ms. Carter, Ms. Guier, Mr. Harman, Ms. Lambert, Ms. Sweet, Mr. Wong and Mr. Lee

Excused: 7 - Mr. Dunn, Ms. Herbold, Ms. Trout-Manuel, Mr. Pedersen, Ms. Michaud and Mr. Clarke

Briefing

9. Briefing No. 2020-B0055

Clean Water Plan

Mike Reed, Committee staff, briefed the committee. Sonia-Lynn Abenojar, Regional Engagement Project Manager, Wastewater Treatment Division (WTD), Tiffany Knapp, Planning Project Manager and Alternate Program Manager, WTD, and Steve Tolzman, Program Manager and Planning Project Manager, WTD, also briefed the committee and answered questions from the members. Mark Isaacson, Director, WTD, also answered questions from the members.

This matter was Presented

Other Business

There was no further business to come before the Committee.

Adjournment

The meeting was adjourned at 5:10 p.m.

Approved this _____ day of _____

Clerk's Signature

King County

Metropolitan King County Council
Regional Water Quality Committee

STAFF REPORT

Agenda Item:	7	**Name:**	Mike Reed
Proposed No.:	2020-0278	**Date:**	September 2, 2020

SUBJECT

Proposed Motion 2020-0278 would acknowledge receipt of a report addressing the management of biosolids, including a description and evaluation of options for the use of biosolids.

SUMMARY

The 2019 Supplemental Budget included a proviso requiring the Executive to prepare a report on options for the management and use of biosolids that are generated through the wastewater treatment process. A report responding to the proviso has been transmitted to Council, as an attachment to Proposed Motion 2020-0278, which would acknowledge receipt of the report. The report discusses three alternatives for biosolids management—continuing the current strategy of generating and application of Class B biosolids; undertaking a project to support production and use of Class A biosolids; and undertaking a “pyrolysis” project for the production of a “biochar” product from biosolids.

BACKGROUND

In June, 2019, the Council adopted Ordinance 18930, the 2019 Supplemental Budget, which included a proviso requiring a report on biosolids management. Specifically, Proviso P2 in Section 108 of Ordinance 18835, reads:

> P3 PROVIDED FURTHER THAT: Of this appropriation, $100,000 shall not be expended or encumbered until the executive transmits a report on the management of biosolids generated in the processing of wastewater at county facilities and a motion that acknowledges receipt of the report, and a motion acknowledging receipt is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section, and proviso number in both the title and body of the motion.
>
> The primary existing biosolids processing strategy utilized by the county emphasizes the land application of biosolids generated by the wastewater treatment process at county facilities ("biosolids") in forest and farm environments. The report shall describe and evaluate alternative options for the use of those

biosolids. The report should also address alternative biosolids management approaches that may lead to an expansion or diversification of the markets for those biosolids.

The report shall include, but not be limited to:

A. As an alternative option to be evaluated, the construction of a local biosolids facility that could generate by-products to include gas, electricity, Class A soil enhancer/amendment or for other productive uses;

B. To compare the costs and benefits of the alternative options to the existing strategy a financial analysis comparing the alternative options to the existing strategy, including the transportation costs of the existing strategy;

C. The size of the physical footprint needed for a biosolids facility sited locally, at which those biosolids could be further refined into marketable by-products, including gas, electricity and Class A soil enhancer or amendment;

D. The volume of storage capacity required to store biosolids under the existing biosolids strategy and projected future storage capacity requirements. To the extent that under the existing biosolids strategy involves storage, the study shall also describe: (1) the volume of the storage; and (2) the proportion of total storage capacity that is being reached, described as peak storage levels over the past year;

E. The mapped locations of current land application of biosolids; and

F. A financial analysis of a strategy to transition all or a portion of the current production of biosolids to Class A biosolids, including discussion of the financial viability of the transition.

The executive should file the report and a motion required by this proviso by June 1, 2020, in the form of a paper original and an electronic copy with the clerk of the council, who shall retain the original and provide an electronic copy to all councilmembers, the council chief of staff and the lead staff for the regional water quality committee and the committee of the whole, or their successors.

Proposed Motion 2020-0278 was transmitted to Council on August 6, 2020. The motion included an attached report entitled “Alternative Options for the Use of Biosolids”, dated August 1, 2020 (Report).

The Report describes the two types of biosolids designated by regulations:

- Class A biosolids have virtually no detectable pathogens and can be used by the public for activities such as landscaping and gardening.
- Class B biosolids are treated, but do have detectable levels of pathogens and require a permit for use in activities such as agriculture and forestry.

King County beneficially uses 100 percent of its Loop biosolids, a Class B product, as a fertilizer replacement and soil amendment, primarily in forestry and agriculture. These

biosolids return carbon and nutrients to the soil. In recent years, 75-80% of Loop biosolids have gone to agricultural use in eastern Washington; one percent has been used by the program's compost partner, GroCo Inc., for the creation of a Class A compost product; the remainder has been used in forestry application. Concern has emerged regarding the market resiliency of the biosolids program with the closure of the GroCo Inc., and fluctuations in forestry application.

The Report describes alternative management strategies for biosolids, including continuing the Class B program, an Option One: Class A strategy, and an Option Two: Pyrolysis strategy:

Baseline: Class B Program

This option would continue the existing Class B biosolids program at King County's three regional treatment plants, focusing on land application in Western Washington forestry and Eastern Washington agriculture. King County currently produces 130,000 wet tons of biosolids annually. Investments would be needed to maintain the digesters that produce the biosolids to handle increased solids treatment volumes through 2050.

Option One: 100 Percent Class A

This option would pair Class A digestion at treatment plants with a soil blending facility, as well as composting Class B biosolids into a Class A compost. It is not feasible to compost all of King County's biosolids, but including a composting element provides market diversity that could generate revenue through product sales and reduce the cost of transitioning to a 100 percent Class A program. This option includes the upgrade of digester equipment at two regional treatment plants to produce Class A biosolids, and construction of an offsite soil blending and composting facility. Class A biosolids from one treatment plant would go to the soil blending facility to create a soil blend for sale to the public or commercial customers; Class A biosolids from the second treatment plant would go to agriculture and forestry land application sites. Class B biosolids produced at the third treatment plant would go to the composting and soil blending facility to be composted into a Class A garden product for retail sale.

Option Two: Pyrolysis

This option would produce a potential Class A product called biochar, which is a charcoal-like material that can be used as a soil amendment for improved soil health, though it does not provide significant plant fertilization. Other potential uses include water filtration. In this option, all three treatment plants would continue to produce Class B biosolids; these biosolids would be transported to a new offsite facility to be dried, compressed, and intensively heated to produce biochar. King County would own and operate the pyrolysis facility and a private partner would transport and sell the biochar product. This option includes biosolids drying technology; for pyrolysis, biosolids must be dried to 60-90 percent solids. Pyrolysis results in volume reduction and a marketable end product.

Table 1.
Total Costs for Biosolids Options Escalated through 2050

	Baseline: Class B	Alternative Option One: 100 Percent Class A	Alternative Option Two: Pyrolysis
Escalated Capital Costs	$335,000,000	$590,000,000	$1,115,000,000
2050 Operating & Maintenance Costs	$40,500,000	$49,000,000	$39,000,000
2050 Annual Transportation Costs	$6,000,000	$4,000,000	$1,500,000
2050 Annual Revenue	$11,100,000	$19,500,000	$10,500,000
2050 Annual Net Operating & Maintenance Costs and Minus Revenue	$29,400,000	$29,500,000	$28,500,000

Proposed Motion 2020-0278

Proposed Motion 2020-0278 has been transmitted to the Council and is anticipated for dual referral to the Regional Water Quality Committee and the Committee of the Whole. The proposed motion would acknowledge the receipt of the report addressing management of biosolids. Passage of the motion by Council would release the withheld $100,000 of the Wastewater Treatment Division's 2019-2020 biennial budget authorization.

INVITED

- Erika Kinno, Policy and Research Project Manager, Wastewater Treatment Division

ATTACHMENTS

1. Proposed Motion 2020-0278
    a. Attachment A: Alternative Options for the Use of Biosolids, dated August 1, 2020
2. Transmittal Letter, dated August 6, 2020
3. Wastewater Treatment Division's Alternative Options for the Use of Biosolids Presentation

KING COUNTY

Signature Report

1200 King County Courthouse
516 Third Avenue
Seattle, WA 98104

Motion

Proposed No. 2020-0278.1 **Sponsors** Lambert

A MOTION acknowledging receipt of a report on the management of biosolids, including a description and evaluation of alternative options for the use of biosolids prepared in accordance with the 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, as amended by Ordinance 18930, Section 72, Proviso P3.

WHEREAS, the King County 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, as amended by Ordinance 18930, Section 72, Proviso P3, states that $100,000 shall not be expended or encumbered until the executive transmits a report on the management of biosolids generated in the processing of wastewater at county facilities, and a motion that acknowledges receipt of the report and the motion is passed by the council, and

WHEREAS, the executive has transmitted to the council the requested report entitled Alternative Options for the Use of Biosolids along with a motion acknowledging the receipt thereof by June 1, 2020;

NOW, THEREFORE, BE IT MOVED by the Council of King County:

Receipt of the report addressing the management of biosolids, including a

18 description and evaluation of alternative options for the use of biosolids, Attachment A to

19 this motion, is hereby acknowledged.

20

KING COUNTY COUNCIL
KING COUNTY, WASHINGTON

_____

Claudia Balducci, Chair

ATTEST:

_____

Melani Pedroza, Clerk of the Council

APPROVED this _____ day of _____, _____.

_____

Dow Constantine, County Executive

Attachments: A. Alternative Options for the Use of Biosolids August 1, 2020

Alternative Options for the Use of Biosolids

August 1, 2020

King County

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Proviso Text

Ordinance 18930, Section 72, Proviso P3[1]
P3 PROVIDED FURTHER THAT:
Of this appropriation, $100,000 shall not be expended or encumbered until the executive transmits a report on the management of biosolids generated in the processing of wastewater at county facilities and a motion that acknowledges receipt of the report, and a motion acknowledging receipt is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section, and proviso number in both the title and body of the motion.

The primary existing biosolids processing strategy utilized by the county emphasizes the land application of biosolids generated by the wastewater treatment process at county facilities ("biosolids") in forest and farm environments. The report shall describe and evaluate alternative options for the use of those biosolids. The report should also address alternative biosolids management approaches that may lead to an expansion or diversification of the markets for those biosolids.

The report shall include, but not be limited to:

A. As an alternative option to be evaluated, the construction of a local biosolids facility that could generate by-products to include gas, electricity, Class A soil enhancer/amendment or for other productive uses;

B. To compare the costs and benefits of the alternative options to the existing strategy a financial analysis comparing the alternative options to the existing strategy, including the transportation costs of the existing strategy;

C. The size of the physical footprint needed for a biosolids facility sited locally, at which those biosolids could be further refined into marketable by-products, including gas, electricity and Class A soil enhancer or amendment;

D. The volume of storage capacity required to store biosolids under the existing biosolids strategy and projected future storage capacity requirements. To the extent that under the existing biosolids strategy involves storage, the study shall also describe: (1) the volume of the storage; and (2) the proportion of total storage capacity that is being reached, described as peak storage levels over the past year;

E. The mapped locations of current land application of biosolids; and

F. A financial analysis of a strategy to transition all or a portion of the current production of biosolids to Class A biosolids, including discussion of the financial viability of the transition.

The executive should file the report and a motion required by this proviso by June 1, 2020[2], in the form of a paper original and an electronic copy with the clerk of the council, who shall retain the original and provide an electronic copy to all councilmembers, the council chief of staff and the lead staff for the regional water quality committee and the committee of the whole, or their successors.

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[1] Link to Ordinance 18930
[2] Due COVID 19, the King County Council passed Motion 15620, which extends due dates on reports by 60 days.

Executive Summary

Background

This report examines alternative options for the King County Loop Biosolids Program[3] in accordance with Ordinance 18930, Section 72, Proviso P3. The information in this report is based on a technical study completed in 2020 by the consultant Brown and Caldwell[4], which is attached as Appendix A, as well as an extensive number of other relevant King County studies on Class A options. Analyses provided in this report are informed by current operational and capital costs, King County strategic objectives, and environmental and wastewater treatment process information for King County's three regional treatment plants: West Point, South Plant, and Brightwater.

The mission of the Wastewater Treatment Division (WTD) of the Department of Natural Resources and Parks (DNRP) is to protect public health and enhance the environment by collecting and treating wastewater while recycling valuable resources for the Puget Sound region. The Biosolids Program, housed within the WTD's Resource Recovery section, manages the distribution and use of, the biosolids product created by recycling King County's wastewater, which is called Loop.

Regulations established two types of biosolids: Class A and Class B. Class A biosolids have virtually no detectable pathogens and can be used by the public for activities such as landscaping and gardening. Class B biosolids are treated, but do have detectable levels of pathogens and require a permit for use for in activities such as agriculture and forestry.

Since 1984, King County has beneficially used 100 percent of its Loop biosolids, a Class B product, as a fertilizer replacement and soil amendment, primarily in forestry and agriculture. Loop biosolids return valuable carbon and nutrients back to the soil and help King County fight climate change. However, with fluctuations in forestry application and the May 2020 business closure of the County's Biosolids Program's compost partner, GroCo Inc., the market resiliency of the Biosolids Program has decreased. In recent years, over 75-80 percent of Loop biosolids went to agricultural use in eastern Washington. GroCo Inc. used one percent of King County's Loop biosolids to create its Class A compost product locally. While one percent is small, the Class A GroCo Inc. compost product made with Loop was the only publicly accessible product for King County residents and gardeners.

The current DNRP Biosolids Program, which produces a Class B product, complies with regulations and policies on federal, state, and County levels, under the Clean Water Act Part 503, Washington Administrative Code Chapter 173-308, and King County Code 28.86.090 Biosolids Policies, respectively. King County could transition from producing a 100 percent Class B product at its treatment plants to the production of Class A biosolids in the future through either treatment plant upgrades or a construction of a composting facility.

[3] The term "biosolids" refers to the solid organic matter recovered from the wastewater treatment process that can be used as a soil amendment or enhancement. Loop is the brand name of the biosolids produced at King County's three wastewater treatment plants.

[4] The report from Brown and Caldwell is attached as Appendix A

Report Requirements

DNRP contracted with Brown and Caldwell to research Class A alternative options for this proviso response. The resulting report is attached as Appendix A. Each option analyzed assumes the use of 100 percent of King County's biosolids to enable comparison of costs and benefits with the existing Class B Biosolids Program. The report details the estimated cost and benefits of maintaining the existing Class B program as a baseline and two alternative options projected out to the year 2050. The options are:

- *Baseline: Class B* - Continuation of the existing Class B Biosolids Program, including necessary upgrades to address future treatment capacity needs and maintain the treatment system that produces biosolids.
- *Alternative Option One: Class A* – This option includes Class A digestion at the treatment plants paired with a soil blending facility[5], as well as composting[6] Class B biosolids into a Class A compost, thereby transitioning to a 100 percent Class A biosolids program by leveraging different technologies.
- *Alternative Option Two: Pyrolysis* – This option would involve the creation of a public-private partnership to dry and pyrolyze[7] Class B biosolids into biochar[8] at a new offsite pyrolysis facility. It should be noted that biochar may only be considered Class A biosolids under the state biosolids rule WAC 173-308 on a case by case basis. However, a pyrolysis option was included to show the costs and benefits of an emerging technology and a different programmatic direction.

Construction of a Local Facility
The *Baseline: Class B* option assumes that all changes would take place on the sites of the regional treatment plants. Both *Alternative Option One: 100 Percent Class A* and *Alternative Option Two: Pyrolysis* would require the construction of offsite local facilities, outside of the treatment plant footprints. In *Alternative Option One: 100 Percent Class A*, it would be necessary to site, permit, and construct a soil blending and composting facility. To accomplish *Alternative Option Two: Pyrolysis*, King County would need to site, permit, and construct a drying and pyrolysis facility.

Costs and Benefits
The alternative options were compared on a variety of factors including capital and operating costs, transportation costs, environmental impacts, equity and social justice factors, technical and

[5] Digestion refers to the process in which microorganisms break down biodegradable material, like solids in wastewater. When it is done in the absence of oxygen it is called anaerobic digestion. Class A digestion creates biosolids that meet United States Environmental Protection Agency standards by operating at a temperature of 122°F to 140°F, called thermophilic temperatures, in order to reduce pathogens to the level required for Class A biosolids. In order to make a marketable product, Class A digestion can be combined with soil blending, which involves mixing Class A biosolids with sand and woody materials, such as bark and sawdust, to create blends that can be used as potting mix or topsoil.
[6] Composting is an aerobic biological process that uses microorganisms in the presence of air to decompose organic material and to produce heat to reduce pathogens to Class A requirements. Composting biosolids involves mixing Class B biosolids with woody materials and composting them.
[7] Pyrolysis is a decomposition process that occurs at temperatures in excess of 572°F in the absence of air. The process produces a charcoal-like soil amendment called biochar.
[8] Biochar is a charcoal-like soil amendment.

implementation difficulty, and synergy with King County objectives and WTD priorities. Table 1 shows a summary of the results.

Table 1. Total Costs and Scores			
	Baseline: Class B	Alternative Option One: 100 Percent Class A	Alternative Option Two: Pyrolysis
Escalated Capital Costs	$335,000,000	$590,000,000	$1,115,000,000
2050 Operating & Maintenance Costs	$40,500,000	$49,000,000	$39,000,000
2050 Annual Transportation Costs	$6,000,000	$4,000,000	$1,500,000
2050 Annual Revenue	$11,100,000	$19,500,000	$10,500,000
2050 Annual Net Operating & Maintenance Costs and Minus Revenue	$29,400,000	$29,500,000	$28,500,000
Triple Bottom Line Score[9]	High	Very High	Medium

Table 1: Total Costs and Scores

Physical Footprint
All physical site requirements used in this analysis are approximate. Actual site requirements would be refined further based on selected technology and actual site constraints, during WTD's capital project delivery process. The physical footprint required is 30-40 acres for an offsite soil blending and compost facility in *Alternative Option One: 100 Percent Class A* and 12 acres for an offsite pyrolysis facility in *Alternative Option Two: Pyrolysis*. The *Baseline Class B* does not require an offsite facility.

Storage Requirements and Mapped Locations of Current Land Application
The current biosolids program is designed to transfer biosolids from the treatment plants directly to land application sites for use as soon as the biosolids are fully treated. Biosolids are temporarily stored in emergency situations when it is not possible to haul biosolids and/or land apply in either eastern or western Washington due to inclement weather and mountain pass closure. WTD contracts with the City of Everett Wastewater Treatment Plant to store biosolids at the facility during these weather events and typically uses less than half of the available space during peak storage times. A map of the locations where biosolids are land applied for agriculture or forestry uses is included.

Financial Analysis
Analyses find that all identified options are costly, ranging from $335 million to $1.1 billion in capital investments, and face a number of technical and physical challenges, such as footprint constraints, permitting challenges, and the implementation of new technologies. See Section B in this report for details. Development of a Class A program is encouraged by state and federal statute, but would require changes in the King County Code to align the code with state law, thus enabling King County to produce Class A or Class B biosolids.

[9] For more information on Triple Bottom Line, see Appendix B.

Conclusion

This report finds that opportunities exist for King County to explore transition to Class A biosolids as a long-term, phased approach over many decades. Transitioning to Class A could be incorporated into planning efforts for improvements to the County's regional treatment plants to address capacity needs, asset management (i.e., repair, refurbishment or replacement of aging equipment), and other physical plant needs and County goals.

Any development of a Class A program would require changes to biosolids policies in King County Code, since the King County Code currently prohibits the production and sale of anything other than Class B Biosolids.[10] WTD is currently in the process of designing a small-scale temporary compost pilot project at South Treatment Plant to test composting and explore marketability of a County-owned Class A compost. The current cost estimate for the pilot project is $3.4 million with project completion anticipated in 2022/2023. This work in developing the pilot project to produce Class A compost at South Treatment Plant could help inform future planning efforts.

Background

Department Overview: The Department of Natural Resources and Parks (DNRP) works in support of sustainable and livable communities and a clean and healthy natural environment. Its mission is to foster environmental stewardship and strengthen communities by providing regional parks, protecting the region's water, air, land, and natural habitats, and reducing, safely disposing of, and creating resources from wastewater and solid waste.

The Wastewater Treatment Division (WTD) of DNRP protects public health and enhances the environment by collecting and treating wastewater while recycling valuable resources for the Puget Sound region. The King County Biosolids Program is housed within the Resource Recovery Section of WTD.

The Resource Recovery Section manages the administration and delivery of products and programs from renewable resources [11] captured from the wastewater treatment process. The Resource Recovery Section is comprised of a strategic support team and five programs: Sustainability, Technology Assessment and Innovation, Energy, Recycled Water, and Biosolids. The Biosolids Program manages the distribution and use of Loop, a branded biosolids product created by recycling the County's wastewater. Loop is a natural soil builder and endlessly renewable resource that has been returning carbon and nutrients to the land for almost 50 years.

Key Historical Conditions: Since its inception, the King County Biosolids Program has taken a market-based approach to biosolids management, focusing on creating high quality marketable products, and developing strong customer relationships. The Biosolids Program has successfully produced and distributed its biosolids for almost 50 years with full regulatory compliance and beneficial use.

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[10] King County Code 28.86.090 Biosolids policies (BP).

[11] A renewable resource is a natural resource which will replenish to replace the portion depleted by usage and consumption. Biogas, biosolids, and recycled water are three byproducts of the wastewater system that are considered renewable resources.

The Biosolids Program, in conjunction with University of Washington scientists, began researching and developing a program in 1972 for biosolids to be used on forestlands and land that needed to be reclaimed from other uses such as mining. In 1978, the Biosolids Program entered a long-standing partnership with GroCo, Inc. to compost a portion of its biosolids into a retail garden product. After nearly two decades of operations, the Biosolids Program added two agricultural projects in Yakima and Douglas Counties.

In 1993, federal biosolids regulations were added to The Clean Water Act of 1972 (CWA) and 40 CFR Part 503 of the CWA established standards, which consist of general requirements, pollutant limits, management practices, and operational standards, for the final use of biosolids generated during the treatment of domestic sewage. Washington State followed suit, developing the biosolids rule, or chapter 173-308 in the Washington Administrative Code (WAC) in 1998. It is important to note that the biosolids rule established the requirement for beneficial use of biosolids that "encourages the maximum beneficial use of biosolids" and "recognizes biosolids as a valuable commodity." The biosolids rule incorporates all the legal requirements in the federal rule, with additional site-specific plans for land application and public notice requirements. Regulations established two types of biosolids: Class A and Class B. Class A biosolids have virtually no detectable pathogens and can be used without a permit. King County produces Class B biosolids, which are treated, but do have detectable levels of pathogens and require a permit for use.

In addition to developing a successful Class B program, the Biosolids Program examined opportunities for Class A options many times over the past several decades. Class A options have not been undertaken due to prioritizing other operational and infrastructure needs.

Key Current Conditions: King County currently produces approximately 130,000 wet tons of biosolids each year at three regional treatment plants, which is equivalent to filling a stadium 70 feet high or filling 8,000 Metro buses. Each of King County's treatment plants is slightly different, but all use a technology called anaerobic digestion, which is a large heated tank where microorganisms break down the solids, similar to how a human stomach digests food. King County uses 100 percent of the Class B Loop biosolids produced at the County's wastewater treatment plants in a beneficial way on land, primarily as a fertilizer replacement in forestry and agriculture as shown below in Figure 1. However, with fluctuations in forestry use over the past decade, the program became more reliant on agricultural uses, reducing options for the Biosolids Program if biosolids use in agriculture declines.

Farmers in Douglas and Yakima Counties currently use most (80-85 percent) of King County's biosolids. In May 2020, the Biosolids Program's compost partner GroCo Inc., which used one percent of King County's Loop product as an ingredient to produce a retail garden product called GroCo compost, closed its business. Composting involves mixing biosolids with woody material, such as sawdust, yard clippings, or wood chips, and then microorganisms break down the material into a garden product called compost. While one percent is a small amount and King County did not own the final product, GroCo compost made with Loop was the only publicly accessible product for use by King County residents and gardeners. Other composters in the region are already nearing capacity, meaning they cannot accept more biosolids for use in compost, and have not shown interest in partnering with DNRP.

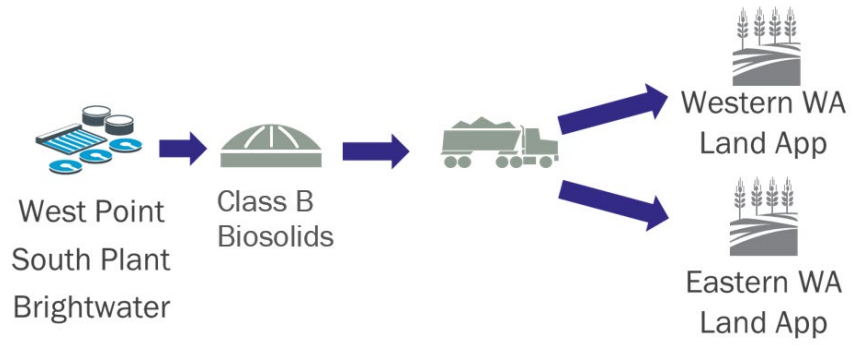

Figure 1: Depiction of the Baseline: Class B, Existing Program

King County's Biosolids Program also plays a key role in accomplishing the goals of the Clean Water Healthy Habitat initiative and the Strategic Climate Action Plan, primarily through carbon sequestration from land application.[12] In 2019, Loop biosolids use provided 20 percent of the carbon offsets for DNRP's carbon footprint.[13] Energy capture and reuse from the anaerobic digesters[14] at King County's wastewater treatment plants allow WTD to operate in a more energy efficient manner. In addition, DNRP's partnership with GroCo Inc. for Class A biosolids allowed DNRP to participate in King County's Equity and Social Justice Initiatives by supporting community gardens in underserved areas with compost donations and by maintaining a robust and far-reaching outreach and education program.

Report Methodology: DNRP contracted the consulting firm of Brown and Caldwell to assist WTD with research for this report. DNRP staff from operations, finance, community services, resource recovery, engineering, and planning participated in the development of this report. Building on the foundation of previous Class A evaluations, the consultants referred to past reports and conducted additional research. Environmental and treatment process information was modeled to compare differences between options. DNRP staff and the consultants participated in a workshop to review and adjust the model, and assumptions, and reach consensus on the Triple Bottom Line[15] analysis provided in Appendix B to this document. The consultant technical memorandum/report is attached as Appendix A.

Report Requirements

Taking into account federal, state, and local biosolids regulations and policies, current and future wastewater treatment plant capacity, and the strategic environmental and social objectives of King County, the following report details potential Class A options for the County's Biosolids Program. The report requires the following:

[12] Carbon Sequestration refers to the process of removing carbon dioxide from the atmosphere.
[13] Carbon Offsets refer to actions take to compensate for carbon dioxide emissions. Offsets can be traded as part of environmental programs.
[14] Some wastewater treatment plants use anaerobic digesters to provide an oxygen-free environment for microorganisms to break down organic matter in wastewater. The anaerobic digestion process produces wastewater digester gas, a methane-rich byproduct that can be used as an energy source.
[15] The Triple Bottom Line is an analysis method to account for environmental, economic, and social factors, and is commonly used in planning or feasibility studies to evaluate King County alternatives, options, and projects.

A. As an alternative option to be evaluated, the construction of a local biosolids facility that could generate by-products to include gas, electricity, Class A soil enhancer/amendment or for other productive uses;
B. To compare the costs and benefits of the alternative options to the existing strategy a financial analysis comparing the alternative options to the existing strategy, including the transportation costs of the existing strategy;
C. The size of the physical footprint needed for a biosolids facility sited locally, at which those biosolids could be further refined into marketable by-products, including gas, electricity and Class A soil enhancer or amendment;
D. The volume of storage capacity required to store biosolids under the existing biosolids strategy and projected future storage capacity requirements. To the extent that under the existing biosolids strategy involves storage, the study shall also describe: (1) the volume of the storage; and (2) the proportion of total storage capacity that is being reached, described as peak storage levels over the past year;
E. Mapped Locations of Current Land Application of Biosolids; and
F. A financial analysis of a strategy to transition all or a portion of the current production of biosolids to Class A biosolids, including discussion of the financial viability of the transition.

Overview

In order to develop alternative options to the current Class B program, various biosolids processing technologies were explored in detail and assessed on several criteria. A detailed explanation of criteria and assessment process can be found in Appendix A.[16] After assessment, favorable technologies were developed into alternative options and compared to the baseline Class B program, all projected out to the year 2050. The options compared in the report are as follows:

Baseline: Class B Program

This option consists of continuing the 100 percent Class B biosolids program at King County's three regional treatment plants, focusing on land application in western Washington forestry and eastern Washington agriculture.

As the region's population continues to grow, King County must maintain sufficient solids treatment capacity at its regional treatment plants.[17] King County currently produces approximately 130,000 wet tons of biosolids each year, and each treatment plant has unique operating processes and constraints. Even though this option continues the existing program, using the existing technology, investments will still be needed to maintain the equipment (i.e. digesters) that produce Class B biosolids to handle increasing solids treatment capacity needs through 2050. Therefore, investments are assumed in this option just to continue the existing Class B biosolids program while meeting solids treatment capacity needs through 2050.

Alternative Option One: 100 Percent Class A

[16] See Table 1 on page 4 of Technical Memorandum in Appendix A.
[17] The assumed projects are high-level concepts developed to support this study. Capital projects to expand solids treatment capacity have not yet been determined through WTD planning or capital project delivery processes.

This option includes Class A digestion at the treatment plants paired with a soil blending facility[18], as well as composting[19] Class B biosolids into a Class A compost, thereby transitioning to a 100 percent Class A biosolids program by leveraging different technologies. Combining these two technologies is necessary due to the large volume of biosolids produced by King County; it is not feasible to compost all of King County's biosolids[20], but including composting provides valuable product and market diversity that could reduce the cost of transitioning to a 100 percent Class A program through revenue from product sales. Since this option is a combination of different technologies and facilities, informed by the unique constraints of each treatment plant, it also allows the flexibility of potentially phasing investments over time.

This option, shown in Figure 2, includes the upgrade of digester equipment at two regional treatment plants to produce Class A biosolids and the construction of an offsite soil blending and composting facility. The Class A biosolids produced at one of these treatment plants would be transported to the offsite compost and soil blending facility to create a marketable soil blend for retail sale to the public, or used directly by local commercial customers. The Class A biosolids produced at the other treatment plant would be delivered directly to agriculture and forestry land application sites in western and eastern Washington. The Class B biosolids produced at the third regional treatment plant would be transported to the composting and soil blending facility to be composted into a Class A garden product (compost) for retail sale.

Notably, the option outlined below and the technology selected for each treatment plant is just one example of how a combination of technologies and strategies could be deployed to achieve a Class A biosolids option. It should also be noted that this option would require changes to biosolids policies in King County Code to allow the production and sale of Class A biosolids.[21]

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[18] Digestion refers to the process in which microorganisms break down biodegradable material, like solids in wastewater. When it is done in the absence of oxygen it is called anaerobic digestion. Class A digestion creates biosolids that meet United States Environmental Protection Agency standards by operating at a temperature of 122°F to 140°F, called thermophilic temperatures, in order to reduce pathogens to the level required for Class A biosolids. In order to make a marketable product, Class A digestion can be combined with soil blending, which involves mixing Class A biosolids with sand and woody materials, such as bark and sawdust, to create blends that can be used as potting mix or topsoil.

[19] Composting is an aerobic biological process that uses microorganisms in the presence of air to decompose organic material and to produce heat to reduce pathogens to Class A requirements. Composting biosolids involves mixing Class B biosolids with woody materials and composting them.

[20] A compost market assessment showed that there is market opportunity for King County biosolids compost representing approximately 20 percent of the total biosolids production.

[21] King County Code 28.86.090 Biosolids policies (BP).

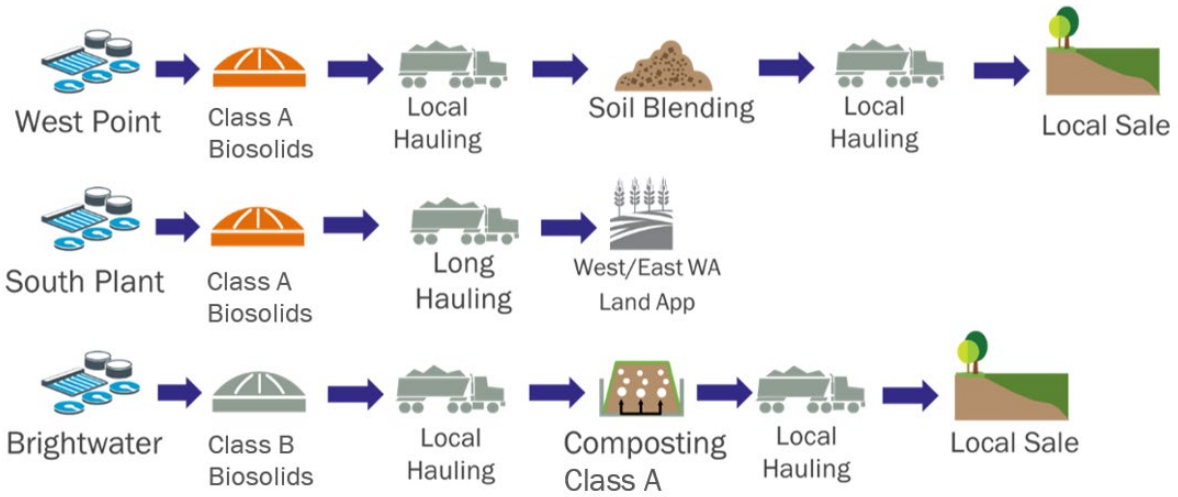

Figure 2: Depiction of Alternative Option One: 100 Percent Class A

Alternative Option Two: Pyrolysis

Although pyrolysis[22] technology did not meet all the original technology evaluation criteria[23], a pyrolysis alternative option is included to demonstrate the benefits and tradeoffs of an emerging technology and a different programmatic direction. This alternative option, illustrated in Figure 3, would produce a potential Class A product called biochar. Biochar is a charcoal-like material that can be used as a soil amendment for improved soil health, though it does not provide much fertilization for plants. It has other potential uses as well, such as water filtration. In this option, all three treatment plants would continue to produce Class B biosolids while making changes required to address capacity needs through 2050.[24] One hundred percent of those biosolids would be hauled to a new offsite facility to be dried, compressed, and heated at a very high temperature to produce biochar.

[22] Pyrolysis is a decomposition process that occurs at temperatures in excess of 572°F in the absence of air. The process produces a charcoal-like soil amendment called biochar.

[23] An offsite pyrolysis facility did not pass the screening because pyrolysis did not meet the federal definition for established technologies, did not produce more gas to increase renewable energy production, and may increase greenhouse gas emissions. In addition, pyrolysis is not an approved Class A treatment process under the state biosolids rule (WAC 173-308), meaning it can only be considered Class A on a case by case basis. Only four biosolids pyrolysis facilities are operational in the United States with the largest facility, located in Redwood City, California, processing only 7,000 wet tons per year (compared to King County's 130,000 wet tons).

[24] The assumed capital projects are high-level concepts that were developed to support this study. Capital projects to expand digestion capacity have not yet been determined through WTD planning or capital project delivery processes.

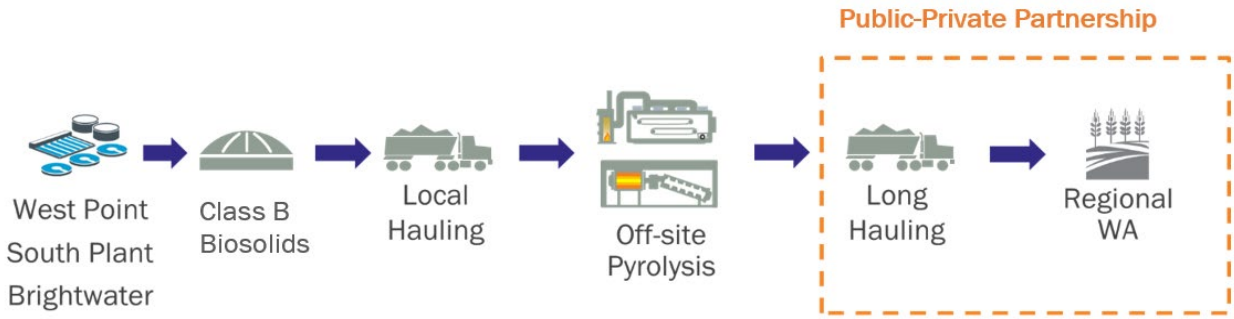

Figure 3: Depiction of Alternative Option Two: Pyrolysis

Other utilities, such as Silicon Valley Clean Water, have used a public-private partnership for this type of option and this option assumes that King County would own and operate the pyrolysis facility and a private partner would transport and sell the biochar product. Contractual arrangements can vary, but the most common pyrolysis contractual arrangements are for the private partner to own and operate the pyrolysis facility, and distribute and sell the biochar product. King County adjusted this to retain control of the pyrolysis facility to ensure quality control and regulatory compliance, and to reflect King County's standard contractual arrangements. Given the emergent nature of the biochar market, King County does not have the staff or infrastructure to handle the sale of the product. This is in contrast to the compost market, in which King County has decades of experience.

This option also includes biosolids drying technology. In order for pyrolysis to be effective, biosolids must first be dried to 60 to 90 percent solids. King County's biosolids are approximately 25 percent solids and 75 percent water. The advantages of pyrolysis include volume reduction and generation of a marketable end-product. Research also demonstrates the reduction of some contaminants of emerging concern, such as triclosan and nonylphenol.[25] It should also be noted that this option would require significant changes to biosolids policies in the King County Code.[26]

A. Construction of a Local Facility

Both *Alternative Option One: 100 Percent Class A* and *Alternative Option Two: Pyrolysis* would require the construction of offsite local facilities, outside of the treatment plant footprints. The *Baseline: Class B* option assumes that all changes would take place on the sites of the regional treatment plants.

For *Alternative Option One: 100 Percent Class A*, it would be necessary to site, permit, and construct a soil blending and composting facility. At this facility, Class A biosolids from one of the regional treatment plants would be mixed with woody materials and/or sand to create soil blends for retail sale. Class A biosolids do not require additional treatment and could be used by the general public straight from the treatment plant, but soil blending allows for a higher quality, lower odor product, and more variety of products for different markets. Class B biosolids from the third regional treatment plant would be transported to this same facility to be mixed with woody material and composted to create a Class A

[25] Lee et al., 2018; Paz-Ferreiro et al., 2018; Ross et al., 2016
[26] King County Code 28.86.090 Biosolids policies (BP).

product for retail sale. Class A biosolids from the second regional treatment plant would go straight from the treatment plant to land application in eastern and western Washington.

To accomplish *Alternative Option Two: Pyrolysis*, King County would need to site, permit, and construct a drying and pyrolysis facility. Class B biosolids from the three regional treatment plants would be transported to this site. The Class B biosolids would be dried to 60-90 percent solids using drying equipment and then run through pyrolysis equipment to create biochar, which could be sold as a soil amendment or water filtration medium.

More information about the physical footprint of these facilities is outlined in section C of this report.

B. Costs and Benefits

Costs and benefits of the alternative options were compared to a continuation of the existing program. The types of costs and benefits included are defined in Table 2. In order to capture the complexity and compare these costs and benefits, several aspects were considered, including non-monetary costs and benefits. Non-monetary costs and benefits were provided through a greenhouse gas inventory[27] and a triple bottom line analysis[28]. The Office of Performance, Strategy, and Budget has reviewed the fiscal information contained in this report.

Table 2. Types of Costs and Benefits			
Description		Benefits	
Capital Costs	Fixed expenses for the purchase of land, buildings, construction, and equipment or upgrade of physical systems or equipment. Includes design, permitting, and site acquisition.	Revenue	Money received by King County from customers as payment for products and any associated services.
Operating Costs	Day to day costs to operate facilities and equipment, and to implement and run programs. Includes staff and labor, maintenance and parts replacement, material use, energy and water consumption, and end-use including transportation.	Non-monetary benefits	Greenhouse gas offsets, carbon sequestration and qualitative environmental, social and economic benefits such as cleaner air.
Non-monetary Costs	Greenhouse gas emissions and qualitative environmental, social and economic costs, such as odor or increased traffic.		

Table 2: Types of Costs and Benefits

[27] A greenhouse gas inventory is an accounting of greenhouse gas emissions and offsets. The greenhouse gas emission scopes and factors were based on the guidelines published by The Climate Registry (TCR) and Intergovernmental Panel on Climate Change (IPCC) and updated with recent publications.
[28] The triple bottom line is an analysis method to account for environmental, economic, and social factors, and is commonly used in planning or feasibility studies to evaluate King County alternatives, options, and projects.

Capital Costs

All options involve large capital investments to construct new systems as well as increased operational costs to and implement new processes by 2050. There are significant capital costs for three options.

Estimated total capital costs[29] for each option are shown in Table 3. For this study, capital costs were escalated to the construction midpoint of 2028 using an escalation rate of three percent to account for inflation and to estimate project capital costs and schedules. The totals represent implementation at all three treatment plants. Technical details detailed costs for each option can be found in Appendix A.

Table 3. Summary of Escalated Capital Cost (in $ millions)	
Options	Estimated Total Project Capital Cost (Escalated to midpoint of construction in 2028)
Baseline: Class B	$335
Alternative Option One: 100 Percent Class A	$590
Alternative Option Two: Pyrolysis	$1,115

Table 3: Summary of Escalated Capital Cost

Even though the continuation of the current program, *Baseline: Class B,* does not require construction of a new offsite facility, it would require significant capital upgrades to the treatment plant digesters, (replacing or adding digesters and supporting systems), such as those that capture biogas for renewable energy or treat odor. These investments are needed to provide additional capacity to process more solids as the region's population increases. Capital costs for this option are estimated to be $335,000,000.

Alternative Option One: 100 Percent Class A requires the construction of an offsite composting and soil blending facility. This would entail land acquisition and building a facility that includes components such as an aeration system to blow air through the compost, odor control systems, and ancillary equipment such as front end loaders and mixers. This option requires changes to two treatment plants to add Class A digesters, as well as maintaining and upgrading existing Class B equipment at one treatment plant to address solids capacity needs. Capital costs for this option are estimated to be $590,000,000.

Alternative Option Two: Pyrolysis has the same requirements as the *Baseline: Class B* option at the treatment plants, which maintains and upgrades Class B digesters at the three treatment plants to serve an increased regional population. This option also requires land acquisition and the construction of an offsite drying and pyrolyzing facility, which includes components such as buildings, a dryer, boilers, pyrolysis units, and odor control. This option requires the most engineering and equipment. Capital costs for this option are estimated to be over one billion dollars.

[29] Estimated capital costs of either offsite facilities or upgraded digestion presented in this report are pre-planning level estimates based on the Association for the Advancement of Cost Engineering (AACE International) standards. WTD's capital cost estimating guidelines require capital costs to be estimated at key phases to further refine cost estimates as the project moves through the capital delivery process. Planning level estimates are conceptual and therefore have low levels of accuracy (+/-100 percent). These were input into King County's cost models.

Operation and Maintenance Costs and Revenues

In addition to the capital costs, all options have operation and maintenance costs and revenues. Operation and maintenance costs are the day to day costs to run the facility or program and include biosolids processing at the treatment plants and Biosolids Program operations such as research, compliance, monitoring, transportation, and application to customer sites in agriculture and forestry. Revenues from biosolids product sales, as well as electricity and renewable natural gas (produced by the digesters), are also included. Revenues are highly variable based on the market. The assumptions are variable due to the uncertainty of a 50-year projection. Market assumptions were made with knowledge of 2020 conditions only and were conservative. There is opportunity to optimize production and local sale of Class A products to decrease cost and increase revenue.

Total annual operations and maintenance costs were roughly the same for all three – the baseline and two options. Annual operations costs are presented for the year 2050, which assumes fully executed capital projects, full maturity of product markets and revenue, and a linear projected increase of biosolids production from 2018-2050. A summary of annual operations and maintenance costs and revenue is provided in Table 4, which includes annual transportation costs as part of operations and maintenance. Transportation costs alone for each option are provided in Table 5.

Table 4. Summary of 2050 Annual Operations and Maintenance (O&M) and Revenues (in $ millions)

Options	O&M	Revenues	Total
Baseline: Class B	**$40.50**	**($11.10)**	**$29.40**
Alternative Option One: 100 Percent Class A	**$49.00**	**($19.50)**	**$29.50**
Alternative Option Two: Pyrolysis	**$39.00**	**($10.50)**	**$28.50**

Table 4: Summary of 2050 Annual Operations and Maintenance and Revenues

Transportation Costs

Currently, King County contracts with a hauling company to drive 10 to 15 trucks of biosolids to eastern or western Washington land application sites from the treatment plants every day. The County owns a total of 35 trucks used for hauling and the County pays the contractor's hauling fees and fuel costs. Transportation costs highlighted in this section include hauling fees and fuel costs for the *Baseline: Class B*, *Alternative Option One: 100 Percent Class A*, and *Alternative Option Two: Pyrolysis*. These costs are included in the annual operating costs in Table 4, but are displayed separately for each option in Table 5, in millions of dollars.

Baseline: Class B assumes a continuation of the current hauling contract and has the highest transportation costs, due to the large proportion of product going to eastern Washington. *Alternative Option One: 100 Percent Class A* also assumes a continuation of the current hauling contract, but results in a lower transportation cost because the compost and soil blend products can be sold locally. *Alternative Option Two: Pyrolysis* has significantly lower transportation costs because, while a hauling contractor would still need to transport the biosolids from the treatment plants to an offsite pyrolysis facility, the distribution of the biochar product would be handled by a private business partner rather

than King County. This shifts the cost of transportation to the private partner, who could offset it through product sales and/or use it to negotiate the terms of the public-private partnership.

Table 5. Summary of 2050 Annual Transportation Cost (in $ millions)	
Options	Transportation (Hauling and Fuel)
Baseline Class B	$6.00
Alternative Option One: 100 Percent Class A	$4.00
Alternative Option Two: Pyrolysis	$1.50

Table 5: Summary of 2050 Annual Transportation Costs

Non-monetary Costs and Benefits

King County's capital and operating budget and project prioritization is informed by more than just monetary costs. It also includes qualitative costs, risks, and benefits that extend beyond economic considerations. To capture the non-monetary costs and benefits of each option, a greenhouse gas inventory and triple bottom line analysis were conducted.

Greenhouse Gas Inventory

Environmental benefits speak directly to several of King County's priority initiatives, such as the Strategic Climate Action Plan and Clean Water, Healthy Habitat. A greenhouse gas emissions inventory[30] was developed for each of the options based on the County's flow and load projections for the 2050 annual average load at each regional treatment plant.[31] The inventory is based on greenhouse gas emitted during operation of the biosolids treatment facilities, transportation, and application of biosolids.

All options provide a net carbon credit, meaning they have the environmental benefits of having more carbon offsets and carbon sequestration than they do carbon emissions. Those net credits are shown in Figure 4 as credits, debits, and net credit in annual metric tons of carbon dioxide equivalent (mt CO_2E) per year (yr). To put these carbon credits into every day metrics, the *Baseline: Class B* option takes the equivalent of 14,000 cars off the road each year, *Alternative Option One: 100 Percent Class A* takes the equivalent of 13,000 cars off the road each year, and *Alternative Option Two: Pyrolysis* takes the equivalent of 3,000 cars off the road each year.

The greenhouse gas emissions from each option, presented as negative carbon debits, include transportation, process fuel and chemical use, fugitive emissions[32], and electricity consumption. The positive carbon credits come from electricity produced and sold, renewable natural gas production, carbon sequestration, and fertilizer offset from land application of biosolids.

[30] A greenhouse gas inventory is an accounting of greenhouse gas emissions and offsets. The greenhouse gas emission scopes and factors were based on the guidelines published by The Climate Registry (TCR) and Intergovernmental Panel on Climate Change (IPCC) and updated with recent publications.
[31] See King County Brightwater Treatment Plant Peak Flow and Wasteload Projections 2010-2060, 2019, King County. South Treatment Plant Peak Flow and Wasteload Projections 2010-2060, 2019, and King County. West Point Treatment Plant Peak Flow and Wasteload Projections 2010-2060, 2019 for more information.
[32] Fugitive emissions are emissions of gases or vapors from leaks or other unintended releases of gases from pressurized equipment.

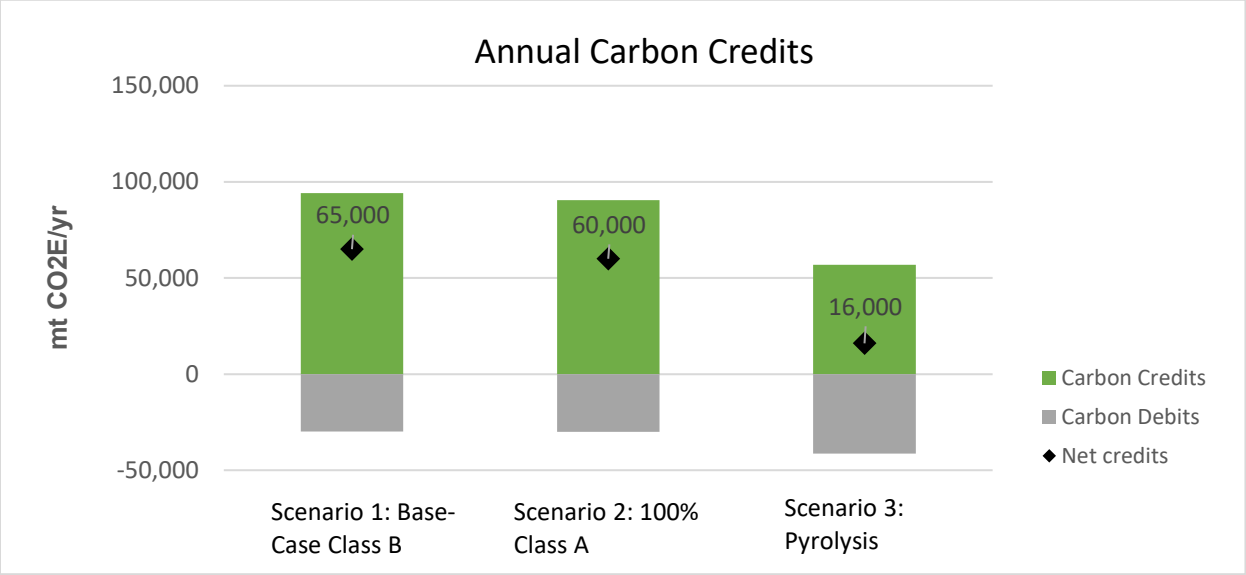

Figure 4: Annual Carbon Credits and Debits

Triple Bottom Line Analysis

Each option has differing environmental, equity, and social impacts. In order to capture the complexity of the costs and benefits of each option, a triple bottom line analysis was conducted. The three options were compared on a number of different environmental, social, and economic factors, such as traffic, odor, and noise increases, difficulty of implementation and operation, energy use, and market diversification. The weighted scores that are highest represent the best scenarios. Full triple bottom line results can be viewed in Appendix B.

The triple bottom line total score was very high for *Alternative Option One: 100 Percent Class A*, high for *Baseline: Class B*, and medium for *Alternative Option Two: Pyrolysis*.

- *Baseline: Class B* had high to very high scores in all criteria except flexibility to meet future regulations and market diversification/risk, both highly weighted criteria.
- *Alternative Option One: 100 Percent Class A* had the highest overall score due to very high scores in greenhouse gas emissions, flexibility to meet future regulations, market diversification/risk, and solids handling capacity. This scenario had high to very high scores in all other criteria, with the exception of noise, odor, traffic, and capital costs. Noise, odor, and traffic are equity impacts that would need to be considered and properly mitigated in the siting of a facility.

Alternative Option Two: Pyrolysis scored low to medium in each individual criteria category. Lower scoring criterion for pyrolysis included greenhouse gas emissions, energy use, regulatory compliance and beneficial use, capital cost, market risk/diversification, process reliability, and permitting.

C. Physical Footprint

New offsite facilities would require acquiring land. For each option, the amount of land required, or the physical footprint of the site, was estimated as shown in Table 6. All footprints assumed in this analysis are approximate, since land acquisition and site selection is an in depth regulatory and community

process. Actual footprint size would be refined further if an option was implemented, as it would vary based on the specifics of the technology and actual site constraints for the land selected.

Table 6. Physical Footprint (Land) Required	
Options	Number of Acres
Baseline: Class B	0
Alternative Option One: 100 Percent Class A	30-40
Alternative Option Two: Pyrolysis	12

Table 6: Physical Footprint (Land) Required

Baseline: Class B would require no additional land to continue Class B operations since there are no new offsite facilities and all changes are assumed to be at the treatment plant within the existing property boundaries.[33]

Alternative Option One: 100 Percent Class A would require a new offsite facility for composting and soil blending, since there is not enough space at any of King County's three treatment plants for this component. This facility would require 30-40 acres total.

- An offsite soil blending and compost facility would require 23 acres for the composting treatment process, which includes receiving feedstocks[34], mixing feedstocks, composting, curing, screening, compost storage, and administrative buildings. The site would include a seven-acre buffer area to minimize any impacts to surrounding properties, with an additional 10 acres for soil blending and for product storage prior to retail sales, for a total of 40 acres.
- All other changes in this option are assumed to be made at the treatment plants within the existing property boundaries.

Alternative Option Two: Pyrolysis would require 12 acres total.
Due to existing space limitations at King County's three regional treatment plants, an off-site location would be required for a drying and pyrolysis system. An offsite pyrolysis facility processing 100 percent of King County's biosolids would require 12 acres to accommodate 12 belt dryers, three pyrolysis units, and ancillary equipment such as odor control, storage hoppers, conveyors, and boilers.

D. Storage Volume

The current King County Biosolids Program is designed to transfer biosolids from the treatment plants directly to land application sites for use as soon as the biosolids are fully treated. Biosolids are only temporarily stored in emergency situations when it is not possible to haul biosolids and/or land apply in either eastern or western Washington due to inclement weather and mountain pass closure. DNRP

[33] While the Brightwater and South treatment plants both have space allocated for additional digesters in their site footprint, there are competing space requirements from other high priority projects, such as the anticipated nutrient removal requirements being developed by the Washington State Department of Ecology. The West Point treatment plant is especially limited, with no additional acreage available and significant challenges working within the existing footprint.
[34] Feedstock refer to raw material used to supply or fuel an industrial process, such as composting.

contracts with the City of Everett Wastewater Treatment Plant to store biosolids at the facility during these weather events.

Temporary storage of biosolids requires an impermeable surface accessible by the trucks used for hauling, such as a paved area, and water runoff protections. The storage area at the City of Everett Wastewater Treatment Plant is a 60 foot by 100 foot paved space, which can hold approximately one week's worth of biosolids production from King County's three regional wastewater treatment plants. WTD can store approximately 100 truckloads (around 3,200 wet tons) on the site at a time. Biosolids are loaded into trucks at the treatment plant, hauled to the storage site, and unloaded. Stored biosolids are removed from the storage area and hauled to customers as soon as weather permits, generally within no more than a few days. In 2019, WTD took 88 loads to the storage area, totaling 2,775 wet tons. Over the last five years, WTD has sent on average 51 loads per year to the storage area and used no more than 44 percent of the total available space during peak storage times. Annual and future storage needs are difficult to predict, as they are determined by weather.

Baseline: Class B would require a similar temporary storage area or areas to the current City of Everett Wastewater Treatment facility space. *Alternative Option: 100 Percent Class A* would decrease storage needs, due to increased local hauling and diversity of products. In addition, the composting and soil blending facility proposed would be large enough to include a storage area similar to the current temporary storage option. Storage needs for *Alternative Option Two: Pyrolysis* would depend on the efficacy of the drying and pyrolysis equipment. Similar to *Alternative Option One: 100 Percent Class A*, the offsite pyrolysis facility could be designed to include temporary storage.

E. Map of Biosolids Applications

The map below in Figure 5 shows the locations where customers use King County's Loop biosolids to grow their plants and crops, referred to as land application. The green icons show the forestry customers while the yellow icons show the agriculture customers, with major cities starred as geographic reference points.

Figure 5: Mapped Locations of Current Land Application of Biosolids shown with green and yellow icons. The Washington State Department of Natural Resource land and Snoqualmie Forest are in King County. Natural Selection Farms is in Yakima County. Boulder Park Inc. is in Douglas County and West Lincoln Project in Lincoln County.

F. Financial Analysis

The financial analysis conducted shows that, regardless of Class B or A biosolids, significant investments are needed at all three treatment plants in the next 30 years to meet solids processing capacity needs for a growing population.

A summary explanation of how the options compare is below in Table 7.

Table 7. Total Costs and Scores			
	Baseline: Class B	Alternative Option One: 100 Percent Class A	Alternative Option Two: Pyrolysis
Estimated Escalated Capital Costs	$335,000,000	$590,000,000	$1,115,000,000
2050 Annual Net Operating & Maintenance Costs and Minus Revenue	$29,400,000	$29,500,000	$28,500,000
Triple Bottom Line Score[35]	High	Very High	Medium

Table 7: Total Costs and Scores

Baseline: Class B requires significant capital investment to maintain the existing system and address projected capacity needs. Biosolids are a byproduct of necessary sanitation and public health infrastructure so production is continuous and cannot be turned off or halted. If the County cannot beneficially use its biosolids due to unexpected circumstances, such as the sudden loss or inaccessibility of a customer, the cost to landfill is projected to be at least $3 million per month due to hauling and landfill fees. Landfilling biosolids also requires a regulatory waiver and creates potential for regulatory fines.

Alternative Option One: 100 Percent Class A decreases the regulatory challenges and risk, because it can diversify the Loop product line with multiple Class A products (compost, soil blends, biosolids). Producing multiple products diversifies the biosolids program's customer base, a key strategic plan goal that will ensure the biosolids program can continue to meet its regulatory mandate to beneficially use biosolids. Implementing an option like *Alternative Option One: 100 Percent Class A*, thereby transitioning King County's entire biosolids program to Class A, would require a long-term, phased approach since it requires multiple large and expensive capital projects.

Alternative Option Two: Pyrolysis adds regulatory challenges and risk to the existing program by processing 100 percent of Loop at one off site facility, which does not provide programmatic redundancy or distribution options. The financial analysis demonstrated that *Alternative Option Two: Pyrolysis* is the highest cost option. In addition, biochar has a limited and uncertain market and is only considered Class A under the state biosolids rule on a case by case basis.

As indicated by WTD's Clean Water Planning efforts, there are many competing priority needs and the County must make the right investment according to its priorities. Therefore, any major capital investment, including transitioning King County's biosolids program to Class A, would require a long-term, phased approach over the next 30 years because of the cost and the need to prioritize capital investments. A phased approach maintains the existing Class B program while slowly adding Class A as it aligns with other organizational goals such as adding solids treatment capacity.

[35] For more information on Triple Bottom Line, see Appendix B.

Conclusion

The study concluded that all future options, Class A or B, are costly and require significant technical and physical improvements. As digester capacity expansion is needed over the next 30 years at each of the regional treatment plants, opportunities to explore phased transition to Class A biosolids can be incorporated into planning efforts to address treatment capacity needs and maintain aging equipment.

Any development of a Class A program would require changes to biosolids policies in King County Code, since the King County Code currently prohibits the production and sale of anything other than Class B Biosolids.[36] WTD is currently in the process of designing a small-scale temporary compost pilot project at South Treatment Plant to test composting and explore marketability of a County-owned Class A compost. The current cost estimate for the pilot project is $3.4 million with project completion anticipated in 2022/2023. This work in developing the pilot project to produce Class A compost at South Treatment Plant could help inform future planning efforts.

Appendices

Appendix A: Technical Memorandum
Appendix B: Combined Financial, Environmental, and Social Costs and Benefits

[36] King County Code 28.86.090 Biosolids policies (BP).

Technical Memorandum

701 Pike Street
Suite 1200
Seattle, WA 98101

T: 206.624.0100
F: 206.749.2200

Prepared for: King County Wastewater Treatment Division

Project Title: System-Wide Treatment Plant Flow and Loading Study

Brown and Caldwell Project No.: 151084

Technical Memorandum

Subject: Class A Biosolids Technology Evaluation

Date: April 20, 2020

To: Catherine Gowan, King County Biosolids Manager

From: Patricia Tam, Brown and Caldwell Project Manager

Copy to: Ashley Mihle, John Conway

Prepared by: _____
Trung Le, Engineer III

Reviewed by: _____
Steve Krugel, Senior Vice President

Limitations:

This document was prepared solely for King County Department of Natural Resources and Parks in accordance with professional standards at the time the services were performed and in accordance with the contract between King County Department of Natural Resources and Parks and Brown and Caldwell dated August 1, 2017. This document is governed by the specific scope of work authorized by King County Department of Natural Resources and Parks; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by King County Department of Natural Resources and Parks and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 1: Introduction

The purpose of this technical memorandum (TM) is to document the supporting materials and results of the Class A biosolids technology evaluation prepared for King County (County). This TM was developed to assist the County in preparing their response to Council Proviso 2019-0148.P3 Version 2. The proviso calls for the identification of Class A alternatives to the current Class B biosolids application in forest and farm environments. The County is interested in diversifying the biosolids products to increase resiliency. This evaluation built upon the King County Treatment Plant Flows and Loadings Study. The previous evaluation identified and screened solids treatment technologies for each of the County's three regional treatment plants. Other earlier studies conducted for the County on Class A biosolids treatment alternatives were also used as background materials for this study.

This TM documents the following subtasks performed for this evaluation:

- Class A technology screening
- Overview descriptions of the short-listed technologies, including a more detailed description of the gasification/pyrolysis technology
- Development of biosolids treatment and reuse scenarios
- Conceptual modeling of each scenario to evaluate solids production, energy usage, and greenhouse gas (GHG) emissions.
- Development of conceptual capital and operating and maintenance (O&M) cost estimates
- Evaluation of the scenarios based on triple bottom line (TBL) criteria.

Preliminary results of the TBL evaluation were discussed in a review workshop with the County. This TM incorporates feedback from the County received at that workshop.

Section 2: Technology Screening

The first task for this study was to pre-screen potential Class A technologies to identify those that could produce a Class A biosolids product. The approach used was to first synthesize previous studies on biosolids processing technologies and perform an initial screening for Class A technologies; this resulted in a comprehensive list of relevant Class A technologies. Screening criteria were developed to further reduce the selection of Class A technologies to those potentially suitable for County biosolids management.

The following documents were used as references:

- King County Treatment Plant Flows and Loadings Study King County Biosolids Strategic Plan 2016 – 2037
- King County 2005 Class A Biosolids Workplan

The draft biosolids technology evaluation from the King County Treatment Plant Flows and Loadings Study, was used as the starting point for this evaluation with some modifications as described in the following sections below.

2.1 Biosolids Technology Screening Criteria

Four categories of screening criteria were developed and include:

- Technology maturity
- Improved process
- Resource recovery
- Environmental impacts

Details of each category are described below.

2.1.1 Technology Maturity

Technology maturity relates to the state of development and implementation of a given technology and is directly related to the risk/reliability of its adoption. The use of non-established technologies typically has a high degree of risk related to failure in the successful application of the technology and in meeting the required performance. Given these risks, non-established technologies were screened from the evaluation.

The implementation of international technologies in the U.S. poses challenges that are related to differences in regulations, materials and feedstocks, design standards, and market drivers. International technologies require adaption to U.S. standards and environment, which generally correlates to additional costs. A steeper learning curve may also result from being the first/early adopter of international technologies. Due to the increase in the risk of failure in meeting performance, international technologies that have no U.S. implementations were screened from the evaluation.

This analysis is based on the most current available information. The technology market for biosolids is constantly changing and adapting to new technology developments, maturation of technologies, and the discontinuation of others. Reassessing current non-established and non-U.S. implemented technologies in the future may result in these technologies advancing for further consideration. The three tiers of technology maturity used in this evaluation include:

- **Established:** This tier represents technology that has been well-established in the industry for solids processing applications; these technologies have broad usages with long records of performance.
- **Non-established:** This tier represents technologies that fall within the two following categories:
  - **Embryonic:** This first tier represents technology in its early development state or that has been demonstrated at bench or small pilot scales in a laboratory environment. In some cases, an embryonic technology may be proven at full scale with a different feedstock, but not with wastewater sludge. It may be in operation at one or two full-scale plants for a short duration but has not achieved a long-term proven status; therefore, technologies deemed embryonic were eliminated from further consideration.
  - **Innovative:** Innovative technology is commercially viable and has been proven at full scale in one or more installations. Innovative technologies have a shorter track record of reliable operation than established technologies (e.g., typically less than 5 years).
- **U.S. Implementation:** Many wastewater technologies have a global presence and the exchange of technologies internationally is common practice. When foreign technologies established in other markets enter the U.S. market, critical technical challenges can arise as well as issues with navigating and receiving approval from U.S. regulatory agencies. This presents a potential risk that can have negative and costly consequences for implementation.

2.1.2 Improved Processes and Existing Technology Enhancement

Improved processes and existing technology enhancement are summarized as follows:

- **Improved processes:** Technologies categorized as improved processes include those that will improve current solids treatment performance. For example, improvements can include increased process efficiency, increased digester gas production, reduced power and polymer consumption, resource recovery, improved biosolids product quality, and a reduced required quantity of solids. Current solids treatment technologies at each WWTP have been proven acceptable under current conditions and are designated as the baseline case (existing) scenario technology. Any technology that will likely degrade performance from the baseline case was eliminated from further consideration.
- **Existing technology enhancement:** Technologies in this category are optimization strategies that can improve overall process performance while using existing infrastructure. These require minor infrastructure modifications or minor new component additions without adding major new process tankage.

2.1.3 Resource Recovery

Resource recovery relates to the beneficial use of biosolids and digester gas:

- **Class A biosolids:** This comprises technologies that produce Class A biosolids with one of U.S. Environmental Protection Agency's (EPA) Process to Significantly Reduce Pathogens processes or that have achieved Class A equivalency. This does not include technologies that can potentially produce biosolids products meeting Class A requirements but require site-specific equivalency determination and/or daily pathogen monitoring/reporting to prove compliance on each biosolids batch.
- **New biosolids product:** These technologies produce biosolids products other than dewatered Class B cake, which is currently produced at the County's WWTPs.
- **More gas production:** These technologies increase digester gas production over conventional mesophilic digestion. All major County plants currently produce and beneficially use digester gas. Increased digester gas production can be achieved by digester pretreatment and/or advanced digestion processes. Technologies that reduce or eliminate gas production were eliminated from further consideration.

2.1.4 Environmental Impacts

Environmental impacts include the impact on GHG emissions from the solids treatment processes. GHG emissions reductions can be achieved by reducing power and chemical consumption, increasing digester gas production, increasing or providing a higher level of beneficial use for digester gas, or reducing vehicle fuel consumption. BC eliminated technologies that significantly increase GHG emissions from further consideration.

2.2 Biosolids Technology Screening Results

The criteria established in **Section 2.1** were used to perform a technology screening. **Table 1** shows the preliminary technology screening results. This screening table originated from work completed for the King County Treatment Plant Flows and Loadings Study and was adapted for this study as described below. Technologies with acceptable maturity (or will have beneficial impacts over existing processes) were given a "✓" mark on that criterion. Technologies with detrimental impacts (as described above) are given an "x" mark on that criterion. Table cells were left blank where the technology was neutral or not applicable with respect to the criterion. Any technology with an "x" in any criterion was eliminated from further evaluation and shown as shaded cells in **Table 1** below.

Table 1. Class A Technology Screening

Parameter	Technology	Solids Processing Technologies							
		Technology Maturation		Improved Process	Resource Recovery				Environmental Impacts
		Established	U.S. Installations	Improved Process	Existing Enhancements	Class A Biosolids	New Biosolids Product	More Gas Production	GHG Emissions Reduction
Anaerobic Digestion	Conventional Mesophilic Anaerobic Digestion (CMAD) (baseline case South Plant, West Point, Brightwater)	✓	✓			X			
	Conventional TAD or TPAD with Batch Tanks	✓	✓	✓	✓	✓	✓	✓	✓
	Acid/Gas Anaerobic Digestion (AGAD)	✓	✓	✓		X		✓	✓
	Post Aerobic Digestion (PAD)	X	✓	✓		X			X
	Dual digestion (ATAD plus thermophilic anaerobic)	✓	✓	X	X	✓	✓	X	X
	Recuperative thickening (e.g., OMNIVORE™)	X	✓	✓	✓	X			
Digestion Pretreatment	Thermal hydrolysis (Cambi)	✓	✓	✓		✓	✓	✓	
	Thermal hydrolysis (Biothelys™, Exelys™, LysoTherm®, Haarslev™)	X	X	✓		✓	✓		
	Thermal-chemical hydrolysis (PONDUS)	X	✓	✓		X		✓	
	Enzymatic hydrolysis (Monsal)	X	X	✓		X		✓	✓
	Mechanical (Crown)	X	X	✓		X		✓	
	Ultrasonic (sonix™, Sonolyzer®)	X	X	✓		X		✓	
	Electrokinetic (BioCrack)	X	X	✓		X		✓	
Other Stabilization Technologies	Alkaline stabilization	✓	✓	X		✓	✓	X	X
	Incineration with power generation	✓	✓	X		X		X	X
	Compositing (raw sludge)	✓	✓	X		✓	✓	X	X
	Thermal drying (raw sludge)	✓	✓	X		✓	✓	X	X
	Gasification/pyrolysis	X	✓			—[2]	✓	X	—[3]
	Hydrothermal oxidation (AquaCritox®)	X	X				✓	X	✓
	Hydrothermal liquefaction–gasification (Genifuel Corporation)	X	X				✓	X	✓
Product Enhancement Post-Digestion and Dewatering	Thermal drying	✓	✓	X		✓	✓	X	X
	Solar Drying	✓	✓	X[1]		✓	✓		
	Thermal-chemical hydrolysis (Lystek)	X	✓	X		✓	✓		
	Composting	✓	✓	✓		✓	✓		
	Soil blending, Post Class A Digestion	✓	✓	✓		✓	✓		

[1] *Solar drying is only feasible in eastern Washington due to the lower solar radiation of the region. Auxiliary heating in terms of natural gas would be needed to supplement drying requirements.*

[2] *The Washington Department of Ecology (Ecology) does not have a policy that covers pyrolysis and will require a review of Class A designation for these systems on a case by case bases.*

[3] *Some gasification and pyrolysis systems can become energy neutral or positive based on the dry solids content of the dewatered cake entering the system. The Bioforcetech system evaluated was paired with a belt dryer rather than a biodryer based on the manufacturer's recommendation. This pairing resulted in the system requiring external energy input.*

Several changes were made to the draft biosolids technology evaluation prepared during theKing County Treatment Plant Flows and Loadings Study and are noted below:

1. Added Class A solar drying to the list based on its inclusion in the evaluation from the *KC Strategic Plan 2018-2037*
2. TAD and TPAD alternatives were combined with batch tanks as one alternative.
3. The ATAD component of Dual Digestion does not produce gas and requires significant additional energy to digest. TAD/TPAD with batch tanks represents a better alternative for enhanced Class A digestion for County plants.
4. Cambi thermal hydrolysis process (THP) is the only THP technology with a U.S. Installation. Cambi will be the representative technology for THP.
5. Class A Biosolids was updated to be a screening criterion
6. U.S. Installations was added as a screening criterion
7. PAD was updated with an X for GHG due to energy use for aeration
8. Thermal drying was updated with an X for improved process due to increase in energy use
9. Thermal-Chemical Hydrolysis (Lystek) was updated with an X for improved process due to the creation of a liquid product that would require additional trucking and application, not consistent with County product goals
10. Off-site and on-site designations were removed to be more generic for soil blending and composting

A short-list of the technologies remaining after this screening process is shown in **Table 2**. All technologies that received negative marks in any criterion were removed from further consideration. Pyrolysis did not meet the specified criteria for screening but was included in the evaluation due to interest from the County Council.

Table 2. Class A Technology Short List

Parameter	Solids Processing Technologies									
		Technology Maturation		Improved Process	Resource Recovery				Environmental Impacts
	Technology	Established	U.S. Installations	Improved Process	Existing Enhancements	Class A Biosolids	New Biosolids Product	More Gas Production	GHG Emissions Reduction
Anaerobic Digestion	Conventional Mesophilic Anaerobic Digestion (CMAD) (baseline case South Plant, West Point, Brightwater)	✓	✓			X			
	Conventional TAD or TPAD with Batch Tanks	✓	✓	✓	✓	✓	✓	✓	✓
Digestion Pretreatment	Thermal hydrolysis (Cambi)	✓	✓	✓		✓	✓		
Other Stabilization Technologies	Gasification/pyrolysis	X	✓			– [1]	✓	X	–[2]
Product Enhancement Post-Digestion and Dewatering	Composting	✓	✓	✓		✓	✓		
	Soil blending, Post Class A Digestion	✓	✓	✓		✓	✓		

[1] *Ecology does not have a policy that covers pyrolysis and will require a review of Class A designation for these systems on a case by case bases.*

[2] *Some gasification and pyrolysis systems can become energy neutral or positive based on the dry solids content of the dewatered cake entering the system. The Bioforcetech system evaluated was paired with a belt dryer rather than a biodryer based on the manufacturer's recommendation. This pairing resulted in the system requiring external energy input.*

Section 3: Biosolids Technologies

This section provides a brief overview of the short-listed technologies. A longer discussion on pyrolysis technologies is included and covers the status of the technology and the biochar market. This discussion was not included in the previous evaluation under Task 450 as it had not passed the technology screening.

3.1 Anaerobic Digestion

3.1.1 Mesophilic Anaerobic Digestion

Mesophilic anaerobic digestion (MAD) is the most commonly used anaerobic digestion process in the U.S. Mesophilic digesters are operated within the mesophilic temperature range, 95 to 102 degrees Fahrenheit (°F), at solids retention times (SRTs) exceeding 15 days. Typically, loading criteria range from 100 to 160 pounds of volatile solids (lb-VS) per 1,000 cubic feet (ft^3) per day (d) with limiting loadings rates of 200 lb-VS/1,000 ft^3/d. The process produces substantial methane-rich digester gas that has high thermal value and is commonly used as a renewable fuel.

Mesophilic digestion produces a Class B biosolids as defined by the U.S. Environmental Protection Agency's (USEPA) Part 503 regulations and is suitable for most large-scale agricultural, forest, and mine reclamation applications. Class B biosolids have some application restrictions to protect public health and safety.

3.1.2 Thermophilic Anaerobic Digestion

Thermophilic anaerobic digestion (TAD) occurs at temperatures between 120 and 135°F, at conditions suitable for thermophilic microorganisms. Biochemical reactions increase with temperature; therefore, microbial reactions in TAD are much faster than mesophilic digestion. The advantages of TAD include increased solids destruction capability, improved dewatering, increased gas production, and increased pathogen destruction. Because of the increased biochemical reaction rate, loadings to a TAD have been reported as high as 500 lb-VS/1,000-ft^3/d, significantly higher than those of MAD.

Disadvantages of TAD include higher energy requirements for heating, poorer supernatant quality, and higher dewatering odor requiring treatment. In addition, thermophilic dewatered cake has slightly higher initial end product odor due to higher ammonia that dissipates relatively quickly. Higher solids destruction rates in a thermophilic digester release greater concentrations of ammonia which contributes to the poorer supernatant quality, potentially impacting the plant's liquids steam processes. TAD also requires additional heat exchangers and heat resources relative to MAD to heat the digester to higher temperatures; however, heat recovery systems can greatly reduce heating costs. **Figure 1** is a photograph of the TAD operated by Metro Vancouver at the Annacis Island Wastewater Treatment Plant (WWTP) in Delta, British Columbia.

Figure 1. Thermophilic anaerobic digesters at Annacis Island WWTP

If properly configured, TAD can produce Class A biosolids. To prevent the potential for short-circuiting and increased pathogen levels above the Class A criterion in the biosolids, batch tanks are often used. The wastewater solids are held in a batch tank for a set period of time (24 hours hold time required for Class A at 131°F) to prevent the opportunity for any solids to pass through the entire digestion process in a shorter time period than required (i.e., short-circuiting the process). To meet USEPA requirements for Class A biosolids, separate batch tanks (or batch operation of the digesters) would need to be included with a TAD process. Without batch operation, the biosolids from the TAD process operated at higher temperatures and configured properly can potentially produce biosolids that meet Class A requirements for pathogen reduction, but would require testing of each biosolids batch.

3.1.3 Temperature-Phased Anaerobic Digestion

Temperature-phased anaerobic digestion (TPAD) incorporates the advantages of TAD and mitigates some of the disadvantages through the incorporation of MAD to improve performance. TPAD uses digesters in series, where the first stage is thermophilic followed by a mesophilic stage. The high biochemical reaction rate in the thermophilic phase improves solids destruction capability, improves dewaterability of the sludge, increases gas production, and increases pathogen destruction rates. The following mesophilic stage(s) improves the performance of the overall digestion system and helps mitigate the disadvantages of TAD (specifically, poorer supernatant quality and odors). The higher temperature of the thermophilic stage and configuration's ability to minimize short-circuiting contributes to greater pathogen destruction. As with TAD, TPAD can be configured with batch tanks to produce Class A biosolids. Also similar to TAD, a greater number of heat exchangers and heat resources are required to heat the wastewater solids to thermophilic temperatures and then cool the solids to mesophilic temperatures. Figure 2 is a photograph of the TPAD system at Western Lake Superior Sanitary District's WWTP in Duluth, Minnesota.

Figure 2. TPAD at Western Lake Superior Sanitary District WWTP

3.2 Digestion Pretreatment

3.2.1 Thermal Hydrolysis Process (THP)

Class A THP is a mature technology in Europe and worldwide with full-scale facilities in service since 1995; the first installation in the U.S. (Blue Plains plant in Washington, DC) has been operating since late 2014 and other U.S. installations are in the planning, design, and construction phases. THP is a pretreatment process prior to anaerobic digestion. There are two primary manufacturers of Class A THP – Cambi and Veolia. Class A THP uses medium-pressure steam to create high temperature and pressure conditions, which lyse (break open) bacterial cells and promote the release and solubilization of particulate organic material, making the feed solids more amenable to digestion. Figure 3 depicts a typical process flow of the Cambi Class A THP system for pretreatment of wastewater solids before digestion.

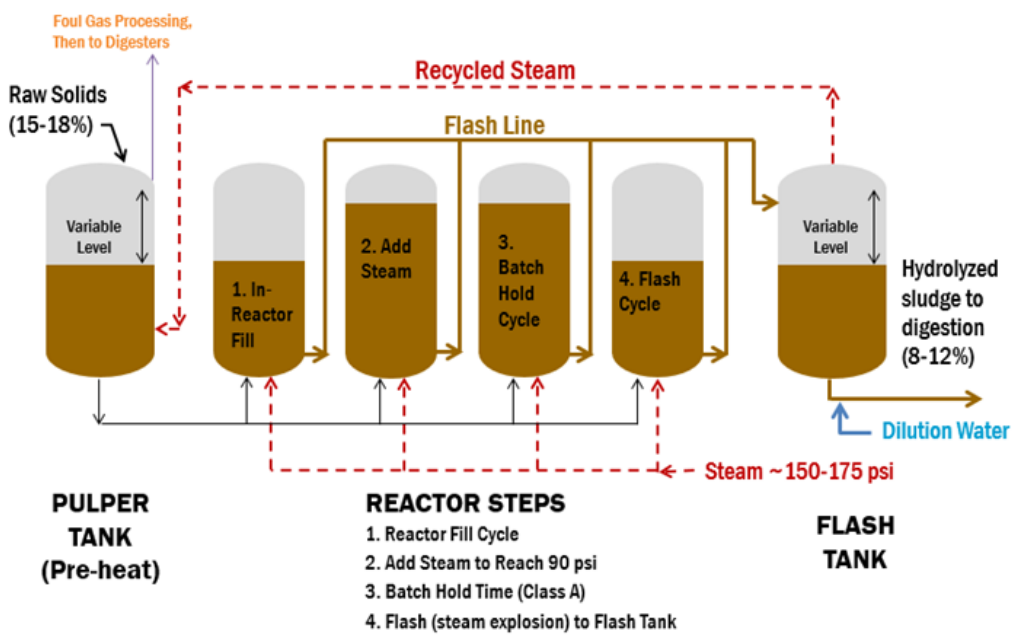

Figure 3. Cambi thermal hydrolysis process

THP systems can approximately double conventional MAD organic loading rates because of the modified characteristic of the feedstocks. This more efficient use of digester volume reduces the number of digesters required. Ancillary buildings and equipment are required to operate a THP system, including steam boilers, solids screening, pre-dewatering, raw cake storage and pumping, and solids dilution and cooling systems. While THP systems can reduce the required digester volume, the ancillary systems impact total system cost, complexity, and footprint.

The vast majority of Class A THP systems have been implemented by Cambi. However, competitor THP systems (Biothelys™, Exelys™, LysoTherm®, Haarslev™) have been installed in Europe, and Veolia's Biothelys system has been installed in the United Kingdom. Due to the lack of U.S. installations from THP manufacturers, this evaluation will use Cambi's THP system as the representative technology for THP systems alternatives.

3.3 Product Enhancement Post-Digestion and Dewatering

3.3.1 Composting

Composting is the most common method used to produce Class A biosolids in the U.S. To meet the criteria for Class A, composted biosolids must meet regulated metals, pathogen and vector attraction reduction limits, comply with required sampling and analysis protocols, maintain compost temperature and retention time records, and meet product labeling requirements.

Digested biosolids dewatered cake can be composted with sawdust, wood chips, yard clippings, storm debris, food waste, manure or crop residues, and food processing wastes. The final composted product provides nutrients and organic matter and sequesters carbon, thereby conserving resources, restoring soils, and combating climate change. Additionally, composting has been a long used process to reduce environmental contamintants. Research and composting applications have shown that aerobic composting can be effective at reducing antimicrobial resistant genes/bacteria and organic pollutants (Semple et al., 2001; Youngquist et al., 2016; Ozaki et al., 2017).

Composted biosolids are used in agriculture, horticulture, and landscaping just like any other retail soil product. Professional landscapers and master gardeners use composted biosolids for landscaping new homes and businesses. Home gardeners also find composted biosolids to be an excellent alternative to typical fertilizer.

Many composting technologies are available in the market and can vary from low-tech with limited process control to high-tech with precise process control. Many of these technologies can improve the composting process by providing better control of environmental factors, aeration rates, temperature, etc. In-vessel composting is one such method that uses silos, structures, plastic material, or other physical barriers to improve the composting process. Generally, these technologies provide the best composting process with the most efficient use of space and overall best product quality. Windrow composting is the most simplistic and widely used composting method. Windrow composting uses long rows and short piles of mixed biosolids and organic material that are mechanically aerated with a front-end loader or a windrow turner. This method is typically less controlled, uses a significant amount of space, and requires greater manual labor. Aerated static pile (ASP) composting is a high-rate composting method that sits between windrow and in-vessel composting. It is more compact and can be covered or uncovered. Piles or windrows are placed on top of porous bulking agents like wood chips with channels or pipes that provided negative or positive forced aeration through the piles while removing process water. ASPs are the second most widely used composting system and commonly used for biosolids composting.

3.3.2 Soil Blending and Manufactured Soils

Soil blending can be used to improve overall product quality or to change the product characteristics by blending biosolids with other organic and inorganic materials. However, the feedstock to any soil blending operation must be a Class A biosolids cake. These manufactured soils can be formulated to provide specific characteristics for unique applications and to reach a wider market through product diversification. Soil blended products can be publicly distributed in bag or bulk form. Generally, public reception of blended products tends to be positive due to similarities with existing non-biosolids soil conditioning products and reduced odors. The City of Tacoma produces several blended products including their most popular product, TAGRO Classic, which is comprised of two parts Class A dewatered cake, two parts sawdust, and one-part sand. Other blended products that are offered include mulch products that contain 80 percent woodchips and 20 percent biosolids and a potting soil mix of 20 percent biosolids, 20 percent maple sawdust, and 60 percent clean, aged bark. TAGRO has been largely successful with their blended products with demand often exceeding supply.

3.4 Other Stabilization Technologies

3.4.1 Gasification and Pyrolysis

Gasification and pyrolysis are technologies that have been widely used in other industries, principally using wood waste as a carbon source, but with very limited applications in the wastewater/biosolids industry. The following sections provide a description of the technologies and a discussion of the status of their development.

3.4.1.1 Technology Description

Pyrolysis is the thermal decomposition and partial mineralization of carbonaceous materials occurring in an anaerobic environment. Thermal decomposition typically occurs at temperatures in excess of 300°C. The anaerobic environment can promote the breakdown of carbon-rich feedstocks into an energetically favorable endpoint (e.g. methane) to generate a modest amount of combustible gas called syngas or pygas. The condensable fraction of the syngas can be stored and used as a liquid fuel and is often referred to as bio-oil. The remaining solid residue is a high-value product called biochar. Biochar has a thermal value similar to coal, functions as an adsorbent like activated carbon, and can also be used as a soil conditioner to improve overall soil health. A basic configuration of a pyrolysis unit and its major components is provided below in Figure 4.

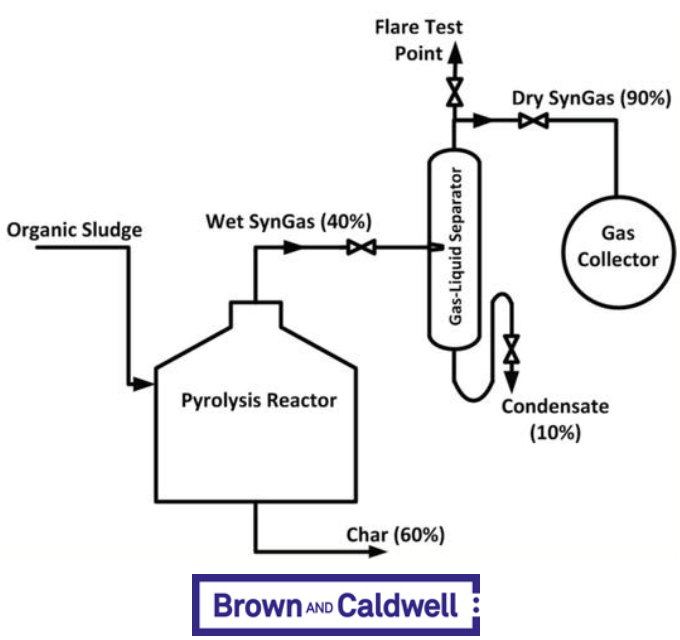

Figure 4. Basic configuration of a pyrolysis unit

The advantages of pyrolysis include residuals volume reduction, the potential for net energy production, carbon fixing into a stable form in biochar, and generation of a value-added product in biochar. In addition to the various end uses for biochar, research has also demonstrated the removal of contaminants of emerging concern such as triclosan and nonylphenol to non-detect levels during pyrolysis (Lee et al., 2018; Paz-Ferreiro et al., 2018; Ross et al., 2016). While pyrolysis itself can be energy positive, it requires prior biosolids drying to 60 to 90 percent total solids, requiring a substantial increase in energy input and representing a substantial additional investment in capital outlay and operational and maintenance costs for the biosolids dryer. As described further below, biochar management contracts are now commercially available at no cost to the generator with opportunities for revenue sharing.

Pyrolysis is often linked with gasification, which is another thermal process that combines the thermal decomposition step of pyrolysis with a controlled oxidation zone where limited air, oxygen, or steam is added to partially oxidize the volatilized organics. In gasification, the oxidation zone is consequently followed by a reductive zone where further cracking and reforming of the gases takes place to produce a syngas made up of lighter hydrocarbons compared to that of pyrolysis, with a smaller condensable fraction. While the condensable fraction of pygas has an energetic value and has been successfully processed into a usable liquid fuel with various feedstocks, it is highly acidic and unstable when heated making it difficult to handle. A basic configuration of a gasification unit and its major components is provided below in **Figure 5**.

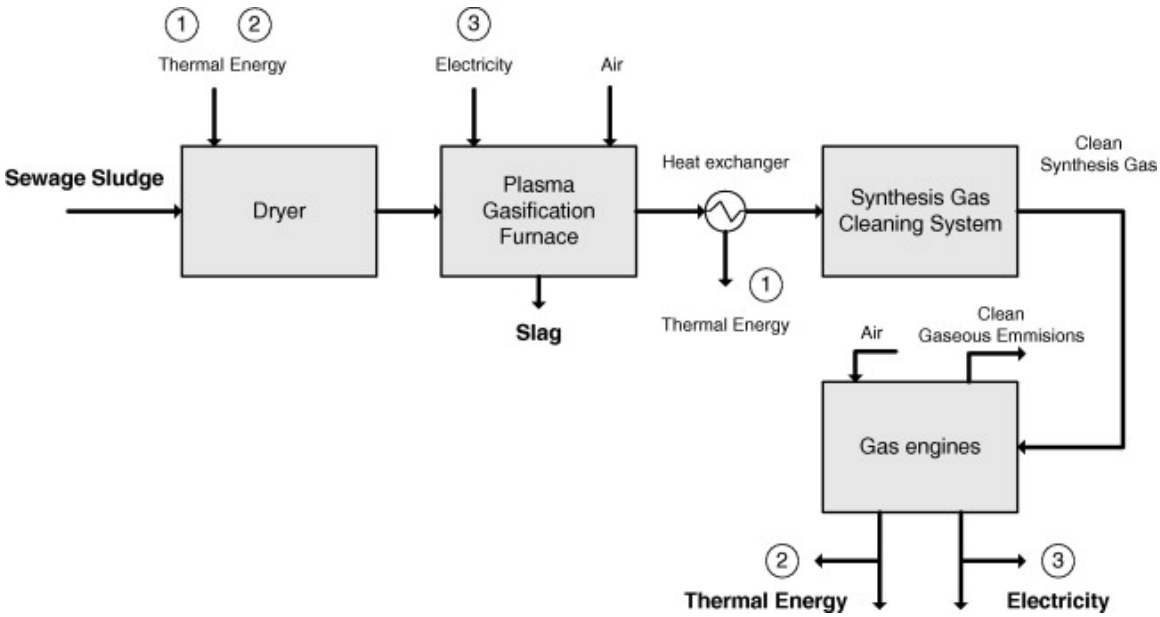

Figure 5. Basic configuration of a gasification unit

3.4.1.2 State of Technology

Applications of biosolids-based pyrolysis and gasification systems have been extremely limited due to the high technical risks, large capital cost, and the additional research and process adaption that is required when transferring technologies from other industries. The non-homogenous characteristics of biosolids, which can fluctuate in the amount of organic and inorganic content, can result in operational challenges. These challenges include impacts to the energy balance of the system requiring external natural gas or the addition of wood feedstocks to prevent interruption in the pyrolysis process. These conditions could dramatically increase operational costs and reduce the overall reliability of the system. The variations in the characteristics of biosolids may also change final product quality and increase the corrosion of the systems

which would require additional maintenance. These factors can impact the long-term success of programs and can result in failure which is further discussed in Section 3.4.1.6.

Only three biosolids pyrolysis/gasification facilities are operational in the U.S. with the largest facility processing 7,000 wet tons per year. This facility represents only 6 percent of the biosolids produced from the County's biosolids management program. This is out of a total of 33 U.S. gasification and pyrolysis facilities, where the other 30 plants process other feedstocks such as wood waste into syngas and biochar The limited number of facilities suggests that the technology remains an emerging technology with needs for a longer operation history, more research, and additional installations.

Table 3 below lists identified projects currently in operation, taken out of service, or are under planning, design, or construction.

Table 3. Biosolids Pyrolysis and Gasification Projects

Company	Facility	Location	Feedstock	Type	Scale	Status	Biosolids Capacity (WT/Yr)
Aries Clean Energy	Linden Roselle Sewerage Authority complex	Linden, New Jersey	Biosolids	Gasification/ Pyrolysis	Full-scale	Q4 2020	130,000
Aries Clean Energy	Lebanon Waste-to-Energy Plant	Lebanon, Tennessee	Woodwaste and biosolids	Gasification/ Pyrolysis	Full-scale	2016 - present	1,095
Aries Clean Energy	City of Covington	Covington, Tennessee	Woodwaste and biosolids	Gasification/ Pyrolysis	Full-scale	2014 - present	730
Aries Clean Energy	Aries-Holloway Bioenergy Facility	Lost Hills, California	Agricultural biomass	Gasification/ Pyrolysis	Full-scale	Q3 2021	60,225
Max West	Sanford Utility Department	Sanford, Florida	Biosolids	Gasification/ Pyrolysis	Full-scale	2009-2014 decommissioned	14235
Bioforcetech	Silicon Valley Clean Water	Redwood City, California	Biosolids	Pyrolysis	Full-scale	2017 - present	7000
Bioforcetech	Edmonds Wastewater Treatment plant	Edmonds, Washington	Biosolids	Pyrolysis	Full-scale	2021	-
Anaergia	Rialto Bioenergy Facility	San Bernardino, California	Biosolids and foodwaste (70%)	Pyrolysis	Full-scale	2020	109,500
Anaergia	Encina Wastewater Authority	Carlsbad, California	Biosolids	Pyrolysis	Pilot/ demonstration	2014	-
KORE Infrastructure	LACSD joint Water Pollution Control Plant	Carson, California	Biosolids	Pyrolysis	Pilot/ demonstration	2008-2015	1000

The chemical, material, and energy industries have shown a growing demand for investments in pyrolysis and gasification plants as a means for the development of alternative fuels and carbon products. Approximately 272 gasification plants are in operation worldwide and 74 additional plants are under construction based on a 2014 update of the gasification facilities database by Global Syngas Technologies Council. According to some research studies, the global market for biochar is expected to increase to the range of $653M-$3,100M by 2027 (TechSci Research, 2019; Research Nester, 2018). The largest growth in pyrolysis/gasification applications can be seen in the use of agriculture waste, biomass, organics, plastic/tire, and coal to produce renewable natural gas production, biochar, and bio-oil. Recent bans in international recycling outlets for plastics has also seen an increase in investment in plastics-to-oil solutions. In the last decade, the aviation industry has begun a campaign to decarbonize air travel by using sources for renewable aviation fuel (IRENA, 2017). All of these market drivers have spurred the rapid development of the pyrolysis and gasification industry.

3.4.1.3 European and International Applications

The adoption of pyrolysis and gasification technologies in Europe has advanced more rapidly than the U.S. No other international applications could be found outside of Europe and the U.S. In Europe, the use of pyrolysis and gasification technologies has been limited to the energy, materials, and forestry industry. Similar to the U.S., there are limited applications of pyrolysis and gasification of biosolids. Less than a dozen facilities use biosolids as a feedstock and are primarily small scale facilities. Europe's application of biosolids pyrolysis and gasification can be classified as emerging and likely faces similar risks and regulatory development requirements as the U.S.

3.4.1.4 United States Applications

Gasification has been evaluated with different feedstocks over the past few decades and has faced a number of historical operational challenges including concerns for dioxin formation in oxygenated pockets, difficulty in scaling reactors, and deformation or slag formation from residual product within the reactor. The most recent example of full-scale biosolids gasification occurred at the Maxwest Sanford Florida facility that operated from 2009 to 2014. The system operated as a 20-dry ton per day regional biosolids receiving and processing facility; however, the system was never able to achieve the targeted operational efficiency or reliability and was decommissioned. The technology has since been sold to a new company, Aries Clean Energy, who successfully operates two full-scale gasifiers that run on a combined feedstock of wood waste and biosolids. These facilities process only a fraction of biosolids compared to wood-waste and more details can be seen in Table 3. Aries Clean Energy recently obtained funding and has started construction of a regional biosolids gasification facility in Linden, New Jersey.

Pyrolysis has been evaluated at a number of facilities at pilot scale, including Los Angeles, California by Kore Infrastructure and Encina, California by Anaergia. The first full-scale biosolids pyrolysis unit was commissioned in June 2017 at the Silicon Valley Clean Water Authority in Redwood, California. The unit was supplied by Bioforcetech, an Italy-based technology provider, and is capable of processing 1,300 pounds of dry biosolids product per hour. The unit was approved by EPA as a non-incineration process and permitted by the Bay Area Air Quality Management District as a process heater. Regulations for biosolids biochar are currently undefined. Washington state approval for a Class A biosolids product will be on a case by case basis until additional research or updates to regulations occur.

3.4.1.5 Biochar Market

In 2018, a survey of the U.S. biochar industry was conducted in North America. The survey was sent to both biochar producers and consumers (Draper et al., 2018). Out of an estimated 135 U.S. biochar producers, 61 producers (18 percent resellers) responded. These producers reported that their primary pyrolysis feedstock was woody biomass but could also include other organic materials such as manure, grass, agricultural waste, construction waste, fiber, and food waste. Data from the survey suggested that the annual production of biochar in the U.S. was 35,000 to 70,000 tons. End-uses for biochar were primarily in agricultural application, draining, cannabis production, and odor control. This is consistent with biochar potential uses in compost, soil amendment, gardening, livestock bedding, and land and water reclamation projects (Draper et al., 2018). The average price from all producers was $129 per cubic yard or approximately $763 per ton assuming a bulk density of 338 pounds per cubic yard.

The largest expected market growth for biochar is for crop application and then for use for water purification and filtration (Draper et al., 2018). In the Pacific Northwest region, several producers of biochar currently provide a variety of products.

Table 4 below summarizes biochar producers and prices in the Pacific Northwest.

Table 4. Summary of Biochar Producers in the Pacific Northwest

Producer	State	Feedstock	Product	Bagged Price ($/CY)[1]	Bulk Price ($/CY)[1]	Bulk Price ($/DT)[2]
Pacific Biochar	California/Oregon	Forestry Residues	Blacklite Mix #6	$164	$135	$521
Sonoma Biochar	California	Wood waste	Sonoma Biochar	$470	$240	$1420
Oregon Biochar Solutions	Oregon	Wood Waste Residues	Rogue Biochar	$150	$110	$799
Sunriver Biochar	Oregon	Wood	Sunriver Biochar	$500	-	-
Biochar Supreme	Washington	Forestry Residues	Black Owl Premium Biochar	$1054	$350	$2071
Olympic Biochar	Washington	Paper Mill Byproduct	Olympic Biochar	$135	$105	$621

[1] *Prices reflect November 2019 values from respective websites.*

[2] *Assumes an average dry bulk density of 338 lbs per cubic yard.*

Although biochar has a potentially high value, market studies have suggested that the demand for the product does not currently meet the supply. The high price of biochar is cost prohibited for wider adoption of the product by more general consumers such as conventional agriculture, home garden, lawn care, and commercial nurseries. The high price point of biochar in general agriculture would require unrealistic increases in crop productivity to break even with cost. Biochar is more likely to be used as a small faction additive to blended products for wider distribution.

The recent growth in biochar suppliers is likely reflective of early adopters who are positioning for potential future demand. This occurrence is typical in emerging markets. However, a search for biochar producers indicated that the market is still in its infancy. Approximately half of the producers documented in a 2015 survey are no longer in business.

Biosolids-based biochar has not been tested in the biochar market and its market acceptance is unknown. Considering that applications for biochar currently are in high value and niche products, biosolids biochar is unlikely to portray similar positive associations when compared to virgin wood-based biochar. Bioforcetech has suggested a price per ton in the range of $250, which is approximately 15 to 25 percent of the market price for other biochar products. Biosolids biochar may find more success in mixed/blended products compared to pure products.

3.4.1.6 Risks and Challenges

Implementation of technologies with high capital requirements, limited applications, and advanced or complex processes presents a challenge of high technical and financial risk. A recent report from Waste Gasification and Pyrosis Technology Risk Assessment by the environmental-leaning company GAIA estimated that billions have been lost in the development of failed pyrolysis and gasification projects. The report cites $2 billion lost from just four UK projects (GAIA, 2017). Failure of gasification and pyrolysis systems have largely been associated with restrictive capital costs, technical and system failures, and limitations in the market demand of end products.

Due to the slow traction and implementation of pyrolysis and gasification technologies, significant consolidation of independent and “start-up” companies has occurred over the last decade. This shift has seen larger companies purchasing and absorbing pyrolysis and gasification technologies to bolster their product lines. However, this change in the vendor market indicates that some companies have financial vulnerabilities and the precarious financial nature of startup companies in sustaining long-term operation. The acquisition of smaller pyrolysis and gasification companies by larger conglomerates does allow for a reduction in the risk of investing in new technologies which have the financial backing.

Table 5 lists gasification and pyrolysis companies that have conducted business ventures in North America in the past decade but have undergone bankruptcy or acquisition.

Table 5. Pyrolysis and Gasification Company Consolidation and Bankruptcy

Company	Status
MaxWest Environmental Systems	Declared Bankruptcy. Acquired by Aries Clean Energy
Oneida Seven Generations Corp	Defunct
Navitus Sustainable Industries	Defunct
Lehigh Technologies	Acquired by Michelin
GE Gasification Division	Acquired by Air Products
U.S. Linc Energy Ltd	Declared Bankruptcy
Solena Fuels	Declared Bankruptcy
Lima Energy	Declared Bankruptcy
KiOR (Inaeris Technologies)	Declared Bankruptcy
Plasco Energy Group	Declared Bankruptcy, Acquired RMB Advisory
RWE (Germany), Uhde,	Acquired ThyssenKrupp Uhde
Carbon Resources Recovery GmbH	Acquired by Klean Industries
Thermogenicx	Defunct

3.4.2 Bioforcetech

Bioforcetech was founded in 2012 and is part of the is the Presezzi Extrusion Group based in Italy. Their first U.S.-based pyrolysis system came online in June 2017 at the Silicon Valley Clean Water Authority in Redwood, California.

Figure 6 below shows the biodryer and pyrolysis unit located in Silicon Valley. Bioforcetech has since supplied two biosolids pyrolysis units in Italy and is in the planning phase at the City of Edmonds, Washington for a pyrolysis system that is coupled with solids belt dryers to replace the city's incinerator. Their European partner PYREG GmbH, has 16 operating plants with two biosolids facilities in Europe. Because Bioforcetech is the only company currently using pyrolysis on biosolids alone in the U.S., it was selected as the representative pyrolysis technology for this study.

Their pyrolysis technology is a 24/7 autonomous system that operates at temperatures between 450 to 750˚C. The pyrolysis process is coupled with a biodryer that uses biogenic heat to supplement the energy required for drying before pyrolysis. This allows for a low-energy and high-efficiency system that can potentially be energy self-sufficient. For the biodyer to work, it operates at a low capacity and may not suitable for all projects. Bioforcetech has partnered with Centrisys to offer a higher capacity compact low-temperature belt dryer. For this study, Bioforcetech recommended the use of the belt-dryer with the pyrolysis system.

The pyrolysis process works by first thermal drying the biosolids to greater than 70 percent dry solids through the use of a belt dryer. The dried biosolids are then fed to the pyrolysis unit where natural gas is used to start-up the process to reach the pyrolysis temperatures. The high temperatures volatilize the organic carbon to produce pygas. The pyrgas is combusted in a separate chamber and used to heat the outer casing of the reactor allowing the process to be self-sustained without natural gas at that point.

Bioforcetech provides a variety of different contracts and funding options to utilities. Bioforcetech's implementation at Silicon Valley Clean Water Authority is currently though a 10-year biosolids management contract where Bioforcetech owns and operates the system. However, Bioforcetech now offers multiple pyrolysis supply contracts where they can operate the system under short and long-term agreements or offer training and startup support to plant staff.

Figure 6. Silicon Valley Clean Water Authority biosolids drying and pyrolysis system

3.4.3 Mass and Energy Balance

BC performed a mass and energy balance analysis for biosolids pyrolysis to evaluate vendor-supplied performance data and develop expected operating criteria for input into BC's SWEET model for estimating overall system energy and greenhouse gas profiles. At the time of this report, there is limited data published related to mass and energy yield assessments for biosolids pyrolysis. Two mass and energy studies perform laboratory scale pyrolysis reactions with a similar experimental setup and temperature range. The first study conducted by Yuan et al. (2013), operated bench-scale pyrolysis reactions until gas production ceased and did not present the residence time of the reaction. This study presented substantially higher yields of biochar than the second, conducted by McNamara et al. (2016), which performed all pyrolysis experiments for a duration of at least 40 minutes. The reported duration of the second study more closely matches the target retention time of the Bioforcetech system (30 min.) evaluated for this project and the reported biochar mass yield. It is likely that the 2013 experiment performed the pyrolysis experiments at shorter retention times than the Bioforcetech system, thus the 2016 study was used to evaluate the mass and energy yields for this project.

The 2016 study collected mass and energy content data from a digested and dried biosolids pyrolysis feed product generated from the Milorganite production facility in Milwaukee, Wis., and the resulting volatilized and biochar fractions from pyrolysis. The gas from the system was run through an impinger to collect the oil (or tar) fraction and the data for the oil and non-condensable gas is presented separately. A summary of the mass and energy yield data presented as a percentage of the mass and energy content of the feed biosolids

at a range of temperatures is provided below in **Table 6**. The original mass data reported for the pyrolysis products was within 8 percent of the feed mass and was normalized below to project the full mass yield for the SWEET model. The difference in the sum of the energy yield percentage data for the products from 100 percent represents the enthalpy of the reaction. If the sum of the energy yields is less than 100 percent, that means that the process was exothermic and did not require additional heat input to sustain the operation. Where the energy yield content sum is higher, that difference represents the cost of energy for pyrolysis.

Table 6. Mass and Energy Yield Data

Nominal Temp (°C)	Biochar		Oil		Syngas	
	Mass	Energy	Mass	Energy	Mass	Energy
300	71%	81%	25%	8.2%	4.1%	0.1%
400	57%	55%	37%	26%	5.3%	1.1%
500	46%	33%	46%	68%	8.3%	5.8%
600	44%	31%	46%	37%	10%	10%
700	41%	30%	47%	37%	12%	11%
800	39%	26%	43%	55%	17%	19%

Source: Summarized from McNamara et. al. (2016)

An example schematic of the mass and energy yield data is provided below in **Figure 7** to provide a diagram of the experimental setup and products generated from a pyrolysis run at 500 °C.

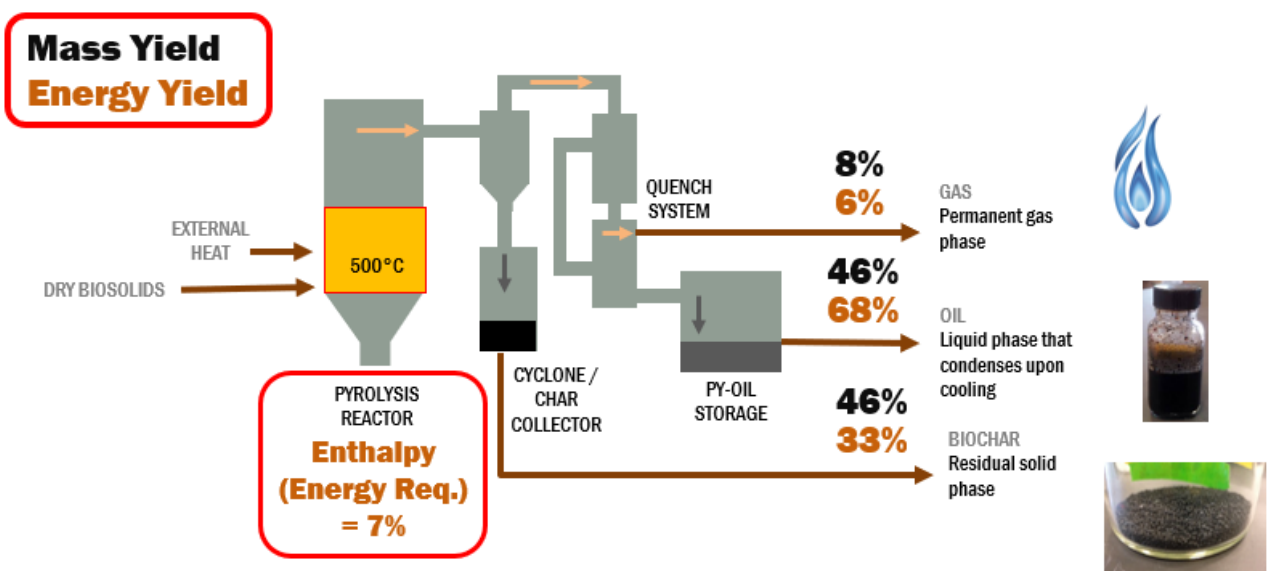

Figure 7. Diagram of mass and energy yield data at 500 °C

The mass and energy yield data summarized from the study by McNamara et. al. was compared to the performance data for the commercial pyrolysis units proposed by Bioforcetech for this project. Bioforcetech supplies two pyrolysis units called the P-Five and P-Three that are operated at a temperature range of 350 °C to 720 °C.

The major difference between the laboratory scale study and the Bioforcetech proposal is that the Bioforcetech system immediately combusts the pyrolysis volatile fraction before condensation can take place, circulates the hot exhaust gas through the pyrolysis reactor jacket to provide thermal energy to the reaction (if required), and then transfers the thermal energy through an air-to-water heat exchanger to potable or filtered process water to supply useful thermal energy in the form of the hot water. Thus the energy yield projected by Bioforcetech represents the useful thermal energy in the form of hot water and accounts for the inefficiencies of heat transfer throughout the process. A process schematic of the Bioforcetech system with exhaust heat recovery is presented below in **Figure 8**.

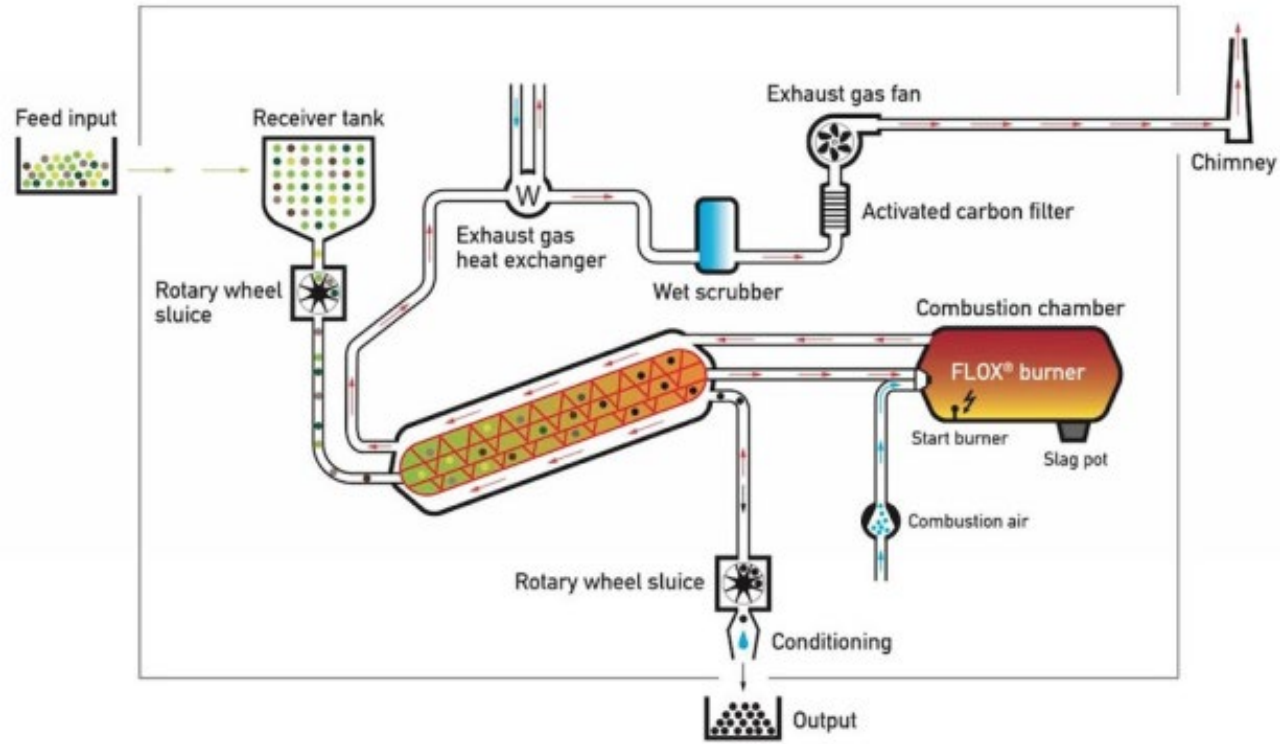

Figure 8. Bioforcetech pyrolysis system process schematic

(Source: Bioforcetech)

A summary of the capacity data for each pyrolysis unit, along with the anticipated mass and energy yield for each system based on the proposal provided by Bioforcetech is provided below in **Table 7.**

Table 7. Mass and Energy Yield Data Summarized from Bioforcetech Proposal

Parameters	Source	P-Three	P-Five
Max Throughput (lb-total solids/hour)	Reported	264	792
Min. Feed (% total solids)	Reported	60%	
Max Biochar Production (lb/hour)	Reported	106	317
Biochar Mass Yield	Calculated	40%	
Max Energy Production (MMBtu/hr)	Reported	0.5	1.5
Useful Thermal Energy Yield[1]	Calculated	27%	

[1] *Useful thermal energy recovered in hot water assuming energy content of 7,000 Btu/lb of digested biosolids feed.*

The calculated biochar mass yield of 40 percent most closely resembles the 41 percent mass yield observed at 600 °C and is within 5 percent of the mass yield observed at 700°C in the study summarized above, showing good agreement. At 600 °C, the energy yield of the combined oil and gas fraction was 48 percent in the lab study. When compared to the reported useful thermal energy yield of the Bioforcetech system of 27 percent, this represents a thermal efficiency of 58 percent through the combustion and heat exchangers systems assuming no energy is required by the reactor. This is within a reasonable range assuming each component has a thermal efficiency of 75 percent to 80 percent and also shows good agreement with the lab-scale study.

Based on the results of this analysis, the SWEET model was updated with the lab-scale mass and energy yield parameters for 600°C. The useful thermal energy generation was calculated based on the thermal efficiency of 58 percent calculated from the Bioforcetech proposal assuming an energy content of 7,000 Btu/lb in the digested biosolids feed. The useful thermal energy was assumed to be at temperatures suitable for heating a belt dryer and was used to offset the natural gas demand required for fueling the hot water dryer heating boiler.

3.4.4 Biochar

Limited research exists on the GHG emissions impacts of biochar's application on agriculture and soils. Biochar has been stated to impact emissions by limiting biogenic carbon mineralization by carbon fixation, improving soil health and thereby reducing natural GHG emissions from the soil, and increasing crop productivity.

Pyrolysis converts approximately 10 to 50 percent of the organic carbon biomass into a stable recalcitrant carbon. The recalcitrant carbon is "fixed" and highly stable resisting decomposition over the span of hundreds to thousands of years. Under normal circumstances, natural organic matter decay would have mineralized the carbon into CO_2. Pyrolysis changes that natural carbon-neutral process into a carbon-negative process. The potential for biochar's use to offset carbon emission was recently accepted by the international panel for climate change (IPCC) as a promising negative emissions technology. The IPCC categories the production and use of biochar under viable options for carbon dioxide removal.

Current literature is inconclusive on the impacts of biochar on soil CO_2, CH_4, and N_2O emissions. This is largely due to the large variety and complexity of soil systems. Primary factors that influence CO_2, CH_4, and N2O emissions include biochar type, crop selection, crop rotation, temperature, moisture/precipitation, cropping systems, and soil type. Several field studies and meta-analysis studies have found that biochar reduced N_2O emissions from soil (Cayuela et al., 2015; Cross et al, 2011; Fidel et al., 2018; Liu et al., 2018). Other studies have found an increase in N_2O emissions or no impact after the first year (Borchard et al., 2019; Wang et al., 2019). The N_2O emissions reductions were most apparent in paddy and sandy soils (Borchard et al., 2019; Wang et al., 2019). CH4 emissions were seen to increase when used in paddy fields (Wang et al., 2019; Zhang et al., 2010). In this study, only the fixed carbon sequestration was considered. Given the vast number of variables that can influence biochar's effect on soil GHG emissions, field testing and monitoring of biochar may be required for better estimation of GHG emission reductions. This would allow for site and application-specific impacts of biosolids based biochar.

Data provided by Bioforcetech showed that 28.6 percent of the Silicon Valley Clean Water facility's biochar was comprised of carbon. Biosolids biochar has less carbon content than woody biomass biochar and would reflect less carbon sequestration. Assuming similar conditions for the County's theoretical biochar and that 90 percent of the carbon remained fixed over its lifetime, an emissions factor was calculated to reduce 0.9337 kg of CO_2e per kg of biochar applied. **Attachment A** provides more details on estimating carbon sequestration value.

A more thorough literature review and field emissions sampling may be required to refine the assessment of biochar's impacts on GHG emissions.

Section 4: Development of Conceptual Scenarios

The technologies screened and described in the previous sections are building blocks of comprehensive biosolids treatment and use scenarios available to the County. The applicability of the short-listed technologies at each County wastewater treatment plant was dependent on the site-specific constraints, process compatibility, and County preferences. Four scenarios were developed for evaluation in this study from the short-listed technologies and each provides biosolids management for all biosolids produced by KC wastewater treatment plants. It is important to emphasize that the scenarios outlined below are just example of how a combination of appropriate technologies and strategies could be deployed. The examples below do not necessarily represent specific strategies for the named facilities, but rather high-level strategies that could be applied in a variety of combinations. The four scenarios are presented below.

- Scenario 1: Base-case - Existing MAD with 100 percent Class B land application to western and eastern Washington
- Scenario 2: Enhanced Class A - Existing mesophilic digestion at Brightwater with Class B biosolids hauled to an off-site Class A composting facility and local sales; Cambi at South Plant with Class A land application in western and eastern Washington (40 percent/60 percent); and TAD with batch tanks at West Point and off-site soil blending with local sales
- Scenario 3: Pyrolysis - Existing mesophilic digestion at all three plants with dewatered cake hauled to off-site thermal drying and pyrolysis treatment. Biochar byproduct contracted to Bioforcetech under a public-private partnership.
- Scenario 4: Optimized Class A - Existing mesophilic digestion at Brightwater with Class B biosolids hauled to an off-site Class A composting facility and local sales; TAD with batch tanks at South Plant with Class A land application in western and eastern Washington (40 percent/60 percent); and TAD with batch tanks at West Point and off-site soil blending with local sales

The development of the first three scenarios was intended to represent a comparison between the existing program, the feasibility of a 100 percent Class A biosolids program, and a pyrolysis program. Scenario 4 was later included to represent an optimized and more cost-effective Class A program than Scenario 2. All off-site facilities were assumed to be located in the South King County area based on details from the *WTD – Class A Basis of Estimate for a Composting Facility* (King County Project No. 1132733).

4.1 Flows and Loads

The sizing for each of the scenarios was based on flows and loads that were projected to a 2050 design year. Raw influent flows and loadings for each of the three plants were provided by the County as part of the Flows and Loads Study to evaluate treatment plant capacity limitations. A plant-wide solids mass balance model calibrated during that study was used to calculate digester feed solids loading rates from the 2050 raw influent flows and loadings. Tables 8 and 9 list the 2050 annual average and 2050 max month loadings, respectively. Table 10 contains details on the peaking factors. The peaking factors are based on a combination of loading projections provided by the County and historical data at each plant.

Table 8. 2050 Annual Average Flows and Load

Parameters	West Point	South Plant	Brightwater
Digester feed TS load (lb/d)	225,860	263,760	93,910
Digester feed TVS load (lb/d)	182,890	226,530	84,400
Digester feed %TS	6.1	6.2	5.8
Dewatered solids TS load (lb/d)	101,170	120,810	39,450

Dewatered solids %TS	28.5	22.9	20.0

Table 9. 2050 Max Month Flows and Load

Parameters	West Point	South Plant	Brightwater
Digester feed TS load (lb/d)	255,760	303,520	110,640
Digester feed TVS load (lb/d)	207,660	259,700	94,300
Digester feed %TS	6.1	6.2	5.8
Dewatered solids TS load (lb/d)	114,240	139,470	49,400
Dewatered solids %TS	28.5	22.9	20.0

Table 10. Digester Peaking Factors

Parameters	West Point	South Plant	Brightwater
Digester feed max 2-week/max month load	1.18	1.20	1.10
Digester feed max week/max month load	1.22	1.23	1.12
Digester feed max day/max month load	1.60	1.30	1.50

4.2 Scenario 1: Base-case

Scenario 1 was intended to represent maintaining the existing conditions of the County's biosolids management program. Each of the three plants would continue with MAD to produce a Class B biosolids product that would then be trucked to western and eastern Washington for land application. This scenario assumed all solids would be directed to land application to simplify the evaluation even though the current program produces a small amount of Class A compost (less than 1 percent of the Class B biosolids).

Figure 9 is a diagram of Scenario 1. Assumptions on existing digester capacity were taken from the analysis in the King County Treatment Plant Flows and Loadings Study.

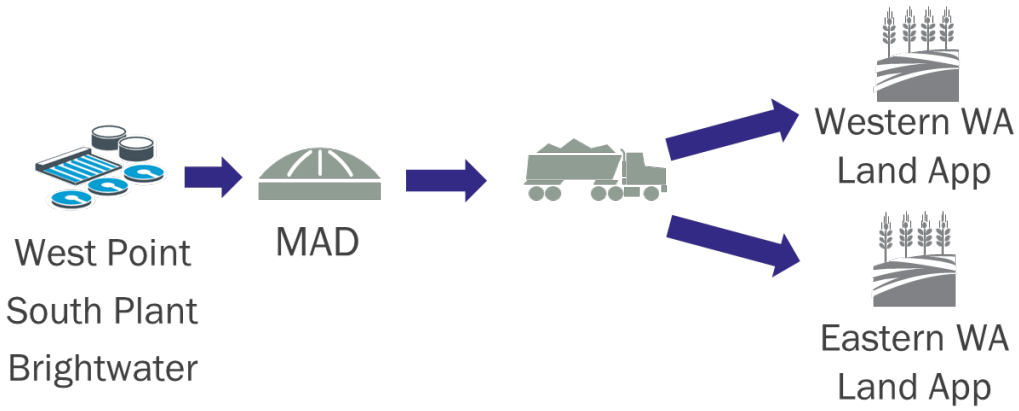

Figure 9. Scenario 1: Base-Case

4.2.1 West Point

The 2050 flows and loads projections indicate that West Point would need two additional 2.4 MG mesophilic digesters to meet future capacity requirements based on an organic loading limit of 0.17 lb VS/ft^3/d. However, West Point currently faces site footprint constraints to accommodate additional digesters. Without

demolition of other existing facilities or locating in spaces allocated for future liquid stream treatment, West Point would need to convert to an intensification technology such as Class B TAD that would increase capacity without requiring additional digester buildout. For the purpose of evaluating the base case Scenario 1 in this study, two additional MAD digesters were used for costing which has a higher cost than the conversion of mesophilic digesters to TAD.

4.2.2 South Plant

The 2050 flows and loads projections indicate that South Plant would need one additional 2.75 MG mesophilic digester to meet capacity requirements based on an organic loading limit of 0.20 lb VS/ft^3/d. South Plant has available space for four (4) additional digesters and would be able to site the one new digester, but South Plant's footprint availability and constraints are subject to change as other projects may take priority due to regulatory requirements or other plant needs.

4.2.3 Brightwater

The 2050 flows and loads projection indicates that Brightwater would need one additional 1.25 MG mesophilic digester to meet capacity requirements based on an organic loading limit of 0.17 lb VS/ft^3/d. Brightwater currently has available space for two additional digesters and should be able to site the one new digester.

4.3 Scenario 2: Enhanced Class A

Scenario 2 was developed for comparison to other scenarios as a representative mix of Class A processes that could provide a 100 percent Class A biosolids management program for the County. West Point would be converted to a TAD-batch Class A process and would truck their dewatered cake to an off-site soil blending facility. A more detailed alternatives analysis would be needed in the future prior to selection of the final thermophilic technology, TAD or TPAD. The Class A soil blended product would then go to local sales and distribution. South Plant would be converted to a Class A THP-MAD process with land application in western and eastern Washington. Brightwater would continue with Class B MAD process and truck their dewatered cake to an off-site Class A composting facility that would be adjacent to the soil blending facility. The Class A compost products would then go to local sales and distribution. **Figure 10** shows a diagram of Scenario 2.

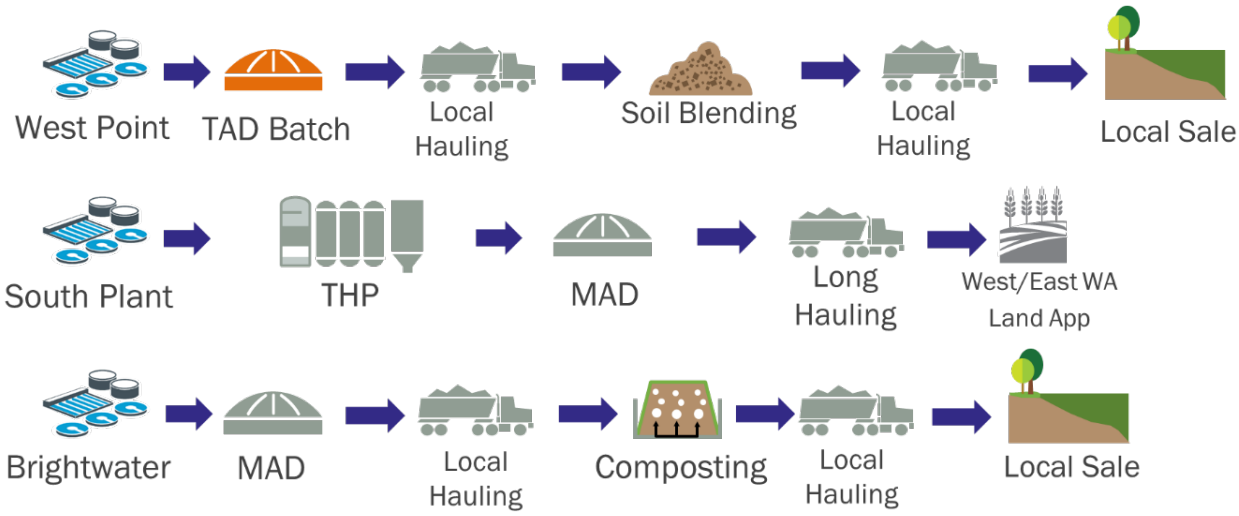

Figure 10. Scenario 2: Enhanced Class A

4.3.1 West Point

Construction of a THP-MAD system at West Point would be challenging if not impossible due to the site limitations which would potentially require the removal of two digesters to fit the ancillary equipment and THP units onsite. Additionally, to construct the new treatment system, temporary trucking of half of West Point's raw wastewater solids to South Plant would be needed for additionally processing throughout a likely three or four-year construction period. Preliminary sizing of a THP-MAD process suggests that its integration at West Point would be challenging and cost prohibited. For the purpose of this study, Therefore, TAD was selected as the Class A digestion process to be implemented at West Point.

TAD can be implemented using different types of configurations with the most common being TAD and TPAD with batch tanks. For this study, TAD with batch tanks (TAD-batch) was selected as the digestion technology.

The application of TAD can increase the organic loading rate on the digesters by more than double current limitations on MAD digesters, freeing up solids digestion capacity. This was reflected in the fact that no new TAD digesters would be required for 2050 flows and loads with an organic loading limit of 0.4 lbs VS/ft^3/d. The implementation of TAD-Batch would require space for a 1.6 MG rectangular batch tank complex which represents the peak day flow. Conversion from MAD to TAD would require fixing digester covers and mixing, and heating upgrades.

4.3.2 South Plant

The available space at South Plant makes it compatible with THP-MAD. THP-MAD would require pre-dewatering, screening, solids storage hoppers, steam boilers, and four (4) CAMBI THP process trains. No new digesters would be required for a THP-MAD process based on 2050 flows and loads and an organic load limit of 0.4 lbs VS/ft^3. THP-MAD would require fixed covers, mixing, and heating upgrades.

4.3.3 Brightwater

Under all scenarios, it was assumed Brightwater would stay with MAD and require 1 new digester for 2050 loads. Note that existing Brightwater digesters have fixed covers and they were designed with space allocation for potential future conversion to TAD Dewatered cake from Brightwater would be trucked to an off-site Class A composting facility for further treatment.

4.3.4 Off-Site Composting Facility

In Scenarios 2 and 4, an off-site Class A composting facility would process the Brightwater dewatered cake. The 2050 flows and load is equal to 35,857 WT/yr, which is approximately 19 percent of the dewatered cake of King County in 2050. The composting process would use aerated static piles. The site would require space for receiving and mixing, composting, curing, screening, and compost and feedstock storage. The site would also include an administration/operation building and space for maintenance staff. The approximate site size is 23 acres and 30 acres with a buffer.

Figure 11 below shows the basic layout for an off-site composting facility.

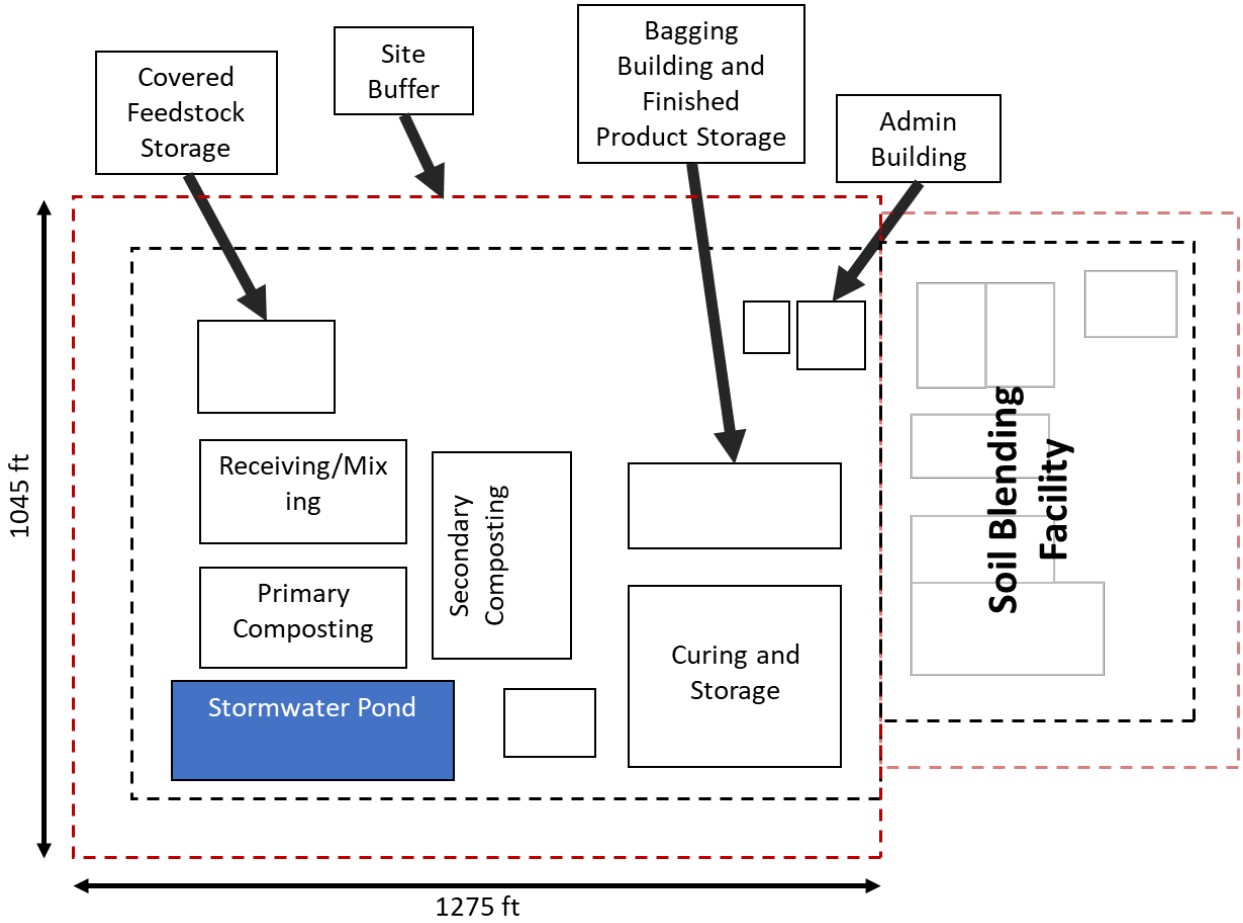

Figure 11. Example layout of an off-site Class A composting facility

4.3.5 Off-Site Soil Blending Facility

An off-site soil blending facility would process West Point's Class A dewatered cake to create a high quality blended biosolids product. The intent of this blended product is to diversify the County's program and potentially generate some revenues from bulk and bagged sale of the product. The soil-blending facility would be designed based on the City of Tacoma's blended product Tagro. This would require mixing biosolids with sand and sawdust at a ratio of 40:40:20 biosolids: sawdust: sand.

The soil blending facility would need space storage space for biosolids cake, sawdust, sand, or other material. Two horizontal auger batch mixers will be used to mix the product.

Figure 12 below shows the basic components of an off-site soil blending facility. The facility was assumed to be adjacent to the composting facility and would require additional space for the soil-blending processes. The administration and operations building, stormwater, and bagging facility was assumed to be shared with the adjacent composting facility. Additional space will be needed for mixing and storage. The approximate size of the soil blending facility would require an additional 9 acres and 11 acres with additional buffer.

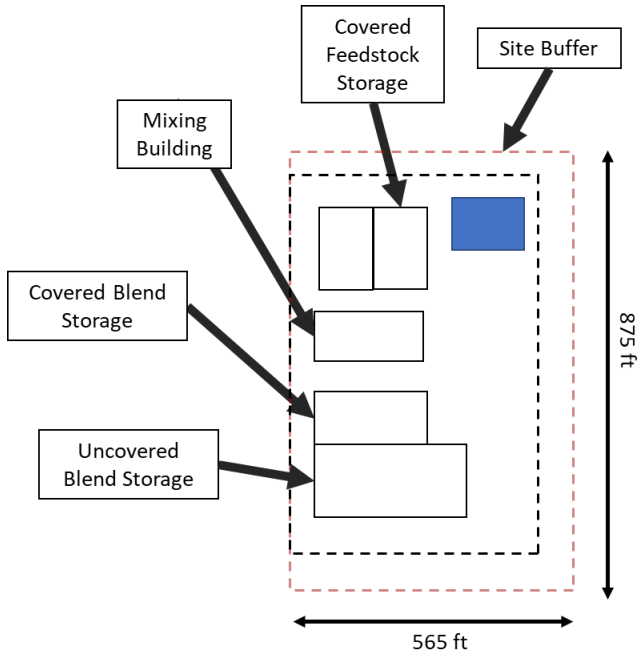

Figure 12. Example layout of an off-site soil blending facility

4.4 Scenario 3: Off-Site Pyrolysis

Scenario 3 includes the application of a pyrolysis system for all of King County's biosolids production. West Point, South Plant, and Brightwater would continue with their current Class B processes similar to Scenario 1. The dewatered cake would be transported to the pyrolysis facility to be thermally dried and pyrolyzed into biochar. The end use of biochar would be part of a public-private partnership (P3) in which Bioforcetech would transport the biochar and sell it. Approximately 10 percent of the profit would be returned to the County. Figure 13 shows a diagram of Scenario 3.

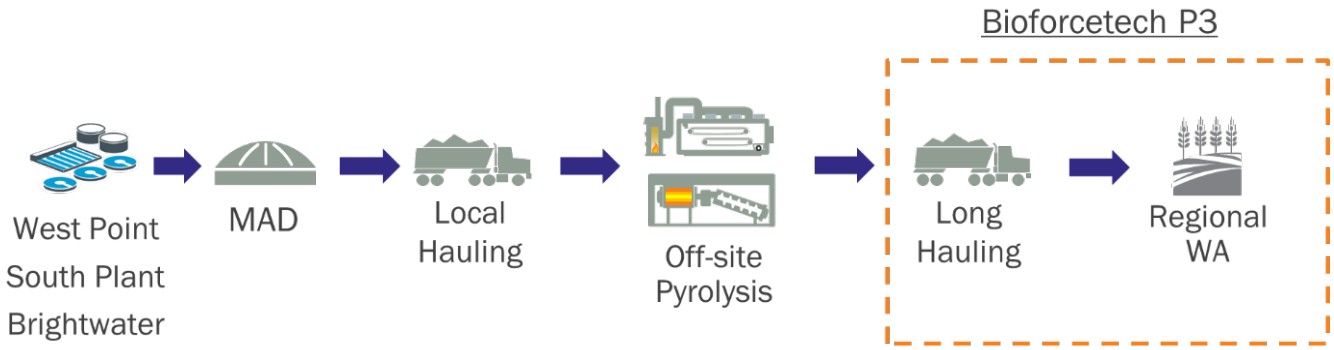

Figure 13. Scenario 3: Off-site Pyrolysis

4.4.1 West Point

Refer to **Section 3.2.1** for in-plant changes. Dewatered cake from West Point would be trucked to the off-site pyrolysis facility for further treatment.

4.4.2 South Plant

Refer to **Section 4.2.2** for in-plant changes. Dewatered cake from South Plant would be trucked to the off-site pyrolysis facility for further treatment.

4.4.3 Brightwater

Refer to **Section 4.2.3** for in-plant changes. Dewatered cake from Brightwater would be trucked to the off-site pyrolysis facility for further treatment.

4.4.4 Off-Site Pyrolysis facility

Due to site constraints at West Point, South Plant, and Brightwater, an off-site location would be required for a pyrolysis system. Bioforcetech would be used as the representative technology for pyrolysis due to it being the only technology with a U.S. installation. A belt dryer will be used upstream of the pyrolysis system rather than the Bioforcetech's Biodryer due to its low capacity which would increase cost and space requirements. This design is based on another ongoing design of a Bioforcetech facility located in Edmonds, Washington. To meet the demand 2050 flows and load projections, the site would need 12 DLT 1120 belt dryers and 24 BFT P-THREE pyrolysis units. Ancillary equipment would be needed such as odor control, storage hoppers, conveyors, and boilers. The approximate size of a facility would require 6.2 acres and 12 acres with additional buffer.

Figure 14 shows the basic footprint of the off-site pyrolysis facility.

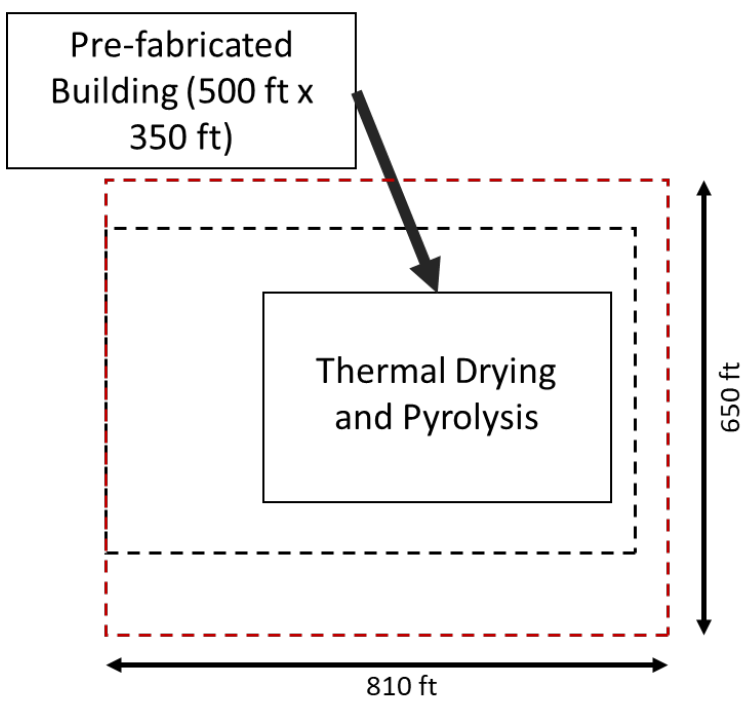

Figure 14. Example layout of an off-site pyrolysis facility

4.5 Scenario 4: Optimized Class A

Scenario 4 was added due to the high cost of the THP process and to provide an opportunity to compare a different Class A digestion approach. Scenario 4 is identical to Scenario 2 except that South Plant would also be converted to a TAD-Batch Class A digestion process instead of a THP-MAD process. **Figure 15** shows a diagram of Scenario 4.

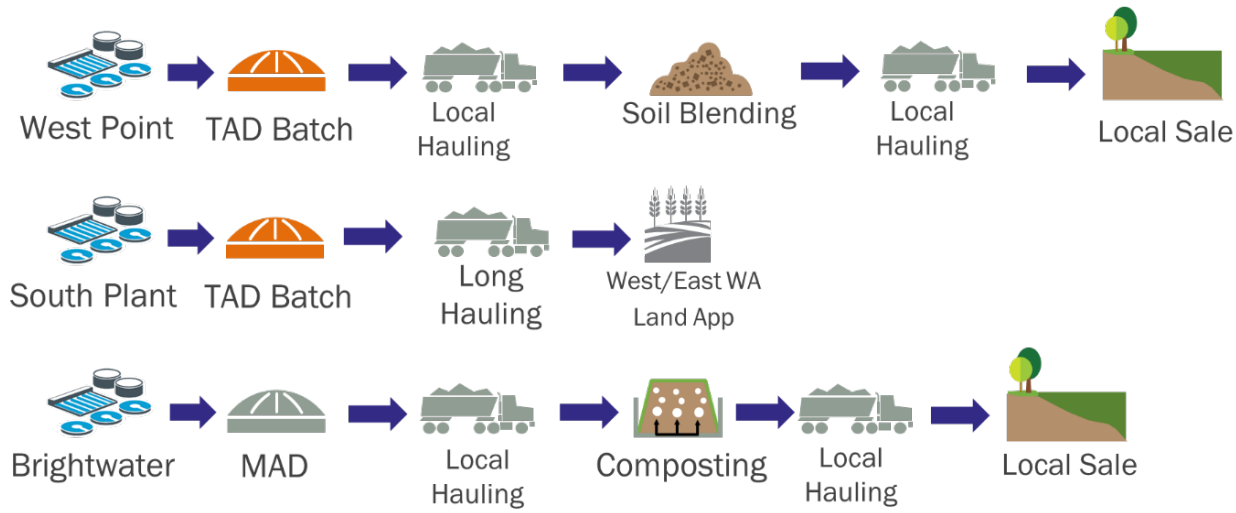

Figure 15. Scenario 4: Optimized Class A

Refer to **Section 4.3** above for details on West Point, Brightwater, soil blending, and composting.

Section 5: Solids, Energy, and Greenhouse Gas Evaluation

With the four scenarios defined, a technical evaluation of the solids, energy, and GHG emissions for each scenario was completed. BC's Solids-Water-Energy-Evaluation Tool (SWEET) was used to evaluate the mass and energy balance and the performance of the scenarios at a high level. SWEET tracks volatile solids, inert solids, and water through potential process alternatives, and considers the energy required to power and heat those processes. This allows for energy production and material recovery to be estimated based on the 2050 flows and loads. A GHG inventory was developed for each scenario-based material consumption, electricity, process fuel, transportation fuel, fugitive emissions, carbon sequestration, and fertilizer offsets.

The following sections describe the results of the evaluations using SWEET.

5.1 Mass and Energy Results

Mass and energy outputs for each scenario were developed based on annual average 2050 flows and loads and are summarized in **Table 11**. The solids treatment process performances were based on the design criteria presented in **Attachment A**, while power, chemical, and vehicle fuel consumption were based on historical data. The results of the SWEET model were used to develop the TBL and O&M costs.

Several assumptions were made to complete mass and energy balances. These are summarized in **Attachment A**. The results of the SWEET model can be seen in **Attachment B.**

Table 11. Summary of Mass and Energy Outputs from the SWEET (2050 Flows and Loads)				
Parameter	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
Final Product, Wet (WT/d)	539	689	63	744
Trucks Required (Trucks/d)	19	67	22	68
Vehicle Fuel Consumption (gal/day)	1952	1360	104	1445
Electricity Demand (MWh/d)	75	101	203	85
Electricity Generation (MWh/d)[1]	-42	-45	-42	-45
Net Power (MWh/d)	33	56	160	40
Natural Gas Consumption (scfm)	145	260	708	210
Digester Gas Produced (scfm)	3325	3419	3325	3502
Methane Injected into Pipeline (scfm)	778	787	778	829
Polymer Use (lb/day)	4611	6359	4611	4344

[1] *Electricity generated through co-gen at West Point is sold to Seattle City Light and not used internally.*

5.2 Greenhouse Gas Emission Results

A GHG emissions inventory was developed for each of the scenarios based on the annual average 2050 flows and loads. GHG inventories for the scenarios were developed based on GHGs emitted during operation of the biosolids treatment facilities, and transportation and end-use of biosolids.

The emission scopes and factors were based on the guidelines published by The Climate Registry (TCR) and Intergovernmental Panel on Climate Change (IPCC) and updated with recent publications. Emissions were divided into three categories representing the system boundaries of direct and indirect emissions of GHG:

- **Scope 1 emissions** are direct emissions from sources owned by the agency (e.g., emissions from fuel combustion by the agency, fugitive emissions from the agency's facilities)
- **Scope 2 emissions** are indirect emissions from sources outside the agency's facility boundaries (e.g., emissions from the production of electricity consumed by the agency)
- **Scope 3 emissions** are all other indirect emissions such as emissions from the manufacturing of materials used by the agency (e.g., polymer used for dewatering)

Emissions were not considered for the construction of the facilities. This is largely due to the fact that lifecycle emissions have been shown to be more significant than those emitted during construction and from construction materials.

The GHG emissions from each scenario are listed in **Table 12** and shown in **Figure 16** below. The negative emissions are shown as carbon credits and come from electricity produced and sold, renewable natural gas production, carbon sequestration and fertilizer offset from land application of biosolids. More detailed information on GHG emissions can be found in **Attachment B**.

Table 12. Summary of GHG Emissions (2050 Flows and Loads) Metric Tons of CO_2 Equivalent per Year					
Scope	Parameter	Scenario 1: Base-case	Scenario 2: Enhanced Class A	Scenario 3: Pyrolysis	Scenario 4: Optimized Class A
Scope 1	Fugitive Emissions	9,444	8,489	8,536	8,642
	Fuel Combustion (Boilers, Machines)	4,042	9,452	19,735	8,055

	Scope 1 Total	**13,486**	**17,941**	**28,270**	**16,697**
Scope 2	Electricity Usage	104	112	104	112
	Electricity Exported	-100	-107	-100	-107
	Scope 2 Total	**3.6**	**4.4**	**3.6**	**4.4**
Scope 3	Polymer Consumption	6,885	9,949	6,885	6,942
	Natural Gas Use	1,068	1,915	5,213	1,546
	Hauling, Transportation, Application	8,467	4,433	924	4,803
	Scope 3 Total	**16,421**	**16,297**	**13,023**	**13,290**
	Scope 1-3 Total	**29910**	**34242**	**41297**	**29992**
Credits	Fertilizer Offset	-9,766	-9,694	-6,029	-9,638
	Carbon Sequestration	-52,919	-47,589	-19,410	-47,216
	Pipeline RNG	-31,501	-31,884	-31,501	-33,585
	Credits Total	**-94,186**	**-89,167**	**-56,940**	**-90,438**
	Total (metric tons CO2e /year)	**-64,276**	**-54,925**	**-15,643**	**-60,446**
	Difference from S1 - Base-case (metric tons CO2e /year)	**0**	**+9,351**	**+48,632**	**+3,830**

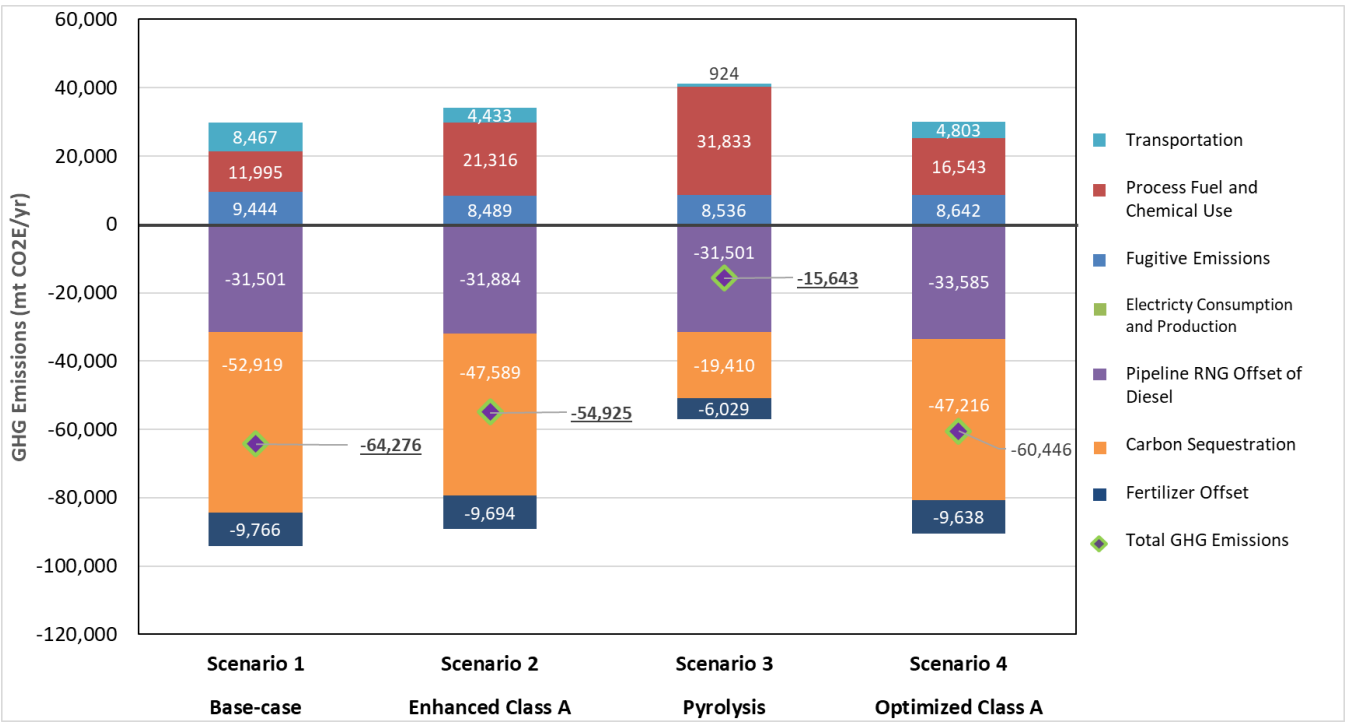

Figure 16. Summary of GHG emissions

(based on 2050 flows and loads)

The results of the GHG inventories showed that Scenario 1: Base-case had the lowest GHG emissions with Scenario 4: Optimized Class A and Scenario 2: Enhanced Class A following closely. Scenario 1: Base-case

also had the lowest sum for Scope 1-3 emissions as shown in **Table 13** below. Scenario 3: Pyrolysis had more significant GHG emissions due to the lower carbon sequestration and increase in emissions from process fuel usage. An analysis of biochar's carbon sequestration potential is included in **Section 3.5.8**.

Section 6: Cost Assessment

A simplified 20-year net present value (NPV) was developed for each of the scenarios to account for both the total escalated project capital cost and the operation and maintenance (O&M) costs. The NPV are intended to be used only as comparative costs between alternatives. Salvage and replacement cost were not included. Total project capital cost (TPCC) were escalated to 2028 and discounted back to 2020. The O&M assumed operation from 2030 to 2050 and was escalated based on solids growth projections and then discounted back to 2020 for an NPV. For both capital and O&M costs, the calculations were performed using an escalation rate of 3 percent and a discount rate of 5.25 percent. Escalated TPCCs were provided in **Table 13** below and represent the true TPCC of the project. **The escalated TPCC is a better reflection of the costs that may impact budget, sewer rates, and other planning impacts**. However, future evaluations with more detailed costing will be needed to provide the classification accuracy ranges needed to understand impacts to the program. The sections below discuss these concepts in further detail.

Figure 17 below summarizes the general approach.

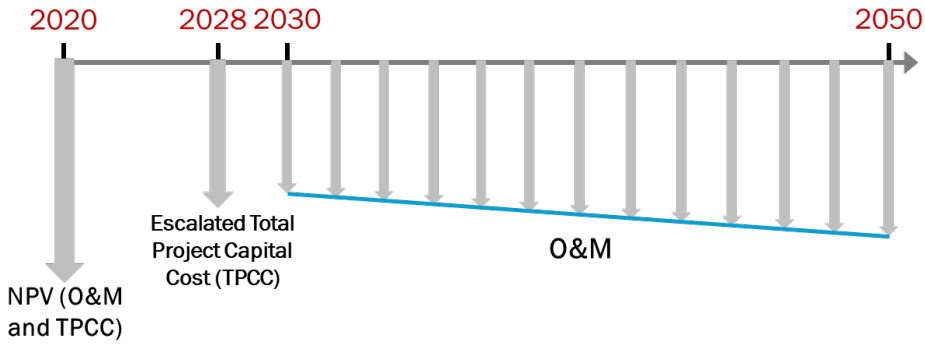

Figure 17. Diagram of cash flow

6.1 Total Project Capital Costs

Estimated construction costs were developed based on pre-Class 5 AACE International standards for each scenario. These costs were input into the County's cost models to develop TPCC. To reflect the present value of capital cost, project capital cost was escalated to an assumed midpoint of construction of 2028 and then discounted back to 2020. **Table 13** provides a summary of the estimated construction, project capital cost, and escalated and discounted project capital cost. More detailed information on the project capital costs can be found in **Attachment C**.

Table 13. Summary of Capital Costs (in 2020 $ millions)

Scenarios	Facility	Estimated Construction	Total Project Capital Cost	Total Project Capital Cost (Escalated to midpoint 2028)	Total Project Capital Cost (Escalated and Discounted)
S1	West Point	$76	$142	$180	$119
	South Plant	$44	$83	$105	$70
	Brightwater	$20	$39	$50	$33

	Total	**$139**	**$264**	**$335**	**$222**
S2	West Point	$69	$129	$163	$108
	Soil Blending	$32	$58	$74	$49
	South Plant	$292	$520	$659	$438
	Brightwater	$20	$39	$50	$33
	Composting	$68	$120	$152	$101
	Total	**$481**	**$867**	**$1,098**	**$729**
S3	West Point	$76	$142	$180	$119
	South Plant	$44	$83	$105	$70
	Brightwater	$20	$39	$50	$33
	Pyrolysis	$371	$617	$782	$519
	Total	**$510**	**$881**	**$1,117**	**$741**
S4	West Point	$69	$129	$163	$108
	Soil Blending	$32	$58	$74	$49
	South Plant	$61	$115	$146	$97
	Brightwater	$20	$39	$50	$33
	Composting	$68	$120	$152	$101
	Total	**$250**	**$462**	**$585**	**$388**

6.2 Operation and Maintenance Costs

O&M costs were considered over a 20-year period and presented as a net present value. O&M costs were associated only with solids treatment including processing, handling and end-use. These costs considered labor, maintenance and parts replacement, material use, energy consumption, and end-use. Revenues from biosolids product sales, electricity and renewable natural gas were also included. Revenues from the biosolids product sales assumed a stepwise increase. Refer to Attachment C for more details. The O&M costs related to labor and parts replacement were built from data provided by the County. O&M costs were escalated based on the discount rate as well as a linear projection of biosolids increase from 2018 to 2050.

Table 14 and Figure 18 provides details on the biosolids growth projections used for this analysis. Attachment C provides more detailed on O&M costs.

Table 14. Summary of Solids Growth

Parameter	West Point	South Plant	Brightwater	Total
2018 Dewatered Cake (WT/yr)	49258	64332	15948	129537
2050 Dewatered Cake (WT/yr)	64784	96279	35998	197061
2050 Percent of Total	32.9%	48.9%	18.3%	-
Years	32	32	32	32
Percent Change	31.5%	49.7%	125.7%	52.1%
Slope	1.0%	1.6%	3.9%	1.6%

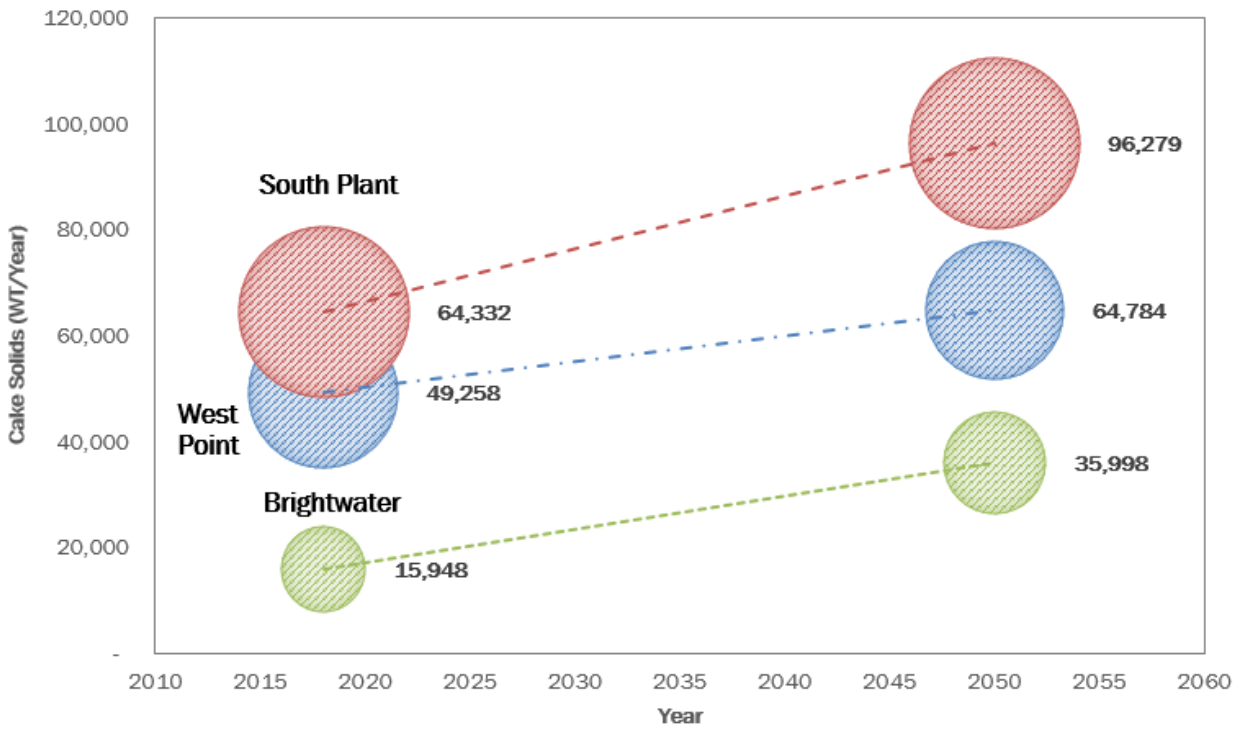

Figure 18. Diagram of solids growth projections

Table 15 provides a summary of NPV O&M for each scenario.

Table 15. Summary of Net Present Value O&M and Revenues (in 2020 $ millions)

Scenarios	Facility	O&M	Revenues	Total
S1	West Point	$171	($20)	$151
	South Plant	$220	($100)	$120
	Brightwater	$72	($1)	$71
	Total	**$463**	**($122)**	**$342**
S2	West Point	$123	($20)	$103
	Soil Blending	$97	($29)	$68
	South Plant	$262	($102)	$160
	Brightwater	$48	$0	$48
	Composting	$73	($34)	$39
	Total	**$602**	**($184)**	**$418**
S3	West Point	$122	($19)	$104
	South Plant	$149	($98)	$51
	Brightwater	$48	$0	$48
	Pyrolysis	$132	($4)	$127
	Total	**$451**	**($121)**	**$330**
S4	West Point	$123	($20)	$103

	Soil Blending	$97	($29)	$68
	South Plant	$194	($108)	$86
	Brightwater	$48	$0	$48
	Composting	$73	($34)	$39
	Total	**$534**	**($191)**	**$344**

Table 16 provides a summary of annual O&M and revenues presented in 2050 dollars, which reflects the fully operational scenarios and full maturity of the biosolids market/revenues.

Table 16. Summary of 2050 Annual O&M and Revenues (in $ millions)

Scenarios	Facility	O&M	Revenues	Total
S1	West Point	$14.3	($1.7)	$12.6
	South Plant	$19.0	($8.7)	$10.3
	Brightwater	$6.8	($0.1)	$6.7
	Total	**$40.1**	**($10.4)**	**$29.6**
S2	West Point	$10.3	($1.7)	$8.6
	Soil Blending	$8.1	($3.7)	$4.4
	South Plant	$22.7	($8.8)	$13.8
	Brightwater	$4.5	$0.0	$4.5
	Composting	$6.8	($4.3)	$2.5
	Total	$52.3	($18.5)	$33.8
S3	West Point	$10.2	($1.6)	$8.7
	South Plant	$12.9	($8.4)	$4.4
	Brightwater	$4.5	$0.0	$4.5
	Pyrolysis	$11.4	($0.6)	$10.9
	Total	**$39.0**	**($10.6)**	**$28.4**
S4	West Point	$10.3	($1.7)	$8.6
	Soil Blending	$8.1	($3.7)	$4.4
	South Plant	$18.9	($9.4)	$9.6
	Brightwater	$4.5	$0.0	$4.5
	Composting	$6.8	($4.3)	$2.5
	Total	**$48.6**	**($19.0)**	**$29.6**

Section 7: Triple Bottom Line

A triple bottom line (TBL) was adapted from the *KC Biosolids Program Strategic Plan 2018-2037* and modified to fit the needs of this study. Four criteria categories were developed: social, environmental, economic, and technical. A detailed description of each of the criteria and more details on the TBL and rationale for rating each criterion and scenario can be found in Attachment D.

Each criterion received a raw score between 0 to 5 points. The calculation of the total weighted score can be described by the formula below.

$$Total\ Weighted\ Score = \sum \left(Weighting\ x\ \frac{Raw\ Score}{Max\ Possible\ Score} \right)$$

High total weighted scores represent the best scenarios.

7.1 Social and Equity Criteria Category

The social and equity criteria category considered how each scenario could increase or decrease the quality of life of King County residents, taking into account the differing baselines for the communities around South, West Point, and Brightwater Treatment Plants. These criteria were adapted from the County's *The Determinants of Equity Report*. Table 17 summarizes the scores of the social and equity criteria category.

Table 17. Social and Equity Criteria Category Scoring

Criterion	Weighting factor	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
Built and Natural Environment					
E1. Noise	2	5	2	3	2
E2. Odors	3	4	2	2	2
E3. Traffic	2	4	2	3	2
E4. Economic Development/Jobs	5	3	4	3	4
E5. Food Systems	3	3	4	2	4
Total score (out of 15 point possible)		11	9	8	9

7.2 Environmental Criteria Category

King County is dedicated to environmental stewardship and has adopted several initiatives to tackle climate change. As part of the *2015 Strategic Climate Action Plan*, the County has committed to meeting countywide GHG emissions reduction targets of 50 percent by 2030 and 80 percent by 2050. Additionally, the KC Wastewater Treatment Department has set a target goal of carbon-neutral operations by 2025. The environmental criteria category takes into consideration these goals and other environmental criteria. Table 18 summarizes the scores of the environmental criteria category.

Table 18. Environmental Criteria Category Scoring

Criterion	Weighting factor	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
Sustainability					
C1. Greenhouse Gas Emissions	10	5	4	1	5
C2. Energy Production/Usage	5	5	3	2	4
C3. Fossil Fuel Usage	5	5	4	2	5

C4. 100% Beneficial Reuse Regulatory Compliance	5	3	5	2	5
C5. Flexibility to Meet Future Regulations	5	2	4	5	3
Total score (out of 30 point possible)		25	24	13	27

7.3 Economic Criteria Category

The economic criteria category considers the capital cost and lifecycle cost of the operation and maintenance of the scenarios. This category also evaluates the long-term sustainability of the biosolids management program in terms of diversification of outlets for biosolids application and risks associated with the single option program. Table 19 summarizes the scores of the economic criteria category.

Table 19. Economic Criteria Category Scoring

Criterion	Weighting factor	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
E1. Net Present Value	10	4	2	2	3
E2. Total Project Capital Cost	5	5	1	1	3
E3. Market Diversification/Risk	10	2	5	2	5
Total score (out of 25 point possible)		17	15	9	19

7.4 Technical Criteria Category

Different technologies offer varying levels of operation, footprints, permitting requirements, and improvements to existing processes. This category considers the technical components of each scenario. Table 20 summarizes the scores of the technical criteria category.

Table 20. Technical Criteria Category Scoring

Criterion	Weighting factor	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
T1. Process Reliability	10	5	4	2	5
T2. Constructability/Footprint	3	3	4	3	5
T3. Site Permitting	2	5	3	2	3
T4. Addressing Solids Handling Capacity	5	3	5	3	5
T5. Compatibility with Capital and Planning Projects	5	4	2	3	3
T6. Operational Complexity	5	5	2	3	4
Total score (out of 30 point possible)		26	21	16	26

7.5 TBL Score Summary

The scores for the four criteria categories were combined for the total scores for each scenario. Table 21 below provides a summary of those scores.

Table 21. Summary of Total TBL Scores					
Criteria Category	Category Weights	Scenario 1 Base-case	Scenario 2 Enhanced Class A	Scenario 3 Pyrolysis	Scenario 4 Optimized Class A
Social and Equity	15	11	9	8	9
Environmental	30	25	24	13	27
Economic	25	17	15	9	19
Technical	30	26	21	16	26
Total score (out of 100 points possible)		79	69	46	81

The results of the TBL evaluation indicated that Scenario 4: Optimized Class A scored the highest with Scenario 1:Base-case close in score (less than 10 percent difference). Scenario 3: Pyrolysis scored significantly lower for the total score and scored worse in each individual criteria category compared to the other scenarios.

Section 8: Conclusions

The results of the study indicated that Scenario 4: Optimized Class A was the best scenario overall with Scenario 1: Base-case coming close in the TBL analysis. Scenario 4: Optimized Class A had similar scoring in most criteria but had slightly better ratings in the environmental, economic and technical categories. This is largely due to the reduced risk of the program through diversification and the ability to meet future capacity and regulatory concerns. Scenario 2: Enhanced Class A did not score as well due to the complexity and increase processes that were required to get to a Class A program. The cost of the program was also significantly higher compared to Scenario 4: Optimized Class A. Scenario 3: Pyrolysis scored poorly in every category compared to all three other scenarios due to the technical risks, costs, and uncertainty of the biochar market.

Scenario 1: Base-case had the lowest NPV and total project capital cost overall. It also had the best GHG footprint but Scenario 4: Optimized Class A was within 6 percent. However, Scenario 1: Base-case did not score favorably in several criteria due to risks associated with a Class B single market exposure. Scenario 1: Base-case represents the current biosolids management program used by the County which sends more than 70 percent of the biosolids produced to eastern Washington for Class B land application. This program, as reflected in the scoring of the TBL, has significant risks due to the limited diversification of end-uses for the biosolids. Expanding a Class B program into more markets faces significant regulatory, economic and market barriers. Trends in the Class B biosolids market indicate it will only become more difficult in the future. The failure of their only end-use market could result in having to landfill at high cost, currently estimated around $3 million dollars per month, which could result in regulatory fines and would also result in significant GHG emissions until further beneficial markets could be established.

Scenario 2: Enhanced Class A did not score as well as Scenario 1: Base-case or Scenario 4: Optimized Class A due to the higher cost and complexity of the implementation of the thermal hydrolysis system at South Plant. Changing this technology to a TAD-Batch system resulted in more favorable scores due to the lower cost and greater simplicity of the solution.

Scenario 3: Pyrolysis was scored the lowest and had the second-highest lifecycle cost. The ratings for this scenario suffered from the fact that the technology is new and not fully proven, uses more energy than other options due to the need to dry the biosolids, and had high costs. Pyrolysis and gasification have the potential for applications but they may be limited to situations where other more favorable alternatives are not

available. The risk of an undeveloped biochar market also adds to the concern of the potential failure of the biosolids management program.

In this study, the three alternative Scenarios 2, 3, and 4 represent a full conversion to a 100 percent Class A program. An incremental approach or a mixed Class A and Class B program may be more realistic due to reduced costs and the ability to grow investments to match Class A market demand.

This study was intended as a high-level analysis for categories of Class A treatment processes. Once major program directions are established, management approved project(s) would be submitted through the County Wastewater Treatment Division's capital project process where they must compete with other capital projects for prioritization and budget allocation, The capital project process would further optimize and develop the options for each individual plant and potential off-site facilities as required.

Section 9: Sensitivity Discussion

A sensitivity analysis was not a component of the scope for this work; however, this section presents a discussion on variables that could impact the results of the evaluation.

- Gas utilization strategy impacts both the revenues and GHG impacts of any biosolids management program. Electric utilities in this region have composite power sources that include a large and growing component of low-emissions based electricity generation such as hydro-electric, wind, solar, etc. South Plant currently has a purchasing agreement that adds a premium to their electricity rate for sourcing their power from renewable energy with PSE that is set to elapse by 2025. If this purchasing agreement cannot be renewed, the GHG impact of electricity consumption at South Plant could increase. As utilities increase their portfolio of renewable power generation, the net GHG benefit of cogeneration could also decrease.
- RINs and LCFS credits for sale of biogas at South Plant are the largest source of revenue and GHG benefit for the County. The RIN and LCFS market are variable and revenues could increase or decrease in the future. In addition, decisions on future gas use at all three plants will change the overall net revenues and benefits. However, this decision is largely independent of Class A decisions as long as the County remains invested in anaerobic digestion as their principal biosolids treatment option.
- GHG carbon sequestration due to biosolids land application ranges and varies based on various characteristics of the soil system to which the biosolids are applied. Values from King County were used and assumed to represent the biosolids applications in this study.
- Biochar carbon sequestration values were based on the assumption that the biochar carbon content was 28.6 percent and that 90 percent of this carbon remained fixed and would not convert to CO_2. No other benefits such as reduced soil emissions were considered.
- The assumption for tipping fees for woodchips and sawdust may impact the overall economic evaluation for composting and soil blending, and this market is variable. The City of Tacoma currently purchases sawdust for soil blending to prevent contamination and to maintain Class A designation. The County may also need to purchase sawdust for soil blending to also prevent contamination. A tipping fee could be used for wood waste from tree disposal and other less controlled sources since composting would allow for the time and temperature requirements for Class A.
- Land application rate and revenues from biosolids products can vary due to variables such as public perception/media, weather, agricultural tariffs, and a change of regulations. This study assumed that application rates and revenues follow typical values.
- Capital costs, the timing of capital investments, and the blend of Class A and Cass B options will impact the overall costs and TBL scores.

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Attachment A: Solids-Water-Energy Evaluation Tool Design Basis and Assumptions

Operations and Maintenance Assumptions					
Cost Element	Units	Baseline Value	Value in Model	Notes for Baseline Values	References
Operation Assumptions					
Biogas Utilization					
Gas Upgrading Efficiency (1 - % Methane Loss)	%	90	90		
Methane content	%	60	60		
Biogas Utilization					
West Point Cogen Usage	%	43.5	43.5		KC Value (2017 - present)
West Point Boiler Usage	%	5.9	5.9		kC Value (2017 - present)
West Point Raw Sewage Pumps Usage	%	8.6	8.6		kC Value (2017 - present)
West Point Waste Gas Burner (Flare) Usage	%	42.0	42.0		kC Value (2017 - present)
South Plant Cogen Usage	%	0.0	0.0		kC Value (2017 - present)
South Plant Boiler Usage	%	0.0	0.0		kC Value (2017 - present)
South Plant Gas Upgrading Usage	%	84.5	84.5		kC Value (2017 - present)
South Plant Waste Gas Burner (Flare) Usage	%	15.5	15.5		kC Value (2017 - present)
Brightwater Boiler Usage	%	30.0	30.0		
Brightwater Waste Gas Burner (Flare) Usage	%	70.0	70.0		
West Point Plant Heat Demand (Building + Process)	MMBTU/h	8.500	8.500	Ranges from 4 to 13 MMBTU/h with peak 17.1(2014)	2016 Biogas Op Study
South Plant Heat Demand (Building + Process)	MMBTU/h	12.500	12.500	Ranges from 4 to 13 MMBTU/h with peak 17.6(2014)	2016 Biogas Op Study
Composting/Soil Blending					
Operational Parameters refer to CMPST and Sblend Sheets				Operational Parameters refer to CMPST and Sblend Sheets	Operational Parameters refer to CMPST and Sblend Sheets
Dewatering					
West Point Centrifuge Polymer Use	lb active/DT	30	30		
South Plant Centrifuge Polymer Use	lb active/DT	35	35		
South Plant Centrifuge THP Predewatering Use	lb active/DT	15	15	Assumed Value	
South Plant Centrifuge THP Cake Solids	%	30	30	Assumed Value	
Brightwater Centrifuge Polymer Use	lb active/DT	35	35		KC Brightwater Treatment System Technical facts and info sheet
Digestion					
West Point Mesophilic digestion VSR	%	64.01	64.01	Average History Data 01/2012-08/2017	
South Plant Mesophilic digestion VSR	%	60.03	60.03	Digester 1-4 - 56.96, Digester 1-5 - 60.03, Average History Data 07/2014-07/2017	
Brightwater Mesophilic digestion VSR	%	60.94	60.94	Average History Data 01/2013-08/2017	
THP-MAD VSR	%	62	62	Assumed slight boost in VSR	
THP-MAD Gas Production	CF gas/lb VSR-d	16.24	16.24	Assumed match of existing SP specific gas production	
THP-MAD Digester Feed	%	9	9	Assumed from SFPUC	
TAD-Batch VSR West Point	%	68	68	Assumed slight boost in VSR. TAD VSR was similar to MAD. 68 to 74 in coupled thermo-meso (TPAD) pilot. Full-scale Meso 64-78	1999 pilot study
TAD-Batch VSR West Point	%	64	64	Assumed 4% increase	
TAD-Batch Gas Production	CF gas/lb VSR-d	15	15	Assumed match of existing WP specific gas production	
West Point Mesophilic Gas Production	CF gas/lb VSR-d	15	15	01/14-01/15 -> 1.5 MSCF/d	
South Plant Mesophilic Gas Production	CF gas/lb VSR-d	16.24	16.24	Average History Data 07/2014-07/2017	
Brightwater Mesophilic Gas Production	CF gas/lb VSR-d	16	16		BW Technical Facts document
West Point LHV	Btu/scf	555	555	540-570 calc from 2010-2015	2016 Biogas Op Study
South Plant LHV	Btu/scf	550	550	500-600	2013 SP Biogas Utilization Study
Brightwater Plant LHV	Btu/scf	550	550	Assumed Similar to WP and SP	
Pyrolysis					
Pyrolysis Temperature	°C	550	550		BFT Biochar Testing Data Sheet
Thermal Drying and Pyrolysis Mass Reduction	%	87.92	87.92		BFT Proposal
Pyrolysis VSR Reduction	%	75.91	75.91	Calculated based on final biochar VS	BFT Biochar Testing Data Sheet
Biochar VS	%	33.3	33.3	Assumed 1 - (Ash and N)	BFT Biochar Testing Data Sheet
Biochar ASH	%	64.3	64.3		BFT Biochar Testing Data Sheet
Biochar N	%	2.4	2.4		BFT Biochar Testing Data Sheet
Biochar C	%	28.6	28.6		BFT Biochar Testing Data Sheet
Biochar P					
Thermal Hydrolysis (CAMBI)					
Steam Requirements	lb Steam/lb DS	1.1	1.1	SFPUC and Cambi	
Cost Assumptions					
Biosolids Hauling and Disposal					
Land Application, Cost (Program Average)	$/WT	$67.42	$67	Net program cost ($8.7M = $67.42/wt)	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Land Application, Cost (Western WA, Forestry)	$/WT	$71.20	$71	Calculated from Program Breakdown (Hauling, fuel, equipment, application, program)	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Land Application, Cost (Eastern WA, Ag)	$/WT	$62.70	$63	Calculated from Program Breakdown (Hauling, fuel, equipment, application, program)	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Land Application, Cap Equipment/truck Cost/Yr	$/yr	$400,000.00	$400,000	Cost for capital expense average including truck purchase average from 2013-2018	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Land Application, Revenue (Western WA, Forestry)	$/WT	$7.61	$7.6	204K annual average timber sales (2015-2019)	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Land Application, Revenue (Eastern WA, Ag)	$/WT	$1.73	$1.7	178K Revenue from nitrogen value	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Biosolids Revenue Program Start-up Structure					
Revenue Year 1-2 (Commercial)	%	25	25	Compost and Soil Blend Sales	
Revenue Year 3-8 (Commercial)	%	50	50	Compost and Soil Blend Sales	
Revenue Year 9-14 (Commercial)	%	75	75	Compost and Soil Blend Sales	
Revenue Year 15-20 (Commercial)	%	100	100	Compost and Soil Blend Sales	
Revenue Year 1-2 (Consumer)	%	15	15	Compost and Soil Blend Sales	
Revenue Year 3-8 (Consumer)	%	35	35	Compost and Soil Blend Sales	
Revenue Year 9-14 (Consumer)	%	60	60	Compost and Soil Blend Sales	
Revenue Year 15-20 (Consumer)	%	90	90	Compost and Soil Blend Sales	
Chemical Costs					
Polymer Cost	$/lb-Active Poly	2.00	2.00		
Composting					
Hauling Fee (Bulk Material)	$/WT	$7.06	$7.06	Contract fee	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Hauling Fee (Fixed local)	$/WT	$6.65	$6.65	Contract fee	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019

Composting Operation Cost	$/wt Biosolids	$155.98	$156	Adjusted by adding two more operators to KC Estimate. Labor, Maintenance, Program op	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Annual Equipment Upgrades	$/yr	$80,000.00	$80,000		
Compost Revenues					
Tipping Fee	$/WT	$20.00	$20.00		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bagged Product	$/CY	$67.50	$67.50		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bagged Product	$/2 CF Bag	$5.00	$5.00		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bulk Retail	$/CY	$25.00	$25		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bulk Wholesale	$/CY	$10.00	$10		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Economics					
Escalation Rate	%				
Discount Rate (WTB) (Cost of Capital)	%	5.25	5.25		King County Communication, December 2019
Discount Rate (OMB)	%	7	7		King County Communication, December 2019
WTD Real Discounted Rate	%	2.18	2.18		King County Communication, December 2019
Present Worth Comparison	years	20	20		
P:A for 20 years					
Annual Growth in Electricity Consumption	%	1	1		King County Communication, December 2019
Electricity Costs					
Electricity Costs (Average)	$/kWh	$0.0745	$0.0745		
West Point	$/kWh	$0.0781	$0.0781		King County Communication, December 2019
South Plant	$/kWh	$0.0758	$0.0758		King County Communication, December 2019
BrightWater	$/kWh	$0.0697	$0.0697		King County Communication, December 2019
Cogen Electricity Revenues	$/SCF to Cogen	$0.0056	$0.0056	2018 - 223M Biogas SCF/yr ~$1.25M sale -> 0.005593 $/SCF to Cogen	King County Communication, KC BiogasData.xlsx, December 2019
Fuel Costs					
Diesel	$/gal	$3.60	$3.60	2019 Average	EIA Data Wholesale
Propane	$/therm	$0.86	$0.86	11/26/2018-11/26/2019	EIA Data Wholesale
Propane	$/gal	$0.78	$0.78	11/26/2018-11/26/2019	EIA Data Wholesale
Renewable Natural Price (Sold)	$/scf Biogas	$0.0196	$0.0196	SP 2017 and 2018 Average	King County Communication, KC BiogasData.xlsx, December 2019
Renewable Natural Price (Sold)	$/scf Scrubbed	$0.0218	$0.0218	SP 2017 and 2018 Average	King County Communication, KC BiogasData.xlsx, December 2019
RNG RIN Market Price (Current)	$/MMBtu	$23.40	$23.40	2014-2019 Median Value	
RNG CA LCFS Market Price (Current)	$/MMBtu	$6.21	$6.21	2019 Average Value	
RIN Premium Allocation	%	70	70		
LCFS Premium Allocation	%	65	65		
NG Market Sale Price (Current)	$/1000 scf	$2.70	$2.70		
NG Market Purchase Price (Current)	$/1000 scf	$6.76	$6.76		EIA, December 2019
NG Market Purchase Price (Current)	$/MMBtu	$6.76	$6.76		EIA, December 2019
Potable Water					
Potable Water	$/CCF	5.98	5.98	1 CCF = 748 gal	Seattle Public Utilities Website, December 2019
Pyrolysis					
Hauling Fee (Fixed local)	$/WT	$6.65	$6.65		
Hauling Fee (Biochar)	$/WT	$0.0	$0.0	Bioforcetech's responsibility for hauling, distributing, and selling	Bioforcetech Communication, December 2019
Biochar Value	$/WT	$250.0	$250.0	Bioforcetech's approximate sale value	Bioforcetech Communication, December 2019
KC Share of Biochar Value	%	10	10	Bioforcetech share of profit to KC	Bioforcetech Communication, December 2019
Revenue Year 1-2 (P3 Contract)	%	30	30		
Revenue Year 3-8 (P3 Contract)	%	40	40		
Revenue Year 9-14 (P3 Contract)	%	80	80		
Revenue Year 15-20 (P3 Contract)	%	100	100		
O&M Hours	hrs/yr	500	500		
Operation and Maintenance	$/WT	$15.46	$15.46		
Spare parts and Components	$/yr	$1,500,000	$1,500,000	$750,000 for 120,000 WT/yr. Scaled to 200,000 WT/yr	
Soil Blending					
Hauling Fee (Bulk Material)	$/WT	$7.06	$7.06	Contract fee	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Hauling Fee (Fixed local)	$/WT	$6.65	$6.65	Contract fee	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Soil Blending Operation Cost	$/wt Biosolids	$102.60	$102.60	Labor, Maintenance, Program op. Reduced based on shared cost with Composting	King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2020
Sawdust	$/WT	$14.29	$14.29	Assume high quality sawdust needed that is free of seeds and disease	
Fine Sand Cost	$/WT	$8.23	$8.23		
Soil Blend Revenues					
Tipping Fee	$/WT	$25.00	$25.00		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bagged Product	$/CY	$54.00	$54.00		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bagged Product	$/2 CF Bag	$4.00	$4.00		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bulk Retail	$/CY	$20.00	$20		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Bulk Wholesale	$/CY	$10.00	$10		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Treatment Plants					
West Point					
Operation and Maintenance	$/wt	$128	$128		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Additional Operation and Maintenance (THP-MAD)	$/wt	$6	$6	Estimated	
South Plant					
Operation and Maintenance	$/wt	$100	$100		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019
Additional Operation and Maintenance (THP-MAD)	$/wt	$26	$26	Estimated	
Brightwater					
Operation and Maintenance	$/WT	$102	$102		King County Communication, CurrentProgrambudgetbreakdown.xlsx, December 2019

GHG Emissions Assumption					
Emissions element	**Units**	**Baseline Value**	**Value in Model**	**Notes for Baseline Values**	**References**
Unit Conversions					
1 Btu =	kWh	0.0002928	0.0002928		
1 MMBtu =	kWh	293	293		
1 kg =	lb	2.205	2.205		
1 scf NG=	MMBtu	0.001	0.001	HHV	
1 scf Scrubbed Biogas	MMBtu	0.00099	0.00099		
1 gal Gasoline	MMBtu	0.114	0.114		
1 gal Diesel	MMBtu	0.137381	0.137381		
1 GGE	MMBtu	0.125	0.125		
1 gal =	L	3.785	3.785		
1 tonne (MT) =	kg	1000	1000		
1 scf CH4=	lb	0.042	0.042		Biogas Volume Calculator v2, BEAM, EPA GHG Tool v5
1 scf Natural Gas (Compressed)=	lb	0.0458	0.0458		
Global Warming Potential					
CO2	kg CO2e/kg CO2e	1	1		IPCC (2014). Climate Change 2014 Synthesis Report Fifth Assessment Report
CH4	kg CO2e/kg CH4	28	28		IPCC (2014). Climate Change 2014 Synthesis Report Fifth Assessment Report
N2O	kg CO2e/kg N2O	265	265		IPCC (2014). Climate Change 2014 Synthesis Report Fifth Assessment Report
Electricity					
Brightwater Electricity	kg CO2e/MWh	8.9	8.9	SnoPUD (80% Hydro, <10% Nuclear, 7% Wind)	King County Communication, Sep 2019
South Plant Electricity	kg CO2e/MWh	0	0	PSE, KC purchasing 100% renewable	King County Communication, Sep 2019.
West Point Electricity	kg CO2e/MWh	6.5	6.5	Seattle City Light (91% Hydro, 4% Nuclear)	King County Communication, Sep 2019
Heating					
Coal	kg CO2e/MMBtu	121	121	Includes production emmissions	Biomass Energy Centre (UK)
Coal	kg CO2e/MMBtu	104	104	Combustion only (no production)	2015 Climate Registry Table 12
Oil	kg CO2e/MMBtu	92	92	Includes production emmissions	Biomass Energy Centre (UK)
Oil No.2	kg CO2e/MMBtu	74	74	Combustion only (no production)	2015 Climate Registry Table 12
Nat Gas	kg CO2e/MMBtu	67	67	Includes production emmissions	Biomass Energy Centre (UK)
Nat Gas	kg CO2e/MMBtu	53	53	Combustion only (no production)	2015 Climate Registry Table 12
Biogas	kg CO2e/MMBtu	0	0	Excludes CO2 because biogas is biogenic	2015 Climate Registry Table 12.9.1
Chemicals					
Polymer	kg CO2e/kg polymer	9.00	9.00	Emission for use of ploymer	BEAM default
Lime	kg CO2e/kg lime	0.90	0.90	Emission for use of lime (stabilization)	BEAM default
Methanol	kg CO2e/gal methanol	3.71	3.71	Credit for methonal displaced	NY Hunts Pt GHG SWEET model
Transportation Fuels					
Gasoline	kg CO2e/L	2.83	2.83	Includes production emmissions	Elsayed et al., 2003
Gasoline	kg CO2e/L	2.80	2.80	Includes production emmissions	Biomass Energy Centre (UK)
Gasoline	kg CO2e/L	2.32	2.32	Combustion only (no production)	2015 Climate Registry Table 13
Diesel	kg CO2e/L	3.14	3.14	Includes production emmissions	Biomass Energy Centre (UK)
Diesel	kg CO2e/L	2.70	2.70	Combustion only (no production)	2015 Climate Registry Table 13
Transportation					
Fuel for biosolids land application	kg CO2e/WT solids applied	4.55	4.55		BEAM default
Fuel for Composting Machinery	Gallon/Day	274.00	274.00	Front End Loader (3.5 gal/hr -> 8 hrs) [4], Vertical/Horiz Aug Mixers (7 gph ->6 hrs) [2], Trommel Screen (1 gal/hr->6 hrs)[1], Grinder (12 gal/hr -> 6 hrs) [1]	
Fuel for Soil Blending Machinery	Gallon/Day	234.00	234.00	Front End Loader (3.5 gal/hr -> 8 hrs) [3], FEL (3.5 gal/hr -> 4 hrs) [1],Vertical/Horiz Aug Mixers (7 gph ->6 hrs) [2], Trommel Screen (1 gal/hr->4 hrs)[1], Grinder (12 gal/hr -> 4 hrs) [1]	
KC Fuel for Forestry Application	Gallon/WT	0.44	0.44	11,000 gallons of Diesel per 25,000 WT (2018)	King County Communication, Nov 2019
KC Fuel for Biosolids Land Application	Gallon/WT	0.32	0.32	33,000 gallons of Diesel per 103,000 WT (2018)	King County Communication, Nov 2019
Passenger Vehicle Mileage	Miles/gallon gasoline	25.00	25.00		https://www.fueleconomy.gov/
Local Distribution Truck (full)	Miles/gallon diesel	6.00	6.00		
Local Distribution Truck (empty)	Miles/gallon diesel	10.00	10.00		
KC Biosolids Truck Hauling Mileage (full)	Miles/gallon diesel	4.18	4.18		King County Communication, Nov 2019
KC Biosolids Truck Hauling Mileage (empty)	Miles/gallon diesel	8.00	8.00	Estimated	
KC Truck Capacity	WT/truck	31.00	31.00		King County Communication, Nov 2019
Local Distribution Truck Capacity	CY/truck	18.00	18.00	15 CY for topsoil and 22 CY for mulch. Assume in between for compost	
Local Compost/Soil Blend Capacity	CY/truck	3.00	3.00		
Transportation (Miles)					
WTP Transportation to Off-site processing, Roundtrip	Miles	30	30	Distance to off-site composting, soil-blending, or pyrolysis	
Feedstock (Sand), Roundtrip	Miles	75	75	Average distance to several local bulk aggregate companies	
Feedstock (Woodchips, Sawdust), Roundtrip	Miles	160	160	Distance From Renton to Hampton Lumber Mills (selected for size via google)	
Western Washington (Foresty/or local agriculture), Roundtrip	Miles	70	70		King County Communication, Nov 2019
Eastern Washington (Agriculture), Roundtrip	Miles	420	420		King County Communication, Nov 2019
Local Application (Compost or local retail), Roundtrip	Miles	25	25		King County Communication, Nov 2019
Regional Application (Biochar), Roundtrip	Miles	200	200		
End-use					
Scenario 1					
Bulk Land Application	%				
Western Washington Split	%	10	10		
Eastern Washington Split	%	90	90		
Scenario 2					
Bulk Land Application (South Plant)	WT/Day				
Western Washington Split (100% Forestry)	%	40	40		King County Communication, Nov 2019
Eastern Washington Split (100% Agriculture)	%	60	60		King County Communication, Nov 2019
Soil Blending (West Point)	WT/Day				
Bagged	%	20	20		King County Communication, Nov 2019
Donated	%	10	10		King County Communication, Nov 2019
Bulk Wholesaler		40	40		
Bulk Retail	%	30	30		King County Communication, Nov 2019
Composting (Brightwater)	WT/Day				
Bagged	%	20	20		King County Communication, Nov 2019

Donated	%	10	10		King County Communication, Nov 2019
Bulk Wholesaler	%	40	40		
Bulk Retail	%	30	30		King County Communication, Nov 2019
Scenario 3					
Biochar Retail	%	100	100		
Fertilizer Offset (BEAM)					
Nitrogen Amount Added	%	4.00%	4.00%	%N by dry weight	
Nitrogen Offset	kg CO2e/kg N applied	-4	-4	Credit for N applied; Can assume 4% N by dry weight	BEAM default
Phosphorus Amount Added	%	1.50%	1.50%	%P by dry weight	
Phosphorus Offset	kg CO2e/kg P applied	-2	-2	Credit for P applied; Can assume 1.5% P by dry weight	BEAM default
Fertilizer Offset (King County)					
Nitrogen and Phosphorus Offset (Agriculture)	kg CO2e/ kg dry biosolds	-0.29	-0.29	Agriculture 1.54 (0.29 fertilizer offset, 1.25 accumulation of carbon in the soil)	King County Communication, December 2019
Nitrogen and Phosphorus Offset (Forestry)	kg CO2e/ kg dry biosolds	0	0	Forestry 1.0 (1.0 accumulation of carbon in the soil)	King County Communication, December 2019
Nitrogen and Phosphorus Offset (Compost)	kg CO2e/ kg dry biosolds	-0.29	-0.29	Compost 0.64 (0.29 fertilizer offset, 0.41 accumulation of carbon in the soil)	King County Communication, December 2019
Sequestration (BEAM)					
Land Application	kg CO2e/ kg dry biosolds	-0.25	-0.25		BEAM default
Mine Reclamation	kg CO2e/kg dry biosolds	-1.3	-1.3		BEAM Data Table for BC copper mine
Compost	kg CO2e/ kg dry biosolds	-0.25	-0.25		BEAM default
Soil Blend	kg CO2e/ kg dry biosolds	-0.25	-0.25		BEAM default
Sequestration (King County)					
Land Application (Agriculture)	kg CO2e/ kg dry biosolds	-1.25	-1.25	Agriculture 1.54 (0.29 fertilizer offset, 1.25 accumulation of carbon in the soil)	King County Communication, December 2019
Land Application (Forestry)	kg CO2e/kg dry biosolds	-1	-1	Forestry 1.0 (1.0 accumulation of carbon in the soil)	King County Communication, December 2019
Compost	kg CO2e/ kg dry biosolds	-0.41	-0.41	Compost 0.64 (0.29 fertilizer offset, 0.41 accumulation of carbon in the soil)	King County Communication, December 2019
Soil Blend	kg CO2e/ kg dry biosolds	-0.41	-0.41	Assumed same as compost impacts	
Fugitive Emissions					
Digester (fixed cover)	of CH4 production	0.0001	0.0001	Through pressure relief valve only; 10% gas loss for 10 hrs/yr	sjk estimate
Digester (floating cover)	of CH4 production	0.017	0.017	Based on 80-ft dia digester and 4-in annulus w/o water bath for skirt	sjk estimate
Sludge Dewatering (high s.g.)	g CH4/L of sludge	0.000022	0.000022	Assume 5% gas in sludge flow from well-mixed digester; no odor treatment	sjk estimate
Sludge Dewatering (low s.g.)	g CH4/L sludge	0.086	0.086	Assume 20% gas in sludge flow from poorly-mixed digester; no odor treatment	sjk estimate
Sludge Dewatering with biofilter	g CH4/ L sludge	0.013	0.013	Assume 40% removal in inorganic media biofilter (20% for organic media)	sjk estimate: Nikiema et al., 2005
Sludge Drying	g CH4/L sludge	0.01	0.01	Without RTO emission control; from residual and soluble gas	sjk estimate
Sludge Drying	g CH4/L sludge	0.0001	0.0001	With RTO emission control at 1% slip (Andritz drier)	sjk est; E. Jacobson on RTO
Cogen (recip engine; low eff)	of CH4 to engine	0.02088	0.02088		Willis et al. 2013
Cogen (recip engine; high eff)	of CH4 to engine	0.00438	0.00438		Willis et al. 2013
Cogen Turbine/Microturbine	of CH4 to turbine	0.00012	0.00012		Willis et al. 2013
Boiler (very efficient)	of CH4 to boiler	0.00005	0.00005	Also see "Heating (boiler)" above for alternative CH4 and N2O emissions	Willis et al. 2013
Gas upgrading with thermal ox	of CH4 to scrubber	0.001	0.001	PA and membrane scrubbers 10% slip and 1% slip from thermal oxidizer	Eron Jacobson
Gas upgrading	of CH4 to scrubber	0.015	0.015	Water solvent w/o RTO 1.5% slip	Eron Jacobson
Fuel cell	of CH4 to fuel cell	0.0105	0.0105	Requires gas upgrade prior to fuel cell	Willis et al. 2013
Flare (candle stick)	of CH4 to flare	0.05	0.05		Willis et al. 2013
Flare (modern enclosed)	of CH4 to flare	0.004	0.004	BC specs 1%; typically achieve 0.4%	sjk estimate
Flare (efficient)	of CH4 to flare	0.003	0.003		BEAM Data Tables
Flare (enclosed; low NOx)	of CH4 to flare	0.00003	0.00003		Willis et al. 2013
Land Application (High), CH4	g CH4/L sludge	0.01	0.01	From residual and soluble gas after dewatering; same as drying	sjk estimate
Land Application (High), N2O	kg N2O/ kg N	0.50%	0.005	From residual and soluble gas after dewatering; same as drying	sjk estimate
Land Application (Low), CH4	g CH4/L sludge	0.01	0.01	From residual and soluble gas after dewatering; same as drying	sjk estimate
Land Application (Low), N2O	kg N2O/ kg N	0.002	0.002	From residual and soluble gas after dewatering; same as drying	sjk estimate
Landfill (poor capture), CH4 Capture		0.2	0.2	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Landfill (poor capture), CH4 Oxidation		0.1	0.1	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Landfill (good capture), CH4 Capture		0.75	0.75	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Landfill (good capture), CH4 Oxidation		0.4	0.4	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Sludge Lagoon, CH4 Capture		0	0	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Sludge Lagoon, CH4 Oxidation		0	0	Assume 40% additional VSR (sjk estimate from Sacramento FSLs)	BEAM Data Tables
Compost (uncovered)	kg CH4/kg C dry wt	0.01	0.01		BEAM Data Tables
Compost (uncovered)	kg N2O/kg N dry wt	0.013	0.013		BEAM Data Tables
Compost (covered with biofilter)	kg CH4/kg C dry wt	0.006	0.006	Assume 40% removal in inorganic media biofilter (20% for organic media)	sjk estimate; Nikiema et al., 2005
Compost (with C:N above 30)					
Soil Blend, CH4	kg CH4/kg dry wt	0.01	0.01	Assume same as uncovered compost	sjk estimate
Soil Blend, N2O	kg N02 initial N	0.013	0.013	Assume same as uncovered compost	sjk estimate
Incineration, CH4	kg CH4/ kg dry solids	0.0000485	0.0000485	Assumes 20% TS cake	BEAM Data Tables
Incineration, N2O	kg N2O/kg dry wt	0.00049	0.00049	Assumes 20% TS cake	BEAM Data Tables

S1 Output Summary	
Final TS, Wet (WT/D)	0
NG Req. (cfh)	8706
NG (LHV MMBtu/h)	8
Net heat (MMBtu/h)	11
Electricity Req. (kWh)	3138
Power Generation (kWh)	1760
Net Power (kWh)	-1378
No. of Trucks Required (trucks/day)	19
Digester Gas Produced (scfm)**	3325
Methane Produced (scfm)**	1995
Scrubbed Gas (scfm)**	700
Polymer Use (lb/day)	4611

Scenario 1 - [Baseline] 100% Class B application with MAD at all three plants

West Point

	Feedstock		Stabilization		Gas Utilization						Dewatering		End Use	
													100% Land Application	
Dry Mass Flow	225860	PPD	Digester (Meso)		CHP Engine		Boiler		Flare		Centrifuge		100295	PPD
TS	6.1%					909		909					28.5%	
VS	81%					NG LHV		NG LHV					61%	
VSR	64%													
Calorific Value	10,000	Btu/lb VS									92%	Capture		
			VSR	64.0%							29%	TS		
					Therm Eff.	36%	Therm Eff.	85%						
	Feedstock Type				Nat gas usage, cfh		Nat gas usage, cfh						End Use	
	PS + WAS				0		0						Land Application	
					Biogas Fuel use	44%	Biogas Fuel use	10%						
%														
					Engine Electrical Eff.									
			Sludge Inlet Temp		34%									
			65	F	Heat Recovery		Heat Recovery							
			Operation Temp		6.36	MMBtu/hr	2.02	MMBtu/hr						
			98	F										
			555	Btu/cf										
			15	cf/lb VS										
			5.09	MMBtu/hr										
	Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption	
	0	hp	40	hp/unit	289	hp/unit	40	hp/unit	0	hp/unit	225	hp/unit	0	hp/unit
	90%	Efficiency	100%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency
			Shell Heat Loss											
			15%											
			Duty No.	5	Duty No.	1	Duty No.	2	Duty No.	2	Duty No.	4		
											Polymer Use			
											30	lbs/DT		
Wet Mass Flow	154,276	lb/hr	149,398	lb/hr	149,398	lb/hr	149,398	lb/hr	149,398	lb/hr	14,663	lb/hr	14,663	lb/hr
Dry Mass Flow	9,411	lb/hr	4,533	lb/hr	4,533	lb/hr	4,533	lb/hr	4,533	lb/hr	4,179	lb/hr	4,179	lb/hr
	112.9	DTPD	54.4	DTPD	54.4	DTPD	54.4	DTPD	54.4	DTPD	50.1	DTPD	50.1	DTPD
VS	7,620	lb/hr	2,743	lb/hr	2,743	lb/hr	2,743	lb/hr	2,743	lb/hr	2,528	lb/hr	2,528	lb/hr
Water	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	10,484	lb/hr	10,484	lb/hr
TS	6.10%		3.03%		3.03%		3.03%		3.03%		28.50%		28.50%	
VS	81%		61%		61%		61%		61%		61%		61%	
VSR	4,878	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
Wet flow	308.3	gpm	298.6	gpm	298.6	gpm	298.6	gpm	298.6	gpm	29.3	gpm	29.3	gpm
Calorific Value	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	0.0	Btu/lb VS
Electrical Demand	0.0	kW	149.2	kW	239.7	kW	66.3	kW	0.0	kW	746.0	kW	0.0	kW
Unit Heat Bal.	0	MMBtu/hr	-5.85	MMBtu/hr	6.36	MMBtu/hr	2.02	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Total Heat Bal.	0	MMBtu/hr	-5.85	MMBtu/hr	0.50	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr
Unit Aux. Fuel Bal.	0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Cum. Aux. Fuel Bal.	0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Unit Process Fuel Bal.	0	MMBtu/hr	40.61	MMBtu/hr	-17.66	MMBtu/hr	-2.38	MMBtu/hr	-20.57	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Cum Unit Process Fuel Bal.	0	MMBtu/hr	40.61	MMBtu/hr	22.94	MMBtu/hr	20.57	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Generated Steam	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
Power Generation	0	MW	0.00	MW	1.76	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW
No of Trucks Required	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	6.00	trucks/day
Vehicle Fuel Consumption	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day
Digester Gas Produced	0	scfm	1219	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Methane Production	0	scfm	732	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Methane Utilized	0	scfm	0	scfm	-318	scfm	-43	scfm	-371	scfm	0	scfm	0	scfm
Scrubbed Gas	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Unit Polymer Use	0	lb/day	0	lb/day	0	lb/day	0	lb/day	0	lb/day	1632	lb/day	0	lb/day

South Plant

Feedstock	Stabilization	Gas Utilization				Dewatering	End Use
							100% Land Application
263760 PPD	Digester (Meso)	CHP Engine	Boiler	Biogas Upgrading	Flare	Centrifuge	121334 PPD
6.2%		909 NG LHV	909 NG LHV				22.9%
85.88%							71%
60.0%							
10,000 Btu/lb VS						95% Capture	
	VSR 60.0%					23% TS	
		Therm Eff. 38%	Therm Eff. 85%				
Feedstock Type		Nat gas usage, cfh	Nat gas usage, cfh	Nat gas usage, cfh			End Use
PS + WAS		0	8,706	0			Land Application
		Biogas Fuel use 0%	Biogas Fuel use 0%	Biogas Fuel use 85%			
	Sludge Inlet Temp	Engine Electrical Eff.					
	65 F	30%					
	Operation Temp	Heat Recovery	Heat Recovery				
	98 F	0.00 MMBtu/hr	6.73 MMBtu/hr				
	550 Btu/cf						
	16.24 cf/lb VS						
	5.85 MMBtu/hr						
Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption
0 hp/unit	40 hp/unit	145 hp/unit	40 hp/unit	738 hp/unit	0 hp/unit	225 hp/unit	0 hp/unit
90% Efficiency	100% Efficiency	90% Efficiency	90% Efficiency	100% Efficiency	90% Efficiency	90% Efficiency	90% Efficiency
	Shell Heat Loss						
	15%						
	Duty No. 4	Duty No. 0	Duty No. 2	Duty No. 1	Duty No. 2	Duty No. 4	
						Polymer Use	
						35 lbs/DT	
177,258 lb/hr	171,592 lb/hr	171,592 lb/hr	171,592 lb/hr	171,592 lb/hr	171,592 lb/hr	22,077 lb/hr	22,077 lb/hr
10,990 lb/hr	5,324 lb/hr	5,324 lb/hr	5,324 lb/hr	5,324 lb/hr	5,324 lb/hr	5,056 lb/hr	5,056 lb/hr
131.9 DTPD	63.9 DTPD	63.9 DTPD	63.9 DTPD	63.9 DTPD	63.9 DTPD	60.7 DTPD	60.7 DTPD
9,439 lb/hr	3,773 lb/hr	3,773 lb/hr	3,773 lb/hr	3,773 lb/hr	3,773 lb/hr	3,583 lb/hr	3,583 lb/hr
166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	17,021 lb/hr	17,021 lb/hr
6.20%	3.10%	3.10%	3.10%	3.10%	3.10%	22.90%	22.90%
86%	71%	71%	71%	71%	71%	71%	71%
5,666 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
354.2 gpm	342.9 gpm	342.9 gpm	342.9 gpm	342.9 gpm	342.9 gpm	44.1 gpm	44.1 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0.0 kW	119.4 kW	0.0 kW	66.3 kW	550.4 kW	0.0 kW	746.0 kW	0.0 kW
0 MMBtu/hr	-6.73 MMBtu/hr	0.00 MMBtu/hr	6.73 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-6.73 MMBtu/hr	-6.73 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	7.91 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	7.91 MMBtu/hr	7.91 MMBtu/hr	7.91 MMBtu/hr	7.91 MMBtu/hr	7.91 MMBtu/hr
0 MMBtu/hr	50.61 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	-42.76 MMBtu/hr	-7.84 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	50.61 MMBtu/hr	50.61 MMBtu/hr	50.61 MMBtu/hr	7.84 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	9.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	1534 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	920 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	-778 scfm	-143 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	700 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	2236 lb/day	0 lb/day

Brightwater

Feedstock	Stabilization	Gas Utilization		Dewatering	End Use
					100% Land Application
93910 PPD	Digester (Meso)	Boiler	Flare	Centrifuge	39295 PPD
5.8%		909 NG LHV			20.0%
90%					78%
61%					
10,000 Btu/lb VS				93% Capture	
	VSR 60.9%			20% TS	
		Therm Eff. 85%			
Feedstock Type PS + WAS		Nat gas usage, cfh 0			End Use Land Application
		Biogas Fuel Use 70%			
	Sludge Inlet Temp 65 F	Heat Recovery 11.22 MMBtu/hr			
	Operation Temp 98 F				
	550 Btu/cf				
	16 cf/lb VS				
	2.23 MMBtu/hr				
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 100% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 200 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
	Shell Heat Loss 15%				
	Duty No. 3	Duty No. 1	Duty No. 1	Duty No. 2	
				Polymer Use 35 lbs/DT	
67,464 lb/hr	65,321 lb/hr	65,321 lb/hr	65,321 lb/hr	8,186 lb/hr	8,186 lb/hr
3,913 lb/hr	1,770 lb/hr	1,770 lb/hr	1,770 lb/hr	1,637 lb/hr	1,637 lb/hr
47.0 DTPD	21.2 DTPD	21.2 DTPD	21.2 DTPD	19.6 DTPD	19.6 DTPD
3,517 lb/hr	1,374 lb/hr	1,374 lb/hr	1,374 lb/hr	1,271 lb/hr	1,271 lb/hr
63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	6,549 lb/hr	6,549 lb/hr
5.80%	2.71%	2.71%	2.71%	20.00%	20.00%
90%	78%	78%	78%	78%	78%
2,143 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
134.8 gpm	130.5 gpm	130.5 gpm	130.5 gpm	16.4 gpm	16.4 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0 kW	89.5 kW	33.2 kW	0.0 kW	331.6 kW	0.0 kW
0 MMBtu/hr	-2.56 MMBtu/hr	11.22 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-2.56 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	-13.20 MMBtu/hr	-5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	4.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	571 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	343 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	-240 scfm	-103 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	743 lb/day	0 lb/day

S2 Output Summary	
Final TS, Wet (WT/D)	0
NG Req. (cfh)	15611
NG (LHV MMBtu/h)	14
Net heat (MMBtu/h)	9
Electricity Req. (kWh)	4222
Power Generation (kWh)	1886
Net Power (kWh)	-2336
No. of Trucks Required (trucks/day)	34
Digester Gas Produced (scfm)**	3419
Methane Produced (scfm)**	2052
Scrubbed Gas (scfm)**	708
Polymer Use (lb/day)	6359

Scenario 2 - TAD with Batch Tanks at West Point to Soil Blending, Cambi at South Plant to direct Land App, and Brightwater with MAD and Off-site Composting

West Point

Off-site Soil Blending

	Feedstock	Stabilization	Energy Recovery	Gas Utilization			Dewatering	End Use	Feedstock	Feedstock	Feedstock	End Use
								100% Off-Site Soil Blending				Local Retail
Dry Mass Flow	225860 PPD	Digester (Thermo)	HEX	CHP Engine	Boiler	Flare	Centrifuge	93568 PPD	93568 PPD	45963 PPD	252634 PPD	392165 PPD
TS	6.1%			909 NG LHV	909 NG LHV			28.5%	28.5%	60.0%	95.0%	58.5%
VS	81%							58%	57.66%	95.00%	0.00%	25%
VSR	68%									0.0%	0.0%	
Calorific Value	10,000 Btu/lb VS								10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	
							92% Capture					
							29% TS					
		VSR 68.0%										
				Therm Eff. 36%	Therm Eff. 85%							
	Feedstock Type PS + WAS			Nat gas usage, cfh 0	Nat gas usage, cfh 0			End Use Off-Site Soil Blending	Feedstock Type Dewatered Cake	Feedstock Type Sawdust	Feedstock Type Fine Sand	End Use Local Retail
			Inlet Temperature 131 F	Biogas Fuel use 44%	Biogas Fuel use 10%							
			Outlet Temperature 100 F									
%				Engine Electrical Eff. 34%								
		Sludge Inlet Temp 65 F	HEX Efficiency 70 %	Heat Recovery 6.82 MMBtu/hr	Heat Recovery 2.16 MMBtu/hr							
		Operation Temp 131 F	3.24 MMBtu/hr									
		560 Btu/cf										
		15 cf/lb VS										
		10.18 MMBtu/hr										
	Energy Consumption 0 hp 90% Efficiency	Energy Consumption 40 hp 90% Efficiency	Energy Consumption 150 hp 90% Efficiency	Energy Consumption 145 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 225 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
		Shell Heat Loss 15%										
		Duty No. 5	Duty No. 1	Duty No. 2	Duty No. 2	Duty No. 2	Duty No. 4					
							Polymer Use 30 lbs/DT					
Wet Mass Flow	154,276 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	13,680 lb/hr	13,680 lb/hr	13,680 lb/hr	16,871 lb/hr	27,952 lb/hr	27,952 lb/hr
Dry Mass Flow	9,411 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	3,899 lb/hr	3,899 lb/hr	3,899 lb/hr	5,814 lb/hr	16,340 lb/hr	16,340 lb/hr
	112.9 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	46.8 DTPD	46.8 DTPD	46.8 DTPD	69.8 DTPD	196.1 DTPD	196.1 DTPD
VS	7,620 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,248 lb/hr	2,248 lb/hr	2,248 lb/hr	4,067 lb/hr	4,067 lb/hr	4,067 lb/hr
Water	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	9,781 lb/hr	9,781 lb/hr	9,781 lb/hr	11,058 lb/hr	11,612 lb/hr	11,612 lb/hr
TS	6.10%	2.84%	2.84%	2.84%	2.84%	2.84%	28.50%	28.50%	28.50%	34.46%	58.46%	58.46%
VS	81%	58%	58%	58%	58%	58%	58%	58%	58%	70%	25%	25%
VSR	5,182 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Wet flow	308.3 gpm	297.9 gpm	297.9 gpm	297.9 gpm	297.9 gpm	297.9 gpm	27.3 gpm	27.3 gpm	27.3 gpm	33.7 gpm	55.9 gpm	55.9 gpm
Calorific Value	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
Electrical Demand	0.0 kW	165.8 kW	124.3 kW	239.7 kW	66.3 kW	0.0 kW	746.0 kW	0.0 kW	0.0 kW	0.0 kW	0.0 kW	0.0 kW
Unit Heat Bal.	0 MMBtu/hr	-11.71 MMBtu/hr	3.24 MMBtu/hr	6.82 MMBtu/hr	2.16 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Total Heat Bal.	0 MMBtu/hr	-11.71 MMBtu/hr	-8.47 MMBtu/hr	-1.66 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Unit Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum. Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Unit Process Fuel Bal.	0 MMBtu/hr	43.53 MMBtu/hr	0.00 MMBtu/hr	-18.93 MMBtu/hr	-2.55 MMBtu/hr	-22.05 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum Unit Process Fuel Bal.	0 MMBtu/hr	43.53 MMBtu/hr	43.53 MMBtu/hr	24.59 MMBtu/hr	22.05 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Generated Steam	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Power Generation	0 MW	0.00 MW	0.00 MW	1.89 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0 MW	0.00 MW	0.00 MW	0.00 MW
No of Trucks Required	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	6.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	11.00 trucks/day
Vehicle Fuel Consumption	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
Digester Gas Produced	0 scfm	1295 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Methane Production	0 scfm	777 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Methane Utilized	0 scfm	0 scfm	0 scfm	-338 scfm	-45 scfm	-394 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Scrubbed Gas	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Unit Polymer Use	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	1522 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day

South Plant

Feedstock

263760	PPD
6.2%	
85.88%	
62.0%	
10,000	Btu/lb VS
Feedstock Type	
PS + WAS	
Energy Consumption	
0	hp/unit
90%	Efficiency
177,258	lb/hr
10,990	lb/hr
131.9	DTPD
9,439	lb/hr
166,268	lb/hr
6.20%	
86%	
5,852	lb/hr
354.2	gpm
10,000	Btu/lb VS
0.0	kW
0	MMBtu/hr
0	MMBtu/hr
0	MMBtu/hr
0	MMBtu/hr
0	MMBtu/hr
0	MMBtu/hr
0	lb/hr
0	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Stabilization

Pre-dewatering

98%	Capture
17%	TS
Energy Consumption	
150	hp
90%	Efficiency
Duty No.	4
Polymer Use	
15	lbs/DT
65,274	lb/hr
10,770	lb/hr
129.2	DTPD
9,250	lb/hr
54,504	lb/hr
16.50%	
86%	
5,735	lb/hr
130.4	gpm
10,000	Btu/lb VS
497.3	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
1978	lb/day

Dilution water

lb/day	
0	
Energy Consumption	
0	hp
90%	Efficiency
65,274	lb/hr
10,770	lb/hr
129.2	DTPD
9,250	lb/hr
54,504	lb/hr
16.50%	
86%	
5,735	lb/hr
130.4	gpm
10,000	Btu/lb VS
0.0	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Thermal Hydrolysis

Sludge Inlet Temp	
65	F
Operation Temp	
302	F
11.49	MMBtu/hr
Energy Consumption	
100	hp
100%	Efficiency
Shell Heat Loss	
5%	
Duty No.	3
65,274	lb/hr
10,770	lb/hr
129.2	DTPD
9,250	lb/hr
54,504	lb/hr
16.50%	
86%	
5,735	lb/hr
130.4	gpm
10,000	Btu/lb VS
223.8	kW
-12.07	MMBtu/hr
-12.07	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Dilution water

lb/day	
1305479	
Energy Consumption	
0	hp
90%	Efficiency
119,669	lb/hr
10,770	lb/hr
129.2	DTPD
9,250	lb/hr
108,899	lb/hr
9.00%	
86%	
5,735	lb/hr
239.1	gpm
10,000	Btu/lb VS
0.0	kW
0.00	MMBtu/hr
-12.07	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Digester (Meso)

VSR	62.0%
Sludge Inlet Temp	
65	F
Operation Temp	
98	F
550	Btu/cf
16.24	cf/lb VS
0.00	MMBtu/hr
Energy Consumption	
40	hp
100%	Efficiency
Shell Heat Loss	
15%	
Duty No.	4
113,934	lb/hr
5,035	lb/hr
60.4	DTPD
3,515	lb/hr
108,899	lb/hr
4.42%	
70%	
0	lb/hr
227.7	gpm
10,000	Btu/lb VS
119.4	kW
0.00	MMBtu/hr
-12.06	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
51.22	MMBtu/hr
51.22	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
1552	scfm
931	scfm
0	scfm
0	scfm
0	lb/day

Gas Utilization

CHP Engine

909	
NG LHV	
Therm Eff.	38%
Nat gas usage, cfh	
0	
Biogas Fuel use	0%
Engine Electrical Eff.	
30%	
Heat Recovery	
0.00	MMBtu/hr
Energy Consumption	
145	hp/unit
90%	Efficiency
Duty No.	0
113,934	lb/hr
5,035	lb/hr
60.4	DTPD
3,515	lb/hr
108,899	lb/hr
4.42%	
70%	
0	lb/hr
227.7	gpm
10,000	Btu/lb VS
0.0	kW
0.00	MMBtu/hr
-12.06	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
51.22	MMBtu/hr
51.22	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Boiler

909	
NG LHV	
Therm Eff.	85%
Nat gas usage, cfh	
15,611	
Biogas Fuel use	0%
Heat Recovery	
12.06	MMBtu/hr
Energy Consumption	
40	hp/unit
90%	Efficiency
Duty No.	2
113,934	lb/hr
5,035	lb/hr
60.4	DTPD
3,515	lb/hr
108,899	lb/hr
4.42%	
70%	
0	lb/hr
227.7	gpm
10,000	Btu/lb VS
66.3	kW
12.06	MMBtu/hr
0.00	MMBtu/hr
14.19	MMBtu/hr
14.19	MMBtu/hr
0.00	MMBtu/hr
51.22	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Biogas Upgrading

Nat gas usage, cfh	
0	
Biogas Fuel use	85%
Energy Consumption	
747	hp/unit
100%	Efficiency
Duty No.	1
113,934	lb/hr
5,035	lb/hr
60.4	DTPD
3,515	lb/hr
108,899	lb/hr
4.42%	
70%	
0	lb/hr
227.7	gpm
10,000	Btu/lb VS
557.1	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
14.19	MMBtu/hr
-43.29	MMBtu/hr
7.94	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
-787	scfm
708	scfm
0	lb/day

Flare

Energy Consumption	
0	hp/unit
90%	Efficiency
Duty No.	2
113,934	lb/hr
5,035	lb/hr
60.4	DTPD
3,515	lb/hr
108,899	lb/hr
4.42%	
70%	
0	lb/hr
227.7	gpm
10,000	Btu/lb VS
0.0	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
14.19	MMBtu/hr
-7.94	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
-144	scfm
0	scfm
0	lb/day

Dewatering

Centrifuge

95%	Capture
30%	TS
Energy Consumption	
225	hp/unit
90%	Efficiency
Duty No.	4
Polymer Use	
35	lbs/DT
15,938	lb/hr
4,781	lb/hr
57.4	DTPD
3,338	lb/hr
11,157	lb/hr
30.00%	
70%	
0	lb/hr
31.9	gpm
10,000	Btu/lb VS
746.0	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
14.19	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
0.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
2115	lb/day

End Use

100%	Land Application
114755	PPD
30.0%	
70%	
End Use	
Land Application	
Energy Consumption	
0	hp/unit
90%	Efficiency
15,938	lb/hr
4,781	lb/hr
57.4	DTPD
3,338	lb/hr
11,157	lb/hr
30.00%	
70%	
0	lb/hr
31.9	gpm
0.0	Btu/lb VS
0.0	kW
0.00	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
14.19	MMBtu/hr
0.00	MMBtu/hr
0.00	MMBtu/hr
0	lb/hr
0.00	MW
7.00	trucks/day
0	gal/day
0	scfm
0	scfm
0	scfm
0	scfm
0	lb/day

Brightwater

Feedstock	Stabilization	Gas Utilization		Dewatering	End Use
93910 PPD	Digester (Meso)	Boiler	Flare	Centrifuge	100% Land Application
5.8%		909 NG LHV			39295 PPD
90%					20.0%
61%					78%
10,000 Btu/lb VS					
				93% Capture	
				20% TS	
	VSR 60.9%				
		Therm Eff. 85%			
Feedstock Type PS + WAS		Nat gas usage, cfh 0			End Use Land Application
		Biogas Fuel use 70%			
	Sludge Inlet Temp 65 F	Heat Recovery 11.22 MMBtu/hr			
	Operation Temp 98 F				
	550 Btu/cf				
	16 cf/lb VS				
	2.23 MMBtu/hr				
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 100% Efficiency Shell Heat Loss 15%	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 200 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
	Duty No. 3	Duty No. 1	Duty No. 1	Duty No. 2 Polymer Use 35 lbs/DT	
67,464 lb/hr	65,321 lb/hr	65,321 lb/hr	65,321 lb/hr	8,186 lb/hr	8,186 lb/hr
3,913 lb/hr	1,770 lb/hr	1,770 lb/hr	1,770 lb/hr	1,637 lb/hr	1,637 lb/hr
47.0 DTPD	21.2 DTPD	21.2 DTPD	21.2 DTPD	19.6 DTPD	19.6 DTPD
3,517 lb/hr	1,374 lb/hr	1,374 lb/hr	1,374 lb/hr	1,271 lb/hr	1,271 lb/hr
63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	6,549 lb/hr	6,549 lb/hr
5.80%	2.71%	2.71%	2.71%	20.00%	20.00%
90%	78%	78%	78%	78%	78%
2,143 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
134.8 gpm	130.5 gpm	130.5 gpm	130.5 gpm	16.4 gpm	16.4 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0 kW	89.5 kW	33.2 kW	0.0 kW	331.6 kW	0.0 kW
0 MMBtu/hr	-2.56 MMBtu/hr	11.22 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-2.56 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	-13.20 MMBtu/hr	-5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	4.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	571 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	343 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	-240 scfm	-103 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	743 lb/day	0 lb/day

Off-site Composting

Feedstock	Feedstock	Feedstock	Feedstock	Stabilization	End Use
					Local Retail
39295 PPD	132465 PPD	16611 PPD	Compost		162685 PPD
20.0%	55.0%	55.0%			50.0%
77.61%	95.00%	89.68%			89%
15.0%	15.0%	15.0%			
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS			
				50% TS	
				VSR 15.0%	
Feedstock Type Dewatered Cake	Feedstock Type Virgin Woodchips	Feedstock Type Screened Overs			End Use Local Retail
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 260 hp 90% Efficiency		Energy Consumption 0 hp/unit 90% Efficiency
			Duty No. 1		
8,186 lb/hr	18,222 lb/hr	19,480 lb/hr	13,557 lb/hr		13,557 lb/hr
1,637 lb/hr	7,157 lb/hr	7,849 lb/hr	6,779 lb/hr		6,779 lb/hr
19.6 DTPD	85.9 DTPD	94.2 DTPD	81.3 DTPD		81.3 DTPD
1,271 lb/hr	6,514 lb/hr	7,135 lb/hr	6,065 lb/hr		6,065 lb/hr
6,549 lb/hr	11,065 lb/hr	11,631 lb/hr	6,779 lb/hr		6,779 lb/hr
20.00%	39.28%	40.29%	50.00%		50.00%
78%	91%	91%	89%		89%
191 lb/hr	977 lb/hr	1,070 lb/hr	0 lb/hr		0 lb/hr
16.4 gpm	36.4 gpm	38.9 gpm	27.1 gpm		27.1 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS		0.0 Btu/lb VS
0.0 kW	0.0 kW	0.0 kW	215.5 kW		0.0 kW
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr		0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW		0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day		6.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day		0 gal/day
0 scfm	0 scfm	0 scfm	0 scfm		0 scfm
0 scfm	0 scfm	0 scfm	0 scfm		0 scfm
0 scfm	0 scfm	0 scfm	0 scfm		0 scfm
0 scfm	0 scfm	0 scfm	0 scfm		0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day		0 lb/day

S3 Output Summary	
Final TS, Wet (WT/D)	0
NG Req. (cfh)	42506
NG (LHV MMBtu/h)	39
Net heat (MMBtu/h)	11
Electricity Req. (kWh)	8441
Power Generation (kWh)	1760
Net Power (kWh)	-6681
No. of Trucks Required (trucks/day)	22
Digester Gas Produced (scfm)**	3325
Methane Produced (scfm)**	1995
Scrubbed Gas (scfm)**	700
Polymer Use (lb/day)	4611

Scenario 3 - MAD at all three plants with off-site Thermal Drying and Pyrolysis

West Point

	Feedstock		Stabilization		Gas Utilization								Dewatering		End Use	
															100%	Off-site Processing
Dry Mass Flow	225860	PPD	Digester (Meso)		CHP Engine		Boiler		Flare		Centrifuge		100295	PPD
TS	6.1%					909		909					28.5%	
VS	81%					NG LHV		NG LHV					61%	
VSR	64%													
Calorific Value	10,000	Btu/lb VS									92%	Capture		
			VSR	64.0%							29%	TS		
					Therm Eff.	36%	Therm Eff.	85%						
		Feedstock Type				Nat gas usage, cfh		Nat gas usage, cfh						End Use
		PS + WAS				0		0						Off-site Processing
					Biogas Fuel use	44%	Biogas Fuel use	10%						
%														
						Engine Electrical Eff.								
						34%								
			Sludge Inlet Temp			Heat Recovery		Heat Recovery						
			65	F		6.36 MMBtu/hr		2.02 MMBtu/hr						
			Operation Temp											
			98	F										
			555	Btu/cf										
			15	cf/lb VS										
			5.09	MMBtu/hr										
	Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption		Energy Consumption	
	0	hp	40	hp/unit	289	hp/unit	40	hp/unit	0	hp/unit	225	hp/unit	0	hp/unit
	90%	Efficiency	100%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency	90%	Efficiency
			Shell Heat Loss											
			15%											
			Duty No.	5	Duty No.	1	Duty No.	2	Duty No.	2	Duty No.	4		
											Polymer Use			
											30	lbs/DT		
Wet Mass Flow	154,276	lb/hr	149,398	lb/hr	149,398	lb/hr	149,398	lb/hr	149,398	lb/hr	14,663	lb/hr	14,663	lb/hr
Dry Mass Flow	9,411	lb/hr	4,533	lb/hr	4,533	lb/hr	4,533	lb/hr	4,533	lb/hr	4,179	lb/hr	4,179	lb/hr
	112.9	DTPD	54.4	DTPD	54.4	DTPD	54.4	DTPD	54.4	DTPD	50.1	DTPD	50.1	DTPD
VS	7,620	lb/hr	2,743	lb/hr	2,743	lb/hr	2,743	lb/hr	2,743	lb/hr	2,528	lb/hr	2,528	lb/hr
Water	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	144,865	lb/hr	10,484	lb/hr	10,484	lb/hr
TS	6.10%		3.03%		3.03%		3.03%		3.03%		28.50%		28.50%	
VS	81%		61%		61%		61%		61%		61%		61%	
VSR	4,878	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
Wet flow	308.3	gpm	298.6	gpm	298.6	gpm	298.6	gpm	298.6	gpm	29.3	gpm	29.3	gpm
Calorific Value	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	0.0	Btu/lb VS
Electrical Demand	0.0	kW	149.2	kW	239.7	kW	66.3	kW	0.0	kW	746.0	kW	0.0	kW
Unit Heat Bal.	0	MMBtu/hr	-5.85	MMBtu/hr	6.36	MMBtu/hr	2.02	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Total Heat Bal.	0	MMBtu/hr	-5.85	MMBtu/hr	0.50	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr	2.52	MMBtu/hr
Unit Aux. Fuel Bal.	0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Cum. Aux. Fuel Bal.	0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Unit Process Fuel Bal.	0	MMBtu/hr	40.61	MMBtu/hr	-17.66	MMBtu/hr	-2.38	MMBtu/hr	-20.57	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Cum Unit Process Fuel Bal.	0	MMBtu/hr	40.61	MMBtu/hr	22.94	MMBtu/hr	20.57	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
Generated Steam	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
Power Generation	0	MW	0.00	MW	1.76	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW
No of Trucks Required	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	6.00	trucks/day
Vehicle Fuel Consumption	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day
Digester Gas Produced	0	scfm	1219	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Methane Production	0	scfm	732	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Methane Utilized	0	scfm	0	scfm	-318	scfm	-43	scfm	-371	scfm	0	scfm	0	scfm
Scrubbed Gas	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
Unit Polymer Use	0	lb/day	0	lb/day	0	lb/day	0	lb/day	0	lb/day	1632	lb/day	0	lb/day

South Plant

Feedstock	Stabilization	Gas Utilization				Dewatering	End Use
							100% Offsite Processing
263760 PPD	Digester (Meso)	CHP Engine	Boiler	Biogas Upgrading	Flare	Centrifuge	121334 PPD
6.2%		909 NG LHV	909 NG LHV				22.9%
85.88%							71%
60.0%							
10,000 Btu/lb VS							
	VSR 60.0%					95% Capture	
						23% TS	
		Therm Eff. 38%	Therm Eff. 85%				
Feedstock Type PS + WAS		Nat gas usage, cfh 0	Nat gas usage, cfh 8,706	Nat gas usage, cfh 0			End Use Offsite Processing
		Biogas Fuel use 0%	Biogas Fuel use 0%	Biogas Fuel use 85%			
		Engine Electrical Eff. 30%					
	Sludge Inlet Temp 65 F	Heat Recovery 0.00 MMBtu/hr	Heat Recovery 6.73 MMBtu/hr				
	Operation Temp 98 F						
	550 Btu/cf						
	16.24 cf/lb VS						
	5.85 MMBtu/hr						
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 100% Efficiency	Energy Consumption 145 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 738 hp/unit 100% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 225 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
	Shell Heat Loss 15%						
	Duty No. 4	Duty No. 0	Duty No. 2	Duty No. 1	Duty No. 2	Duty No. 4	
						Polymer Use 35 lbs/DT	

177,258	lb/hr	171,592	lb/hr	171,592	lb/hr	171,592	lb/hr	171,592	lb/hr	171,592	lb/hr	171,592	lb/hr	22,077	lb/hr	22,077	lb/hr
10,990	lb/hr	5,324	lb/hr	5,324	lb/hr	5,324	lb/hr	5,324	lb/hr	5,324	lb/hr	5,324	lb/hr	5,056	lb/hr	5,056	lb/hr
131.9	DTPD	63.9	DTPD	63.9	DTPD	63.9	DTPD	63.9	DTPD	63.9	DTPD	63.9	DTPD	60.7	DTPD	60.7	DTPD
9,439	lb/hr	3,773	lb/hr	3,773	lb/hr	3,773	lb/hr	3,773	lb/hr	3,773	lb/hr	3,773	lb/hr	3,583	lb/hr	3,583	lb/hr
166,268	lb/hr	166,268	lb/hr	166,268	lb/hr	166,268	lb/hr	166,268	lb/hr	166,268	lb/hr	166,268	lb/hr	17,021	lb/hr	17,021	lb/hr
6.20%		3.10%		3.10%		3.10%		3.10%		3.10%		3.10%		22.90%		22.90%	
86%		71%		71%		71%		71%		71%		71%		71%		71%	
5,666	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
354.2	gpm	342.9	gpm	342.9	gpm	342.9	gpm	342.9	gpm	342.9	gpm	342.9	gpm	44.1	gpm	44.1	gpm
10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	10,000	Btu/lb VS	0.0	Btu/lb VS
0.0	kW	119.4	kW	0.0	kW	66.3	kW	550.4	kW	0.0	kW	0.0	kW	746.0	kW	0.0	kW
0	MMBtu/hr	-6.73	MMBtu/hr	0.00	MMBtu/hr	6.73	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
0	MMBtu/hr	-6.73	MMBtu/hr	-6.73	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	7.91	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
0	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	7.91	MMBtu/hr	7.91	MMBtu/hr	7.91	MMBtu/hr	7.91	MMBtu/hr	7.91	MMBtu/hr	7.91	MMBtu/hr
0	MMBtu/hr	50.61	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	-42.76	MMBtu/hr	-7.84	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
0	MMBtu/hr	50.61	MMBtu/hr	50.61	MMBtu/hr	50.61	MMBtu/hr	7.84	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr	0.00	MMBtu/hr
0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr	0	lb/hr
0	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW	0.00	MW
0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	0.00	trucks/day	9.00	trucks/day
0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day	0	gal/day
0	scfm	1534	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
0	scfm	920	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm	0	scfm
0	scfm	0	scfm	0	scfm	0	scfm	-778	scfm	-143	scfm	0	scfm	0	scfm	0	scfm
0	scfm	0	scfm	0	scfm	0	scfm	700	scfm	0	scfm	0	scfm	0	scfm	0	scfm
0	lb/day	0	lb/day	0	lb/day	0	lb/day	0	lb/day	0	lb/day	0	lb/day	2236	lb/day	0	lb/day

Brightwater

Feedstock	Stabilization	Gas Utilization		Dewatering	End Use
					100% Off-Site Processing
93910 PPD	Digester (Meso)	Boiler	Flare	Centrifuge	39295 PPD
5.8%		909 NG LHV			20.0%
90%					78%
61%					
10,000 Btu/lb VS				93% Capture	
	VSR 60.9%			20% TS	
		Therm Eff. 85%			
Feedstock Type		Nat gas usage, cfh			End Use
PS + WAS		0			Off-Site Processing
		Biogas Fuel Use 70%			
	Sludge Inlet Temp				
	65 F	Heat Recovery			
	Operation Temp	11.22 MMBtu/hr			
	98 F				
	550 Btu/cf				
	16 cf/lb VS				
	2.23 MMBtu/hr				
Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption	Energy Consumption
0 hp/unit	40 hp/unit	40 hp/unit	0 hp/unit	200 hp/unit	0 hp/unit
90% Efficiency	100% Efficiency	90% Efficiency	90% Efficiency	90% Efficiency	90% Efficiency
	Shell Heat Loss				
	15%				
	Duty No. 3	Duty No. 1	Duty No. 1	Duty No. 2	
				Polymer Use	
				35 lbs/DT	
67,464 lb/hr	65,321 lb/hr	65,321 lb/hr	65,321 lb/hr	8,186 lb/hr	8,186 lb/hr
3,913 lb/hr	1,770 lb/hr	1,770 lb/hr	1,770 lb/hr	1,637 lb/hr	1,637 lb/hr
47.0 DTPD	21.2 DTPD	21.2 DTPD	21.2 DTPD	19.6 DTPD	19.6 DTPD
3,517 lb/hr	1,374 lb/hr	1,374 lb/hr	1,374 lb/hr	1,271 lb/hr	1,271 lb/hr
63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	6,549 lb/hr	6,549 lb/hr
5.80%	2.71%	2.71%	2.71%	20.00%	20.00%
90%	78%	78%	78%	78%	78%
2,143 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
134.8 gpm	130.5 gpm	130.5 gpm	130.5 gpm	16.4 gpm	16.4 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0 kW	89.5 kW	33.2 kW	0.0 kW	331.6 kW	0.0 kW
0 MMBtu/hr	-2.56 MMBtu/hr	11.22 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-2.56 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	-13.20 MMBtu/hr	-5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	4.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	571 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	343 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	-240 scfm	-103 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	743 lb/day	0 lb/day

Off-site Pyrolysis

Feedstock	Drying and Pyrolysis		Gas Utilization	End Use
				100% Contracted P3
260925 PPD	Thermal Dryer	Pyrolysis	Boiler	125590 PPD
24.6%	909 NG LHV		909 NG LHV	100.0%
67.9%				0%
2%				
10,000 Btu/lb VS	90.0% TS			
		Therm Eff. 50%	Therm Eff. 85%	
Feedstock Type PS + WAS	Nat gas usage, cfh 0		Nat gas usage, cfh 33,799	End Use Contracted P3
	Biogas Fuel use 0%		Biogas Fuel use 0%	
	Inlet / Out Temp. 60 F	Heat Recovery 21.29 MMBtu/hr	Heat Recovery 26.12 MMBtu/hr	
	300 F	Enthalpy 5.84 MMBtu/hr		
	1,400 Btu/lb			
	45.15 MMBtu/hr			
Energy Consumption 0 hp/unit	Energy Consumption 339 hp/unit	Energy Consumption 94 hp/unit	Energy Consumption 40 hp/unit	Energy Consumption 0 hp/unit
90% Efficiency	90% Efficiency	90% Efficiency	90% Efficiency	90% Efficiency
	Heat Loss 5%			
	Duty No. 12	Duty No. 24	Duty No. 2	
		Temp (°C) 550		
44,166 lb/hr	11,916 lb/hr	5,233 lb/hr	5,233 lb/hr	5,233 lb/hr
10,872 lb/hr	10,724 lb/hr	5,233 lb/hr	5,233 lb/hr	5,233 lb/hr
130.5 DTPD	128.7 DTPD	62.8 DTPD	62.8 DTPD	62.8 DTPD
7,382 lb/hr	7,234 lb/hr	1,743 lb/hr	1,743 lb/hr	0 lb/hr
33,294 lb/hr	1,192 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
24.62%	90.00%	100.00%	100.00%	100.00%
68%	67%	33.3%	33%	0%
148 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
88.3 gpm	23.8 gpm	10.5 gpm	10.5 gpm	10.5 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0 kW	3366.9 kW	1870.0 kW	66.3 kW	0.0 kW
0 MMBtu/hr	-47.41 MMBtu/hr	21.29 MMBtu/hr	26.12 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-47.41 MMBtu/hr	-26.12 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	30.72 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	30.72 MMBtu/hr	30.72 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	3.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day

S4 Output Summary	
Final TS, Wet (WT/D)	0
NG Req. (cfh)	12604
NG (LHV MMBtu/h)	11
Net heat (MMBtu/h)	9
Electricity Req. (kWh)	3668
Power Generation (kWh)	1886
Net Power (kWh)	-1782
No. of Trucks Required (trucks/day)	18
Digester Gas Produced (scfm)**	3502
Methane Produced (scfm)**	2101
Scrubbed Gas (scfm)**	746
Polymer Use (lb/day)	4344

Scenario 4 - TAD-Batch at West Point to Soil Blending, TAD-Batch at South Plant to direct Land App, and Brightwater with MAD and Off-site Composting

West Point

	Feedstock	Stabilization	Energy Recovery	Gas Utilization			Dewatering	End Use
								100% Off-Site Soil Blending
Dry Mass Flow	225860 PPD	Digester (Thermo)	HEX	CHP Engine 909 NG LHV	Boiler 909 NG LHV	Flare	Centrifuge	93568 PPD
TS	6.1%							28.5%
VS	81%							58%
VSR	68%							
Calorific Value	10,000 Btu/lb VS							
		VSR 68.0%					92% Capture	
							29% TS	
				Therm Eff. 36%	Therm Eff. 85%			
				Nat gas usage, cfh 0	Nat gas usage, cfh 0			
	Feedstock Type PS + WAS							End Use Off-Site Soil Blending
			Inlet Temperature 131 F	Biogas Fuel use 44%	Biogas Fuel use 10%			
			Outlet Temperature 100 F					
%								
		Sludge Inlet Temp 65 F	HEX Efficiency 70 %	Engine Electrical Eff. 34%				
		Operation Temp 131 F	3.24 MMBtu/hr	Heat Recovery 6.82 MMBtu/hr	Heat Recovery 2.16 MMBtu/hr			
		560 Btu/cf						
		15 cf/lb VS						
		10.18 MMBtu/hr						
	Energy Consumption 0 hp 90% Efficiency	Energy Consumption 40 hp 90% Efficiency	Energy Consumption 150 hp 90% Efficiency	Energy Consumption 145 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 225 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
		Shell Heat Loss 15%						
		Duty No. 5	Duty No. 1	Duty No. 2	Duty No. 2	Duty No. 2	Duty No. 4	
							Polymer Use 30 lbs/DT	
Wet Mass Flow	154,276 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	149,094 lb/hr	13,680 lb/hr	13,680 lb/hr
Dry Mass Flow	9,411 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	4,229 lb/hr	3,899 lb/hr	3,899 lb/hr
	112.9 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	50.7 DTPD	46.8 DTPD	46.8 DTPD
VS	7,620 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,439 lb/hr	2,248 lb/hr	2,248 lb/hr
Water	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	144,865 lb/hr	9,781 lb/hr	9,781 lb/hr
TS	6.10%	2.84%	2.84%	2.84%	2.84%	2.84%	28.50%	28.50%
VS	81%	58%	58%	58%	58%	58%	58%	58%
VSR	5,182 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Wet flow	308.3 gpm	297.9 gpm	297.9 gpm	297.9 gpm	297.9 gpm	297.9 gpm	27.3 gpm	27.3 gpm
Calorific Value	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
Electrical Demand	0.0 kW	165.8 kW	124.3 kW	239.7 kW	66.3 kW	0.0 kW	746.0 kW	0.0 kW
Unit Heat Bal.	0 MMBtu/hr	-11.71 MMBtu/hr	3.24 MMBtu/hr	6.82 MMBtu/hr	2.16 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Total Heat Bal.	0 MMBtu/hr	-11.71 MMBtu/hr	-8.47 MMBtu/hr	-1.66 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr	0.51 MMBtu/hr
Unit Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum. Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Unit Process Fuel Bal.	0 MMBtu/hr	43.53 MMBtu/hr	0.00 MMBtu/hr	-18.93 MMBtu/hr	-2.55 MMBtu/hr	-22.85 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum Unit Process Fuel Bal.	0 MMBtu/hr	43.53 MMBtu/hr	43.53 MMBtu/hr	24.59 MMBtu/hr	22.05 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Generated Steam	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Power Generation	0 MW	0.00 MW	0.00 MW	1.89 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
No of Trucks Required	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	6.00 trucks/day
Vehicle Fuel Consumption	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
Digester Gas Produced	0 scfm	1295 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Methane Production	0 scfm	777 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Methane Utilized	0 scfm	0 scfm	0 scfm	-338 scfm	-45 scfm	-394 scfm	0 scfm	0 scfm
Scrubbed Gas	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
Unit Polymer Use	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	1522 lb/day	0 lb/day

Off-site Soil Blending

	Feedstock	Feedstock	Feedstock	End Use
Dry Mass Flow	93568 PPD	45963 PPD	252634 PPD	392165 PPD
TS	28.5%	60.0%	95.0%	58.5%
VS	57.66%	95.00%	0.00%	25%
VSR		0.0%	0.0%	
Calorific Value	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	
Feedstock Type	Dewatered Cake	Sawdust	Fine Sand	End Use Local Retail
Energy Consumption	0 hp/unit 90% Efficiency	0 hp/unit 90% Efficiency	0 hp/unit 90% Efficiency	0 hp/unit 90% Efficiency
Wet Mass Flow	13,680 lb/hr	16,871 lb/hr	27,952 lb/hr	27,952 lb/hr
Dry Mass Flow	3,899 lb/hr	5,814 lb/hr	16,340 lb/hr	16,340 lb/hr
	46.8 DTPD	69.8 DTPD	196.1 DTPD	196.1 DTPD
VS	2,248 lb/hr	4,067 lb/hr	4,067 lb/hr	4,067 lb/hr
Water	9,781 lb/hr	11,058 lb/hr	11,612 lb/hr	11,612 lb/hr
TS	28.50%	34.46%	58.46%	58.46%
VS	58%	70%	25%	25%
VSR	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Wet flow	27.3 gpm	33.7 gpm	55.9 gpm	55.9 gpm
Calorific Value	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
Electrical Demand	0.0 kW	0.0 kW	0.0 kW	0.0 kW
Unit Heat Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Total Heat Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Unit Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum. Aux. Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Unit Process Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Cum Unit Process Fuel Bal.	0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
Generated Steam	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
Power Generation	0 MW	0.00 MW	0.00 MW	0.00 MW
No of Trucks Required	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day
Vehicle Fuel Consumption	0 gal/day	0 gal/day	0 gal/day	0 gal/day
Digester Gas Produced	0 scfm	0 scfm	0 scfm	0 scfm
Methane Production	0 scfm	0 scfm	0 scfm	0 scfm
Methane Utilized	0 scfm	0 scfm	0 scfm	0 scfm
Scrubbed Gas	0 scfm	0 scfm	0 scfm	0 scfm
Unit Polymer Use	0 lb/day	0 lb/day	0 lb/day	0 lb/day

South Plant

Feedstock	Stabilization	Energy Recovery	Gas Utilization					Dewatering	End Use
									100% Land Application
263760 PPD	Digester (Thermo)	HEX	CHP Engine	Boiler	Biogas Upgrading	Flare		Centrifuge	112794 PPD
6.2%			909 NG LHV	909 NG LHV					22.9%
85.88%									69%
64.0%									
10,000 Btu/lb VS								95% Capture	
	VSR 64.0%							23% TS	
			Therm Eff. 38%	Therm Eff. 85%					
Feedstock Type PS + WAS									End Use Land Application
			Nat gas usage, cfh 0	Nat gas usage, cfh 12,604	Nat gas usage, cfh 0				
		Inlet Temperature 131 F	Biogas Fuel use 0%	Biogas Fuel use 0%	Biogas Fuel use 85%				
		Outlet Temperature 100 F							
			Engine Electrical Eff. 30%						
	Sludge Inlet Temp 65 F	HEX Efficiency 70 %							
	Operation Temp 131 F	3.72 MMBtu/hr	Heat Recovery 0.00 MMBtu/hr	Heat Recovery 9.74 MMBtu/hr					
	560 Btu/cf								
	16.24 cf/lb VS								
	11.70 MMBtu/hr								
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 40 hp 90% Efficiency	Energy Consumption 150 hp 90% Efficiency	Energy Consumption 145 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 787 hp/unit 100% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency		Energy Consumption 225 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
	Shell Heat Loss 15%								
	Duty No. 4	Duty No. 1	Duty No. 0	Duty No. 2	Duty No. 1	Duty No. 2		Duty No. 4	
								Polymer Use 35 lbs/DT	
177,258 lb/hr	171,217 lb/hr	171,217 lb/hr	171,217 lb/hr	171,217 lb/hr	171,217 lb/hr	171,217 lb/hr		20,523 lb/hr	20,523 lb/hr
10,990 lb/hr	4,949 lb/hr	4,949 lb/hr	4,949 lb/hr	4,949 lb/hr	4,949 lb/hr	4,949 lb/hr		4,700 lb/hr	4,700 lb/hr
131.9 DTPD	59.4 DTPD	59.4 DTPD	59.4 DTPD	59.4 DTPD	59.4 DTPD	59.4 DTPD		56.4 DTPD	56.4 DTPD
9,439 lb/hr	3,398 lb/hr	3,398 lb/hr	3,398 lb/hr	3,398 lb/hr	3,398 lb/hr	3,398 lb/hr		3,227 lb/hr	3,227 lb/hr
166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr	166,268 lb/hr		15,823 lb/hr	15,823 lb/hr
6.20%	2.89%	2.89%	2.89%	2.89%	2.89%	2.89%		22.90%	22.90%
86%	69%	69%	69%	69%	69%	69%		69%	69%
6,041 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr		0 lb/hr	0 lb/hr
354.2 gpm	342.2 gpm	342.2 gpm	342.2 gpm	342.2 gpm	342.2 gpm	342.2 gpm		41.0 gpm	41.0 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS		10,000 Btu/lb VS	0.0 Btu/lb VS
0.0 kW	132.6 kW	124.3 kW	0.0 kW	66.3 kW	586.8 kW	0.0 kW		746.0 kW	0.0 kW
0 MMBtu/hr	-13.45 MMBtu/hr	3.72 MMBtu/hr	0.00 MMBtu/hr	9.74 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-13.45 MMBtu/hr	-9.74 MMBtu/hr	-9.74 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	11.46 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	11.46 MMBtu/hr	11.46 MMBtu/hr	11.46 MMBtu/hr		11.46 MMBtu/hr	11.46 MMBtu/hr
0 MMBtu/hr	54.94 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	-46.42 MMBtu/hr	-8.52 MMBtu/hr		0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	54.94 MMBtu/hr	54.94 MMBtu/hr	54.94 MMBtu/hr	54.94 MMBtu/hr	8.52 MMBtu/hr	0.00 MMBtu/hr		0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr		0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW		0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day		0.00 trucks/day	8.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day		0 gal/day	0 gal/day
0 scfm	1635 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm		0 scfm	0 scfm
0 scfm	981 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm		0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	-829 scfm	-152 scfm		0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	746 scfm	0 scfm		0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day		2079 lb/day	0 lb/day

Brightwater

Feedstock	Stabilization	Gas Utilization		Dewatering	End Use
93910 PPD	Digester (Meso)	Boiler	Flare	Centrifuge	100% Land Application
5.8%		909 NG LHV			39295 PPD
90%					20.0%
61%					78%
10,000 Btu/lb VS				93% Capture	
	VSR 60.9%			20% TS	
		Therm Eff. 85%			
Feedstock Type PS + WAS		Nat gas usage, cfh 0			End Use Land Application
		Biogas Fuel use 70%			
	Sludge Inlet Temp 65 F	Heat Recovery 11.22 MMBtu/hr			
	Operation Temp 98 F				
	550 Btu/cf				
	16 cf/lb VS				
	2.23 MMBtu/hr				
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 40 hp/unit 100% Efficiency	Energy Consumption 40 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 200 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
	Shell Heat Loss 15%				
	Duty No. 3	Duty No. 1	Duty No. 1	Duty No. 2	
				Polymer Use 35 lbs/DT	

Feedstock	Stabilization	Gas Utilization		Dewatering	End Use
67,464 lb/hr	65,321 lb/hr	65,321 lb/hr	65,321 lb/hr	8,186 lb/hr	8,186 lb/hr
3,913 lb/hr	1,770 lb/hr	1,770 lb/hr	1,770 lb/hr	1,637 lb/hr	1,637 lb/hr
47.0 DTPD	21.2 DTPD	21.2 DTPD	21.2 DTPD	19.6 DTPD	19.6 DTPD
3,517 lb/hr	1,374 lb/hr	1,374 lb/hr	1,374 lb/hr	1,271 lb/hr	1,271 lb/hr
63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	63,551 lb/hr	6,549 lb/hr	6,549 lb/hr
5.80%	2.71%	2.71%	2.71%	20.00%	20.00%
90%	78%	78%	78%	78%	78%
2,143 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
134.8 gpm	130.5 gpm	130.5 gpm	130.5 gpm	16.4 gpm	16.4 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0 kW	89.5 kW	33.2 kW	0.0 kW	331.6 kW	0.0 kW
0 MMBtu/hr	-2.56 MMBtu/hr	11.22 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	-2.56 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr	8.66 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	-13.20 MMBtu/hr	-5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	18.86 MMBtu/hr	5.66 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	4.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	571 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	343 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	-240 scfm	-103 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	743 lb/day	0 lb/day

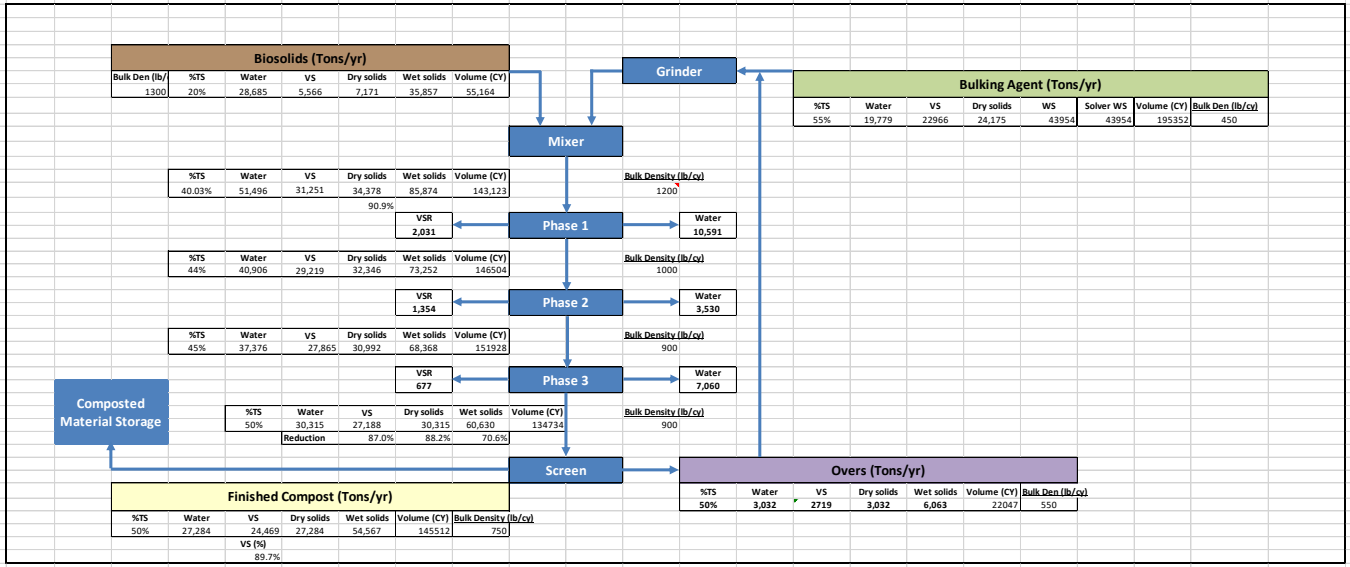
Off-site Composting

Feedstock	Feedstock	Feedstock	Stabilization	End Use
39295 PPD	132465 PPD	16611 PPD	Compost	162685 PPD
20.0%	55.0%	55.0%		50.0%
77.61%	95.00%	89.68%		89%
15.0%	15.0%	15.0%		
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS		
			50% TS	
			VSR 15.0%	
Feedstock Type Dewatered Cake	Feedstock Type Virgin Woodchips	Feedstock Type Screened Overs		End Use Local Retail
Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency	Energy Consumption 260 hp 90% Efficiency	Energy Consumption 0 hp/unit 90% Efficiency
			Duty No. 1	

Feedstock	Feedstock	Feedstock	Stabilization	End Use
8,186 lb/hr	18,222 lb/hr	19,480 lb/hr	13,557 lb/hr	13,557 lb/hr
1,637 lb/hr	7,157 lb/hr	7,849 lb/hr	6,779 lb/hr	6,779 lb/hr
19.6 DTPD	85.9 DTPD	94.2 DTPD	81.3 DTPD	81.3 DTPD
1,271 lb/hr	6,514 lb/hr	7,135 lb/hr	6,065 lb/hr	6,065 lb/hr
6,549 lb/hr	11,065 lb/hr	11,631 lb/hr	6,779 lb/hr	6,779 lb/hr
20.00%	39.28%	40.29%	50.00%	50.00%
78%	91%	91%	89%	89%
191 lb/hr	977 lb/hr	1,070 lb/hr	0 lb/hr	0 lb/hr
16.4 gpm	36.4 gpm	38.9 gpm	27.1 gpm	27.1 gpm
10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	10,000 Btu/lb VS	0.0 Btu/lb VS
0.0 kW	0.0 kW	0.0 kW	215.5 kW	0.0 kW
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr	0.00 MMBtu/hr
0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr	0 lb/hr
0 MW	0.00 MW	0.00 MW	0.00 MW	0.00 MW
0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day	0.00 trucks/day
0 gal/day	0 gal/day	0 gal/day	0 gal/day	0 gal/day
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 scfm	0 scfm	0 scfm	0 scfm	0 scfm
0 lb/day	0 lb/day	0 lb/day	0 lb/day	0 lb/day

KC Brightwater Biosolids Production

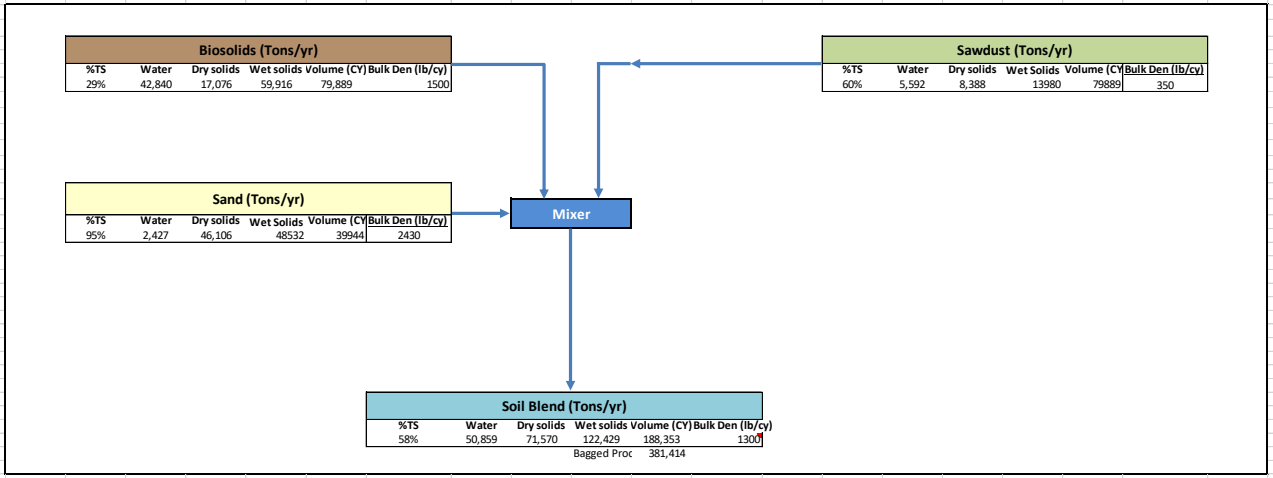
Dry Tons per Year	7,171
%TS	20%
Operation	
Days per Week	5
Hours per Day	8
Feedstock Characteristics	
Biosolids Bulk Density (lb/CY)	1300
Biosolids VS	78%
Bulking Agent Bulk Density (lb/CY)	350
Bulking Agent %TS	55%
Bulking Agent %VS	95%
Screened Overs %TS	60%
Screened Overs %VS	89.7%
Screened Overs Bulk Density (lb/CY)	800
Aerated Static Pile Parameters	
Bulk to Biosolids Ratio (V:V)	3.9
Bulk to Biosolids Ratio (M:M)	1.2
Assumed total solids loss thru phases 1 and 2	8%
Curing loss thru phase 3	5%
Compost Mixture %TS	40%
Screen %TS Requirement	55%
Screenings Recycled	10%
Final Compost %TS	50%
Final Compost Parameters	
Carbon of Biosolids	25.3%
Nitrogen of Biosolids	3.0%
Carbon of Woodchips	45.0%
Nitrogen of Woodchips	0.8%
Carbon of Yardwaste	44.5%
Nitrogen of Yardwaste	2.0%
Carbon of Recycle	25%
Nitrogen of Recycle	1.00%
Carbon:Nitrogen	31.5
Retail Bags Capacity (CF)	2
Percent to Bagging	15%



Equipment Sizing							
Equipment	**Manufacturer**	**Capacity (CF/batch)**	**Real Capacity (CY/batch)**	**Batches per Hour**	**Throughput (CY/Day)**	**Required Volume Mixed (CY/Day)**	**Number of Equipment (N+1)**
Vertical Mixer	ECS/Lucknow 2295	1100	28.5	4	798.5	550	2
Equipment	**Manufacturer**	**Capacity (CF/hr)**	**Real Capacity (CY/hr)**	**Batches per Hour**	**Throughput (CY/Day)**	**Required Throughput (CY/Day)**	**Number of Equipment**
Screen	MultiStar L3 Type	8825	261	N/A	1830	518	1
Equipment	**Manufacturer**	**Capacity (CF/bag)**	**Real Capacity (CF/bag)**	**Bags per Hour**	**Throughput (Bags/Day)**	**Required Throughput (Bags/Day)**	**Number of Equipment**
Bagging Equipment	RotoChopper Go-Bagger 250	2	2	250	1750	1133	1

KC WP Soil Blending

Dry Tons per Year	17,076
Operation	
Days per Week	5
Hours per Day	8
Feedstock Characteristics	
Biosolids Bulk Density (lb/CY)	1500
%TS	29%
Sawdust Bulk Density (lb/CY)	350
Bulking Agent %TS	60%
Sand Density (lb/CY)	2430
Sand %TS	95.0%
Soil Blend	
Biosolids: Sawdust: Sand (V:V:V)	40:40:25
Retail Bags Capacity (CF)	2
Percent to Bagging	15%



Equipment Sizing

Equipment	Manufacturer	Capacity (CF/batch)	Real Capacity (CY/batch	Batches per Hour	Throughput (CY/Day)	Required Volume Mixed (CY/Day)	Number of Equipment (N+1)	
Horizontal Mixer	RotoMix 1220-20	1220	31.6	4	885.6	768	2	
Equipment	**Manufacturer**	**Capacity (CF/hr)**	**Real Capacity (CY/hr)**	**Batches per Hour**	**Throughput (CY/Day)**	**Required Throughput (CY/Day)**	**Number of Equipment**	
Screen	MultiStar L3 Type	8825	261	N/A	1830	724	1	Compost Screener can be used as redundant unit
Equipment	**Manufacturer**	**Capacity (CF/bag)**	**Real Capacity (CF/bag)**	**Bags per Hour**	**Throughput (Bags/Day**	**Required Throughput (Bags/Day)**	**Number of Equipment**	
Bagging Equipment	RotoChopper Go-Bagger 250	2	2	250	1750	1467	1	

Biochar Carbon Sequestration

$$22{,}920\frac{DT}{yr}Biochar\ \times 28.6\%\ Carbon = 6{,}555\frac{tons}{yr}carbon$$

$$6{,}555\frac{tons}{yr}carbon\ \times 90\%\ Fixed = 5{,}900\frac{tons}{yr}fixed\ carbon$$

$$5{,}900\frac{tons}{yr}fixed\ carbon \times 907\frac{kg}{ton} = 5{,}352{,}006\frac{kg}{yr}fixed\ carbon$$

$$5{,}352{,}006\frac{kg}{yr}fixed\ carbon \times \frac{44\ CO_2}{12\ C} = 19{,}624{,}023\ \frac{kg\ CO_2e}{yr}$$

$$\frac{19{,}624{,}023\ \frac{kg\ CO_2e}{yr}}{21{,}017{,}640\frac{kg\ biochar}{yr}} = 0.9337\ \frac{kg\ CO_2e}{kg\ biochar}$$

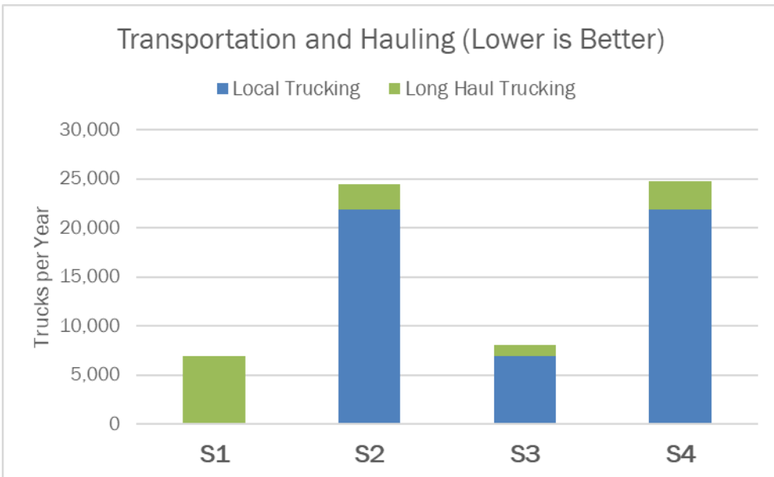
Attachment B: Solids-Water-Energy Evaluation Tool Results

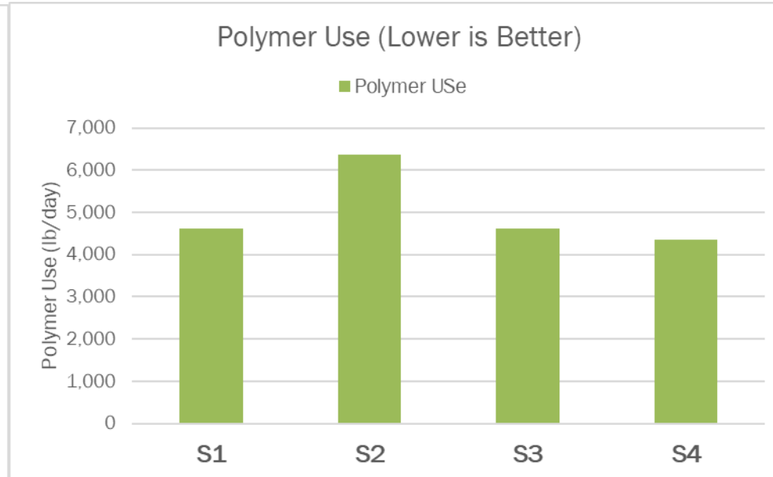
Scenario	Facility	Stabilization	Dewatering	Post Dewatering	Biosolids Classification	End-Use
Scenario 1	West Point	MAD	Centrifuge	-	Class B	Land Application West/East WA
	South Plant	MAD				
	Brightwater	MAD				
Scenario 2	West Point	TAD-Batch	Centrifuge	Composting	Class A	Local Retail
	South Plant	THP-MAD		-		Land Application West/East WA
	Brightwater	MAD		Soil Blending		Local Retail
Scenario 3	West Point	MAD	Centrifuge	Pyrolysis	Unknown (Potential Class A)	Regional Retail
	South Plant	MAD				
	Brightwater	MAD				
Scenario 4	West Point	TAD-Batch	Centrifuge	Composting	Class A	Local Retail
	South Plant	TAD-Batch		-		Land Application West/East WA
	Brightwater	MAD		Soil Blending		Local Retail

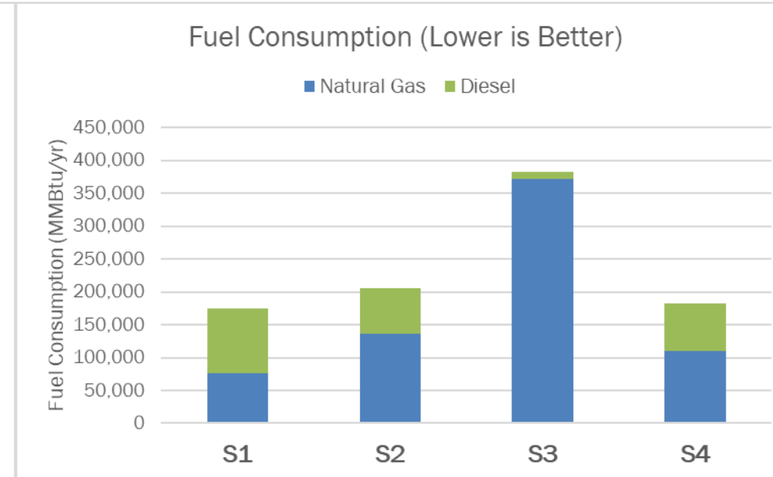
Parameter	S1	S2	S3	S4
Final Product, Wet (WT/d)	539	689	63	744
Trucks Required (Trucks/d)	19	67	22	68
Vehicle Fuel Consumption (gal/day)	1952	1360	104	1445
Electricity Demand (MWh/d)	75	101	203	85
Electricity Generation (MWh/d)	-42	-45	-42	-45
Net Power (MWh/d)*	33	56	160	40
Natural Gas Consumption (scfm)	145	260	708	210
Digester Gas Produced (scfm)	3325	3419	3325	3502
Methane Injected into Pipeline (scfm)	778	787	778	829
Polymer Use (lb/day)	4611	6359	4611	4344

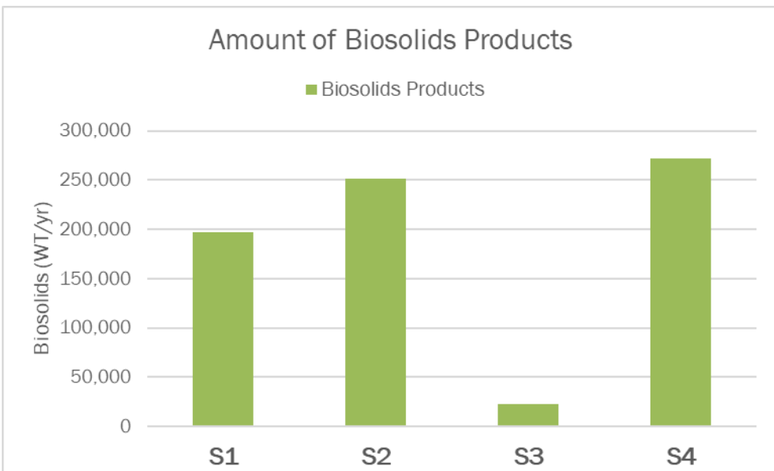
Fuel Consumption	S1	S2	S3	S4
Natural Gas (SCF/yr)	76,267,424	136,752,625	372,349,651	110,410,948
Natural Gas (MMBtu/yr)	76,267	136,753	372,350	110,411
Diesel (gal/yr)	712,453	496,321	77,773	527,438
Diesel (MMBtu/yr)	97,877	68,185	10,685	72,460
Total MMBtu/yr	174,145	204,938	383,034	182,871

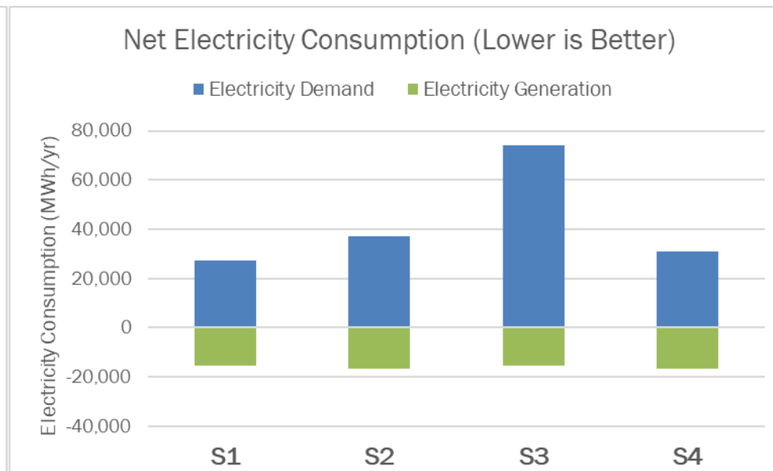
Hauling and Trucking	S1	S2	S3	S4
Local Trucking	0	21,855	6,935	21,855
Long Haul Trucking	6,935	2,555	1,095	2,920


Transportation and Hauling (Lower is Better)
Local Trucking
Long Haul Trucking
Trucks per Year
30,000
25,000
20,000
15,000
10,000
5,000
0
S1
S2
S3
S4


Polymer Use (Lower is Better)
Polymer USe
Polymer Use (lb/day)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
S1
S2
S3
S4


Fuel Consumption (Lower is Better)
Natural Gas
Diesel
Fuel Consumption (MMBtu/yr)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
S1
S2
S3
S4


Amount of Biosolids Products
Biosolids Products
Biosolids (WT/yr)
300,000
250,000
200,000
150,000
100,000
50,000
0
S1
S2
S3
S4


Net Electricity Consumption (Lower is Better)
Electricity Demand
Electricity Generation
Electricity Consumption (MWh/yr)
80,000
60,000
40,000
20,000
0
-20,000
-40,000
S1
S2
S3
S4

Performance Summary				Notes	1	2	3	
Solids Flows and Loads					100% Class B application with MAD at all three plants	TAD-Batch , Cambi, and Off-site Soilblending or Composting	Off-site Pyrolysis	TAD-Batch and Off-site Soil blending or Composting
Element					S1	S2	S3	S4
West Point Treatment plant								
	Solids Loading and Flows							
		PS + WAS	Average Digester Feed Load, dry lbs TS/hr		9,410.8	9,410.8	9,410.8	9,410.8
		PS + WAS	Average Digester Feed Load, %TS		6.1%	6.1%	6.1%	6%
		PS + WAS	Average Digester Feed Load, %VS		81.0%	81.0%	81.0%	81%
	Stabilization							
		Digester	Type		MAD	TAD-BATCH	MAD	TAD-BATCH
		Digester	Biogas Production, mmbtu/hr		40.6	43.5	40.6	44
		Digester	Biogas Production, SCFM		1,219.5	1,295.5	1,219.5	1295
		Digester	Methane Production, SCFM		731.7	777.3	731.7	777
	Gas Utilization							
		Cogen	Biogas Utilization, mmbtu/hr		-17.7	-18.9	-17.7	-18.9
		Cogen	Methane Utilization, SCFM		-318.3	-338.1	-318.3	-338.1
		Boiler	Biogas Utilization, mmbtu/hr		-2.4	-2.5	-2.4	-2.5
		Boiler	Methane Utilization, SCFM		-42.8	-45.5	-42.8	-45.5
		Boiler	NG Utilization, mmbtu/hr		0.0	0.0	0.0	0.0
		Boiler	NG Utilization, SCFM		0.0	0.0	0.0	0.0
		Gas Upgrading	Biogas Utilization, mmbtu/hr		0.0	0.0	0.0	0.0
		Gas Upgrading	Methane Utilization, SCFM		0.0	0.0	0.0	0.0
		Flare	Biogas Utilization, mmbtu/hr		-20.6	-22.0	-20.6	-22.0
		Flare	Methane Utilization, SCFM		-370.6	-393.7	-370.6	-393.7
	Thermal Supply							
		Heat Exchanger	Thermal Energy Production, mmbtu/hr		0.0	3.2	0.0	3.2
		Cogen	Thermal Energy Production, mmbtu/hr		6.4	6.8	6.4	6.8
		Boiler (biogas)	Thermal Energy Production, mmbtu/hr		2.0	2.2	2.0	2.2
		Boiler (NG)	Thermal Energy Production, mmbtu/hr		0.0	0.0	0.0	0.0
		Subtotal	Thermal Energy Production, mmbtu/yr		73,395.0	107,014.1	73,395.0	107014.1
	Thermal Demand							
		Digester	Thermal Energy Demand, mmbtu/hr		-5.9	-11.7	-5.9	-11.7
		Thermal Hydrolysis	Thermal Energy Demand, mmbtu/hr		0.0	0.0	0.0	0.0
		Pyrolysis	Thermal Energy Demand, mmbtu/hr		0.0	0.0	0.0	0.0
		Subtotal	Thermal Energy Demand, mmbtu/yr		-51,287.8	-102,575.6	-51,287.8	-102575.6
	Total Thermal Balance							
		Solids Treatment	Thermal Energy Total, mmbtu/yr		22,107.2	4,438.5	22,107.2	4,438.5
	Electricity Consumption							
		Digestion	Electricity Load, kW		-149.2	-165.8	-149.2	-165.8
		Heat Exchanger	Electricity Load, kW		0.0	-124.3	0.0	-124.3
		CHP	Parasitic Loads, kW		-239.7	-239.7	-239.7	-239.7
		Boiler	Parasitic loads, kW		-66.3	-66.3	-66.3	-66.3
		Gas Upgrading	Parasitic loads, kW		0.0	1.0	0.0	1.0
		Flare	Parasitic loads, kW		0.0	0.0	0.0	0.0

		Dewatering	Electricity Load, kW		-746.0	-746.0	-746.0	-746.0
		Subtotal	Electricity Load, MWh/yr		-10,522.8	-11,748.5	-10,522.8	-11,748.5
	Electricity Production							
		CHP	Electricity Production, kW		1,759.7	1,886.3	1,759.7	1,886.3
		CHP	Electricity Production, MWh/yr		15,415.3	16,523.7	15,415.3	16,523.7
	Total Electricity Balance							
		Solids Treatment	Electricity Total, MWh/yr		-10,522.8	-11,748.5	-10,522.8	-11,748.5
		Solids Treatment	Electricity Export, kWh/yr		15,415.3	16,523.7	15,415.3	16,523.7
		Solids Treatment	Electricity Import, kWh/yr		10,522.8	11,748.5	10,522.8	11,748.5
	Chemical Usage							
		Dewatering	Polymer Use, lb per year		595,636.8	555,684.0	595,636.8	555,684.0
	Hauled Solids							
		Hauling	Average Hauled, wet tons/yr		64,224.3	59,916.4	64,224.3	59,916.4
		Hauling	Dry Solids, %		28.5%	28.5%	28.5%	
		Hauling	Trucks per Day		6.0	6.0	6.0	
		Hauling	Trucks per Year		2,190.0	2,190.0	2,190.0	2,190.0
South Treatment Plant								
	Solids Loading and Flows							
		PS + WAS	Average Digester Feed Load, dry lbs TS/hr		10,990.0	10,990.0	10,990.0	10,990.0
		PS + WAS	Average Digester Feed Load, %TS		6.2%	6.2%	6.2%	6.2%
		PS + WAS	Average Digester Feed Load, %VS		85.9%	85.9%	85.9%	85.9%
	Stabilization							
		Digester	Type		MAD	THP-MAD	MAD	TAD-Batch
		Digester	Biogas Production, mmbtu/hr		50.6	51.2	50.6	54.94
		Digester	Biogas Production, SCFM		1,533.6	1,552.3	1,533.6	1,635.04
		Digester	Methane Production, SCFM		920.2	931.4	920.2	981.03
	Gas Utilization							
		Cogen	Biogas Utilization, mmbtu/hr		0.0	0.0	0.0	0.0
		Cogen	Methane Utilization, SCFM		0.0	0.0	0.0	0.0
		Boiler	Biogas Utilization, mmbtu/hr		0.0	0.0	0.0	0.0
		Boiler	Methane Utilization, SCFM		0.0	0.0	0.0	0.0
		Boiler	NG Utilization, mmbtu/hr		-7.9	-14.2	-7.9	-11.5
		Boiler	NG Utilization, SCFM		-145.1	-260.2	-145.1	-210.1
		Gas Upgrading	Biogas Utilization, mmbtu/hr		-42.8	-43.3	-42.8	-46.4
		Gas Upgrading	Methane Utilization, SCFM		-777.5	-787.0	-777.5	-829.0
		Flare	Biogas Utilization, mmbtu/hr		-7.8	-7.9	-7.8	-8.5
		Flare	Methane Utilization, SCFM		-142.6	-144.4	-142.6	-152.1
	Thermal Supply							
		Cogen	Thermal Energy Production, mmbtu/hr		0.0	0.0	0.0	0
		Boiler (Biogas)	Thermal Energy Production, mmbtu/hr		0.0	0.0	0.0	0.0
		Boiler (NG)	Thermal Energy Production, mmbtu/hr		6.7	12.1	6.7	9.7
		Subtotal	Thermal Energy Production, mmbtu/yr		58,928.0	105,661.9	58,928.0	85,309.0
	Thermal Demand							

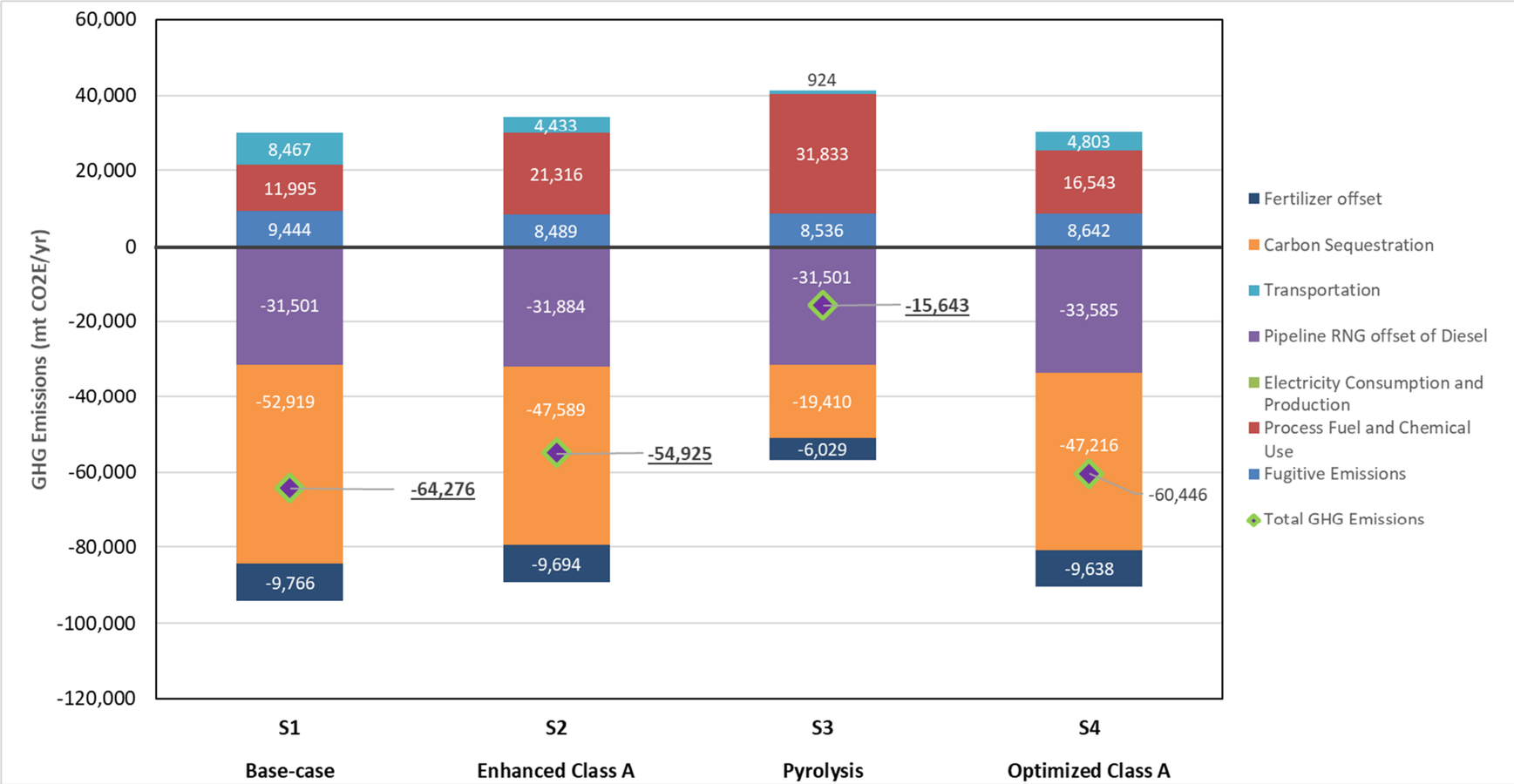
		Digester	Thermal Energy Demand, mmbtu/hr		-6.7	0.0	-6.7	-13.5
		Thermal Hydrolysis	Thermal Energy Demand, mmbtu/hr		0.0	-12.1	0.0	0.0
		Subtotal	Thermal Energy Demand, mmbtu/yr		-58,928.0	-105,662.0	-58,928.0	-117,856.1
	Total Thermal Balance							
		Solids Treatment	Thermal Energy Total, mmbtu/yr		0.0	0.0	0.0	-32,547.0
	Electricity Consumption							
		Digestion	Electricity Load, kW		-119.4	-119.4	-119.4	-133
		THP	Electricity Load, kW		0.0	-223.8	0.0	0
		CHP	Electricity Load, kW		0.0	0.0	0.0	0
		Boiler	Electricity Load, kW		-66.3	-66.3	-66.3	-66
		Gas Upgrading	Electricity Load, kW		-550.4	-557.1	-550.4	-587
		Flare	Electricity Load, kW		0.0	0.0	0.0	0
		Predewatering	Electricity Load, kW		0.0	-497.3	0.0	0
		Dewatering	Electricity Load, kW		-746.0	-746.0	-746.0	-746
		Subtotal	Electricity Load, MWh/yr		-12,983.2	-19,358.9	-12,983.2	-13,418.2
	Electricity Production							
		CHP	Electricity Production, kW		0.0	0.0	0.0	0
		CHP	Electricity Production, MWh/yr		0.0	0.0	0.0	0.0
	Total Electricity Balance							
		Solids Treatment	Electricity Total, MWh/yr		-12,983.2	-19,358.9	-12,983.2	-13,418.2
		Solids Treatment	Electricity Export, kWh/yr		0.0	0.0	0.0	1.0
		Solids Treatment	Electricity Import, kWh/yr		12,983.2	19,358.9	12,983.2	13,418.2
	Process Water Usage							
		THP	Dilution Water, MG/yr		0.0	57.1	0.0	0
	Chemical Usage							
		Predewatering	Polymer Use, lb per year		0.0	722,043.0	0.0	0
		Dewatering	Polymer Use, lb per year		816,156.7	771,898.5	816,156.7	758,712
	Hauled Solids							
		Hauling	Average Hauled, wet tons/yr		96,696.5	69,809.0	96,696.5	89,891
		Hauling	Dry Solids, %		22.9%	30.0%	22.9%	22.9%
		Hauling	Trucks per Day		9.0	7.0	9.0	8
		Hauling	Trucks per Year		3,285.0	2,555.0	3,285.0	2,920.0
Brightwater Treatment Plant								
	Solids Loading and Flows							
		PS + WAS	Average Digester Feed Load, dry lbs TS/hr		3,912.9	3,912.9	3,912.9	3,912.9
		PS + WAS	Average Digester Feed Load, %TS		5.8%	5.8%	5.8%	5.8%
		PS + WAS	Average Digester Feed Load, %VS		89.9%	89.9%	89.9%	89.9%
	Stabilization							
		Digester	Type		MAD	MAD	MAD	MAD
		Digester	Biogas Production, mmbtu/hr		18.9	18.9	18.9	18.9
		Digester	Biogas Production, SCFM		571.5	571.5	571.5	571.5
		Digester	Methane Production, SCFM		342.9	342.9	342.9	342.9

	Gas Utilization						
		Cogen	Biogas Utilization, mmbtu/hr	0.0	0.0	0.0	0.0
		Cogen	Methane Utilization, SCFM	0.0	0.0	0.0	0.0
		Boiler	Biogas Utilization, mmbtu/hr	-13.2	-13.2	-13.2	-13.2
		Boiler	Methane Utilization, SCFM	-240.0	-240.0	-240.0	-240.0
		Gas Upgrading	Biogas Utilization, mmbtu/hr	0.0	0.0	0.0	0.0
		Gas Upgrading	Methane Utilization, SCFM	0.0	0.0	0.0	0.0
		Flare	Biogas Utilization, mmbtu/hr	-5.7	-5.7	-5.7	-5.7
		Flare	Methane Utilization, SCFM	-102.9	-102.9	-102.9	-102.9
	Thermal Supply						
		Cogen	Thermal Energy Production, mmbtu/hr	0.0	0.0	0.0	0.0
		Boiler	Thermal Energy Production, mmbtu/hr	11.2	11.2	11.2	11.2
		Subtotal	Thermal Energy Production, mmbtu/yr	98,296.4	98,296.4	98,296.4	98,296.4
	Thermal Demand						
		Digester	Thermal Energy Demand, mmbtu/hr	-2.6	-2.6	-2.6	-2.6
		Thermal Hydrolysis	Thermal Energy Demand, mmbtu/hr	0.0	0.0	0.0	0.0
		Pyrolysis	Thermal Energy Demand, mmbtu/hr	0.0	0.0	0.0	0.0
		Subtotal	Thermal Energy Demand, mmbtu/yr	-22,427.9	-22,427.9	-22,427.9	-22,427.9
	Total Thermal Balance						
		Solids Treatment	Thermal Energy Total, mmbtu/yr	75,868.5	75,868.5	75,868.5	75,868.5
	Electricity Consumption						
		Digestion	Electricity Load, kW	-89.5	-89.5	-89.5	-89.5
		CHP	Electricity Load, kW	0.0	0.0	0.0	0.0
		Boiler	Electricity Load, kW	-33.2	-33.2	-33.2	-33.2
		Gas Upgrading	Electricity Load, kW	0.0	0.0	0.0	0.0
		Flare	Electricity Load, kW	0.0	0.0	0.0	0.0
		Dewatering	Electricity Load, kW	-331.6	-331.6	-331.6	-331.6
		Subtotal	Electricity Load, MWh/yr	-3,979.1	-3,979.1	-3,979.1	-3,979.1
	Electricity Production						
		CHP	Electricity Production, kW	0.0	0.0	0.0	0.0
		CHP	Electricity Production, MWh/yr	0.0	0.0	0.0	0.0
	Total Electricity Balance						
		Solids Treatment	Electricity Total, MWh/yr	-3,979.1	-3,979.1	-3,979.1	-3,979.1
		Solids Treatment	Electricity Export, kWh/yr	0.0	0.0	0.0	0.0
		Solids Treatment	Electricity Import, kWh/yr	3,979.1	3,979.1	3,979.1	3,979.1
	Chemical Usage						
		Predewatering	Polymer Use, lb per year	0.0	0.0	0.0	0.0
		Dewatering	Polymer Use, lb per year	271,319.5	271,319.5	271,319.5	271,319.5
	Hauled Solids						
		Hauling	Average Hauled, wet tons/yr	35,856.8	35,856.8	35,856.8	35,856.8
		Hauling	Dry Solids, %	20.0%	20.0%	20.0%	20%
		Hauling	Trucks per Day	4.0	4.0	4.0	4.0
		Hauling	Trucks per Year	1,460.0	1,460.0	1,460.0	1,460.0
Off-Site Composting (Brightwater Solids)							

	Solids Loading and Flows							
		Dewatered Cake	Average Load, dry lbs TS/hr			1,637		1,637
		Dewatered Cake	Average Load, %TS			20.0%		20%
		Dewatered Cake	Average, %VS			77.6%		78%
		Woodchips	Average Load, dry lbs TS/hr			5,519		5,519
		Woodchips	Average Load, %TS			55.0%		55%
		Woodchips	Average, %VS			95.0%		95%
		Screened Overs	Average Load, dry lbs TS/hr			692		692
		Screened Overs	Average Load, %TS			55.0%		55%
		Screened Overs	Average, %VS			89.7%		90%
		Feed Mixture	Average Load, dry lbs TS/hr			7849		7,849
		Feed Mixture	Average Load, %TS			40.3%		40%
		Feed Mixture	Average, %VS			90.9%		91%
	Electricity Consumption							
		Composting	Electricity Load, kW			-216		-216
	Fuel Consumption							
		Composting	Fuel Consumption (Diesel), gal/day			274		274
	Hauling and Transportation							
		Composting	Finished Compost, wet tons/yr			59,380		59,380
		Composting	Dry Solids, %			50%		50%
		Composting	Finished Compost, CY/yr			145,512		145,512
		Commercial	Compost, wet tons/yr			41,566		41,566
		Residential	Compost, wet tons/yr			5,938		5,938
		Donated	Compost, wet tons/yr			11,876		11,876
Off-Site Soil Blending (West Point Solids)								
	Solids Loading and Flows							
		Dewatered Cake	Average Load, dry lbs TS/hr			3,899		3,899
		Dewatered Cake	Average Load, %TS			28.5%		29%
		Dewatered Cake	Average, %VS			57.7%		58%
		Sawdust	Average Load, dry lbs TS/hr			1,915		1,915
		Sawdust	Average Load, %TS			60.0%		60%
		Sawdust	Average, %VS			95.0%		95%
		Fine Sand	Average Load, dry lbs TS/hr			10,526		10,526
		Fine Sand	Average Load, %TS			95.0%		95%
		Fine Sand	Average, %VS			0.0%		0%
	Electricity Consumption							
		Soil Blending	Electricity Load, kW			0		0
	Fuel Consumption							
		Soil Blending	Fuel Consumption (Diesel), gal/day			234		234
	Hauling and Transportation							
		Soil Blending	Blended product, wet tons/yr			122,429		122,429
		Soil Blending	Dry Solids, %			58%		58%
		Soil Blending	Blended product, CY/yr			188,353		188,353

		Commercial	Blended product, wet tons/yr			85,700		85,700
		Residential	Blended product, wet tons/yr			24,486		24,486
		Donated	Blended product, wet tons/yr			12,243		12,243
Off-Site Thermal Drying and Pyrolysis								
	Solids Loading and Flows							
		Dewatered Cake	Average Load, dry lbs TS/hr				10,872	
		Dewatered Cake	Average Load, WT/yr				193,448	
		Dewatered Cake	Average Load, %TS				24.6%	
		Dewatered Cake	Average, %VS				67.90%	
	Electricity Consumption							
		Boiler	Electricity Load, kW				66	
		Thermal Drying	Electricity Load, kW				3,367	
		Pyrolysis	Electricity Load, kW				1,870	
		Subtotal	Electricity Load, MWh/yr				46,456.3	
	Thermal Supply							
		Boiler	NG Utilization, mmbtu/hr				30.72	
		Boiler	NG Utilization, SCFM				563	
		Boiler	Thermal Energy Production, mmbtu/hr				26.12	
		Thermal Drying	Thermal Energy Production, mmbtu/hr				0	
		Pyrolysis	Thermal Energy Production, mmbtu/hr				21	
		Subtotal	Thermal Energy Production, mmbtu/yr				415,294	
	Thermal Demand							
		Thermal Drying	Thermal Energy Demand, mmbtu/hr				-47	
		Pyrolysis	Thermal Energy Demand, mmbtu/hr				0	
		Subtotal	Thermal Energy Demand, mmbtu/yr				-415,295	
	Total Thermal Balance							
		Solids Treatment	Thermal Energy Total, mmbtu/yr				-0.2	
	Hauling and Transportation							
		Hauling	Average Hauled, wet tons/yr				22,920.1	
		Hauling	Dry Solids, %				100.0%	
		Hauling	Solids Reduction				51.9%	
		Hauling	Trucks per Day				3.0	
		Hauling	Trucks per Year				1,095.0	

GHG Emission Category	Emission Type	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Scope 1	Fugitive Emissions [SC1FST]	9,444	8,489	8,536	8,642
	Fuel Combustion (Boilers, Machines) [SC1NGST, SC1MST]	4,042	9,452	19,735	8,055
	Subtotal	**13,486**	**17,941**	**28,270**	**16,697**
	Subtotal (Check)	13,486	17,941	28,270	16,697
Scope 2	Electricity Usage [SC2E]	104	112	104	112
	Electricity Exported [SC2EC]	-100	-107	-100	-107
	Subtotal	**4**	**4**	**4**	**4**
	Subtotal (Check)	4	4	4	4
Scope 3	Polymer Consumption [SC3PST]	6,885	9,949	6,885	6,942
	Fertilizer Offset [SC3FCST]	-9,766	-9,694	-6,029	-9,638
	Carbon Sequestration [SC3CCST]	-52,919	-47,589	-19,410	-47,216
	Natural Gas Use (Production) [SC3NGST]	1,068	1,915	5,213	1,546
	Pipeline RNG [SC3BGST]	-31,501	-31,884	-31,501	-33,585
	Hauling, Transportation, Application [SC3TST]	8,467	4,433	924	4,803
	Subtotal	**-77,765**	**-72,871**	**-43,917**	**-77,148**
	Subtotal (Check)	-77,765	-72,871	-43,917	-77,148
	Total	**-64,276**	**-54,925**	**-15,643**	**-60,446**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GHG Emissions (mt CO2E/yr)
8,467
11,995
9,444
-31,501
-52,919
-9,766
-64,276
4,433
21,316
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-31,884
-47,589
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-31,501
-19,410
-6,029
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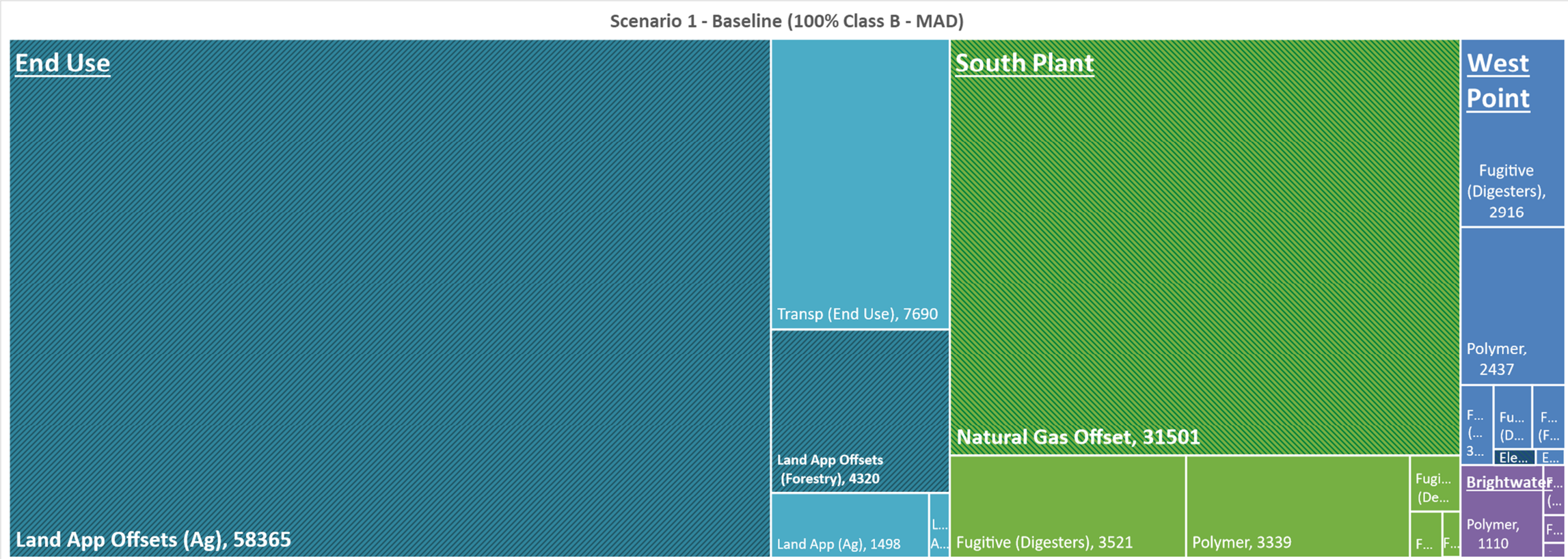
8,642
-33,585
-47,216
-9,638
-60,446
S1
Base-case
S2
Enhanced Class A
S3
Pyrolysis
S4
Optimized Class A
Fertilizer offset
Carbon Sequestration
Transportation
Pipeline RNG offset of Diesel
Electricity Consumption and Production
Process Fuel and Chemical Use
Fugitive Emissions
Total GHG Emissions


Scenario 1 - Baseline (100% Class B - MAD)
End Use
Land App Offsets (Ag), 58365
Transp (End Use), 7690
Land App Offsets (Forestry), 4320
Land App (Ag), 1498
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South Plant
Natural Gas Offset, 31501
Fugitive (Digesters), 3521
Polymer, 3339
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West Point
Fugitive (Digesters), 2916
Polymer, 2437
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Polymer, 1110
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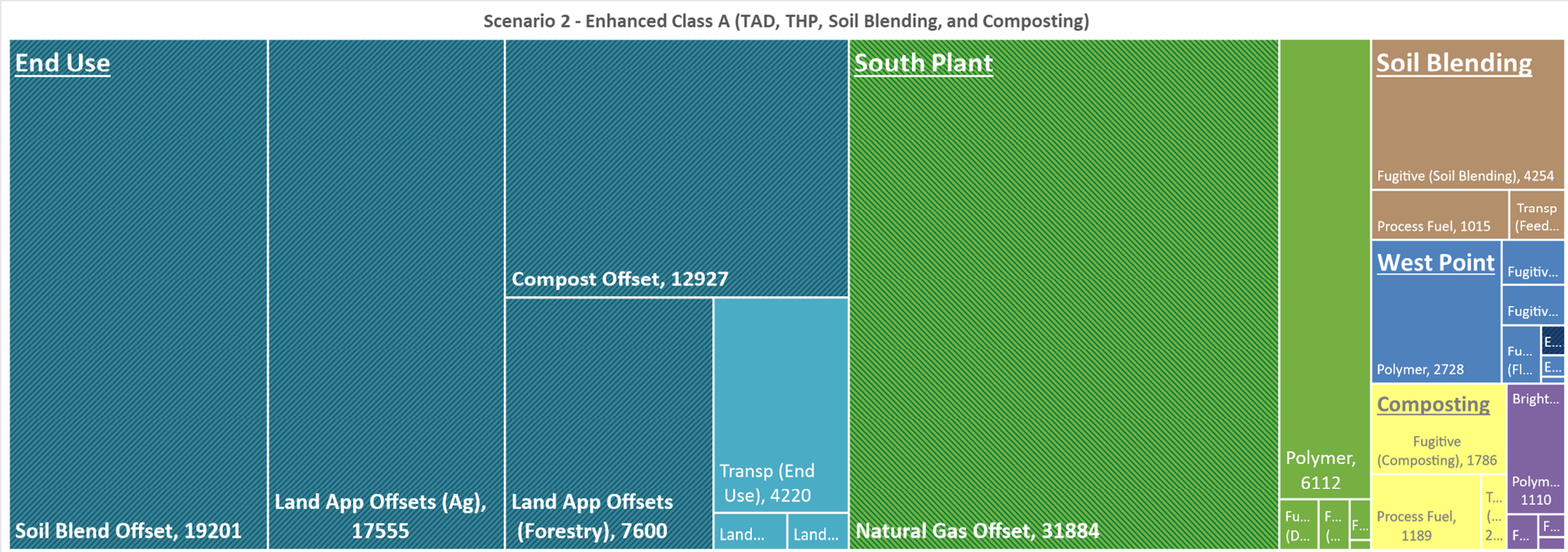
Scenario 2 - Enhanced Class A (TAD, THP, Soil Blending, and Composting)
End Use
Soil Blend Offset, 19201
Land App Offsets (Ag), 17555
Compost Offset, 12927
Land App Offsets (Forestry), 7600
Transp (End Use), 4220
Land...
Land...
South Plant
Natural Gas Offset, 31884
Polymer, 6112
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Soil Blending
Fugitive (Soil Blending), 4254
Process Fuel, 1015
Transp (Feed...
West Point
Polymer, 2728
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Composting
Fugitive (Composting), 1786
Process Fuel, 1189
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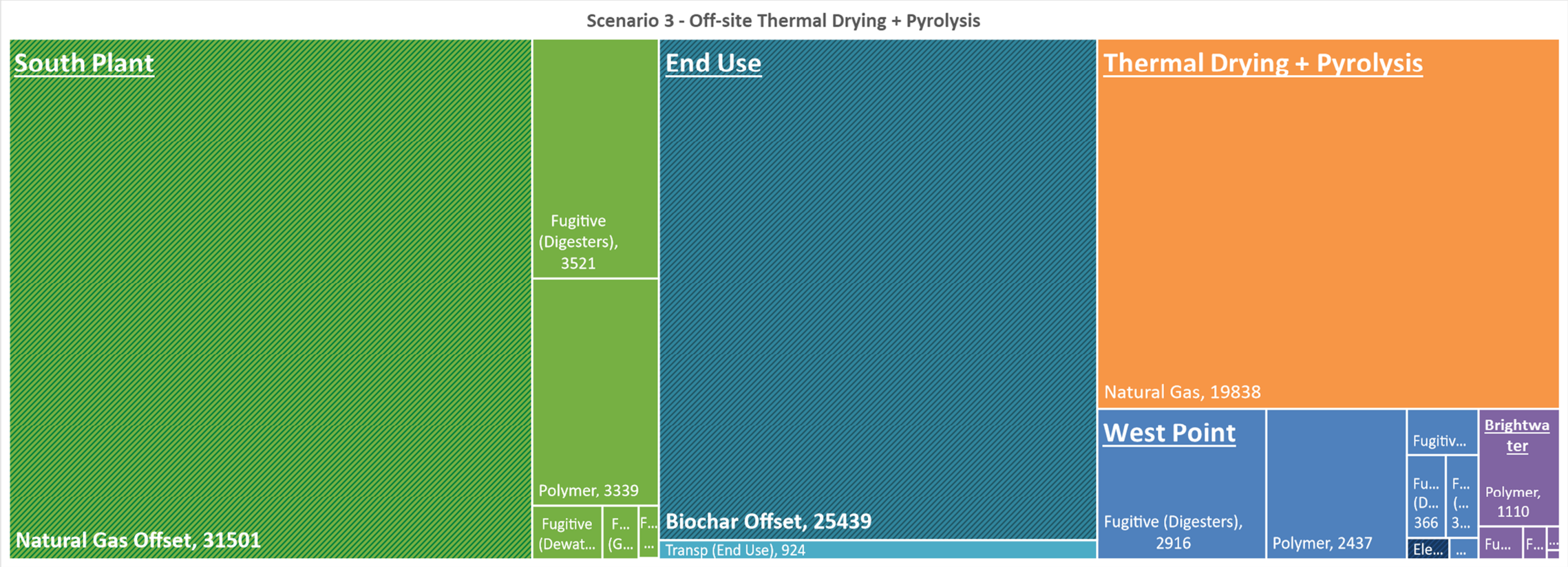
Scenario 3 - Off-site Thermal Drying + Pyrolysis
South Plant
Natural Gas Offset, 31501
Fugitive (Digesters), 3521
Polymer, 3339
Fugitive (Dewat...
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End Use
Biochar Offset, 25439
Transp (End Use), 924
Thermal Drying + Pyrolysis
Natural Gas, 19838
West Point
Fugitive (Digesters), 2916
Polymer, 2437
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Brightwater
Polymer, 1110
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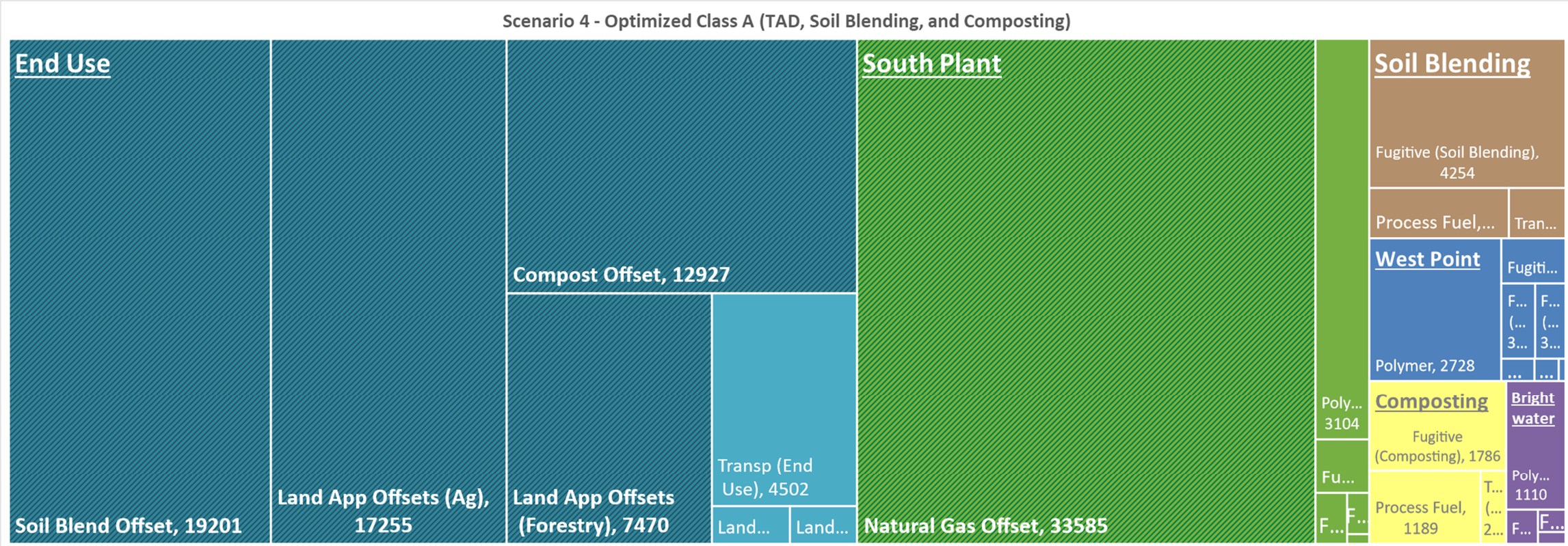
Scenario 4 - Optimized Class A (TAD, Soil Blending, and Composting)
End Use
Soil Blend Offset, 19201
Land App Offsets (Ag), 17255
Compost Offset, 12927
Land App Offsets (Forestry), 7470
Transp (End Use), 4502
Land...
Land...
South Plant
Natural Gas Offset, 33585
Poly... 3104
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Soil Blending
Fugitive (Soil Blending), 4254
Process Fuel,...
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West Point
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Polymer, 2728
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Composting
Fugitive (Composting), 1786
Process Fuel, 1189
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Bright water
Poly... 1110
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GHG Emissions Inventory				Notes	1	2	3	4
GHG Emissions Inventory					Base-case	Enhanced Class A	Pyrolysis	Optimized Class A
Element					S1	S2	S3	S4
West Point Treatment plant								
	Electrical Emissions							
		Solids Treatment	Electricity Production, MWh/yr		15,415	16,524	15,415	16,524
		Solids Treatment	Electricity Sold, MWh/yr		15,415	16,524	15,415	16,524
C	SC2EC	Solids Treatment	Emissions Offset, kg CO2e/yr		-100,199	-107,404	-100,199	-107,404
		Solids Treatment	Electricity Consumption, MWh/yr		-10,523	-11,748	-10,523	-11,748
		Solids Treatment	Electricity Purchased, MWh/yr		10,523	11,748	10,523	11,748
	SC2E	Solids Treatment	Emission, kg CO2e/yr		68,398	76,365	68,398	76,365
	SC2EST		Subtotal, kg CO2e/yr		-31,801	-31,039	-31,801	-31,039
	Natural Gas Emissions							
		Solids Treatment	Thermal Production, MMBtu/yr		73,395	107,014	73,395	107,014
		Solids Treatment	Thermal Consumption, MMBtu/yr		-51,288	-102,576	-51,288	-102,576
		Solids Treatment	Thermal Balance, MMBtu/yr		22,107	4,438	22,107	4,438
		Solids Treatment	External Natural Gas, scf/yr		0	0	0	
	SC1NG	Combustion	Emission, kg CO2e/yr		0	0	0	
	SC1NGST		Subtotal, kg CO2e/yr		0	0	0	
	SC3NG	Extraction/Production	Emission, kg CO2e/yr		0	0	0	
	SC3NGST		Subtotal, kg CO2e/yr		0	0	0	
	Chemical Emissions							
		Dewatering	Polymer Use, lb per yr		595,637	555,684	595,637	555,684
	SC3P	Dewatering	Polymer Manufacturing, kg CO2e/yr		2,436,696	2,727,903	2,436,696	2,727,903
	SC3PST		Subtotal, kg CO2e/yr		2,436,696	2,727,903	2,436,696	2,727,903
	Process Fugitive Emissions							
	SC1F	Digestion	Digester Floating Cover (WP = 5, SP = 4, BW = 0), kg CO2e/yr		2,912,229	0	2,912,229	0
	SC1F	Digestion	Digester Fixed Covers (WP = 0 SP = 1, BW = 3), kg CO2e/yr		3426	21838	3426	21,838
	SC1F	Dewatering	Fugitive Emissions, kg CO2e/yr		365,873	365,128	365,873	365,128
	SC1F	Cogen	Fugitive Emissions, kg CO2e/yr		391,671	416,085	391,671	416,085
	SC1F	Boiler	Fugitive Emissions, kg CO2e/yr		601	639	601	639
	SC1F	Flaring	Fugitive Emissions, kg CO2e/yr		312,362	331,833	312,362	331,833
	SC1FST		Subtotal, kg CO2e/yr		3,986,162	1,135,523	3,986,162	1,135,523
	Hauling and Transportation							
		Hauling	Average Hauled, wet tons/yr		64,224	59,916	64,224	59,916
		Hauling	Dry Solids, %		28.5%	28.5%	28.5%	0
		Hauling	Trucks per year		2,190	2,190	2,190	2,190
		Hauling	Off-site Processing, Total Miles		0	65,700	65,700	65,700
		Hauling	Fuel Usage Round Trip, gal/yr		0	11,965	11,965	11,965
	SC3T	Hauling	Emissions, kg CO2e/yr		0	142,204	142,204	142,204
		Hauling	Eastern Washington, Total Miles		827,820	To Off-site Soil Blending	To Off-site Pyrolysis	To Off-site Soil Blending
		Hauling	Fuel Usage Round Trip, gal/yr		150,760			
	SC3T	Hauling	Emissions, kg CO2e/yr		1,791,771			
		Hauling	Western Washington, Total Miles		15,330			
		Hauling	Fuel Usage Round Trip, gal/yr		53,572			
	SC3T	Hauling	Emissions, kg CO2e/yr		636,704			
	SC3TST		Subtotal, kg CO2e/yr		2,428,474	142,204	142,204	142,204

	Land Application							
		Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr		18,519	To Off-site Soil Blending	To Off-site Pyrolysis	To Off-site Soil Blending
	SC3T	Agriculture	Emissions, kg CO2e/yr		220,097			
		Forestry	KC Fuel for Forestry (Western) Application, gal/yr		2,826			
	SC3T	Forestry	Emissions, kg CO2e/yr		33,585			
	SC3TST		Subtotal, kg CO2e/yr		253,682			
	SC1F	Agriculture	N2O and CH4 Emissions, kg CO2e/yr		316,760			
	SC1F	Forestry	N2O and CH4 Emissions, kg CO2e/yr		35,196			
	SC1FST		Subtotal, kg CO2e/yr		351,955			
	Carbon Offsets							
	SC3FC	Agriculture	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		-4,333,916			
	SC3FC	Forestry	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		0			
	SC3FCST		Subtotal, kg CO2e/yr		-4,333,916			
	SC3CC	Agriculture	Land App Carbon Sequestration, kg CO2e/yr		-18,680,671			
		Forestry	Land App Carbon Sequestration, kg CO2e/yr		-1,660,504			
	SC3CCST		Subtotal, kg CO2e/yr		-20,341,175			
	WP GHG Plant Total							
		Scope 1	CO2 Emissions, mt CO2e/yr		4,338	1,136	3,986	1,136
		Scope 2	CO2 Emissions, mt CO2e/yr		-32	-31	-32	-31
		Scope 3	CO2 Emissions, mt CO2e/yr		-19,556	2,870	2,579	2,870
		Plant Total	CO2 Emissions, mt CO2e/yr		-15,250	3,975	6,533	3,975
		Plant Total Check	CO2 Emissions, mt CO2e/yr		-15,250	3,975	6,533	3,975
South Treatment plant								
	Electrical Emissions							
		Solids Treatment	Electricity Production, MWh/yr		0	0	0	0
		Solids Treatment	Electricity Sold, MWh/yr		0	0	0	0
	SC2E	Solids Treatment	Emissions Offset, kg CO2e/yr		0	0	0	0
		Solids Treatment	Electricity Consumption, MWh/yr		-12,983	-19,359	-12,983	-13418
		Solids Treatment	Electricity Purchased, MWh/yr		12,983	19,359	12,983	13418
	SC2E	Solids Treatment	Emission, kg CO2e/yr		0	0	0	0
	SC2EST		Subtotal, kg CO2e/yr		0	0	0	0
	Natural Gas Emissions							
		Solids Treatment	Thermal Production, MMBtu/yr		58,928	105,662	58,928	85,309
		Solids Treatment	Thermal Consumption, MMBtu/yr		-58,928	-105,662	-58,928	-117,856
		Solids Treatment	External Natural Gas, scf/yr		76,267,424	136,752,625	76,267,424	110,410,948
	SC1NG	Combustion	Emission, kg CO2e/yr		4,042,173	7,247,889	4,042,173	5,851,780
	SC1NGST		Subtotal, kg CO2e/yr		4,042,173	7,247,889	4,042,173	5,851,780
	SC3NG	Extraction/Production	Emission, kg CO2e/yr		1,067,744	1,914,537	1,067,744	1,545,753
	SC3NGST		Subtotal, kg CO2e/yr		1,067,744	1,914,537	1,067,744	1,545,753
		Solids Treatment	Renewable Natural Gas Export, scf/yr		367,809,910	372,282,694	367,809,910	392,134,504
		Solids Treatment	Gallon of Gasoline Equiv, gal/yr		2,913,054	2,948,479	2,913,054	3,105,705
		Solids Treatment	RNG as Diesel Equiv, gal/yr		2,650,525	2,682,757	2,650,525	2,825,814
	SC3BG	Solids Treatment	Emission, kg CO2e/yr		-31,501,228	-31,884,301	-31,501,228	-33,584,517
	SC3BGST		Subtotal, kg CO2e/yr		-31,501,228	-31,884,301	-31,501,228	-33,584,517
	Chemical Emissions							
		Pre-Dewatering	Polymer Use, lb per yr		0	722,043	0	0
	SC3P	Pre-Dewatering	Polymer Manufacturing, kg CO2e/yr		0	2,953,812	0	0
		Dewatering	Polymer Use, lb per yr		816,157	771,899	816,157	758,712
	SC3P	Dewatering	Polymer Manufacturing, kg CO2e/yr		3,338,823	3,157,767	3,338,823	3,103,823

SC3PST		Subtotal, kg CO2e/yr		3,338,823	6,111,579	3,338,823	3,103,823
Process Fugitive Emissions							
SC1F	Digestion	Digester Floating Cover (KP = 5, SP = 4, BW = 0), kg CO2e/yr		3,515,991	0	3,515,991	0
SC1F	Digestion	Digester Fixed Covers (KP = 0, SP = 1, BW = 3), kg CO2e/yr		5,171	26,167	5,171	27,563
SC1F	Dewatering	Fugitive Emissions, kg CO2e/yr		420,225	279,021	420,225	419,307
SC1F	Cogen	Fugitive Emissions, kg CO2e/yr		0	0	0	0
SC1F	Boiler	Fugitive Emissions, kg CO2e/yr		2,038	3,655	2,038	2,951
SC1F	Gas Upgrading	Fugitive Emissions, kg CO2e/yr		218,457	221,113	218,457	232,904
SC1F	Flaring	Fugitive Emissions, kg CO2e/yr		120,216	121,678	120,216	128,166
SC1FST		Subtotal, kg CO2e/yr		4,282,097	651,635	4,282,097	810,891
Hauling and Transportation							
	Hauling	Average Hauled, wet tons/yr		96,696	69,809	96,696	89,891
	Hauling	Dry Solids, %		22.9%	30.0%	22.9%	23%
	Hauling	Trucks per year		3,285	2,555	3,285	2920
	Hauling	Off-site Processing, Total Miles		0	0	98,550	0
	Hauling	Fuel Usage Round Trip, gal/yr		0	0	17,948	0
SC3T	Hauling	Emissions, kg CO2e/yr		0	0	213,306	0
	Hauling	Eastern Washington, Total Miles		1,241,730	643,860	To Off-site Pyrolysis	735,840
	Hauling	Fuel Usage Round Trip, gal/yr		226,140	117,258		134,009
SC3T	Hauling	Emissions, kg CO2e/yr		2,687,656	1,393,600		1,592,685
	Hauling	Western Washington, Total Miles		22,995	71,540		81,760
	Hauling	Fuel Usage Round Trip, gal/yr		80,359	48,799		55,770
SC3T	Hauling	Emissions, kg CO2e/yr		955,055	579,967		662,820
SC3TST		Subtotal, kg CO2e/yr		3,642,712	1,973,567	213,306	2,255,505
Land Application							
	Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr		27,882	13,420	To Off-site Pyrolysis	17,280
SC3T	Agriculture	Emissions, kg CO2e/yr		331,379	159,491		205,370
	Forestry	KC Fuel for Forestry (Western) Application, gal/yr		4,255	12,286		15,821
SC3T	Forestry	Emissions, kg CO2e/yr		50,566	146,023		188,028
SC3TST		Subtotal, kg CO2e/yr		381,945	305,513		393,398
SC1F	Agriculture	N2O and CH4 Emissions, kg CO2e/yr		383,206	161,078		158,326
SC1F	Forestry	N2O and CH4 Emissions, kg CO2e/yr		42,578	241,617		237,489
SC1FST		Subtotal, kg CO2e/yr		425,784	402,695		395,816
Carbon Offsets							
SC3FC	Agriculture	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		-5,243,033	-3,305,811		-3,249,338
SC3FC	Forestry	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		0	0		0
SC3FCST		Subtotal, kg CO2e/yr		-5,243,033	-3,305,811		-3,249,338
SC3CC	Agriculture	Land App Carbon Sequestration, kg CO2e/yr		-22,599,279	-14,249,184		-14,005,769
SC3CC	Forestry	Land App Carbon Sequestration, kg CO2e/yr		-2,008,825	-7,599,565		-7,469,743
SC3CCST		Subtotal, kg CO2e/yr		-24,608,104	-21,848,749		-21,475,512
SP GHG Plant Total							
	Scope 1	CO2 Emissions, mt CO2e/yr		8,750	8,302	8,324	7,058
	Scope 2	CO2 Emissions, mt CO2e/yr		0	0	0	0
	Scope 3	CO2 Emissions, mt CO2e/yr		-52,921	-46,734	-26,881	-51,011
	Plant Total	CO2 Emissions, mt CO2e/yr		-44,171	-38,431	-18,557	-43,952
	Plant Total Check	CO2 Emissions, mt CO2e/yr		-44,171	-38,431	-18,557	-43,952
Brightwater Treatment Plant							
Electrical Emissions							

		Solids Treatment	Electricity Production, MWh/yr		0	0	0	0
		Solids Treatment	Electricity Sold, MWh/yr		0	0	0	0
	SC2E	Solids Treatment	Emissions Offset, kg CO2e/yr		0	0	0	0
		Solids Treatment	Electricity Consumption, MWh/yr		-3,979	-3,979	-3,979	-3,979
		Solids Treatment	Electricity Purchased, MWh/yr		3,979	3,979	3,979	3,979
	SC2E	Solids Treatment	Emission, kg CO2e/yr		35,414	35,414	35,414	35,414
	SC2EST		Subtotal, kg CO2e/yr		35,414	35,414	35,414	35,414
	Natural Gas Emissions							
		Solids Treatment	Thermal Production, MMBtu/yr		98,296	98,296	98,296	98,296
		Solids Treatment	Thermal Consumption, MMBtu/yr		-22,428	-22,428	-22,428	-22,428
		Solids Treatment	Thermal Balance, MMBtu/yr		75,868	75,868	75,868	75,868
		Solids Treatment	External Natural Gas, scf/yr		0	0	0	0
	SC1NG	Combustion	Emission, kg CO2e/yr		0	0	0	0
	SC1NGST		Subtotal, kg CO2e/yr		0	0	0	0
	SC3NG	Extraction/Production	Emission, kg CO2e/yr		0	0	0	0
	SC3NGST		Subtotal, kg CO2e/yr		0	0	0	0
	Chemical Emissions							
		Pre-Dewatering	Polymer Use, lb per yr		0	0	0	0
	SC3P	Pre-Dewatering	Polymer Manufacturing, kg CO2e/yr		0	0	0	0
		Dewatering	Polymer Use, lb per yr		271,320	271,320	271,320	271,320
	SC3P	Dewatering	Polymer Manufacturing, kg CO2e/yr		1,109,944	1,109,944	1,109,944	1,109,944
	SC3PST		Subtotal, kg CO2e/yr		1,109,944	1,109,944	1,109,944	1,109,944
	Process Fugitive Emissions							
	SC1F	Digestion	Digester Floating Cover (KP = 5, SP = 4, BW = 0), kg CO2e/yr		0	0	0	0
	SC1F	Digestion	Digester Fixed Covers (KP = 0, SP = 1, BW = 3), kg CO2e/yr		9,634	9,634	9,634	9,634
	SC1F	Dewatering	Fugitive Emissions, kg CO2e/yr		159,970	159,970	159,970	159,970
	SC1F	Cogen	Fugitive Emissions, kg CO2e/yr		0	0	0	0
	SC1F	Boiler	Fugitive Emissions, kg CO2e/yr		3,372	3,372	3,372	3,372
	SC1F	Gas Upgrading	Fugitive Emissions, kg CO2e/yr		0	0	0	0
	SC1F	Flaring	Fugitive Emissions, kg CO2e/yr		86,703	86,703	86,703	86,703
	SC1FST		Subtotal, kg CO2e/yr		259,679	259,679	259,679	259,679
	Hauling and Transportation							
		Hauling	Average Hauled, wet tons/yr		35,857	35,857	35,857	35,857
		Hauling	Dry Solids, %		20.0%	20.0%	20.0%	20.0%
		Hauling	Trucks per year		1,460	1,460	1,460	1,460
		Hauling	Off-site Processing, Total Miles		0	43,800	43,800	43,800
		Hauling	Fuel Usage Round Trip, gal/yr		0	7,977	7,977	7,977
	SC3T	Hauling	Emissions, kg CO2e/yr		0	94,803	94,803	94,803
		Hauling	Eastern Washington, Total Miles		551,880	To Off-site Composting	To Off-site Pyrolysis	To Off-site Composting
		Hauling	Fuel Usage Round Trip, gal/yr		100,507			
	SC3T	Hauling	Emissions, kg CO2e/yr		1,194,514			
		Hauling	Western Washington, Total Miles		10,220			
		Hauling	Fuel Usage Round Trip, gal/yr		35,715			
	SC3T	Hauling	Emissions, kg CO2e/yr		424,469			
	SC3TST		Subtotal, kg CO2e/yr		1,618,983	94,803	94,803	94803
	Land Application							
		Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr		10,339			
	SC3T	Agriculture	Emissions, kg CO2e/yr		122,881			
		Forestry	KC Fuel for Forestry (Western) Application, gal/yr		1,578			
	SC3T	Forestry	Emissions, kg CO2e/yr		18,751			
	SC3TST		Subtotal, kg CO2e/yr		141,632			

	SC1F	Agriculture	N2O and CH4 Emissions, kg CO2e/yr		124,104	To Off-site Composting	To Off-site Pyrolysis	To Off-site Composting
	SC1F	Forestry	N2O and CH4 Emissions, kg CO2e/yr		13,789			
	SC1FST		Subtotal, kg CO2e/yr		137,894			
	Carbon Offsets							
	SC3FC	Agriculture	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		-188,667			
	SC3FC	Forestry	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr		0			
	SC3FCST		Subtotal, kg CO2e/yr		-188,667			
	SC3CC	Agriculture	Land App Carbon Sequestration, kg CO2e/yr		-7,318,972			
	SC3CC	Forestry	Land App Carbon Sequestration, kg CO2e/yr		-650,575			
	SC3CCST		Subtotal, kg CO2e/yr		-7,969,547			
	SP GHG Plant Total							
		Scope 1	CO2 Emissions, mt CO2e/yr		398	260	260	260
		Scope 2	CO2 Emissions, mt CO2e/yr		35	35	35	35
		Scope 3	CO2 Emissions, mt CO2e/yr		-5,288	1,205	1,205	1,205
		Plant Total	CO2 Emissions, mt CO2e/yr		-4,855	1,500	1,500	1,500
		Plant Total Check	CO2 Emissions, mt CO2e/yr		-4,855	1,500	1,500	1,500
Off-Site Composting								
	Hauling and Transportation							
		Hauling	Feedstock (Sawdust), wet tons/yr			24,175		24,175
		Hauling	Large Trucks per year			779.8		780
		Hauling	Feedstock to Off-site Processing, Total Miles			124,773		124,773
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			22,723		22,723
	SC3T	Hauling	Emissions, kg CO2e/yr			270,065		270,065
		Hauling	Commercial/Donation Usage, wet tons/yr			47,504		47,504
		Hauling	Medium Trucks per year			7,038		7,038
		Hauling	Off-site Processing to Customer, Total Miles			175,941		175,941
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			20,900		20,900
	SC3T	Hauling	Emissions, kg CO2e/yr			248,400		248,400
		Transportation	Residential Usage, wet tons/yr			11,876		11,876
		Transportation	Vehicles per year			42,754		42,754
		Transportation	Fuel (Gasoline) Usage Round Trip, gal/yr			42,754		42,754
	SC3T	Transportation	Emissions, kg CO2e/yr			453,104		453,104
	SC3TST		Subtotal, kg CO2e/yr			971,568		971,568
	Fuel Emissions							
		Composting	Machinery Fuel Consumption (Diesel), gal/day			274		274
	SC1M	Composting	Emissions, kg CO2e/yr			1,188,609		1,188,609
	SC1MST		Subtotal, kg CO2e/yr			1,188,609		1,188,609
	Electrical Emissions							
		Composting	Electricity Consumption, MWh/yr			-1,888		-1,888
		Composting	Electricity Purchased, MWh/yr			1,888		1,888
	SC2E	Composting	Emission, kg CO2e/yr			0		0
	SC2EST		Subtotal, kg CO2e/yr			0		0
	Process Fugitive Emissions							
		Composting	Biosolids, dry lb/hr			1,637.3		1,637
	SC1F	Composting	N2O Emissions, kg CO2e/yr			691,058.6		691,059
	SC1F	Composting	CH4 Emissions, kg CO2e/yr			1,095,262.7		1,095,263
	SC1FST		Subtotal, kg CO2e/yr			1,786,321.3		1,786,321

	Carbon Offsets							
	SC3FC	Land Application	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr			-1,886,283.6		-1,886,284
	SC3FCST	Subtotal, kg CO2e/yr				-1,886,283.6		-1,886,284
	SC3CC	Land Application	Land App Carbon Sequestration, kg CO2e/yr			-11,040,853		-11,040,853
	SC3CCST	Subtotal, kg CO2e/yr				-11,040,853		-11,040,853
		Scope 1	CO2 Emissions, mt CO2e/yr			2,975		2,975
		Scope 2	CO2 Emissions, mt CO2e/yr			0		0
		Scope 3	CO2 Emissions, mt CO2e/yr			-11,956		-11,956
		Plant Total	CO2 Emissions, mt CO2e/yr			-8,981		-8,981
		Plant Total Check	CO2 Emissions, mt CO2e/yr			-8,981		-8,981
Off-Site Soil Blending								
	Hauling and Transportation							
		Hauling	Feedstock (Sawdust), wet tons/yr			13,980		13,980
		Hauling	Large Trucks per year			451.0		451
		Hauling	Feedstock to Off-site Processing, Total Miles			72,157		72,157
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			13,141		13,141
	SC3T	Hauling	Emissions, kg CO2e/yr			156,181		156,181
		Hauling	Feedstock (Fine Sand), wet tons/yr			48,532		48,532
		Hauling	Large Trucks per year			1,565.6		1,566
		Hauling	Feedstock to Off-site Processing, Total Miles			117,417		117,417
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			21,384		21,384
	SC3T	Hauling	Emissions, kg CO2e/yr			254,142		254,142
		Hauling	Commercial/Donation Usage, wet tons/yr			97,943		97,943
		Hauling	Medium Trucks per year			8,371		8,371
		Hauling	Off-site Processing to Customer, Total Miles			209,281		209,281
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			21,048		21,048
	SC3T	Hauling	Emissions, kg CO2e/yr			250,152		250,152
		Transportation	Residential Usage, wet tons/yr			24,486		24,486
		Transportation	Vehicles per year			50,855		50,855
		Transportation	Fuel (Gasoline) Usage Round Trip, gal/yr			50,855		50,855
	SC3T	Transportation	Emissions, kg CO2e/yr			538,963		538,963
	SC3TST	Subtotal, kg CO2e/yr				945,296		945,296
	Fuel Emissions							
		Soil Blending	Machinery Fuel Consumption (Diesel), gal/day			234		234
	SC1M	Soil Blending	Emissions, kg CO2e/yr			1,015,089		1,015,089
	SC1MST	Subtotal, kg CO2e/yr				1,015,089		1,015,089
	Electrical Emissions							
		Soil Blending	Electricity Consumption, MWh/yr			0		0
		Soil Blending	Electricity Purchased, MWh/yr			0		0
	SC2E	Soil Blending	Emission, kg CO2e/yr			0		0
	SC2EST	Subtotal, kg CO2e/yr				0		0
	Process Fugitive Emissions							
		Soil Blending	Biosolids, dry lb/hr			3,898.7		3,899
	SC1F	Soil Blending	N2O Emissions, kg CO2e/yr			1,645,521.9		1,645,522
	SC1F	Soil Blending	CH4 Emissions, kg CO2e/yr			2,607,996.9		2,607,997
	SC1FST	Subtotal, kg CO2e/yr				4,253,518.8		4,253,519
	Carbon Offsets							
	SC3FC	Land Application	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr			-4,501,899.4		-4,501,899

	SC3FCST		Subtotal, kg CO2e/yr			-4,501,899.4		-4,501,899
	SC3CC	Land Application	Land App Carbon Sequestration, kg CO2e/yr			-14,699,522		-14,699,522
	SC3CCST		Subtotal, kg CO2e/yr			-14,699,522		-14,699,522
		Scope 1	CO2 Emissions, mt CO2e/yr			5,269		5,269
		Scope 2	CO2 Emissions, mt CO2e/yr			0		0
		Scope 3	CO2 Emissions, mt CO2e/yr			-18,256		-18,256
		Plant Total	CO2 Emissions, mt CO2e/yr			-12,988		-12,988
		Plant Total Check	CO2 Emissions, mt CO2e/yr			-12,988		-12,988
Off-Site Thermal Drying and Pyrolysis								
	Hauling and Transportation							
		Hauling	Biochar, wet tons/yr				22,920.1	
		Hauling	Large Trucks per year				1,095.0	
		Hauling	Biochar to Customers, Total Miles				219,000.0	
		Hauling	Fuel (Diesel) Usage Round Trip, gal/yr				39,883.7	
	SC3T	Hauling	Emissions, kg CO2e/yr				474,013.5	
	SC3TST		Subtotal, kg CO2e/yr				474,013.5	
	Electrical Emissions							
		Solids Treatment	Electricity Production, MWh/yr				0.0	
		Solids Treatment	Electricity Sold, MWh/yr				0.0	
	SC2E	Solids Treatment	Emissions Offset, kg CO2e/yr				0.0	
		Solids Treatment	Electricity Consumption, MWh/yr				46,456.3	
		Solids Treatment	Electricity Purchased, MWh/yr				46,456.3	
	SC2E	Solids Treatment	Emission, kg CO2e/yr				0.0	
	SC2EST		Subtotal, kg CO2e/yr				0.0	
	Natural Gas Emissions							
		Solids Treatment	Thermal Production, MMBtu/yr				415,294	
		Solids Treatment	Thermal Consumption, MMBtu/yr				-415,295	
		Solids Treatment	Thermal Balance, MMBtu/yr				0	
		Solids Treatment	External Natural Gas, scf/yr				296,082,227	
	SC1NG	Combustion	Emission, kg CO2e/yr				15,692,358	
	SC1NGST		Subtotal, kg CO2e/yr				15,692,358	
	SC3NG	Extraction/Production	Emission, kg CO2e/yr				4,145,151	
	SC3NGST		Subtotal, kg CO2e/yr				4,145,151	
	Process Fugitive Emissions							
	SC1F	Boiler	Fugitive Emissions, kg CO2e/yr				7,913.5	
	SC1FST		Subtotal, kg CO2e/yr				7,913.5	
	Carbon Offsets							
	SC3FC	Land Application	Nitrogen and Phosphorus Fertillizer Offset, kg CO2e/yr				-6,028,670.2	
	SC3FCST		Subtotal, kg CO2e/yr				-6,028,670.2	
	SC3CC	Land Application	Land App Carbon Sequestration, kg CO2e/yr				-19,410,031	
	SC3CCST		Subtotal, kg CO2e/yr				-19,410,031	
		Scope 1	CO2 Emissions, mt CO2e/yr				15,700	
		Scope 2	CO2 Emissions, mt CO2e/yr				0	
		Scope 3	CO2 Emissions, mt CO2e/yr				-20,820	
		Plant Total	CO2 Emissions, mt CO2e/yr				-5,119	
		Plant Total Check	CO2 Emissions, mt CO2e/yr				-5,119	

Attachment C: Cost Estimating

				Notes	NPV LCCA	Project Capital Cost	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
			End of Year																0	1	2	3
			Solids Flows and Loads				49258	49743	50228	50713	51199	51684	52169	52654	53139	53624	54110	54595	154859	156969	159079	161189
S1	West Point Treatment plant																					
	Capital Cost		MAD Additional Digesters			NPV Capital Cost																
						$141,914,692																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$119,384,603																
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr				$3,103,283	$3,133,851	$3,164,418	$3,194,986	$3,225,554	$3,256,122	$3,286,690	$3,317,258	$3,347,825	$3,378,393	$3,408,961	$3,439,529	$3,470,097	$3,500,664	$3,531,232	$3,561,800
	Revenues																					
		CHP	Electricity Sales, $/yr				-$1,185,667	-$1,197,346	-$1,209,025	-$1,220,704	-$1,232,383	-$1,244,062	-$1,255,741	-$1,267,420	-$1,279,099	-$1,290,778	-$1,302,457	-$1,314,136	-$1,325,815	-$1,337,494	-$1,349,173	-$1,360,851
		Land App	Land App East/ West WA Revenue, $/yr				-$113,193	-$114,308	-$115,423	-$116,538	-$117,653	-$118,768	-$119,883	-$120,998	-$122,113	-$123,228	-$124,343	-$125,458	-$126,573	-$127,687	-$128,802	-$129,917
	South Treatment Plant																					
	Capital Cost					NPV Capital Cost																
						$83,127,778																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$69,930,581	$8,585,519	$8,718,754	$8,851,989	$8,985,223	$9,118,458	$9,251,693	$9,384,928	$9,518,163	$9,651,398	$9,784,633	$9,917,868	$10,051,102	$10,184,337	$10,317,572	$10,450,807	$10,584,042
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr				4,106,032	4,169,752	4,233,471	4,297,191	4,360,911	4,424,630	4,488,350	4,552,070	4,615,789	4,679,509	4,743,229	4,806,949	4,870,668	4,934,388	4,998,108	5,061,827
	Revenues																					
		Biogas	Renewable Natural Gas Sales, $/yr				-$5,632,026	-$5,719,427	-$5,806,828	-$5,894,228	-$5,981,629	-$6,069,030	-$6,156,431	-$6,243,832	-$6,331,233	-$6,418,634	-$6,506,035	-$6,593,436	-$6,680,837	-$6,768,238	-$6,855,639	-$6,943,039
		Land App	Land App East/ West WA Revenue, $/yr				-$149,768	-$152,093	-$154,417	-$156,741	-$159,065	-$161,389	-$163,714	-$166,038	-$168,362	-$170,686	-$173,010	-$175,334	-$177,659	-$179,983	-$182,307	-$184,631
	Brightwater Treatment Plant																					
	Capital Cost					NPV Capital Cost																
						$39,098,386																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$32,891,206	$1,980,025	$2,057,820	$2,135,616	$2,213,412	$2,291,208	$2,369,003	$2,446,799	$2,524,595	$2,602,390	$2,680,186	$2,757,982	$2,835,777	$2,913,573	$2,991,369	$3,069,164	$3,146,960
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr				$1,009,486	$1,049,149	$1,088,812	$1,128,475	$1,168,138	$1,207,801	$1,247,464	$1,287,127	$1,326,790	$1,366,453	$1,406,116	$1,445,778	$1,485,441	$1,525,104	$1,564,767	$1,604,430
	Revenues																					
		Land App	Land App East/ West WA Revenue, $/yr				-$36,821	-$38,268	-$39,715	-$41,161	-$42,608	-$44,055	-$45,502	-$46,948	-$48,395	-$49,842	-$51,288	-$52,735	-$54,182	-$55,629	-$57,075	-$58,522
			Subtotal			$222,206,389														$23,577,616	$23,895,277	$24,212,938
			Total		$563,764,215																	
S2	West Point Treatment plant																					
	Capital Cost		TAD-Batch			NPV Capital Cost																
						$128,586,966																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$108,172,760	$7,820,822	$7,897,858	$7,974,895	$8,051,931	$8,128,967	$8,206,004	$8,283,040	$8,360,076	$8,437,113	$8,514,149	$8,591,185	$8,668,221	$8,745,258	$8,822,294	$8,899,330	$8,976,367
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr																$0	$0	$0	$0
	Revenues																					
		CHP	Electricity Sales, $/yr				-$1,259,574	-$1,271,981	-$1,284,388	-$1,296,795	-$1,309,202	-$1,321,609	-$1,334,016	-$1,346,423	-$1,358,830	-$1,371,237	-$1,383,644	-$1,396,051	-$1,408,458	-$1,420,865	-$1,433,272	-$1,445,679
		Land App	Land App East/ West WA Revenue, $/yr																$0	$0	$0	$0
	South Treatment Plant																					
	Capital Cost		THP-MAD			NPV Capital Cost																
						$520,446,443																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$437,821,421	$12,049,067	$12,236,052	$12,423,036	$12,610,020	$12,797,004	$12,983,988	$13,170,972	$13,357,956	$13,544,941	$13,731,925	$13,918,909	$14,105,893	$14,292,877	$14,479,861	$14,666,846	$14,853,830
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr				$3,083,253	$3,131,100	$3,178,948	$3,226,796	$3,274,643	$3,322,491	$3,370,339	$3,418,186	$3,466,034	$3,513,881	$3,561,729	$3,609,577	$3,657,424	$3,705,272	$3,753,120	$3,800,967
	Revenues																					
		Biogas	Renewable Natural Gas Sales, $/yr				-$5,700,514	-$5,788,978	-$5,877,442	-$5,965,906	-$6,054,370	-$6,142,833	-$6,231,297	-$6,319,761	-$6,408,225	-$6,496,688	-$6,585,152	-$6,673,616	-$6,762,080	-$6,850,543	-$6,939,007	-$7,027,471
		Land App	Land App East/ West WA Revenue, $/yr				-$190,406	-$193,361	-$196,316	-$199,270	-$202,225	-$205,180	-$208,135	-$211,090	-$214,045	-$216,999	-$219,954	-$222,909	-$225,864	-$228,819	-$231,774	-$234,728
	Brightwater Treatment Plant																					
	Capital Cost		MAD			NPV Capital Cost																
						$39,098,386																
	Operation and Maintenance					Escalated and Discounted																
		Solids Treatment	Operation and Maintenance, $/yr			$32,891,206	$1,980,025	$2,057,820	$2,135,616	$2,213,412	$2,291,208	$2,369,003	$2,446,799	$2,524,595	$2,602,390	$2,680,186	$2,757,982	$2,835,777	$2,913,573	$2,991,369	$3,069,164	$3,146,960
	Land Application																					
		Land App	Land App East/ West WA Cost, $/yr																	$0	$0	$0
	Revenues																					
		Land App	Land App East/ West WA Revenue, $/yr																	$0	$0	$0
	Off-Site Composting (Brightwater Solids)																					
	Capital Cost		Composting			NPV Capital Cost																
						$119,906,031																
	Hauling and Transportation					Escalated and Discounted																
		Biosolids & Woodchips	Hauling & Fuel Cost, $/yr			$100,869,993														$441,251	$452,726	$464,202
	Operation and Maintenance																					
		Composting	Operation and Maintenance, $/yr																	$4,133,571	$4,241,072	$4,348,573
	Revenues																					
		Woodchips	Tipping Fee, $/yr																	-$588,359	-$603,661	-$618,962
		Composting	Revenue Year (Commercial), $/yr																	-$279,995	-$287,277	-$589,117
		Composting	Revenue Year (Consumer), $/yr																	-$197,214	-$202,343	-$484,101
	Off-Site Soil Blending (West Point Solids)																					
	Capital Cost		Soil Blending			NPV Capital Cost																
						$58,462,405																
	Hauling and Transport					Escalated and Discounted																
		Biosolids & Feedstocks	Hauling & Fuel Cost, $/yr			$49,181,032														$846,764	$854,158	$861,552
	Feedstock Purchase																					
		Fine Sand	Material Purchase, $/yr																	$513,903	$518,391	$522,878
	Operation and Maintenance																					
		Soil Blending	Operation and Maintenance, $/yr																	$5,570,677	$5,619,320	$5,667,963
	Revenues																					
		Soil Blend	Revenue Year (Commercial), $/yr																	-$403,875	-$407,402	-$821,857
		Soil Blend	Revenue Year (Consumer), $/yr																	-$261,711	-$263,996	-$621,324
			Subtotal			$728,936,411														$31,273,581	$31,705,396	$30,800,052
			Total		$1,146,904,715																	

2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	Simple SUM	Present Worth (2020)
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
183299	185409	187519	189629	191740	193850	195960	198070	180180	182290	184400	186510	188621	190731	192841	194951	197061		
$9,007,485	$9,084,131	$9,160,777	$9,237,422	$9,314,068	$9,390,713	$9,467,359	$9,544,004	$9,620,650	$9,697,296	$9,773,941	$9,850,587	$9,927,232	$10,003,878	$10,080,524	$10,157,169	$10,233,815	$198,814,537	$122,420,640.57
																	$0	$0.00
$3,592,368	$3,622,936	$3,653,503	$3,684,071	$3,714,639	$3,745,207	$3,775,775	$3,806,343	$3,836,910	$3,867,478	$3,898,046	$3,928,614	$3,959,182	$3,989,749	$4,020,317	$4,050,885	$4,081,453	$79,291,269	$48,823,833.90
																	$0	$0.00
-$1,372,530	-$1,384,209	-$1,395,888	-$1,407,567	-$1,419,246	-$1,430,925	-$1,442,604	-$1,454,283	-$1,465,962	-$1,477,641	-$1,489,320	-$1,500,999	-$1,512,678	-$1,524,357	-$1,536,036	-$1,547,715	-$1,559,394	-$30,294,694	-$18,654,047.74
-$131,032	-$132,147	-$133,262	-$134,377	-$135,492	-$136,607	-$137,722	-$138,837	-$139,952	-$141,067	-$142,182	-$143,297	-$144,412	-$145,527	-$146,642	-$147,757	-$148,872	-$2,892,166	-$1,780,859.91
																	$244,918,945	**$150,809,566.82**
$10,717,277	$10,850,512	$10,983,747	$11,116,981	$11,250,216	$11,383,451	$11,516,686	$11,649,921	$11,783,156	$11,916,391	$12,049,626	$12,182,860	$12,316,095	$12,449,330	$12,582,565	$12,715,800	$12,849,035	$241,850,408	$148,808,792.69
																	$0	$0.00
5,125,547	5,189,267	5,252,986	5,316,706	5,380,426	5,444,145	5,507,865	5,571,585	5,635,305	5,699,024	5,762,744	5,826,464	5,890,183	5,953,903	6,017,623	6,081,342	6,145,062	$115,665,169	$71,167,934.94
																	$0	$0.00
-$7,030,440	-$7,117,841	-$7,205,242	-$7,292,643	-$7,380,044	-$7,467,445	-$7,554,846	-$7,642,247	-$7,729,648	-$7,817,049	-$7,904,450	-$7,991,851	-$8,079,251	-$8,166,652	-$8,254,053	-$8,341,454	-$8,428,855	-$158,651,764	-$97,617,274.00
-$186,955	-$189,280	-$191,604	-$193,928	-$196,252	-$198,576	-$200,901	-$203,225	-$205,549	-$207,873	-$210,197	-$212,522	-$214,846	-$217,170	-$219,494	-$221,818	-$224,142	-$4,218,912	-$2,595,865.83
																	$194,644,900	**$119,763,587.80**
$3,224,756	$3,302,551	$3,380,347	$3,458,143	$3,535,938	$3,613,734	$3,691,530	$3,769,325	$3,847,121	$3,924,917	$4,002,712	$4,080,508	$4,158,304	$4,236,099	$4,313,895	$4,391,691	$4,469,486	$77,522,124	$47,601,147.62
																	$0	$0.00
$1,644,093	$1,683,756	$1,723,419	$1,763,082	$1,802,745	$1,842,408	$1,882,071	$1,921,734	$1,961,397	$2,001,060	$2,040,723	$2,080,386	$2,120,049	$2,159,712	$2,199,375	$2,239,038	$2,278,701	$39,523,491	$24,268,730.46
																	$0	$0.00
-$59,969	-$61,415	-$62,862	-$64,309	-$65,756	-$67,202	-$68,649	-$70,096	-$71,542	-$72,989	-$74,436	-$75,883	-$77,329	-$78,776	-$80,223	-$81,669	-$83,116	-$1,441,628	-$885,207.19
$24,530,599	$24,848,259	$25,165,920	$25,483,581	$25,801,242	$26,118,903	$26,436,563	$26,754,224	$27,071,885	$27,389,546	$27,707,207	$28,024,868	$28,342,528	$28,660,189	$28,977,850	$29,295,511	$29,613,172	**$115,603,987**	**$70,984,670.89**
$9,053,403	$9,130,439	$9,207,476	$9,284,512	$9,361,548	$9,438,584	$9,515,621	$9,592,657	$9,669,693	$9,746,730	$9,823,766	$9,900,802	$9,977,839	$10,054,875	$10,131,911	$10,208,947	$10,285,984	$199,828,036	$123,044,705.59
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$0	$0.00
-$1,458,086	-$1,470,493	-$1,482,900	-$1,495,307	-$1,507,714	-$1,520,121	-$1,532,528	-$1,544,935	-$1,557,342	-$1,569,749	-$1,582,156	-$1,594,563	-$1,606,970	-$1,619,377	-$1,631,784	-$1,644,191	-$1,656,598	-$32,183,084	-$19,816,829.34
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$167,644,952	**$103,227,876**
$15,040,814	$15,227,798	$15,414,782	$15,601,766	$15,788,750	$15,975,735	$16,162,719	$16,349,703	$16,536,687	$16,723,671	$16,910,655	$17,097,640	$17,284,624	$17,471,608	$17,658,592	$17,845,576	$18,032,560	$339,417,094	$208,840,863.17
																	$0	$0.00
$3,848,815	$3,896,663	$3,944,510	$3,992,358	$4,040,205	$4,088,053	$4,135,901	$4,183,748	$4,231,596	$4,279,444	$4,327,291	$4,375,139	$4,422,987	$4,470,834	$4,518,682	$4,566,529	$4,614,377	$86,853,915	$53,440,580.93
																	$0	$0.00
-$7,115,935	-$7,204,398	-$7,292,862	-$7,381,326	-$7,469,790	-$7,558,254	-$7,646,717	-$7,735,181	-$7,823,645	-$7,912,109	-$8,000,572	-$8,089,036	-$8,177,500	-$8,265,964	-$8,354,427	-$8,442,891	-$8,531,355	-$160,581,063	-$98,804,357.29
-$237,683	-$240,638	-$243,593	-$246,548	-$249,503	-$252,457	-$255,412	-$258,367	-$261,322	-$264,277	-$267,232	-$270,186	-$273,141	-$276,096	-$279,051	-$282,006	-$284,960	-$5,363,656	-$3,300,218.63
																	$260,326,290	**$160,176,868**
$3,224,756	$3,302,551	$3,380,347	$3,458,143	$3,535,938	$3,613,734	$3,691,530	$3,769,325	$3,847,121	$3,924,917	$4,002,712	$4,080,508	$4,158,304	$4,236,099	$4,313,895	$4,391,691	$4,469,486	$77,522,124	$47,601,147.62
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$77,522,124	**$47,601,148**
$475,677	$487,153	$498,628	$510,104	$521,579	$533,055	$544,530	$556,006	$567,481	$578,956	$590,432	$601,907	$613,383	$624,858	$636,334	$647,809	$659,285	$11,005,356	$7,021,548.40
																	$0	$0.00
$4,456,073	$4,563,574	$4,671,074	$4,778,575	$4,886,076	$4,993,576	$5,101,077	$5,208,578	$5,316,078	$5,423,579	$5,531,079	$5,638,580	$5,746,081	$5,853,581	$5,961,082	$6,068,582	$6,176,083	$103,096,544	$65,776,827.67
																	$0	$0.00
-$634,263	-$649,565	-$664,866	-$680,167	-$695,469	-$710,770	-$726,071	-$741,372	-$756,674	-$771,975	-$787,276	-$802,578	-$817,879	-$833,180	-$848,482	-$863,783	-$879,084	-$14,674,437	-$9,362,466.00
-$603,681	-$618,244	-$632,808	-$647,371	-$661,935	-$1,014,747	-$1,036,593	-$1,058,438	-$1,080,283	-$1,102,128	-$1,123,974	-$1,527,759	-$1,556,886	-$1,586,013	-$1,615,140	-$1,644,267	-$1,673,394	-$20,340,047	(12,465,138)
-$496,068	-$508,035	-$520,003	-$531,970	-$543,938	-$952,980	-$973,496	-$994,011	-$1,014,527	-$1,035,042	-$1,055,558	-$1,614,110	-$1,644,883	-$1,675,657	-$1,706,430	-$1,737,203	-$1,767,977	-$19,655,546	(11,910,043)
																	$59,431,870	**$39,060,729**
$868,946	$876,340	$883,734	$891,128	$898,522	$905,916	$913,310	$920,704	$928,098	$935,492	$942,886	$950,279	$957,673	$965,067	$972,461	$979,855	$987,249	$18,340,134	$11,809,836.66
																	$0	$0.00
$527,365	$531,853	$536,340	$540,828	$545,315	$549,802	$554,290	$558,777	$563,265	$567,752	$572,239	$576,727	$581,214	$585,702	$590,189	$594,676	$599,164	$11,130,671	$7,167,417.67
																	$0	$0.00
$5,716,607	$5,765,250	$5,813,893	$5,862,536	$5,911,179	$5,959,822	$6,008,466	$6,057,109	$6,105,752	$6,154,395	$6,203,038	$6,251,681	$6,300,325	$6,348,968	$6,397,611	$6,446,254	$6,494,897	$120,655,743	$77,694,340.45
																	$0	$0.00
-$828,910	-$835,964	-$843,017	-$850,070	-$857,123	-$1,296,265	-$1,306,845	-$1,317,425	-$1,328,005	-$1,338,585	-$1,349,165	-$1,812,993	-$1,827,099	-$1,841,206	-$1,855,312	-$1,869,419	-$1,883,525	-$24,874,060	(15,361,659)
-$626,656	-$631,988	-$637,321	-$642,653	-$647,985	-$1,119,973	-$1,129,114	-$1,138,255	-$1,147,396	-$1,156,537	-$1,165,678	-$1,762,229	-$1,775,940	-$1,789,652	-$1,803,364	-$1,817,075	-$1,830,787	-$21,969,634	(13,408,253)
$31,211,173	$31,622,294	$32,033,415	$32,444,537	$32,855,658	$31,632,711	$32,020,666	$32,408,622	$32,796,578	$33,184,534	$33,572,489	$31,999,811	$32,362,130	$32,724,449	$33,086,768	$33,449,087	$33,811,406	**$103,282,853**	**$67,901,683**

S3	**West Point Treatment plant**																					
	Capital Cost				NPV Capital Cost																	
					$141,914,692																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$119,384,603		$7,781,156	$7,857,802	$7,934,447	$8,011,093	$8,087,738	$8,164,384	$8,241,030	$8,317,675	$8,394,321	$8,470,966	$8,547,612	$8,624,257	$8,700,903	$8,777,549	$8,854,194	$8,930,840
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																$0	$0	$0	$0
	Revenues																					
		CHP	Electricity Sales, $/yr				-$1,185,667	-$1,197,346	-$1,209,025	-$1,220,704	-$1,232,383	-$1,244,062	-$1,255,741	-$1,267,420	-$1,279,099	-$1,290,778	-$1,302,457	-$1,314,136	-$1,325,815	-$1,337,494	-$1,349,173	-$1,360,851
		Land App	Land App East/West WA Revenue, $/yr																$0	$0	$0	$0
	South Treatment Plant																					
	Capital Cost				NPV Capital Cost																	
					$83,127,778																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$69,930,581		$8,585,519	$8,718,754	$8,851,989	$8,985,223	$9,118,458	$9,251,693	$9,384,928	$9,518,163	$9,651,398	$9,784,633	$9,917,868	$10,051,102	$10,184,337	$10,317,572	$10,450,807	$10,584,042
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																$0	$0	$0	$0
	Revenues																					
		Biogas	Renewable Natural Gas Sales, $/yr				-$5,632,026	-$5,719,427	-$5,806,828	-$5,894,228	-$5,981,629	-$6,069,030	-$6,156,431	-$6,243,832	-$6,331,233	-$6,418,634	-$6,506,035	-$6,593,436	-$6,680,837	-$6,768,238	-$6,855,639	-$6,943,039
		Land App	Land App East/West WA Revenue, $/yr																$0	$0	$0	$0
	Brightwater Treatment Plant																					
	Capital Cost				NPV Capital Cost																	
					$39,098,386																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$32,891,206		$1,980,025	$2,057,820	$2,135,616	$2,213,412	$2,291,208	$2,369,003	$2,446,799	$2,524,595	$2,602,390	$2,680,186	$2,757,982	$2,835,777	$2,913,573	$2,991,369	$3,069,164	$3,146,960
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																$0	$0	$0	$0
	Revenues																					
		Land App	Land App East/West WA Revenue, $/yr																$0	$0	$0	$0
	Off-Site Thermal Drying and Pyrolysis																					
	Capital Cost				NPV Capital Cost																	
					$617,273,184																	
	Hauling and Transportation				Escalated and Discounted																	
		Biosolids	Hauling & Fuel Cost, $/yr		$519,276,145															$1,133,355	$1,148,590	$1,163,826
	Operation and Maintenance																					
		Drying + Pyrolysis	Operation and Maintenance, $/yr																	$7,976,332	$8,083,557	$8,190,782
	Revenues																					
		Biochar	Revenue Year (Contract P3), $/yr																	-$136,927	-$138,768	-$187,478
			Subtotal		$741,482,534															$22,953,517	$23,262,734	$23,525,080
			Total	$1,071,510,251																		
S4	**West Point Treatment plant**																					
	Capital Cost		TAD-Batch		NPV Capital Cost																	
					$128,586,966																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$108,172,760		$7,820,822	$7,897,858	$7,974,895	$8,051,931	$8,128,967	$8,206,004	$8,283,040	$8,360,076	$8,437,113	$8,514,149	$8,591,185	$8,668,221	$8,745,258	$8,822,294	$8,899,330	$8,976,367
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																			
	Revenues																					
		CHP	Electricity Sales, $/yr				-$1,259,574	-$1,271,981	-$1,284,388	-$1,296,795	-$1,309,202	-$1,321,609	-$1,334,016	-$1,346,423	-$1,358,830	-$1,371,237	-$1,383,644	-$1,396,051	-$1,408,458	-$1,420,865	-$1,433,272	-$1,445,679
		Land App	Land App East/West WA Revenue, $/yr																			
	South Treatment Plant																					
	Capital Cost		TAD-Batch		NPV Capital Cost																	
					$115,485,340																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$97,151,122															$10,437,136	$10,571,914	$10,706,693
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																	$4,771,147	$4,832,759	$4,894,371
	Revenues																					
		Biogas	Renewable Natural Gas Sales, $/yr																	-$7,215,846	-$7,309,027	-$7,402,208
		Land App	Land App East/West WA Revenue, $/yr																	-$294,642	-$298,447	-$302,251
	Brightwater Treatment Plant																					
	Capital Cost		MAD		NPV Capital Cost																	
					$39,098,386																	
	Operation and Maintenance				Escalated and Discounted																	
		Solids Treatment	Operation and Maintenance, $/yr		$32,891,206		$1,980,025	$2,057,820	$2,135,616	$2,213,412	$2,291,208	$2,369,003	$2,446,799	$2,524,595	$2,602,390	$2,680,186	$2,757,982	$2,835,777	$2,913,573	$2,991,369	$3,069,164	$3,146,960
	Land Application																					
		Land App	Land App East/West WA Cost, $/yr																			
	Revenues																					
		Land App	Land App East/West WA Revenue, $/yr																			
	Off-Site Composting (Brightwater Solids)																					
	Capital Cost		Composting		NPV Capital Cost																	
					$119,906,031																	
	Hauling and Transportation				Escalated and Discounted																	
		Biosolids & Woodchips	Hauling & Fuel Cost, $/yr		$100,869,993															$441,251	$452,726	$464,202
	Operation and Maintenance																					
		Composting	Operation and Maintenance, $/yr																	$4,133,571	$4,241,072	$4,348,573
	Revenues																					
		Woodchips	Tipping Fee, $/yr																	-$588,359	-$603,661	-$618,962
		Composting	Revenue Year (Commercial), $/yr																	-$279,995	-$287,277	-$589,117
		Composting	Revenue Year (Consumer), $/yr																	-$197,214	-$202,343	-$484,101
	Off-Site Soil Blending (West Point Solids)																					
	Capital Cost		Soil Blending		NPV Capital Cost																	
					$58,462,405																	
	Hauling and Transport				Escalated and Discounted																	
		Biosolids & Feedstocks	Hauling & Fuel Cost, $/yr		$49,181,032															$846,764	$854,158	$861,552
	Feedstock Purchase																					
		Fine Sand	Material Purchase, $/yr																	$513,903	$518,391	$522,878
	Operation and Maintenance																					
		Soil Blending	Operation and Maintenance, $/yr																	$5,570,677	$5,619,320	$5,667,963
	Revenues																					
		Soil Blend	Revenue Year (Commercial), $/yr																	-$403,875	-$407,402	-$821,857
		Soil Blend	Revenue Year (Consumer), $/yr																	-$261,711	-$263,996	-$621,324
			Subtotal		$388,266,112															$27,865,605	$28,253,411	$27,304,059
			Total	$757,081,691																		

$9,007,485	$9,084,131	$9,160,777	$9,237,422	$9,314,068	$9,390,713	$9,467,359	$9,544,004	$9,620,650	$9,697,296	$9,773,941	$9,850,587	$9,927,232	$10,003,878	$10,080,524	$10,157,169	$10,233,815	$198,814,537	$122,420,640.57
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$0	$0.00
-$1,372,530	-$1,384,209	-$1,395,888	-$1,407,567	-$1,419,246	-$1,430,925	-$1,442,604	-$1,454,283	-$1,465,962	-$1,477,641	-$1,489,320	-$1,500,999	-$1,512,678	-$1,524,357	-$1,536,036	-$1,547,715	-$1,559,394	-$30,294,694	-$18,654,047.74
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$168,519,843	**$103,766,593**
$10,717,277	$10,850,512	$10,983,747	$11,116,981	$11,250,216	$11,383,451	$11,516,686	$11,649,921	$11,783,156	$11,916,391	$12,049,626	$12,182,860	$12,316,095	$12,449,330	$12,582,565	$12,715,800	$12,849,035	$241,850,408	$148,808,792.69
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$0	$0.00
-$7,030,440	-$7,117,841	-$7,205,242	-$7,292,643	-$7,380,044	-$7,467,445	-$7,554,846	-$7,642,247	-$7,729,648	-$7,817,049	-$7,904,450	-$7,991,851	-$8,079,251	-$8,166,652	-$8,254,053	-$8,341,454	-$8,428,855	-$158,651,764	-$97,617,274.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$83,198,643	**$51,191,519**
$3,224,756	$3,302,551	$3,380,347	$3,458,143	$3,535,938	$3,613,734	$3,691,530	$3,769,325	$3,847,121	$3,924,917	$4,002,712	$4,080,508	$4,158,304	$4,236,099	$4,313,895	$4,391,691	$4,469,486	$77,522,124	$47,601,147.62
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$0	$0.00
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
																	$77,522,124	**$47,601,148**
$1,179,061	$1,194,297	$1,209,533	$1,224,768	$1,240,004	$1,255,239	$1,270,475	$1,285,711	$1,300,946	$1,316,182	$1,331,417	$1,346,653	$1,361,888	$1,377,124	$1,392,360	$1,407,595	$1,422,831	$25,561,855	$16,414,497.08
																	$0	$0.00
$8,298,007	$8,405,232	$8,512,457	$8,619,682	$8,726,907	$8,834,132	$8,941,358	$9,048,583	$9,155,808	$9,263,033	$9,370,258	$9,477,483	$9,584,708	$9,691,933	$9,799,158	$9,906,383	$10,013,608	$179,899,401	$115,522,063.86
																	$0	$0.00
-$189,933	-$192,387	-$194,841	-$197,295	-$199,750	-$404,408	-$409,316	-$414,225	-$419,133	-$424,042	-$428,950	-$542,324	-$548,459	-$554,595	-$560,731	-$566,866	-$573,002	-$7,283,432	(4,468,103)
$23,833,683	$24,142,285	$24,450,888	$24,759,491	$25,068,093	$25,174,492	$25,480,640	$25,786,789	$26,092,937	$26,399,085	$26,705,234	$26,902,917	$27,207,839	$27,512,760	$27,817,681	$28,122,602	$28,427,524	**$198,177,824**	**$127,468,458**

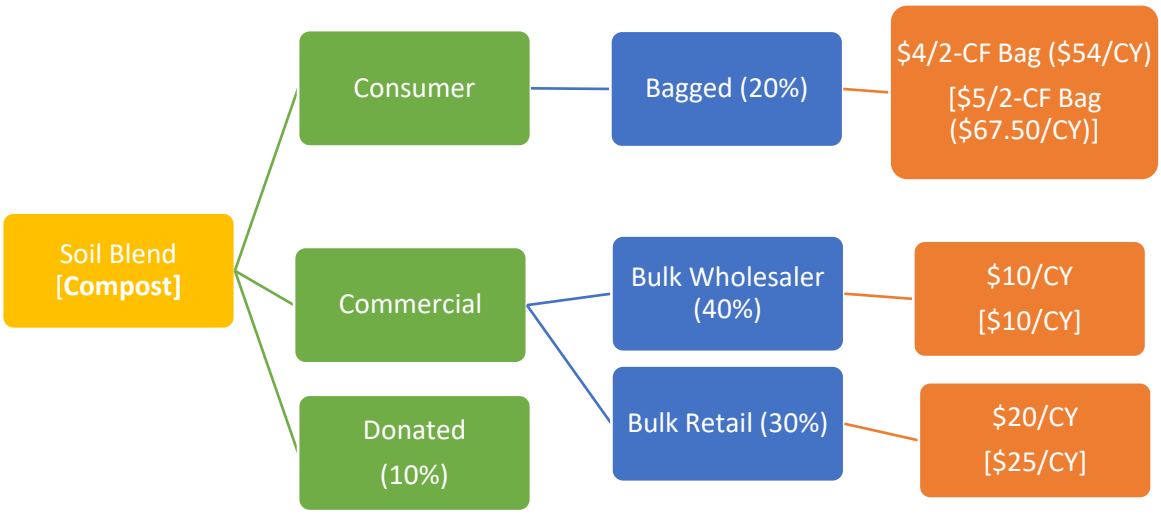
$9,053,403	$9,130,439	$9,207,476	$9,284,512	$9,361,548	$9,438,584	$9,515,621	$9,592,657	$9,669,693	$9,746,730	$9,823,766	$9,900,802	$9,977,839	$10,054,875	$10,131,911	$10,208,947	$10,285,984	$199,828,036	$123,044,705.59
																	$0	$0.00
																	$0	$0.00
																	$0	$0.00
-$1,458,086	-$1,470,493	-$1,482,900	-$1,495,307	-$1,507,714	-$1,520,121	-$1,532,528	-$1,544,935	-$1,557,342	-$1,569,749	-$1,582,156	-$1,594,563	-$1,606,970	-$1,619,377	-$1,631,784	-$1,644,191	-$1,656,598	-$32,183,084	-$19,816,829.34
																	$0	$0.00
																	$167,644,952	**$103,227,876**
$10,841,472	$10,976,251	$11,111,030	$11,245,809	$11,380,587	$11,515,366	$11,650,145	$11,784,924	$11,919,703	$12,054,482	$12,189,260	$12,324,039	$12,458,818	$12,593,597	$12,728,376	$12,863,155	$12,997,934	$234,350,690	$150,533,236.19
$4,955,982	$5,017,594	$5,079,206	$5,140,817	$5,202,429	$5,264,041	$5,325,652	$5,387,264	$5,448,876	$5,510,488	$5,572,099	$5,633,711	$5,695,323	$5,756,934	$5,818,546	$5,880,158	$5,941,769	$107,129,166	$68,813,537.58
-$7,495,389	-$7,588,570	-$7,681,751	-$7,774,932	-$7,868,113	-$7,961,294	-$8,054,475	-$8,147,656	-$8,240,837	-$8,334,018	-$8,427,199	-$8,520,380	-$8,613,561	-$8,706,742	-$8,799,924	-$8,893,105	-$8,986,286	-$162,021,312	-$104,073,055.74
-$306,056	-$309,861	-$313,666	-$317,471	-$321,276	-$325,080	-$328,885	-$332,690	-$336,495	-$340,300	-$344,105	-$347,909	-$351,714	-$355,519	-$359,324	-$363,129	-$366,933	-$6,615,753	-$4,249,574.29
																	$172,842,791	$111,024,144
$3,224,756	$3,302,551	$3,380,347	$3,458,143	$3,535,938	$3,613,734	$3,691,530	$3,769,325	$3,847,121	$3,924,917	$4,002,712	$4,080,508	$4,158,304	$4,236,099	$4,313,895	$4,391,691	$4,469,486	$77,522,124	$47,601,147.62
																	$0	$0.00
																	$0	$0.00
																	$0	$0.00
																	$0	$0.00
																	$77,522,124	**$47,601,148**
$475,677	$487,153	$498,628	$510,104	$521,579	$533,055	$544,530	$556,006	$567,481	$578,956	$590,432	$601,907	$613,383	$624,858	$636,334	$647,809	$659,285	$11,005,356	$7,021,548.40
																	$0	$0.00
$4,456,073	$4,563,574	$4,671,074	$4,778,575	$4,886,076	$4,993,576	$5,101,077	$5,208,578	$5,316,078	$5,423,579	$5,531,079	$5,638,580	$5,746,081	$5,853,581	$5,961,082	$6,068,582	$6,176,083	$103,096,544	$65,776,827.67
																	$0	$0.00
-$634,263	-$649,565	-$664,866	-$680,167	-$695,469	-$710,770	-$726,071	-$741,372	-$756,674	-$771,975	-$787,276	-$802,578	-$817,879	-$833,180	-$848,482	-$863,783	-$879,084	-$14,674,437	-$9,362,466.00
-$603,681	-$618,244	-$632,808	-$647,371	-$661,935	-$1,014,747	-$1,036,593	-$1,058,438	-$1,080,283	-$1,102,128	-$1,123,974	-$1,527,759	-$1,556,886	-$1,586,013	-$1,615,140	-$1,644,267	-$1,673,394	-$20,340,047	-$12,465,137.79
-$496,068	-$508,035	-$520,003	-$531,970	-$543,938	-$952,980	-$973,496	-$994,011	-$1,014,527	-$1,035,042	-$1,055,558	-$1,614,110	-$1,644,883	-$1,675,657	-$1,706,430	-$1,737,203	-$1,767,977	-$19,655,546	-$11,910,043.36
																	$59,431,870	**$39,060,729**
$868,946	$876,340	$883,734	$891,128	$898,522	$905,916	$913,310	$920,704	$928,098	$935,492	$942,886	$950,279	$957,673	$965,067	$972,461	$979,855	$987,249	$18,340,134	$11,809,836.66
$527,365	$531,853	$536,340	$540,828	$545,315	$549,802	$554,290	$558,777	$563,265	$567,752	$572,239	$576,727	$581,214	$585,702	$590,189	$594,676	$599,164	$11,130,671	$7,167,417.67
$5,716,607	$5,765,250	$5,813,893	$5,862,536	$5,911,179	$5,959,822	$6,008,466	$6,057,109	$6,105,752	$6,154,395	$6,203,038	$6,251,681	$6,300,325	$6,348,968	$6,397,611	$6,446,254	$6,494,897	$120,655,743	$77,694,340.45
-$828,910	-$835,964	-$843,017	-$850,070	-$857,123	-$1,296,265	-$1,306,845	-$1,317,425	-$1,328,005	-$1,338,585	-$1,349,165	-$1,812,993	-$1,827,099	-$1,841,206	-$1,855,312	-$1,869,419	-$1,883,525	-$24,874,060	(15,361,659)
-$626,656	-$631,988	-$637,321	-$642,653	-$647,985	-$1,119,973	-$1,129,114	-$1,138,255	-$1,147,396	-$1,156,537	-$1,165,678	-$1,762,229	-$1,775,940	-$1,789,652	-$1,803,364	-$1,817,075	-$1,830,787	-$21,969,634	(13,408,253)
$27,671,172	$28,038,284	$28,405,397	$28,772,509	$29,139,622	$27,872,667	$28,216,614	$28,560,561	$28,904,508	$29,248,455	$29,592,402	$27,975,716	$28,294,026	$28,612,337	$28,930,647	$29,248,958	$29,567,268	**$103,282,853**	**$67,901,683**

Performance Summary				Notes	1	2	3	4
O&M Costs Based on 2050 Flows and Loads					100% Class B application with MAD at all three plants	TAD-Batch , Cambi, and Off-site Soil Blending or Composting	Off-site Pyrolysis	TAD-Batch and Off-site Soil Blending or Composting
Element					S1	S2	S3	S4
West Point Treatment plant								
	Operation and Maintenance							
		Solids Treatment	Operation and Maintenance, $/yr		$8,220,708	$7,669,298	$8,220,708	$7,669,298
		TAD-Batch	Operation and Maintenance, $/yr		$0	$365,490	$0	$365,490
	Process Fuel Consumption							
		Solids Treatment	Natural Gas Consumption, $/yr		$0	$0	$0	$0
	Electricity Consumption							
		Solids Treatment	Electricity Consumption, $/yr		$821,834	$917,555	$821,834	$917,555
	Electricity Sales							
		CHP	Electricity Sales Revenue, $/yr		$1,559,394	$1,656,598	$1,559,394	$1,656,598
	Chemical Usage							
		Dewatering	Polymer Use, $/yr		$1,191,274	$1,111,368	$1,191,274	$1,111,368
		Dewatering (TAD)	Polymer Use, $/yr		$0	$222,274	$0	$222,274
	Land Application							
		Agriculture	Land App Eastern WA Cost, $/yr		$3,624,176	To Off-site Soil Blending	To Off-site Pyrolysis	To Off-site Soil Blending
		Forestry	Land App Western WA Cost, $/yr		$457,277			
		Agriculture	Land App Eastern WA Revenue, $/yr		$99,997			
		Forestry	Land App Western WA, Revenue, $/yr		$48,875			
South Treatment Plant								
	Operation and Maintenance							
		Solids Treatment	Operation and Maintenance, $/yr		$9,717,031	$9,717,031	$9,717,031	$9,717,031
		THP-MAD	Operation and Maintenance, $/yr		$0	$2,479,298	$0	
	Process Fuel Consumption							
		Solids Treatment	Natural Gas Consumption, $/yr		$515,568	$924,448	$515,568	$746,378
	Potable Water Usage							
		THP	Potable Water, $/yr		$0	$456,495	$0	0.0
	Biogas Upgrading Sales							
		Biogas	Renewable Natural gas Value, $/yr		$994,558	$1,006,652	$994,558	$1,060,332
		Biogas	Renwable Natural Gas RINs, $/yr		$5,964,479	$6,037,011	$5,964,479	$6,358,932
		Biogas	Renwable Natural Gas CA LCFS, $/yr		$1,469,818	$1,487,692	$1,469,818	$1,567,022
	Electricity Consumption							
		Solids Treatment	Electricity Consumption, $/yr		$984,123	$1,467,406	$984,123	$1,017,100
	Chemical Usage							
		Predewatering	Polymer Use, $/yr		$0	$1,444,086	$0	$0

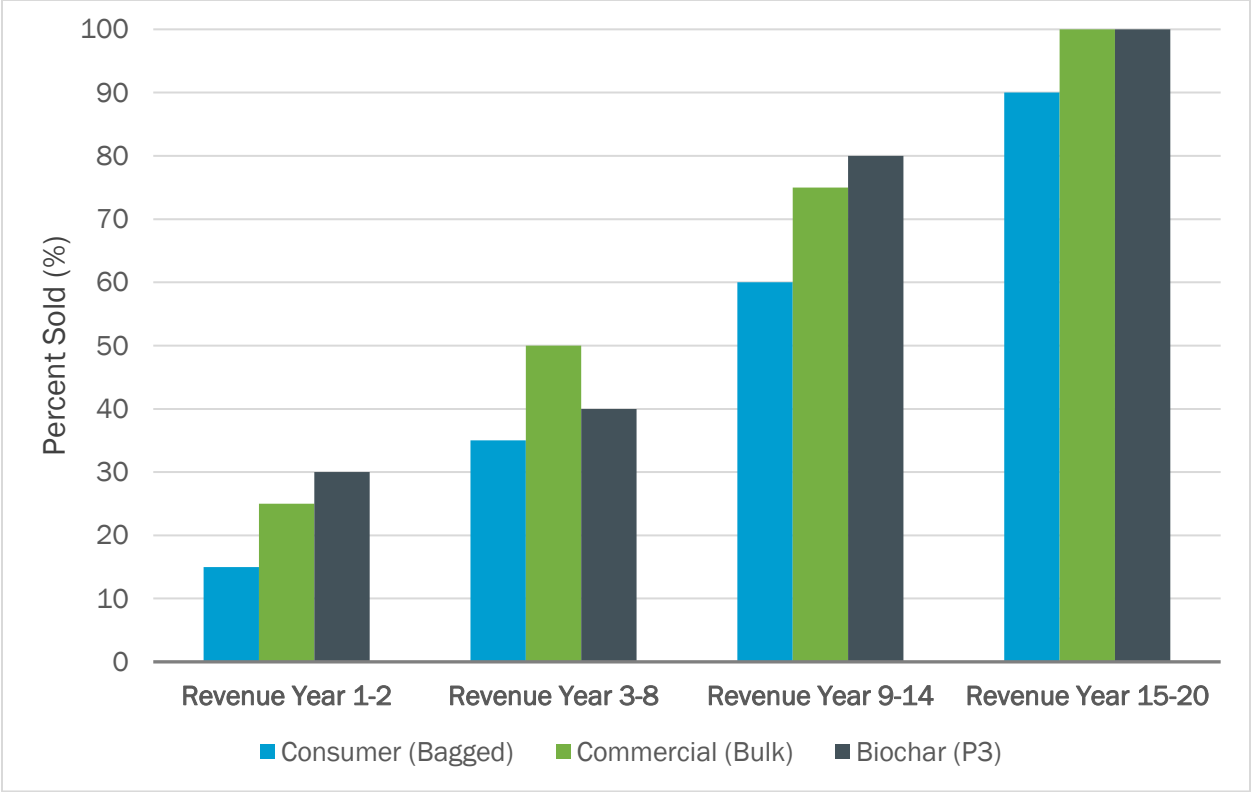
		Dewatering	Polymer Use, $/yr		$1,632,313	$1,543,797	$1,632,313	$1,517,425
	Land Application							
		Agriculture	Land App Eastern WA Cost, $/yr		$5,456,583	$2,626,216	To Off-site Pyrolysis	$3,381,685
		Forestry	Land App Western WA Cost, $/yr		$688,479	$1,988,161		$2,560,085
		Agriculture	Land App Eastern WA Revenue, $/yr		$150,556	$72,462		$93,306
		Forestry	Land App Western WA, Revenue, $/yr		$73,586	$212,499		$273,627
Brightwater Treatment Plant								
	Operation and Maintenance							
		Solids Treatment	Operation and Maintenance, $/yr		$3,649,507	$3,649,507	$3,649,507	$3,649,507
	Process Fuel Consumption							
		Solids Treatment	Natural Gas Consumption, $/yr		$0	$0	$0	$0
	Electricity Consumption							
		Solids Treatment	Electricity Consumption, $/yr		$277,341	$277,341	$277,341	$277,341
	Chemical Usage							
		Dewatering	Polymer Use, $/yr		$542,639	$542,639	$542,639	$542,639
	Land Application							
		Agriculture	Land App Eastern WA Cost, $/yr		$2,023,400	To Off-site Composting	To Off-site Pyrolysis	To Off-site Composting
		Forestry	Land App Western WA Cost, $/yr		$255,301			
		Agriculture	Land App Eastern WA Revenue, $/yr		$55,829			
		Forestry	Land App Western WA, Revenue, $/yr		$27,287			
Off-Site Composting (Brightwater Solids)								
	Hauling and Transportation							
		Biosolids	Hauling Cost, $/yr			$238,448		$238,448
		Biosolids	Fuel Cost (Diesel), $/yr			$28,716		$28,716
		Woodchips	Hauling Cost, $/yr			$310,317		$310,317
		Woodchips	Fuel Cost (Diesel), $/yr			$81,804		$81,804
	Operation and Maintenance							
		Composting	Operation and Maintenance, $/yr			$5,592,946		$5,592,946
		Composting	Equipment Upgrades, $/yr			$80,000		$80,000
	Electricity Consumption							
		Composting	Electricity Costs, $/yr			$143,101		$143,101
	Process Fuel Consumption							
		Composting	Fuel Consumption (Diesel), $/yr			$360,036		$360,036
	Revenues							
		Woodchips	Tipping Fee, $/yr			$879,084		$879,084
		Compost	Revenue Year 1-2 (Commercial)			$418,348		$418,348
		Compost	Revenue Year 3-8 (Commercial)			$836,697		$836,697
		Compost	Revenue Year 9-14 (Commercial)			$1,255,045		$1,255,045
		Compost	Revenue Year 15-20 (Commercial)			$1,673,394		$1,673,394
		Compost	Revenue Year 1-2 (Consumer)			$294,663		$294,663
		Compost	Revenue Year 3-8 (Consumer)			$687,547		$687,547

		Compost	Revenue Year 9-14 (Consumer)			$1,178,651		$1,178,651
		Compost	Revenue Year 15-20 (Consumer)			$1,767,977		$1,767,977
Off-Site Soil Blending (West Point Solids)								
	Hauling and Transport							
		Biosolids	Hauling Cost, $/yr			$398,444		$398,444
		Biosolids	Fuel Cost (Diesel), $/yr			$43,074		$43,074
		Woodchips	Hauling Cost, $/yr			$98,702		$98,702
		Woodchips	Fuel Cost (Diesel), $/yr			$47,308		$47,308
		Fine Sand	Hauling Cost, $/yr			$322,740		$322,740
		Fine Sand	Fuel Cost (Diesel), $/yr			$76,981		$76,981
	Feedstock Purchase							
		Fine Sand	Feedstock Purchase, $/yr			$399,443		$399,443
		Saw Dust	Feedstock Purchase, $/yr			$199,721		$199,721
	Operation and Maintenance							
		Soil Blending	Operation and Maintenance, $/yr			$6,147,421		$6,147,421
		Soil Blending	Equipment Upgrades, $/yr			$40,000		$40,000
	Electricity Consumption							
		Soil Blending	Electricity Costs, MWh/yr			$0		$0
	Process Fuel Consumption							
		Soil Blending	Fuel Consumption (Diesel), $/yr			$307,476		$307,476
	Revenues							
		Soil Blend	Revenue Year 1-2 (Commercial)			$470,881		$470,881
		Soil Blend	Revenue Year 3-8 (Commercial)			$941,763		$941,763
		Soil Blend	Revenue Year 9-14 (Commercial)			$1,412,644		$1,412,644
		Soil Blend	Revenue Year 15-20 (Commercial)			$1,883,525		$1,883,525
		Soil Blend	Revenue Year 1-2 (Consumer)			$305,131		$305,131
		Soil Blend	Revenue Year 3-8 (Consumer)			$711,973		$711,973
		Soil Blend	Revenue Year 9-14 (Consumer)			$1,220,524		$1,220,524
		Soil Blend	Revenue Year 15-20 (Consumer)			$1,830,787		$1,830,787
Off-Site Thermal Drying and Pyrolysis								
	Hauling and Transport							
		Biosolids	Hauling Cost, $/yr				$1,286,429	
		Biosolids	Fuel Cost (Diesel), $/yr				$136,402	
	Operation and Maintenance							
		Drying + Pyrolysis	Operation and Maintenance, $/yr				$2,990,705	
		Drying + Pyrolysis	Spare parts and replacement, $/yr				$1,500,000	
	Electricity Consumption							
		Drying + Pyrolysis	Electricity Costs, $/yr				$3,521,388	
	Process Fuel Consumption							
		Drying + Pyrolysis	Natural Gas Consumption, $/yr				$2,001,516	
	Revenues							
		Biochar	Revenue Year 1-2 (Contract P3)				$171,901	
		Biochar	Revenue Year 3-8 (Contract P3)				$229,201	

		Biochar	Revenue Year 9-14 (Contract P3)				$458,402	
		Biochar	Revenue Year 15-20 (Contract P3)				$573,002	


Soil Blend
[Compost]
Consumer
Commercial
Donated
(10%)
Bagged (20%)
Bulk Wholesaler
(40%)
Bulk Retail (30%)
$4/2-CF Bag ($54/CY)
[$5/2-CF Bag
($67.50/CY)]
$10/CY
[$10/CY]
$20/CY
[$25/CY]

Biochar
P3 Partnership
(BFT)
10% of
$250/ton


Percent Sold (%)
100
90
80
70
60
50
40
30
20
10
0
Revenue Year 1-2
Revenue Year 3-8
Revenue Year 9-14
Revenue Year 15-20
Consumer (Bagged)
Commercial (Bulk)
Biochar (P3)

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	West Point			**Estimator:**	Steve Krugel and Trung Le
Description:	**MAD upgrades**			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD Digester - West Point (2 Additional 2.4 MG Digesters)**	**4.80**	**$/MG**	**8000000**	**$ 38,400,000**
4					$ -
				Construction Cost Markup	$ 11,712,000
				Subtotal Construction Costs	***$ 50,112,000***
				Allowance for Indeterminates (Design Allowance)	$ 12,528,000
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 62,640,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 6,264,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 68,904,000***
				Construction Sales Tax	$ 6,959,304
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 75,863,304***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 137,808
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 76,001,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 22,442,520
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 689,040
				Right-of-Way	$ -
				Misc. Service & Materials	$ 551,232
				Non-WTD Support	$ 585,684
				WTD Staff Labor	$ 7,923,941
				Subtotal Non-Construction Costs	***$ 32,192,418***
				Project Contingency	$ 32,458,059
				Initiatives	$ 1,263,103
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 65,913,580***
				TOTAL PROJECT COST	***$ 141,914,692***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	West Point			**Estimator:**	Steve Krugel and Trung Le
Description:	MAD upgrades			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD Digester - West Point (2 Additional 2.4 MG Digesters)**	**4.80**	**$/MG**	**$ 8,000,000.00**	**$ 38,400,000**
2					
				Item Subtotal Construction Costs (Year 2020)	$ 38,400,000
DIRECT: CONSTRUCTION COST MARK-UPS					
		General Conditions	10%	1.1	$ 3,840,000
		Mobilization/Demobilization	10%	1.1	$ 3,840,000
		Overhead & Profit (OHP)	8%	1.08	$ 3,072,000
		Insurance	1.5%	1.015	$ 576,000
		Bonding	1.0%	1.01	$ 384,000
		Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2020)	$ 50,112,000
				Direct: Subtotal Construction Costs	***$ 50,112,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	**MAD upgrades**			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD Digester - South Plant (1 Additional 2.75 MG Digesters)**	**2.75**	**$/MG**	**8000000**	**$ 22,000,000**
2					$ -
				Construction Cost Markup	$ 6,710,000
				Subtotal Construction Costs	***$ 28,710,000***
				Allowance for Indeterminates (Design Allowance)	$ 7,177,500
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 35,887,500***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 3,588,750
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 39,476,250***
				Construction Sales Tax	$ 3,987,101
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 43,463,351***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 78,953
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 43,542,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 13,941,056
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 394,763
				Right-of-Way	$ -
				Misc. Service & Materials	$ 315,810
				Non-WTD Support	$ 335,548
				WTD Staff Labor	$ 4,851,334
				Subtotal Non-Construction Costs	***$ 19,838,510***
				Project Contingency	$ 19,014,244
				Initiatives	$ 732,720
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 39,585,474***
				TOTAL PROJECT COST	***$ 83,127,778***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	MAD upgrades			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD Digester - South Plant (1 Additional 2.75 MG Digesters)**	**2.75**	**$/MG**	**$ 8,000,000.00**	**$ 22,000,000**
2					$ -
				Item Subtotal Construction Costs (Year 2020)	$ 22,000,000
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 2,200,000
	Mobilization/Demobilization		10%	1.1	$ 2,200,000
	Overhead & Profit (OHP)		8%	1.08	$ 1,760,000
	Insurance		1.5%	1.015	$ 330,000
	Bonding		1.0%	1.01	$ 220,000
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2020)	$ 28,710,000
				Direct: Subtotal Construction Costs	***$ 28,710,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	Brightwater			**Estimator:**	Steve Krugel and Trung Le
Description:	**MAD Upgrades**			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	MAD Digester - Brightwater (1 Additional 1.25MG Digesters)	1.25	$/MG	8000000	$ 10,000,000
2					$ -
				Construction Cost Markup	$ 3,050,000
				Subtotal Construction Costs	***$ 13,050,000***
				Allowance for Indeterminates (Design Allowance)	$ 3,262,500
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 16,312,500***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 1,631,250
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 17,943,750***
				Construction Sales Tax	$ 1,812,319
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 19,756,069***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 35,888
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 19,792,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 7,109,830
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 179,438
				Right-of-Way	$ -
				Misc. Service & Materials	$ 143,550
				Non-WTD Support	$ 152,522
				WTD Staff Labor	$ 2,437,165
				Subtotal Non-Construction Costs	***$ 10,022,504***
				Project Contingency	$ 8,944,338
				Initiatives	$ 339,587
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 19,306,430***
				TOTAL PROJECT COST	***$ 39,098,386***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	Brightwater			**Estimator:**	Steve Krugel and Trung Le
Description:	MAD Upgrades			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD Digester - Brightwater (1 Additional 1.25MG Digesters)**	**1.3**	**$/MG**	**$ 8,000,000.00**	**$ 10,000,000**
2					$ -
				Item Subtotal Construction Costs (Year 2020)	$ 10,000,000
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 1,000,000
	Mobilization/Demobilization		10%	1.1	$ 1,000,000
	Overhead & Profit (OHP)		8%	1.08	$ 800,000
	Insurance		1.5%	1.015	$ 150,000
	Bonding		1.0%	1.01	$ 100,000
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2020)	$ 13,050,000
				Direct: Subtotal Construction Costs	***$ 13,050,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	West Point			**Estimator:**	Steve Krugel and Trung Le
Description:	TAD System at West Point			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD to TAD Digester Upgrades**	**1**	**LS**	**16900000**	**$ 16,900,000**
2	**TAD Batch Tanks**	**1**	**LS**	**19200000**	**$ 19,200,000**
3					$ -
				Construction Cost Markup	$ 11,010,500
				Subtotal Construction Costs	***$ 47,110,500***
				Allowance for Indeterminates (Design Allowance)	$ 9,422,100
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 56,532,600***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 5,653,260
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 62,185,860***
				Construction Sales Tax	$ 6,280,772
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 68,466,632***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 124,372
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 68,591,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 20,557,872
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 621,859
				Right-of-Way	$ -
				Misc. Service & Materials	$ 497,487
				Non-WTD Support	$ 528,580
				WTD Staff Labor	$ 7,237,417
				Subtotal Non-Construction Costs	***$ 29,443,215***
				Project Contingency	$ 29,410,265
				Initiatives	$ 1,142,483
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 59,995,963***
				TOTAL PROJECT COST	***$ 128,586,966***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	TAD System at South Plant			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD to TAD Digester Upgrades**	**1**	**LS**	**13920000**	**$ 13,920,000**
2	**TAD Batch Tanks**	**1**	**LS**	**18360000**	**$ 18,360,000**
3					$ -
				Construction Cost Markup	$ 9,845,400
				Subtotal Construction Costs	***$ 42,125,400***
				Allowance for Indeterminates (Design Allowance)	$ 8,425,080
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 50,550,480***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 5,055,048
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 55,605,528***
				Construction Sales Tax	$ 5,616,158
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 61,221,686***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 111,211
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 61,333,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 18,683,252
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 556,055
				Right-of-Way	$ -
				Misc. Service & Materials	$ 444,844
				Non-WTD Support	$ 472,647
				WTD Staff Labor	$ 6,557,411
				Subtotal Non-Construction Costs	***$ 26,714,209***
				Project Contingency	$ 26,414,132
				Initiatives	$ 1,024,101
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 54,152,443***
				TOTAL PROJECT COST	***$ 115,485,340***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	TAD System at South Plant			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**MAD to TAD Digester Upgrades**	**1.0**	**LS**	**$ 13,920,000**	**$ 13,920,000**
2	Floating Cover to Fixed Cover Upgrade	4.0	EA	$ 1,000,000	$ 4,000,000
3	Heat Exchanger Upgrades	4.0	EA	$ 300,000	$ 1,200,000
4	Boiler upsize	2.0	EA	$ 1,000,000	$ 2,000,000
5	Digester Cleaning, Repairs, and General Upgrades, and New Mixing (	4.0	EA	$ 1,680,000	$ 6,720,000
6	**TAD Batch Tanks**	**1.0**	**LS**	**$ 18,360,000**	**$ 18,360,000**
7	Batch tanks	1.5	$/MG	$ 12,000,000	$ 18,360,000
8					$ -
	Item Subtotal Construction Costs (Year 2020)				$ 32,280,000
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 3,228,000
	Mobilization/Demobilization		10%	1.1	$ 3,228,000
	Overhead & Profit (OHP)		8%	1.08	$ 2,582,400
	Insurance		1.5%	1.015	$ 484,200
	Bonding		1.0%	1.01	$ 322,800
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
	Item Subtotal Construction Costs (Year 2020)				$ 42,125,400
	Direct: Subtotal Construction Costs				***$ 42,125,000***

Base Year	Estimate Year
2019	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Treatment Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	THP-MAD System at South Plant			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	THP-MAD Digester Upgrades	1	LS	10720000	$ 10,720,000
2	Solids Screening and Pre-dewatering	1	LS	84000000	$ 84,000,000
3	Thermal Hydrolysis (CAMBI)	1	LS	53200000	$ 53,200,000
4	Steam Boilers	1	LS	7910000	$ 7,910,000
5	Cooling Towers	1	LS	4690000	$ 4,690,000
6					$ -
				Construction Cost Markup	$ 48,958,600
				Subtotal Construction Costs	***$ 209,478,600***
				Allowance for Indeterminates (Design Allowance)	$ 31,421,790
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 240,900,390***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 24,090,039
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 264,990,429***
				Construction Sales Tax	$ 26,764,033
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 291,754,462***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 529,981
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 292,284,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 71,072,436
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 2,649,904
				Right-of-Way	$ -
				Misc. Service & Materials	$ 2,119,923
				Non-WTD Support	$ 2,252,419
				WTD Staff Labor	$ 26,324,583
				Subtotal Non-Construction Costs	***$ 104,419,266***
				Project Contingency	$ 119,011,113
				Initiatives	$ 4,731,621
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 228,162,000***
				TOTAL PROJECT COST	***$ 520,446,443***

Base Year	Estimate Year
2019	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	1/2/2020
Location:	South Treatment Plant			**Estimator:**	Steve Krugel and Trung Le
Description:	THP-MAD System at South Plant			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**THP-MAD Digester Upgrades**	**1**	**LS**	**$ 10,720,000.00**	**$ 10,720,000**
2	Floating Cover to Fixed Cover Upgrade	4	EA	$ 1,000,000.00	$ 4,000,000
3	Digester Cleaning, Repairs, and General Upgrades, and New Mixing (Draft Tube)	4	EA	$ 1,680,000.00	$ 6,720,000
4	**Solids Screening and Pre-dewatering**	**1**	**LS**	**$ 84,000,000.00**	**$ 84,000,000**
5	**Thermal Hydrolysis (CAMBI)**	**1**	**LS**	**$ 53,200,000.00**	**$ 53,200,000**
6	**Steam Boilers**	**1**	**LS**	**$ 7,910,000.00**	**$ 7,910,000**
7	**Cooling Towers**	**1**	**LS**	**$ 4,690,000.00**	**$ 4,690,000**
				Item Subtotal Construction Costs (Year 2020)	$ 160,520,000
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 16,052,000
	Mobilization/Demobilization		10%	1.1	$ 16,052,000
	Overhead & Profit (OHP)		8%	1.08	$ 12,841,600
	Insurance		1.5%	1.015	$ 2,407,800
	Bonding		1.0%	1.01	$ 1,605,200
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2020)	$ 209,478,600
				Direct: Subtotal Construction Costs	***$ 209,479,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	ASP Composting Facility			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Primary Composting	44,018	SF	$ 157	$ 6,905,580
2	Secondary Composting	69,728	SF	$ 125	$ 8,747,068
3	Process/Maintenance Buildings	67,750	SF	$ 75	$ 5,081,231
4	Office/Administration Building	7,500	SF	$ 150	$ 1,125,000
5	Admin Parking, Roads, Truck Access, Maintenance Yard, Curing and Storage, Screening	178,153	SF	$ 8	$ 1,425,221
6	Dry Wood Storage	26,999	SF	$ 25	$ 674,963
7	Ponds and Collection System	111,409	SF	$ 20	$ 2,228,184
8	Equipment Purchases (ECS)	1	LS	$ 1,955,000	$ 1,955,000
9	Install Equipment Purchases (ECS)	1	LS	$ 1,225,000	$ 1,225,000
10	Site Preparation / Demolition	629,055	SF	$ 1	$ 933,091
11	Site Mass Grading (whole site using avg. of 2.5' of cut to fill)	58,246	CY	$ 5	$ 262,106
12	Water / Sewer / Electrical Services to Site	1	LS	$ 250,000	$ 312,500
13	Site Perimeter - Chain Link Fencing	4,496	LF	$ 30	$ 133,995
14	Site Perimeter - New Landscape	170,023	SF	$ 8	$ 1,428,194
				Construction Cost Markup	$ 9,893,326
				Subtotal Construction Costs	***$ 42,330,460***
				Allowance for Indeterminates (Design Allowance)	$ 11,288,865
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 53,619,325***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 5,644,432
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 59,263,757***
				Construction Sales Tax	$ 5,985,639
				Owner Furnished Equipment	$ 2,825,000
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 68,074,396***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 124,178
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 68,199,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 14,228,182
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 310,444
				Right-of-Way	$ -
				Misc. Service & Materials	$ 1,117,598
				Non-WTD Support	$ 527,754
				WTD Staff Labor	$ 6,941,389
				Subtotal Non-Construction Costs	***$ 23,125,367***
				Project Contingency	$ 27,482,780
				Initiatives	$ 1,099,310
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 51,707,457***
				TOTAL PROJECT COST	***$ 119,906,031***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	ASP Composting Facility			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Primary Composting**	**44,018**	**SF**	$ 156.88	**$ 6,905,580**
2	Primary Compost Process Area	1	LS	$ -	$ -
3	**Secondary Composting**	**69,728**	**SF**	$ 125.45	**$ 8,747,068**
4	Secondary ASP Area	1	LS	$ -	$ -
5	**Process/Maintenance Buildings**	**67,750**	**SF**	$ 75.00	**$ 5,081,231**
6	Pre-process & Tip Building	44,821	SF	$ 75.00	$ 3,361,594
7	Maintenance Building	5,000	SF	$ 75.00	$ 375,000
8	Bagging Building	17,929	SF	$ 75.00	$ 1,344,638
9	**Office/Administration Building**	**7,500**	**SF**	$ 150.00	**$ 1,125,000**
10	**Admin Parking, Roads, Truck Access, Maintenance Yard, Curing and Storage, Screening**	**178,153**	**SF**	$ 8.00	**$ 1,425,221**
11	Admin Parking	2,500	SF	$ 8.00	$ 20,000
12	Roads	59,112	SF	$ 8.00	$ 472,896
13	Truck Access	26,893	SF	$ 8.00	$ 215,142
14	Maintenance Yard	8,964	SF	$ 8.00	$ 71,714
15	Screening Area	13,446	SF	$ 8.00	$ 107,571
16	Curing and Storage Area	67,237	SF	$ 8.00	$ 537,898
17	**Dry Wood Storage**	**26,999**	**SF**	$ 25.00	**$ 674,963**
18	**Ponds and Collection System**	**111,409**	**SF**	$ 20.00	**$ 2,228,184**
19	Contact Water Pond and Collection System	36,409	SF	$ 15.00	$ 546,138
20	Storm water Pond	75,000	SF	$ 5.00	$ 375,000
21	**Equipment Purchases (ECS)**	**1**	**LS**	$ 1,955,000.00	**$ 1,955,000**
22	Wood Grinder (mid-large Horizontal)	1	EA	$ 500,000.00	$ 500,000
23	Mixer System (ECS/LuckNow 2295)	2	EA	$ 260,000.00	$ 520,000
24	Screen (MultiStar L3 Type)	1	EA	$ 550,000.00	$ 550,000
25	Bagging Equipment (RotoChopper Go-Bagger 250)	2	EA	$ 60,000.00	$ 120,000
26	Radial Stacking Conveyors	3	EA	$ 195,000.00	$ 585,000
27	**Install Equipment Purchases (ECS)**	**1**	**LS**	$ 1,225,000.00	**$ 1,225,000**
28	Install Mixer System (ECS/LuckNow 2295)	2	EA	$ 520,000.00	$ 1,040,000
29	Install Bagging Equipment (RotoChopper Go-Bagger 250)	1	EA	$ 120,000.00	$ 120,000
30	Install Radial Stacking Conveyors	3	EA	$ 195,000.00	$ 585,000
31	**Site Preparation / Demolition**	**629,055**	**SF**	$ 1.48	$ 933,091
32	Demo Existing Building (1/4 of site size)	1,315,759	CF	$ 0.50	$ 657,879
33	Demo Existing Hard Surfaces (1/2 of site size)	314,528	SF	$ 0.75	$ 235,896
34	Demo Existing Landscape/Trees (1/4 of site size)	157,264	SF	$ 0.25	$ 39,316
35	**Site Mass Grading (whole site using avg. of 2.5' of cut to fill)**	**58,246**	**CY**	$ 4.50	**$ 262,106**
36	**Water / Sewer / Electrical Services to Site**	**1**	**LS**	$ 250,000.00	**$ 312,500**
37	**Site Perimeter - Chain Link Fencing**	**4,496**	**LF**	$ 29.80	**$ 133,995**
38	**Site Perimeter - New Landscape**	**170,023**	**SF**	$ 8.40	**$ 1,428,194**
	Item Subtotal Construction Costs (Year 2020)				$ 32,437,134
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 3,243,713.38
	Mobilization/Demobilization		10%	1.1	$ 3,243,713.38
	Overhead & Profit (OHP)		8%	1.08	$ 2,594,970.71
	Insurance		1.5%	1.015	$ 486,557.01
	Bonding		1.0%	1.01	$ 324,371.34
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
	Item Subtotal Construction Costs (Year 2020)				$ 42,330,460
	Direct: Subtotal Construction Costs				***$ 42,330,000***

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	ASP Composting Facility			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Equipment Purchases (ECS)**	**1**	**LS**	**$ 2,825,040**	**$ 2,825,040**
2	Large Front End Loader (Cat 980, Type)	**4**	EA	$ 550,000	$ 2,200,000
3	Small Front End Loader (Cat 950, Type)	**1**	EA	$ 300,000	$ 300,000
4	Compost Turner (X67 Type)	**0**	EA	$ 600,000	$ -
5	Forklift	**1**	EA	$ 50,000	$ 50,000
6	Repair Shop Tools	**1**	LS	$ 200,000	$ 200,000
7	Sport Utility Vehicle	**1**	EA	$ 36,960	$ 36,960
8	Pickup Truck	**1**	EA	$ 38,080	$ 38,080
9					
				Item Subtotal Construction Costs (Year)	$ 2,825,040
DIRECT: CONSTRUCTION COST MARK-UPS					
			General Conditions	10%	1.1	included
			Mobilization/Demobilization	10%	1.1	included
			Overhead & Profit (OHP)	10%	1.1	included
			Insurance	1.5%	1.015	included
			Bonding	1.0%	1.01	included
			Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
				Item Subtotal Construction Costs (Year)	$ 2,825,040
				Direct: Subtotal Construction Costs	***$ 2,825,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	**Soil Blending Facility (Adjacent to Composting)**			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Process Building (Prefab Building)**	22,400	SF	157	$ 3,516,800
2	**Feedstock Storage (Tensile Membrane)**	24,600	SF	20	$ 492,000
3	**Finished Product Storage (Tensile Membrane)**	15,000	SF	20	$ 300,000
4	**Misc Buildings**	15,000	SF	75	$ 1,125,000
5	**Office/Administration Building**	5,000	SF	75	$ 375,000
6	**Admin Parking, Roads, Truck Access, Maintenance Yard, Screening, Finished Product Storage (Uncovered)**	150,000	SF	8	$ 1,200,000
7	**Ponds and Collection System**	60,000	SF	22	$ 1,300,000
8	**Equipment Purchases**	1	LS	2,200,000	$ 2,200,000
9	**Install Equipment Purchases**	1	LS	1,510,000	$ 1,510,000
10	**Site Preparation / Demolition**	438,000	SF	2	$ 1,012,875
11	**Site Mass Grading (whole site using avg. of 2.5' of cut to fill)**	40,556	CY	5	$ 182,500
12	**Water / Sewer / Electrical Services to Site**	1	LS	250,000	$ 250,000
13	**Site Perimeter - Chain Link Fencing**	4,000	LF	30	$ 119,200
14	**Site Perimeter - New Landscape**	95,000	SF	8	$ 798,000
				Construction Cost Markup	$ 4,386,319
				Subtotal Construction Costs	***$ 18,767,694***
				Allowance for Indeterminates (Design Allowance)	$ 5,360,674
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 24,128,368***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 2,680,337
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 26,808,705***
				Construction Sales Tax	$ 2,707,679
				Owner Furnished Equipment	$ 2,675,000
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 32,191,384***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 58,967
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 32,250,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 7,718,967
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 147,419
				Right-of-Way	$ -
				Misc. Service & Materials	$ 530,707
				Non-WTD Support	$ 250,611
				WTD Staff Labor	$ 3,602,776
				Subtotal Non-Construction Costs	***$ 12,250,480***
				Project Contingency	$ 13,431,302
				Initiatives	$ 530,272
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 26,212,053***
				TOTAL PROJECT COST	***$ 58,462,405***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	**Soil Blending Facility (Adjacent to Composting)**			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Process Building (Prefab Building)**	**22,400**	**SF**	**$ 157**	**$ 3,516,800**
2	Primary Mixing Area	20,000	SF	$ 157	$ 3,140,000
3	Feedstock Day Storage	2,400	SF	$ 157	$ 376,800
4	**Feedstock Storage (Tensile Membrane)**	**24,600**	**SF**	**$ 20**	**$ 492,000**
5	Feedstock Storage (Sawdust)	15,000	SF	$ 20	$ 300,000
6	Feedstock Storage (Biosolids and Fine Sand)	9,600	SF	$ 20	$ 192,000
7	**Finished Product Storage (Tensile Membrane)**	**15,000**	**SF**	**$ 20**	**$ 300,000**
8	**Misc Buildings**	**15,000**	**SF**	**$ 75**	**$ 1,125,000**
9	Maintenance Building	5,000	SF	$ 75	$ 375,000
10	Bagging Building	10,000	SF	$ 75	$ 750,000
11	**Office/Administration Building**	**5,000**	**SF**	**$ 75**	**$ 375,000**
12	**Admin Parking, Roads, Truck Access, Maintenance Yard, Screening, Finished Product Storage (Uncovered)**	**150,000**	**SF**	**$ 8**	**$ 1,200,000**
13	Admin Parking	2,500	SF	$ 8	$ 20,000
14	Roads	50,000	SF	$ 8	$ 400,000
15	Truck Access	25,000	SF	$ 8	$ 200,000
16	Maintenance Yard	5,000	SF	$ 8	$ 40,000
17	Screening Area	7,500	SF	$ 8	$ 60,000
18	Finished Product Storage (Uncovered)	60,000	SF	$ 8	$ 480,000
19	**Ponds and Collection System**	**60,000**	**SF**	**$ 22**	**$ 1,300,000**
20	Contact Water Pond and Collection System	20,000	SF	$ 25	$ 500,000
21	Stormwater Pond	40,000	SF	$ 20	$ 800,000
22	**Equipment Purchases**	**1**	**LS**	**$ 2,200,000**	**$ 2,200,000**
23	Wood Grinder (mid-large Horizontal)	1	EA	$ 500,000	$ 500,000
24	Mixer System (Horizontal Rotomix 1220-20, Stationary)	2	EA	$ 350,000	$ 700,000
25	Screen (MultiStar L3 Type)	1	EA	$ 550,000	$ 550,000
26	Bagging Equipment (RotoChopper Go-Bagger 250)	1	EA	$ 60,000	$ 60,000
27	Radial Stacking Conveyors	2	EA	$ 195,000	$ 390,000
28	**Install Equipment Purchases**	**1**	**LS**	**$ 1,510,000**	**$ 1,510,000**
29	Install Mixer System (Rotomix 1220-20, Stationary)	2	EA	$ 500,000	$ 1,000,000
30	Install Bagging Equipment (RotoChopper Go-Bagger 250)	1	EA	$ 120,000	$ 120,000
31	Install Radial Stacking Conveyors	2	EA	$ 195,000	$ 390,000
32	**Site Preparation / Demolition**	**438,000**	**SF**	**$ 2.31**	**$ 1,012,875**
33	Demo Existing Building (1/4 of site size)	1,642,500	SF	$ 0.50	$ 821,250
34	Demo Existing Hard Surfaces (1/2 of site size)	219,000	SF	$ 0.75	$ 164,250
35	Demo Existing Landscape/Trees (1/4 of site size)	109,500	SF	$ 0.25	$ 27,375
36	**Site Mass Grading (whole site using avg. of 2.5' of cut to fill)**	**40,556**	**CY**	**$ 4.5**	**$ 182,500**
37	**Water / Sewer / Electrical Services to Site**	**1**	**LS**	**$ 250,000**	**$ 250,000**
38	**Site Perimeter - Chain Link Fencing**	**4,000**	**LF**	**$ 30**	**$ 119,200**
39	**Site Perimeter - New Landscape**	**95,000**	**SF**	**$ 8**	**$ 798,000**
	Item Subtotal Construction Costs (Year 2020)				$ 14,381,375
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 1,438,137.50
	Mobilization/Demobilization		10%	1.1	$ 1,438,137.50
	Overhead & Profit (OHP)		8%	1.08	$ 1,150,510.00
	Insurance		1.5%	1.015	$ 215,720.63
	Bonding		1.0%	1.01	$ 143,813.75
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
	Item Subtotal Construction Costs (Year 2020)				$ 18,767,694
	Direct: Subtotal Construction Costs				***$ 18,768,000***

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	**Soil Blending Facility (Adjacent to Composting)**			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Equipment Purchases (ECS)**	**1**	**LS**	**$ 2,675,040**	**$ 2,675,040**
2	Large Front End Loader (Cat 980, Type)	**3**	EA	$ 550,000	$ 1,650,000
3	Small Front End Loader (Cat 950, Type)	**1**	EA	$ 300,000	$ 300,000
4	Compost Turner (X67 Type)	**0**	EA	$ 600,000	$ -
5	Forklift	**1**	EA	$ 50,000	$ 50,000
6	Repair Shop Tools	**1**	LS	$ 200,000	$ 200,000
7	Sport Utility Vehicle	**1**	EA	$ 36,960	$ 36,960
8	Pickup Truck	**1**	EA	$ 38,080	$ 38,080
9	Articulating Hauler Truck	**1**	EA	$ 400,000	$ 400,000
10					
				Item Subtotal Construction Costs (Year)	$ 2,675,040
DIRECT: CONSTRUCTION COST MARK-UPS					
			General Conditions	10%	1.1	included
			Mobilization/Demobilization	10%	1.1	included
			Overhead & Profit (OHP)	10%	1.1	included
			Insurance	1.5%	1.015	included
			Bonding	1.0%	1.01	included
			Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
				Item Subtotal Construction Costs (Year)	$ 2,675,040
				Direct: Subtotal Construction Costs	***$ 2,675,000***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	Thermal Drying Pyrolysis Off-site Facility			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Office/Administration Building	5000	SF	$ 150	$ 750,000
2	Admin Parking, Roads, Truck Access	50000	SF	$ 8	$ 400,000
3	Process/Maintenance Building	175000	SF	$ 218	$ 38,155,000
4	Equipment Purchases	1	LS	$ 94,828,600	$ 94,828,600
5	Install Equipment Purchases	1	LS	$ 51,783,950	$ 51,783,950
6	Site Preparation / Demolition	270000	SF	$ 2	$ 624,375
7	Water / Sewer / Natural Gas / Electrical Services to Site	1	LS	$ 1,000,000	$ 1,000,000
8	Site Perimeter - Chain Link Fencing	2000	LF	$ 30	$ 60,000
9	Site Perimeter - New Landscape	2000	SF	$ 10	$ 20,000
				Construction Cost Markup	$ 57,102,687
				Subtotal Construction Costs	***$ 244,724,612***
				Allowance for Indeterminates (Design Allowance)	$ 61,181,153
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 305,905,765***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 30,590,577
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 336,496,342***
				Construction Sales Tax	$ 33,986,131
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 370,482,472***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 672,993
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 371,155,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 57,089,958
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,682,482
				Right-of-Way	$ -
				Misc. Service & Materials	$ 6,056,934
				Non-WTD Support	$ 2,860,219
				WTD Staff Labor	$ 31,528,089
				Subtotal Non-Construction Costs	***$ 99,217,682***
				Project Contingency	$ 141,111,944
				Initiatives	$ 5,788,093
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 246,117,719***
				TOTAL PROJECT COST	***$ 617,273,184***

Base Year	Estimate Year
2020	2020

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	12/30/2019
Location:	King County - South End, Site To be Determined			**Estimator:**	Trung Le
Description:	Thermal Drying Pyrolysis Off-site Facility			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Office/Administration Building**	**5,000**	**SF**	**$ 150**	**$ 750,000**
2	**Admin Parking, Roads, Truck Access**	**50,000**	**SF**	**$ 8**	$ 400,000
3	Admin Parking	2,500	SF	$ 8	$ 20,000
4	Roads (Asphalt)	25,000	SF	$ 12	$ 300,000
5	Truck Access	10,000	SF	$ 8	$ 80,000
6	**Process/Maintenance Building**	**175,000**	**SF**	**$ 218.03**	**$ 38,155,000**
7	Pre-Fabricated Building - Process, Maintenance, Electrical, Mechanical	175,000	SF	$ 175	$ 30,625,000
8	Concrete Slab	161,200	SF	$ 25	$ 4,030,000
9	Additional Electrical	175,000	SF	$ 20	$ 3,500,000
10	**Equipment Purchases**	**1**	**LS**	**$ 94,828,600**	**$ 94,828,600**
11	DLT 1120 Belt Dryers	12	EA	$ 2,723,217	$ 32,678,600
12	BFT P-THREE Pyrolysis Unit	24	EA	$ 2,075,000	$ 49,800,000
13	Conveyence System, Sludge Pumps, etc	1	EA	$ 750,000	$ 750,000
14	Hot Water Boilers	2	EA	$ 500,000	$ 1,000,000
15	Storage Hoppers	5	EA	$ 500,000	$ 2,500,000
16	Odor Control	1	LS	$ 7,500,000	$ 7,500,000
17	Storage Containers	2	EA	$ 300,000	$ 600,000
18	**Install Equipment Purchases**	**1**	**LS**	**$ 51,783,950**	**$ 51,783,950**
19	Install DLT 1120 Belt Dryer	12	EA	$ 2,042,413	$ 24,508,950
20	Install BFT P-THREE Pyrolysis Unit	24	EA	$ 1,037,500	$ 24,900,000
21	Install Hot Water Boiler	2	EA	$ 250,000	$ 500,000
22	Install Conveyance System and Hoppers	5	EA	$ 375,000	$ 1,875,000
23	**Site Preparation / Demolition**	**270,000**	**SF**	**$ 2.31**	**$ 624,375**
24	Demo Existing Building	1,012,500	CF	$ 0.50	$ 506,250
25	Demo Existing Hard Surfaces	135,000	SF	$ 0.75	$ 101,250
26	Demo Existing Landscape/Trees	67,500	SF	$ 0.25	$ 16,875
27	**Water / Sewer / Natural Gas / Electrical Services to Site**	**1**	**LS**	**$ 1,000,000**	**$ 1,000,000**
28	**Site Perimeter - Chain Link Fencing**	**2,000**	**LF**	**$ 30.00**	**$ 60,000**
29	**Site Perimeter - New Landscape**	**2,000**	**SF**	**$ 10.00**	**$ 20,000**
	Item Subtotal Construction Costs (Year 2020)				$ 187,221,925
DIRECT: CONSTRUCTION COST MARK-UPS					
	General Conditions		10%	1.1	$ 18,722,192.50
	Mobilization/Demobilization		10%	1.1	$ 18,722,192.50
	Overhead & Profit (OHP)		8%	1.08	$ 14,977,754.00
	Insurance		1.5%	1.015	$ 2,808,328.88
	Bonding		1.0%	1.01	$ 1,872,219.25
	Escalation Multiplier from ENR-CCI		0%	1.0000	$ -
	Item Subtotal Construction Costs (Year 2020)				$ 244,324,612
	Direct: Subtotal Construction Costs				***$ 244,325,000***

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

Project Planning and Delivery Section

BASIS OF ESTIMATE

Project Name	**King County Class A Biosolids Technology Evaluation**
Project Number	151084
Date Prepared	01/24/2020
Requested by	Catherine Gowan, King County WTD
Prepared by	Trung Le, Brown and Caldwell
Estimate Classification	Class 5 AACE International
Estimate Purpose	Formulation Project
Estimate ID (Version)	01
Project Manager	Catherine Gowan
Project Control Engineer	
Cc or Distribution List	John Conway, Ashley Mihle

Note that the accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, and exclusions described herein. Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

Project Name	**Project Title**		
Project Number:	151084.452	Date:	01/24/2020

1.0 Purpose

The purpose of this project was to conduct a Class A biosolids technology evaluation for King County (County). This project was developed to assist the County in preparing their response to King County Council Proviso 2019-0148.P3 Version 2. The proviso calls for the identification of Class A alternatives to the current Class B biosolids application in forest and farm environments. The County is interested in diversifying the biosolids products to increase resiliency. The evaluation built upon the Solids Processing Technology Evaluation (Task 450) that was performed as part of the King County Treatment Plant Flows and Loads Study. The previous evaluation identified and screened solids treatment technologies for each of the County's three regional treatment plants. Other earlier studies conducted for the County on Class A biosolids treatment alternatives were also used as background materials for the study.

The TM documents the following subtasks:

- Class A technology screening
- Overview descriptions of the short-listed technologies, including a more detailed description of the gasification/pyrolysis technology
- Development of biosolids treatment and disposal/reuse scenarios
- Conceptual modeling of each scenario to evaluate solids production, energy usage, and greenhouse gas (GHG) emissions.
- Development of conceptual capital and operating and maintenance (O&M) cost estimates
- Evaluation of the scenarios based on triple bottom line (TBL) criteria.

Class 5 probable cost of construction estimates for the different scenarios were developed and used for the economic analysis and TBL evaluation. The expected accuracy range was +100%/-50% as typical with Class 5 estimates.

2.0 Project Scope Definition

The construction estimates were based on the four scenarios below. These scenarios were developed from the short-listed technologies, and each scenario provides biosolids management for all biosolids produced by King County wastewater treatment plants. They are as follows:

- **Scenario 1: Base-case** - Existing MAD with 100 percent Class B land application to western and eastern Washington
- **Scenario 2: Enhanced Class A** - Existing mesophilic digestion at Brightwater with Class B biosolids hauled to an off-site Class A composting facility and local sales; Cambi at South Plant with Class A land application in western and eastern Washington (40 percent/60 percent); and TAD with batch tanks at West Point and off-site soil blending with local sales
- **Scenario 3: Pyrolysis** - Existing mesophilic digestion at all three plants with dewatered cake hauled to off-site thermal drying and pyrolysis treatment. Biochar byproduct contracted to Bioforcetech under a public-private partnership.
- **Scenario 4: Optimized Class A** - Existing mesophilic digestion at Brightwater with Class B biosolids hauled to an off-site Class A composting facility and local sales; TAD with batch tanks at

South Plant with Class A land application in western and eastern Washington (40 percent/60 percent); and TAD with batch tanks at West Point and off-site soil blending with local sales

The sizing for each of the scenarios was based on flows and loads that were projected to a 2050 design year. Raw influent flows and loadings for each of the three plants were provided by the County as part of flows and loads study to evaluate treatment plant capacity limitations. A plant-wide solids mass balance model calibrated during that study was used to calculate digester feed solids loading rates from the 2050 raw influent flows and loadings. **Table 1** presents a summary of the construction.

Table 1 – Summary of Scenario Construction

Scenarios	Facility	Construction
S1	West Point	2 New Meso Digester
	South Plant	1 New Meso Digester
	Brightwater	1 New Meso Digester
S2	West Point	TAD Conversion (heating upgrades, mixing, cleaning)
	Soil Blending	New Off-Site Facility (buildings, site prep, machinery, utilities, etc)
	South Plant	THP-MAD System (pre-dewatering, screens, steam boilers, etc)
	Brightwater	1 New Meso Digester
	Composting	New Off-Site Facility (buildings, site prep, machinery, utilities, etc)
S3	West Point	2 New Meso Digester
	South Plant	1 New Meso Digester
	Brightwater	1 New Meso Digester
	Pyrolysis	New Off-Site Facility (buildings, site prep, thermal dryers, pyrolysis equipment, odor, utilities, etc)
S4	West Point	TAD Conversion (heating upgrades, mixing, cleaning)
	Soil Blending	New Off-site Facility (buildings, site prep, machinery, utilities, etc)
	South Plant	TAD Conversion (heating upgrades, mixing, cleaning)
	Brightwater	1 New Meso Digester
	Composting	New Off-site Facility (buildings, site prep, machinery, utilities, etc)

Scenario 1

New mesophilic digesters will be required at each of the wastewater treatment plants as reflected in **Table 1**. The cost for these digesters were unit prices sourced from an average of other projects in the region. This estimate was inclusive and assumed similar sizing to existing digesters, materials, digestion mixing, floating/fixed covers, and other ancillary components.

Scenario 2

West Point's conversion to a TAD system would require no additional digesters. However, the existing floating covers and mixing system would need to be upgraded. An additional two boilers would be installed to supply the heat required to maintain thermophilic digestion. A heat pump would be used to cool and recover the heat to preheating of the sludge. The cost estimates included minor repairs and cleaning of the digesters.

South Plant would utilize Cambi's thermal hydrolysis process. This system requires additional ancillary equipment that includes pre-dewatering, screening, blend tanks, and steam boilers. These systems along with the THP process would be housed in a new multi-floor building.

The soil blending facility was sized based on Tacoma's Tagro blended product that is comprised of 40:40:20 biosolids to sawdust to sand. The soil blending would occur in a prefabricated semi-closed building. Feedstocks and a portion of the blended product would be stored under a membrane canopy building. Other facilities include a bagging building. Maintenance and admin buildings would be shared with the adjacent composting facility. Major equipment includes batch auger mixers, trommel screen, front end loaders, hauling trucks, conveyors, a grinder, and bagging equipment.

Brightwater would require the additional construction of a fixed cover mesophilic digester.

The composting facility was modeled based on the aerated static pile system (Option 2) in the Compost Facility Basis of Estimation document (under King County Project 1132733). This system uses a perforated aeration pipe network floor for the active compost phase. The composting and curing process occurs under a roof. Feedstocks are also covered. Additional facilities include maintenance and admin buildings, and a bagging facility. Major equipment includes batch auger mixers, trommel screen, front end loaders, hauling trucks, conveyors, a grinder, and bagging equipment.

Scenario 3

Scenario 3 requires the same construction requirements as Scenario 1 but with the addition of an off-site thermal drying and pyrolysis facility. Major equipment includes thermal dryers, pyrolysis units, and odor control. The facility will be housed in an enclosed prefabricated metal facility. Construction costs were inclusive of utilities and other ancillary components.

Scenario 4

This scenario has the same construction requirements as Scenario 2 except for South Plant which would use TAD instead of THP-MAD. This would significantly reduce the construction requirement and only require the conversion of the MAD system to TAD. This includes replacing existing floating covers with fixed covers and upgrading the mixing system. An additional two boilers would be installed to supply the heat required to maintain thermophilic digestion. A heat pump would be used to cool and recover the heat to preheating of the sludge. The cost estimates included minor repairs and cleaning of the digesters.

3.0 Design Basis

The design basis of the scenarios was developed from KC Class A Biosolids Technology Evaluation Technical Memorandum. Additional information can be found in this technical memorandum.

4.0 Planning Basis

This project is a high-level alternative analysis of feasible Class A biosolids management programs. A more thorough alternatives analysis would need to be completed at a later date to develop further scope parameters, cost and etc.

5.0 Cost Basis

The cost estimate has been prepared in accordance with AACE International as a Class 5 estimation for projects with a maturity level of 0% to 2%. The cost estimate was intended for concept screening and uses costing methodologies such as capacity factored, parametric models, judgment, or analogy. The expected high side accuracy range is +30% to +100% and the low side accuracy is -20% to -50%. For this study, it is expected that the range of accuracy is within -50% to +100% of the estimate. Table 2 represents the total project capital cost for each of the scenarios and is inclusive of all KC WTD allowances.

Table 2 – Total Project Capital Cost

Parameters and Scenarios	Low Range (AACE: -20% to -50%)	Total Project Capital Cost	High Range (AACE: +30% to +100%)
Accuracy Range	-50%	-	+100%
Scenario 1: Base-case	$132,000,000	**$264,000,000**	$528,00,000
Scenario 2: Enhanced Class A	$433,000,000	**$867,000,000**	$1,734,000,000
Scenario 3: Pyrolysis	$441,000,000	**$881,000,000**	$1,762,000,000
Scenario 4: Optimized Class A	$231,000,000	**$462,000,000**	$924,00,000

Methods and sources used to determine construction costs are listed below:

- All construction, direct and indirect costs were estimated utilizing local unit price analysis. The unit price analyses were derived from other local projects or national projects which were adapted using ENR-CCI factors
- All costs are estimated in 2020 dollars unless stated.
- Vendor quotes were provided for thermal drying and pyrolysis equipment in scenario 3
- Costs for THP were derived from 100% design documents and estimations.

6.0 Allowances

The Allowance for Indeterminates (AFI) was applied to the construction cost and varied depending on the sourcing of the cost estimation. The AFI is an allowance that accounts for the cost of known but undefined requirements necessary for a complete and workable project. **Table 3** provides a summary of the AFI selected for each of the cost estimates.

Table 3 – Summary of Data Sourcing and Allowances for Indeterminates

Scenarios	Facility	Modification	Data Source	AFI
S1	West Point	2 New Meso Digester	Compiled Project Data (Various Years)	25%
	South Plant	1 New Meso Digester		
	Brightwater	1 New Meso Digester		
S2	West Point	TAD Conversion (heating upgrades, mixing, cleaning)	100% Design (2018)	20%
	Soil Blending	New Off-site Facility (buildings, site prep, machinery, utilities, etc)	Engineer's Estimate/ Project Data	25%
	South Plant	THP-MAD System (predewatering, screens, steam boilers, etC)	100% Design (2019 West Coast)	15%
	Brightwater	1 New Meso Digester	Compiled Project Data (Various Years)	25%
	Composting	New Off-site Facility (buildings, site prep, machinery, utilities, etc)	Scaled from King County Project (1132733) BOE Compost Facility, Engineer's Estimate/ Project Data	25%
S3	West Point	2 New Meso Digester	Compiled Project Data (Various Years)	25%
	South Plant	1 New Meso Digester		
	Brightwater	1 New Meso Digester		
	Pyrolysis	New Off-site Facility (buildings, site prep, machinery, utilities, etc)	Vendor Quotes	25%
S4	West Point	TAD Conversion (heating upgrades, mixing, cleaning)	100% Design (2018)	20%
	Soil Blending	New Off-site Facility (buildings, site prep, machinery, utilities, etc)	Engineer's Estimate/ Project Data	25%
	South Plant	TAD Conversion (heating upgrades, mixing, cleaning)	100% Design (2018)	20%
	Brightwater	1 New Meso Digester	Compiled Project Data (Various Years)	25%
	Composting	New Off-site Facility (buildings, site prep, machinery, utilities, etc)	Scaled from King County Project (1132733) BOE Compost Facility, Engineer's Estimate/ Project Data	25%

7.0 Assumptions

General assumptions are documented below if not already explicitly stated elsewhere in the estimate basis. Some assumptions were carried over from the BOE 20% Composting Facility estimate previously completed under Project 1132733.

- Off-site facilities (blending, composting, and pyrolysis) are assumed to be located within King County but separate from any existing King County WTD facilities. Impacts to project cost may occur based on the selection of locations.
- Assumptions related to potential South King County site preparation will require:
  - Existing Building Demolition – assumed building covers ¼ of the site and is 15' tall.
  - One half of the existing site is covered by asphalt/concrete requiring removal of same.
  - It is assumed that ¼ of the site will be covered by vegetation/trees that will require removal.
  - Earthwork – the estimate assumes that the site will require rough grading. An assumption of a need to cut and fill the site to obtain required grades would be an average of 2.5 feet in depth across the whole site.
- The WTD Prism cost model default values were used to included costs for permitting, easements, and WTD costs.
- It is assumed that the project generally aligns with WTD's Treatment PRISM cost model.
- It is assumed that all work will be performed utilizing safe work methods at all times.
- It is assumed that work will be sequenced to minimize process, service, and community interruptions.
- Any additional work discovered during project excavation would need to be either a supplemental approval or be approved as an additional project.
- It is assumed that any community impact costs are minimal. Any substantial impacts and their subsequent costs are beyond the scope of this project.
- It is assumed that this project will be engineered to meet any normal area seismic requirements.
- It is assumed that the current site selection is only conceptual, at this time and will be further analyzed under Alternative Analysis.
- Contractor project mark-ups have been included as add-ons to the construction estimates and were left as default values.
- This estimate does not include any allowances for ESJ. It is assumed that ESJ opportunities will be explored at project initiation and that any associated costs will be budgeted for at that time.

8.0 Exclusions

All potential items of cost which might be associated with the project but for which no costs have been included are listed below:

- No land acquisition/purchase costs were included.
- No hazardous waste removal costs such as asbestos, lead paint, or contaminated soils were included.

- Site specific concerns or difficulties unique to a specific site.
- Geotechnical requirements or special foundations.
- Additional work/costs related with neighborhood and homeowners association requirements.
- No estimated costs are included for any potential delays due to interferences.
- No estimated costs were included for sequencing of offline digesters.
- No costs are included for any additional scope beyond that as detailed in the current scope of work.
- No additional estimating allowances for WTD indirect costs have been included in the Total Project Cost estimate since a Routine degree of complexity rating was applied for Construction Management, Permitting & Licenses, Operations Support, Project Management, and Project Controls.
- No allowances for tariffs have been included.

9.0 Exceptions

Not Applicable.

10.0 Risks (Threats and Opportunities)

The magnitude of this evaluation has risks in costing. Siting of off-site facilities can potentially result in unknow costs for preparation, remediation, and permitting requirements.

Pyrolysis represents a new technology that has financial risks due to the uncertainty of operation and market acceptance.

11.0 Contingency

A contingency is a cost element intended to cover uncertainties and unforeseeable elements of cost within the defined project scope. Contingency covers inadequacies in project scope definition, estimating methods, and estimating data.

Contingency specifically excludes changes in project scope, and unforeseen major events such as earthquakes, prolonged labor strikes, etc.

A 30% Project Contingency was added to the base estimate of Total Project Costs (direct and indirect) in accordance with the King County WTD project delivery process. The total project cost at a 50% confidence level is typically used for funding and baselining of a project at this stage of engineering and project development.

12.0 Management Reserve

Management reserves are an owner's contingency and have not been applied per the default County Prism model.

Project Name	**Project Title**		
Project Number:	151084.452	Date:	01/24/2020

13.0 Reconciliation

Not Applicable.

14.0 Benchmarking

Not Applicable.

16.0 Attachments

Not Applicable.

Attachment D: Triple Bottom Line

TBL Evaluation

King County Class A Biosolids Technology Evaluation
Brown and Caldwell
1/28/2020

Scenario 1 - Base Case
Scenario 2 - Enhanced Class A
Scenario 3 - Pyrolysis
Scenario 4 - Optimized Class A

Class A Biosolids Technology Evaluation

ID	Evaluation Criteria	Weighting Factor	Possible Score	Scenario 1- Base Case	Scenario 2 - Enhanced Class A	Scenario 3 - Pyrolysis	Scenario 4 - Optimized Class A	Notes
	Social and Equity Category							
	Built & Natural Environment							
S1	Noise	2	5	5	2	3	2	S2, S3, S4 have more local noise generation due to the operation of offsite facilities. Off-site facilities assumed to be located in South Plant region (based on previous composting study) which has a high ESJ opportunity and high SVI score, impacts to these communities would be more severe.
S2	Odor	3	5	4	2	2	2	Compost, Soil Blending, Pyrolysis will generate some additional odor. More odor generated from soil-blending and composting. Pyrolysis has odors but a smaller footprint. Off-site facilities assumed to be located in South Plant region (based on previous composting study) which has a high ESJ opportunity and high SVI score, impacts to these communities would be more severe.
S3	Traffic	2	5	4	2	3	2	S1 is mostly long haul trucking. S2 has more local trucking and less long haul. Limited long haul trucking in S3 but more local traffic. Off-site facilities assumed to be located in South Plant region (based on previous composting study) which has a high ESJ opportunity and high SVI score, impacts to these communities would be more severe.
S4	Economic Development/Jobs	5	5	3	4	3	4	For Economic Development and Jobs: S2 and S4 would require the greatest amount of additional staff to operate and maintain facilities. S3 would require additional staff to operate offsite facility but less than S2 and S4. S1 would require the least amount of additional staff. Additionally, retail sales of compost and soil blended products would help to support the local economy via nurseries, landscapers, garden stores, and donations. Working Conditions would be the worst for S2 and S4 due to outdoor facility and odors. S3 would deal with odors and potentially hazardous environments
S5	Food Systems	3	5	3	4	2	4	Although S1 contributes the most to agriculture, it is located in Eastern Washington and used for mostly wheat, grains, and hops. S2 and S4 products will be largely sold locally for use in gardens and lawns which would likely see increase in local agriculture production. Biochar is intended for more niche applications such as cannabis production and less on agriculture. Blending into a product may make it more economic for agriculture use.
	Subtotal	**15**		**10.8**	**9.2**	**7.8**	**9.2**	
	Environmental Category							
	Sustainability							
C1	Greenhouse Gas Emissions	10	5	5	4	1	5	S1 and S4 have the lowest GHG emissions and are less than 10% from each other. S2 is close to S1 and S4. S3 has significantly higher GHG emissions than any of the other scenarios Refer to Figure 4-1 in the report or Appendix B
C2	Energy Production/Usage	5	5	5	3	2	4	Energy Production is the same across the scenarios due to no changes in the gas utilization strategy. Electricity was consumed in the order from high to low S2, S3, S4, S1
C3	Fossil Fuel Use	5	5	5	4	2	5	Fossil fuel usage was greatest in S3 with double the fossil fuel usage as S1 and S4. S2 is approximately 20% higher than S1. S1 and S4 are less than 5% of a difference. Refer to Appendix B
C4	100% Beneficial Reuse Regulatory Compliance/Risk	5	5	3	5	2	5	S3 has the highest risk in not meeting 100% beneficial reuse due to the market uncertainty and putting 100% of product into one processing market/customer. There is no redundancy or flexibility through this P3. If the facility fails or BFT can't sell their product, biosolids would likely send to landfill. S3 also has a bit of uncertainty with WA DOE evaluating biosolids biochar on a case-by-case basis for beneficial reuse. S1 has the second lowest score due to limited market diversity and single product. S2 and S4 are more resilient in meeting 100% beneficial reuse goals.
C5	Flexibility to Meet Future Regulations	5	5	2	4	5	3	Current research suggests that biological treatment such as MAD only degrade some contaminants of emerging concern (CEC). TAD has improvements over MAD for degradation of some addition CECE. Composting and THP have been shown to decrease a larger group of CEC while Pyrolysis has been shown to significantly decrease a wide range of different types of CEC. Compost and soil blending can also decrease concentrations through dilution with clean feedstocks .
	Subtotal	**30**		**25**	**24**	**13**	**27**	
	Economic Category							
E1	Lifecycle Cost	10	5	4	2	2	3	S1 was given 4 because it still represents a high cost. S2 and S3 are almost double the cost and given a 2. S4 was given a 3 as it was 50% more of the cost. Refer to Section 5 of the report or Appendix C
E2	Total Project Capital Cost	5	5	5	1	1	3	S1 has lowest capital cost. S4 is two times the capital cost of S1. S2 and S3 is 4 times the capital cost of S1. Refer to Section 5 of the report or Appendix C
E3	Market Diversification/Risk	10	5	2	5	2	5	S2 and S4 have the most product and market diversity compared to S1 and S3. Less risk that comes with single market exposure. S3 has a potentially large market diversity due to uses in non traditional biosolids applications such as industrial and commercial uses but greater risk due to unproven demand for product and single entity handling the biosolids. S1 has the least amount of market diversity but already large available market for product
	Subtotal	**25**		**17**	**15**	**9**	**19**	
	Technical Category							
T1	Process Reliability	10	5	5	4	2	5	S3 has the lowest process reliability given that only one pyrolysis system is in operation in the United States and few in the rest of the world. One THP-MAD facility in the United States but there are more than 30+ facilities in the world with THP-MAD from Cambi
T2	Constructability/Footprint	3	5	3	4	3	5	Constructability/footprint assessed at the treatment plant only. S4 has the least plant footprint requirement and most constructible design. S4 Less footprint than S2. S1 and S3 requires additional digesters which would consume more plant footprint. Constructability issues for additional digesters for S1 and S4.
T3	Site Permitting	2	5	5	3	2	3	Off-site permitting challenging for S2, S3, and S4. S3 air permitting challenging to acquire.
T4	Addressing Solids Handling Capacity	5	5	3	5	3	5	S1 and S3 do not address capacity increases at WP. S2 and S4 provides significant digestion capacity increase at WP and SP
T5	Compatibility with Capital and Planning Projects	5	5	4	2	3	3	S1 has the lowest capital requirements and does not impact future nutrient programs. S2 has increased high capital and ammonia recycle. S3 has increased high capital requirements. S4 has increased ammonia recycle (S4) but lower capital than (S2, S3)
T6	Operational Complexity	5	5	5	2	3	4	Additional processes would result in greater complexity. THP-MAD in S2 and thermal drying and pyrolysis in S3 are the most complex systems. S4 has soil blending and composting process and TAD which increases system complexity compared to S1
	Subtotal	**30**		**25.8**	**20.6**	**15.6**	**26.2**	
	Total	**100**		**78.6**	**68.8**	**45.4**	**81.4**	

Social and Equity Category

The social and equity criteria category factors how each scenario can increase or decrease the quality of life of King County residents, taking into account the differing baselines for the communities around South, West Point, and Brightwater Treatment Plants.

The Center for Disease Control has developed a Social Vulnerability Index (SVI) as an indicator of how resilience communities are to external stresses on human health caused by natural or human-caused disaster, or disease pandemic. The rating is from 0 to 1, with 1 being completely vulnerable and unable to handle external stresses and 0 being very resilient. SVI can be directly correlated to the community's socioeconomic, racial, and language diversity statuses. Less affluent and more diverse communities are often closer to a value of 1. Equity opportunities exist in communities with high diversity and low socioeconomic status. SVI is a tool that King County has used to identify those opportunities for improvement. The table below summarizes the SVI values for the communities around King County's treatment plants.

	West Point	South Plant	Brightwater
Community by Plant (Overall SVI)	0.04	0.69-0.92	0.18
Service Area Average	0.33	-	0.33
County Average SVI	0.36		

Based on this information, the communities surrounding South Plant have more vulnerabilities to external stresses due to greater diversity and low socioeconomic environment. This would indicate that the impacts of projects to the community would be more severe. Therefore for this study, impacts to the community in the South Plant area was scored lower than impacts in other areas.

Built & Natural Environment (Ordinance Definition: Healthy built and natural environments for all people that include mixes of land use that support: jobs, housing, amenities and services; trees and forest canopy; clean air, water, soil and sediment)

Noise (2) – increases in noise is a generally a result of the use of heavy machinery as well as the addition of processes outside the current boundaries of the treatment plants

Traffic (2) – Greater volumes of biosolids will require additional trucking and hauling. These additional vehicles can impact local and regional traffic

Odor/Air Quality (3) – Odor, dust, fumes, and smoke can create a nuisance to surrounding community

Economic Development/Jobs (5) The addition of treatment processes will require an increase in staff to operate and maintain the new facilities, which will create local jobs for the community. Additionally, consideration was given scenarios that were able to increase economic opportunities for farmers, nursery owners, contractors, or other businesses, which in turn could stimulate the local economy, and return benefits to the community through increased capital.

Working conditions for King County public works staff can be impacted based on indoor and outdoor facilities, system complexity, and hazardous and nuisance working conditions.

Food Systems (3)

- Includes information about increased or decreased opportunities for local (<100 miles) food production

Environmental Category

Sustainability

Greenhouse Gas Emissions (10) - King County has developed a Strategic Climate Action Plan with a goal to achieve carbon-neutral operations by 2025. Management of a biosolids program with a focus on energy recovery, low energy solutions, increase in carbon sinks, and the reduction in sources of greenhouse gas (GHG) emissions will aid King County in reaching these goals. A GHG inventory was used to track emissions from the scenarios and include fugitive emissions, carbon sequestration, fertilizer offsets, energy use, and material consumption.

Net Energy Use/Production (5) - The generation and use of renewable energy is one of the major goals of King County's Energy Plan. With a target to reduce normalized energy consumption by at least 10 percent by 2025 and energy neutrality in operations and purchasing by the same deadline, renewable energy production and the reduction in external power consumption is vital to meeting those targets.

Fossil Fuel Use (5) - The non-renewable and limited supply of fossil fuels in the world make its use unsustainable. To conserve energy for future generations, fossil fuel usage will be considered for each scenario. Increased fossil fuel usage will generate a lower rating for the scenario.

100% Beneficial Reuse Regulatory Compliance and Risk (5)

This criterion was intended to evaluate the risks of failing to meet 100% Beneficial reuse regulatory compliance from an environmental standpoint. This criterion is based on the assumption that Class B biosolids would have limited options other than landfill. Landfilling of biosolids has a significant environmental impact as result of GHG emissions several times larger than other sources of GHG emissions.

Flexibility to Meet Future Regulations (5)

Increasing concern over emerging contaminants has become a hot topic for biosolids management programs. As research and studies continue develop the understanding of the health and environmental risk of these compounds, future regulations may be a possible outcome. This criterion considers whether the selected scenarios have any potential to reduce these compounds. General research has suggested that biological processes are less capable of removal of CEC when compared to thermal and chemical based processes.

Economic Category

Lifecycle Cost (10)

Net present worth (NPW) lifecycle costs for capital cost and operations and maintenance (O&M) for each scenario was considered. This cost reflects a 20-year useful service life of each scenario and reflect the potential impacts of O&M to a project. Estimated O&M costs included annual salaries for King County staff to operate and maintain the proposed facilities, general equipment maintenance, energy and material costs, and other related costs.

Capital Cost (5)

Capital costs are the costs associated with the procurement of equipment and construction for each scenario. These costs reflect the upfront cost of the project. Capital cost and O&M can have different impacts on utilities based on available funds and funding sources.

Market Diversification and Risk (10)

Market diversification is indicative of a more sustainable biosolids management program as there is flexibility to shift to different markets when circumstances can reduce demand in others. Exposure to only a single market can put a program at risk. This situation has been seen around the country as a result of legal action, climate change, or negative media. When demand changes unexpectedly for a single market program, the only viable option tends to be landfilling which has financial implications. For this criterion, favorable ratings are given to scenarios that can generate a diversified biosolids program. This criterion considers the financial risk of low market diversification. Class A biosolids generally have more alternative avenues for end-users compared to Class B biosolids and will receive higher scores.

Technical Category

Process Reliability (10)

Process reliability refers to the resiliency of a technology or process. Proven and mature technologies have long track records, wide adoption, and comprehensive experience. These generally reflect a decrease in risk in the adaption and long-term use of a technology or process.

Constructability/Footprint (3)

The limitation of space and high cost of land can make it challenging to implement projects of large scale. This criterion is intended to take into consideration the challenges of construction and the required amount of footprint of each scenario.

Site Permitting (2)

Site permitting can be challenging due to a variety of different regulations including, stormwater, air, and site restrictions. This criterion is intended to consider the challenge of permitting on-site and off-site locations.

Solids Handling Capacity Impact (5)

King County has seen a drastic increase in population over the last two decades and is projected to continue to grow. As population grows, available capacity will decrease resulting in required improvements in solids handling capacity. Intensification processes can increase capacity without significant construction requirements. Scenarios will be rated based on their abilities to increase capacity.

Compatibility with Capital and Planning Projects (5)

This criterion is intended to evaluate the compatibility of the scenarios with future capital and planning projects. This can include impacting future processes/projects such as nitrogen removal.

Operational Complexity (5)

The addition of processes and technologies can increase the complexity of the plant making it more challenging to operate.

Appendix B

Combined Financial, Environmental, and Social Costs and Benefits

Triple Bottom Line (TBL)
The triple bottom line, an analysis method to account for environmental, economic, and social factors, and is commonly used in planning or feasibility studies to evaluate King County alternatives, options, and projects. This triple bottom line analysis was adapted from the King County Biosolids Program Strategic Plan 2018-2037 completed in 2018. The triple bottom line analysis was modified to be more robust and to better align with King County priorities, through the addition of a technical category, consideration of market risk and continuation of 100 percent beneficial reuse, and expanded equity and social justice criteria. Four criteria categories were developed for this effort: social, environmental, economic, and technical. The criteria include King County priorities as well as the Biosolids Program's objectives, especially around risk reduction and resiliency.

Social and Equity Criteria Category
The social and equity criteria category considered how each scenario could increase or decrease the quality of life of King County residents, taking into account the differing baselines for the communities around South, West Point, and Brightwater Treatment Plants. The criteria were adapted from the County's *The Determinants of Equity Report*. *Scenario One: Base-case Class B* scored highest in this category because it did not require any additional construction in overburdened areas. The other two scenarios' scores were similar. However, *Scenario Two: 100 Percent Class A* is better able to support the production of healthy, local food and community education programs and opportunities.

Environmental Criteria Category
King County is dedicated to environmental stewardship and has adopted several initiatives to tackle climate change. As part of the *2015 Strategic Climate Action Plan*, the County has committed to meeting countywide GHG emissions reduction targets of 50 percent by 2030 and 80 percent by 2050. Additionally, WTD has set a target goal of carbon-neutral operations by 2025. The environmental criteria category takes into consideration these goals and other environmental criteria. *Scenario One: Base-case Class B* and *Scenario Two: 100 Percent Class A* both scored well in this category. *Scenario Three: Pyrolysis* scored significantly lower due to high greenhouse gas emissions and high energy and fossil fuel use, as well as a higher risk of not 100 percent beneficially reusing biosolids, as required by Washington State Regulations.

Economic Criteria Category
The economic criteria category considers the capital and operation and maintenance costs of the scenarios, including transportation. This category also evaluates the long-term sustainability of the biosolids management program in terms of diversification of outlets for biosolids application and risks associated with the single option program. *Scenario Two: 100 Percent Class A* scored highest in this category, despite moderate capital costs due to high diversification of products and consequently lower risks. *Scenario 3: Pyrolysis* scored lowest in this category, due to lack of diversification, high capital costs, and uncertain market conditions for biochar.

Technical Criteria Category
Different technologies offer varying levels of operation, footprints, permitting requirements, and improvements to existing processes. This category considers the technical components of each scenario. *Scenario One: Base-case Class B* and *Scenario Two: 100 Percent Class A* both scored well in this category. Both scenarios use reliable processes and are operationally feasible. *Scenario Two: 100 Percent Class A*

scored well due to addressing solids handling capacity effectively and being relatively simple (if costly) to construct. *Scenario Three: Pyrolysis* scored lower due to lack of process reliability, potential difficulty in site permitting, and high operational complexity.

Triple Bottom Line Score Summary

The scores for the four criteria categories were combined for the total scores for each scenario. High weighted scores represent the best scenarios. Total scores were out of 100 points, with 80-100 representing "very high", 60-80 representing "high", 40-60 representing "medium", 20-40 representing low, and 0-20 representing "very low".

Triple bottom line total score was very high for *Scenario Two: 100 Percent Class A*, high for *Scenario One: Base-case Class B*, and medium for *Scenario Three: Pyrolysis*.

- *Scenario Two: 100 Percent Class A* had the highest overall score due to very high scores in greenhouse gas emissions, flexibility to meet future regulations, market diversification/risk and solids handling capacity. This scenario had high to very high scores in all other criterion except noise, odor, traffic and capital costs. Noise, odor, and traffic are equity impacts that would need to be considered and properly mitigated in siting of a facility.
- *Scenario One: Base-case Class B* had high to very high scores in all criterion except flexibility to meet future regulations and market diversification/risk, a highly weighted criterion.

Scenario Three: Pyrolysis scored low to medium in each individual criteria category. Lower scoring criterion for pyrolysis included greenhouse gas emissions, energy use, regulatory compliance and beneficial use, capital cost, market risk/diversification, process reliability, and permitting.

King County

Dow Constantine
King County Executive
401 Fifth Avenue, Suite 800
Seattle, WA 98104-1818
206-263-9600 Fax 206-296-0194
TTY Relay: 711
www.kingcounty.gov

August 6, 2020

The Honorable Claudia Balducci
Chair, King County Council
Room 1200
C O U R T H O U S E

Dear Councilmember Balducci:

This letter transmits the Alternative Options for the Use of Biosolids report called for by Ordinance 18930, Section 72, Proviso P3, and a proposed motion that, if adopted, would acknowledge receipt of the report.

As required, the report evaluates alternative options for the beneficial use of biosolids produced at King County's wastewater treatment plants and compares the costs and benefits to the existing biosolids management strategy. The report also considers alternative biosolids management approaches that may lead to diversification or expansion of the markets for biosolids.

Specifically, the report explores options to transition King County's Biosolids Program from a Class B product to a Class A product that could be sold to the public. The report also explores an alternative biosolids management option using a process known as pyrolysis that refers to the chemical break down of organic matter using high heat. These two options are compared to the County's current approach of producing Class B biosolids for use in forestry and agriculture in eastern Washington.

Future options for continuing the current Class B Biosolids Program or transitioning to a Class A biosolids product are less costly than the pyrolysis option, but still have significant costs and technical challenges. Opportunities to explore a phased transition to a Class A biosolids product could be incorporated into long-term planning efforts to repair or replace the equipment that produces biosolids at the regional treatment plants. Capital improvements will be required over time to provide sufficient solids treatment capacity as the region's population grows and this provides an opportunity to consider Class A options.

In developing this report the Department of Natural Resources and Parks (DNRP) engaged consultant support for the technical and financial analysis. DNRP's Wastewater Treatment Division also held a workshop for internal subject matter experts to review alternatives.

The report furthers the King County Strategic Plan goal of Healthy Environment by exploring biosolids management options that continue to support healthy and productive farms, forests, and open spaces as a nutrient rich soil amendment to build healthy soils and increase plant yield. The report also furthers the Strategic Climate Action Plan goals of reducing countywide greenhouse gas emissions by 50 percent by 2030 and making DNRP's Wastewater Treatment Division carbon neutral by 2025, through the exploration of biosolids management options that continue to sequester carbon.

It is estimated that 160 staff hours were required to produce the report, costing approximately $16,000 in staff hours and $100,635 in consultant costs. The estimated printing cost for this report is nominal.

Thank you for your consideration of this proposed motion and report. This important report will inform future discussions on biosolids management options which would continue to reduce carbon emissions for DNRP and recover resources from wastewater.

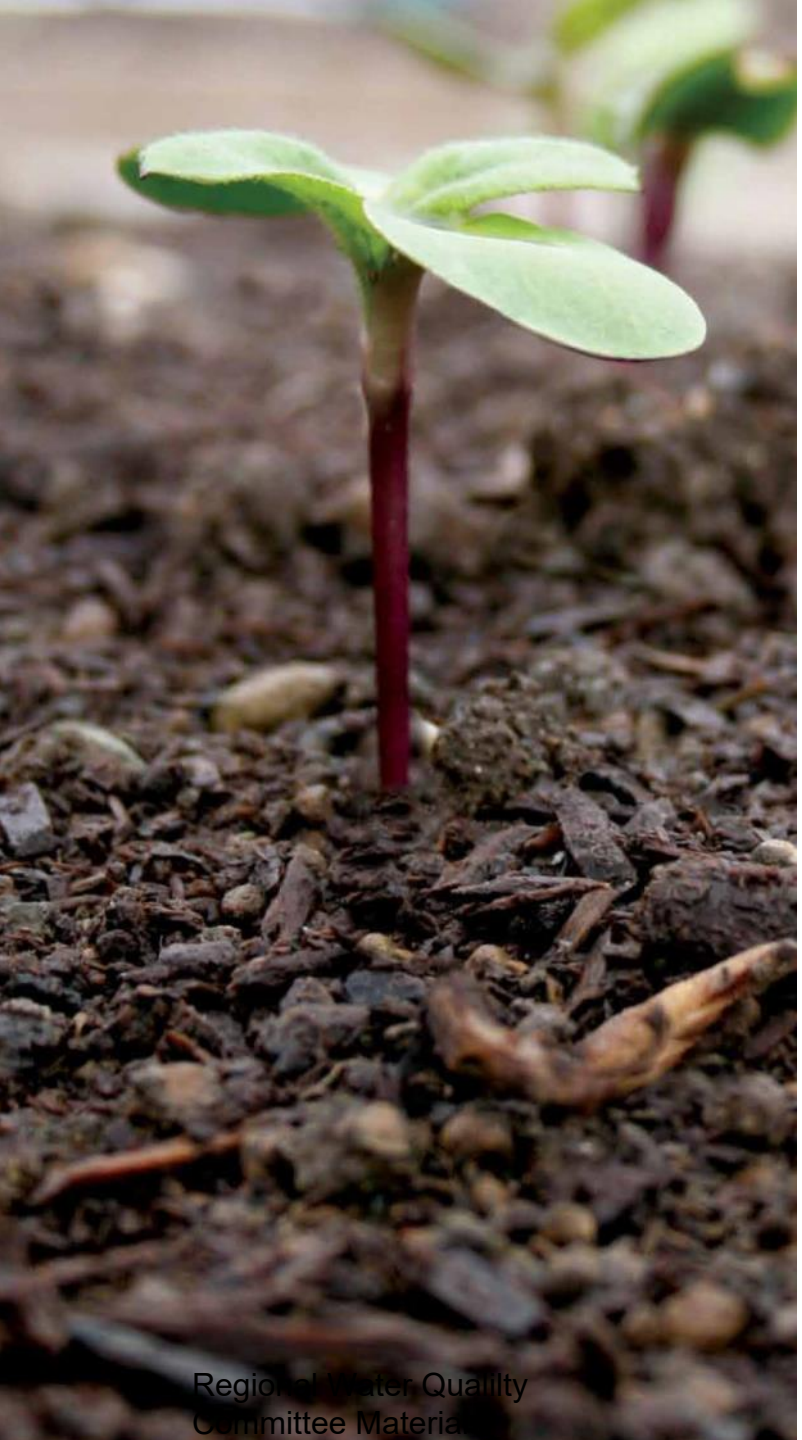
If your staff have any questions, please contact Mark Isaacson, Division Director of the Wastewater Treatment Division of DNRP, at 206-477-4601.

Sincerely,

Dow Constantine
King County Executive

Enclosure

cc: King County Councilmembers
ATTN: Carolyn Busch, Chief of Staff
Melani Pedroza, Clerk of the Council
Shannon Braddock, Deputy Chief of Staff, Office of the Executive
Karan Gill, Director, Council Relations, Office of the Executive
Dwight Dively, Director, Office of Performance, Strategy and Budget
Christie True, Director, Department of Natural Resources and Parks (DNRP)
Mark Isaacson, Division Director, Wastewater Treatment Division, DNRP



ATTACHMENT 3

Alternative Options for the Use of Biosolids

Summary of King County Council proviso and Wastewater Treatment Division response

Erika Kinno
Research & Policy Project Manager

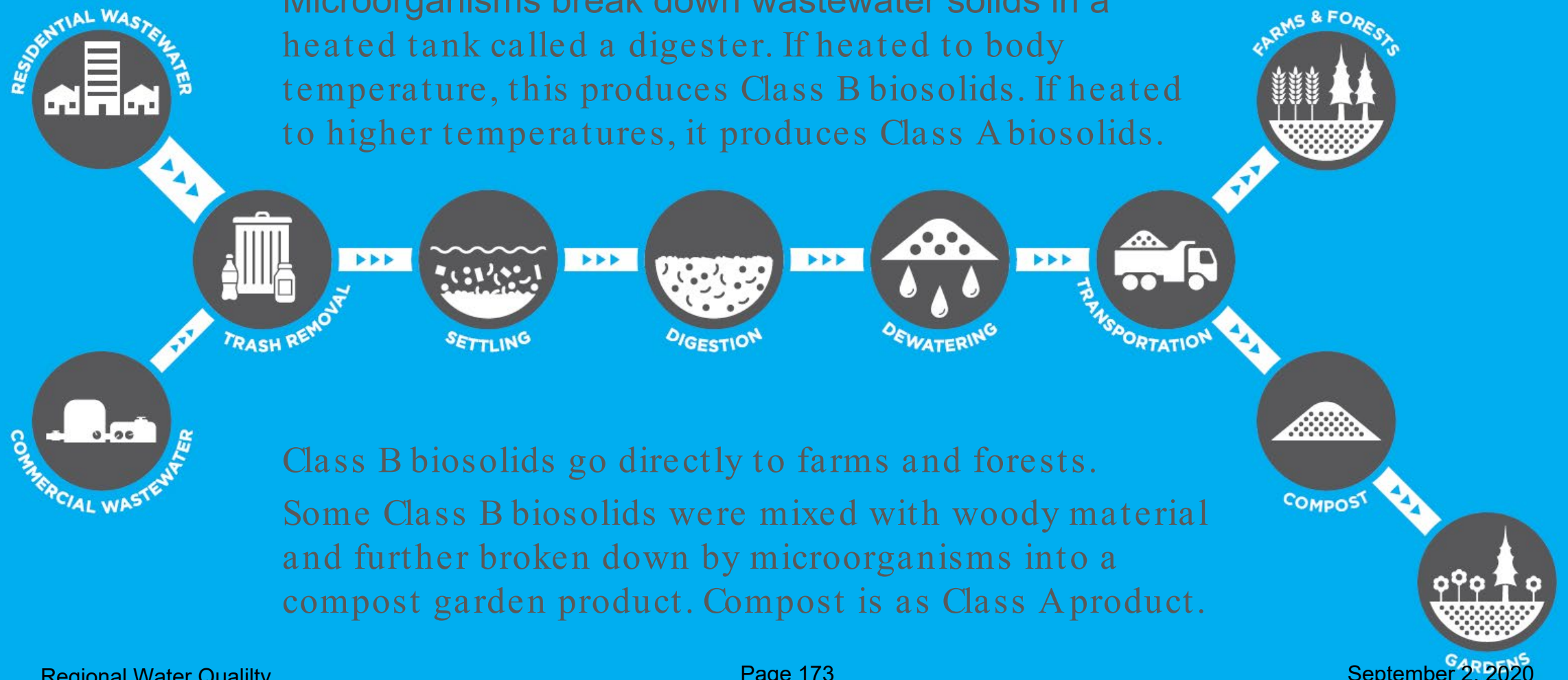
King County | Resource Recovery

What are biosolids?

- A natural soil amendment and fertilizer replacement made from treating wastewater
- Microorganisms transform solids into a nutrient -rich resource
- King County's biosolids are called Loop®

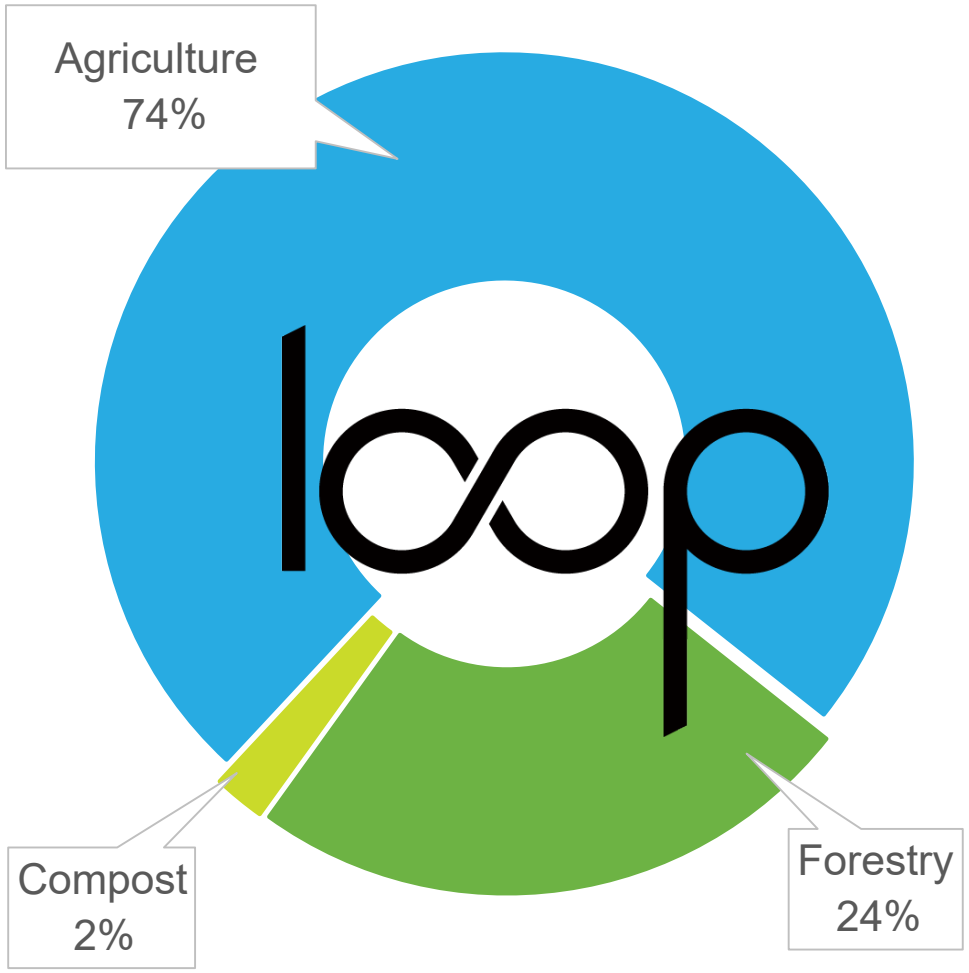
How Loop®Biosolids Products Are Made Now – Digestion and Composting

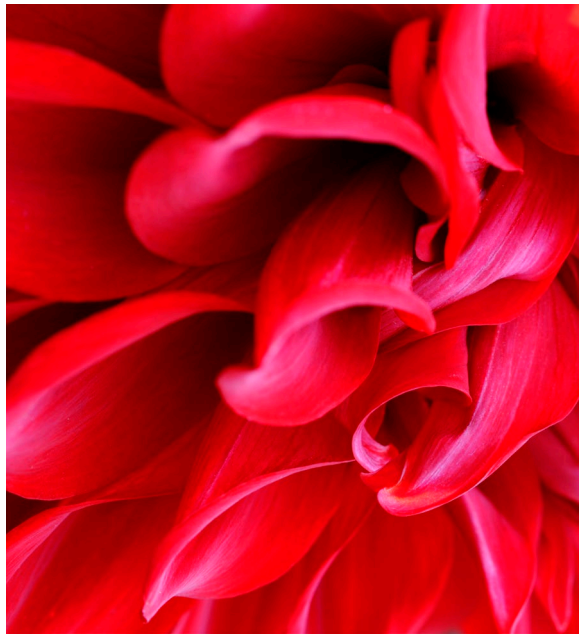
Microorganisms break down wastewater solids in a heated tank called a digester. If heated to body temperature, this produces Class B biosolids. If heated to higher temperatures, it produces Class A biosolids.



Class B biosolids go directly to farms and forests.

Some Class B biosolids were mixed with woody material and further broken down by microorganisms into a compost garden product. Compost is as Class A product.





130,000 wet tons / year biosolids

In 2020, King County's compost partner sold their property and closed.

Class A vs. Class B Biosolids

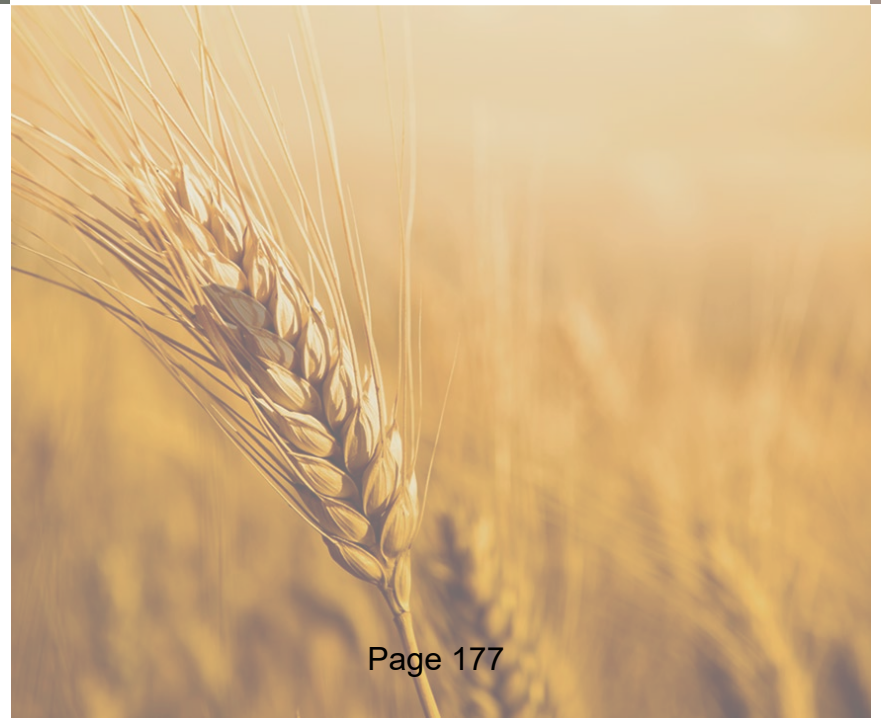
	Class A	Class B
Pathogens	Virtually none	Treated but still detectable
Use permit	None needed	Required
Typical use	Individual public use for landscaping or gardening	Large scale agriculture or forestry

June 2019

- Council requests report:
  - Alternatives for biosolids other than Class B
  - Expansion or diversification of markets for biosolids

Costs and benefits of alternatives to current program

Include local Class A biosolids facility
as one alternative



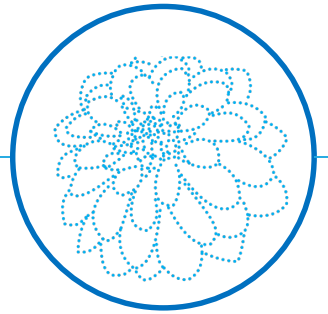
Financial analysis
of transition to Class A

What we reviewed

- Technical study by consultant
- Past Class A studies
- Current program costs and strategy

Baseline Case and Two Alternative Options

projected out to year 2050



Base Case scenario

Continuation of current Class B land application

100% Class A scenario

Package of options to produce Class A products for different uses:

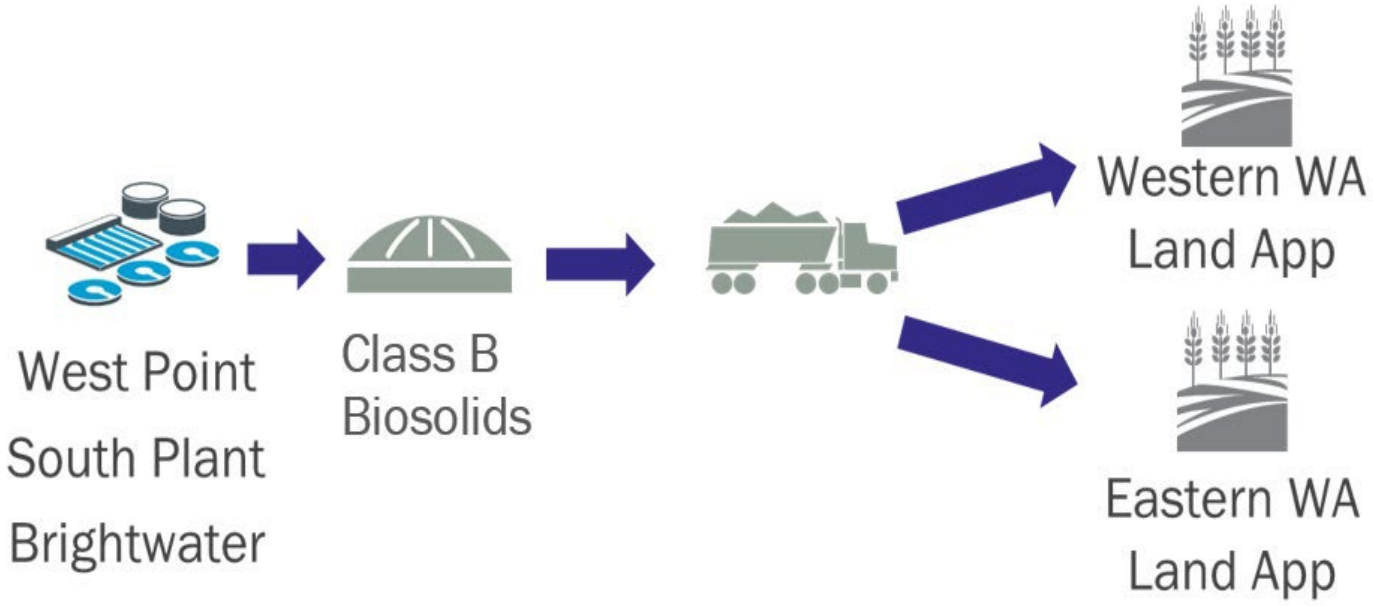
1) upgrades at treatment plants
2) construct an offsite composting facility

Pyrolysis scenario

Public-private partnership to operate an offsite drying and pyrolysis facility

Baseline Case

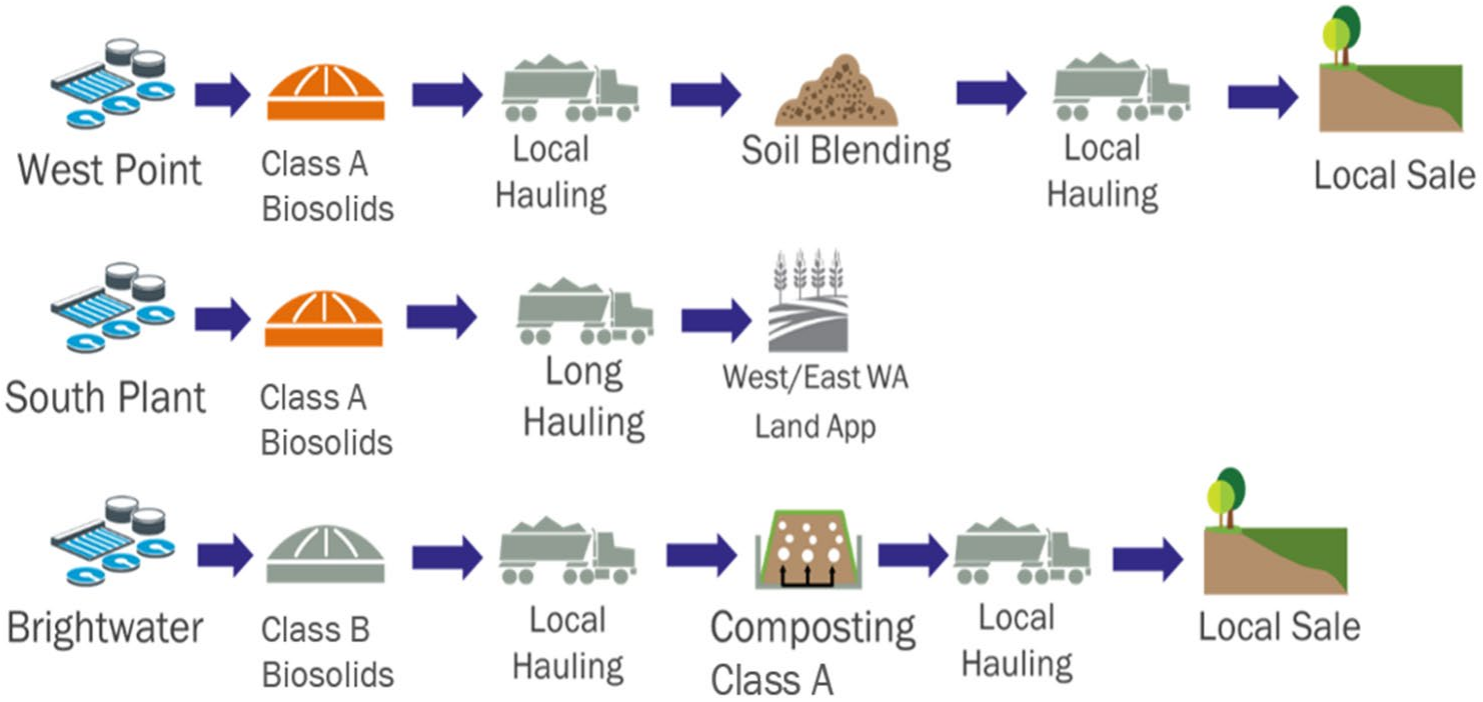
Continuation of current Class B land application



100% Class A option

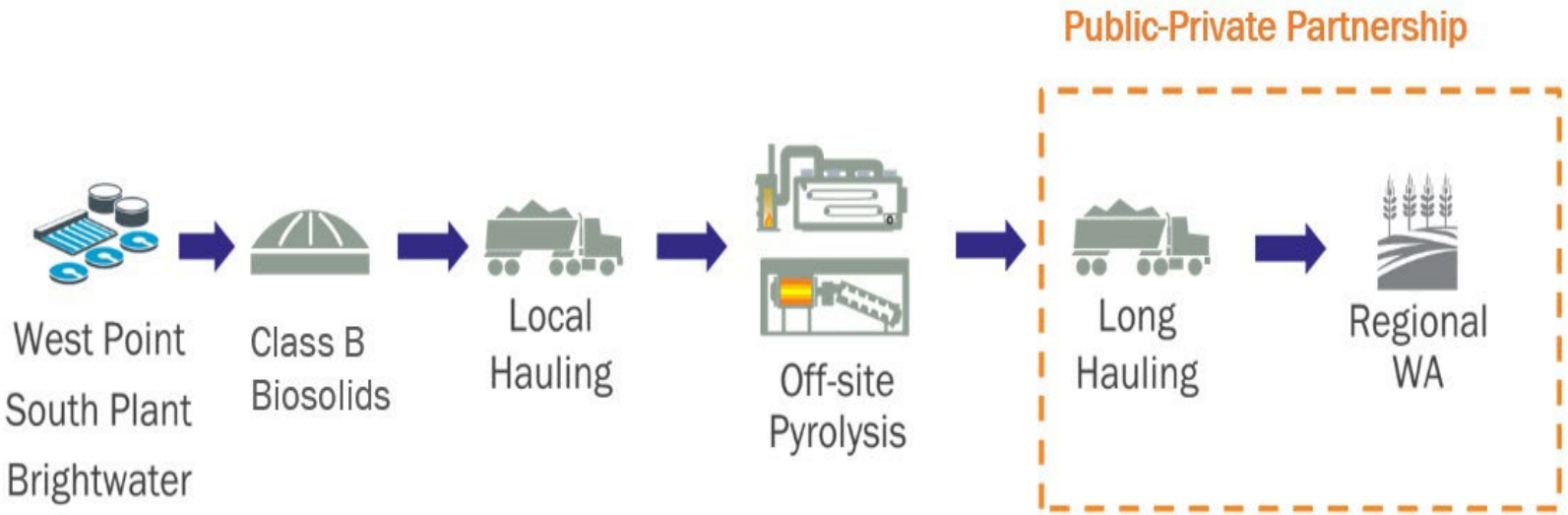
Package of options to produce Class A products for different uses:

1) upgrades at treatment plants
2) construct an offsite composting facility



Pyrolysis option

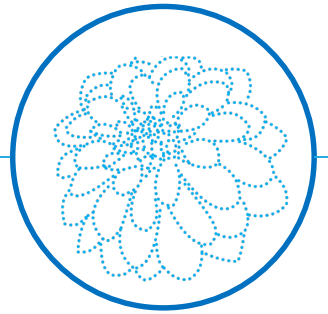
Public-private partnership to operate an offsite drying and pyrolysis facility



COMPARISON – TOTAL COSTS & SCORES

	Base case Class B	Pyrolysis	100% Class A
Triple Bottom Line score	High	Medium	Very High
Escalated capital costs	$335,000,000	$1,115,000,000	$590,000,000
2050 Annual Net Operating and Maintenance Costs	$29,400,000	$29,500,000	$28,500,000
2050 Annual Revenue	$11,100,000	$19,500,000	$10,500,000
2050 Operating and Maintenance Costs	$34,500,000	$45,000,000	$37,500,000
2050 Annual Transportation Costs	$6,000,000	$4,000,000	$1,500,000

What did we learn?



All three options are costly
and face significant technical and physical challenges.

Even with Base Case Class B, digester upgrades will be needed.

Pyrolysis option scored lowest due to

- Costs
- Environmental impacts
- Technical risk
- Regulatory risk

100% Class A option offers opportunities
to integrate a phased transition when upgrades are needed.

Not a one size fits all scenario for all treatment plants.

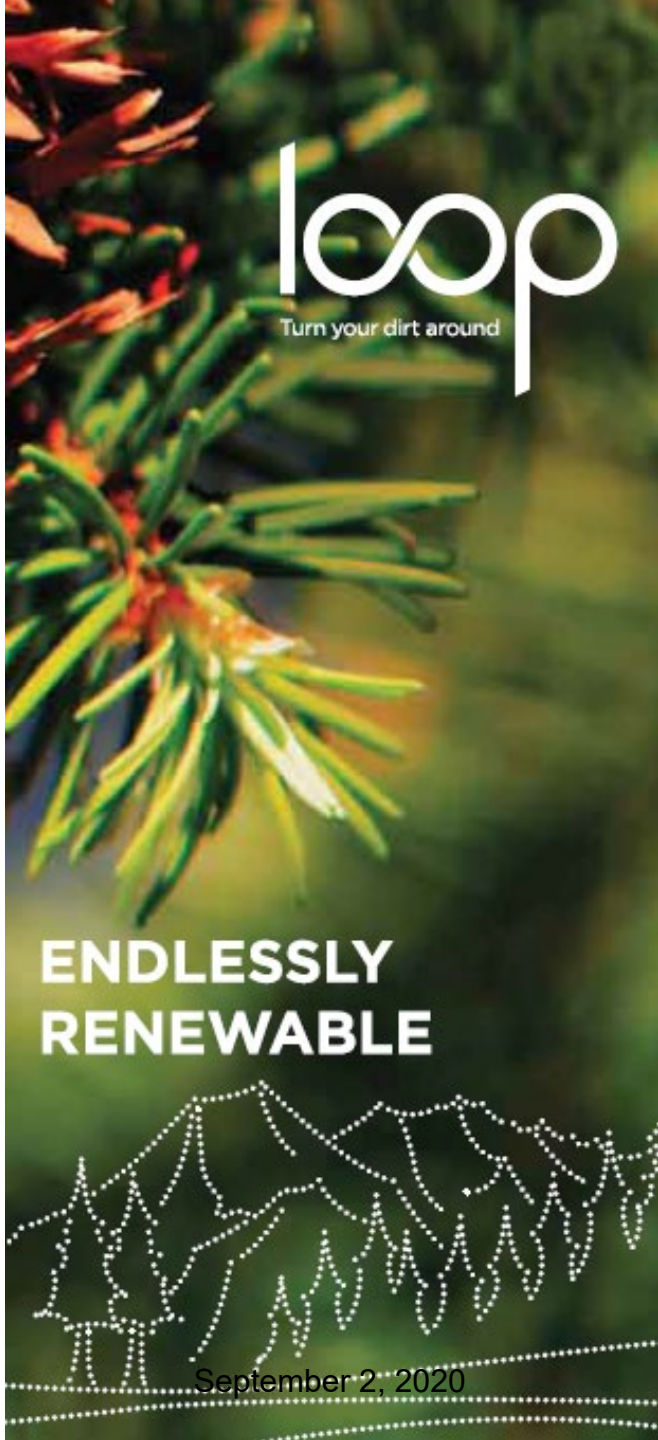
Overall conclusions

01 All future options are costly with technical and physical challenges

02 Digester capacity expansion in next 30 years – synergies

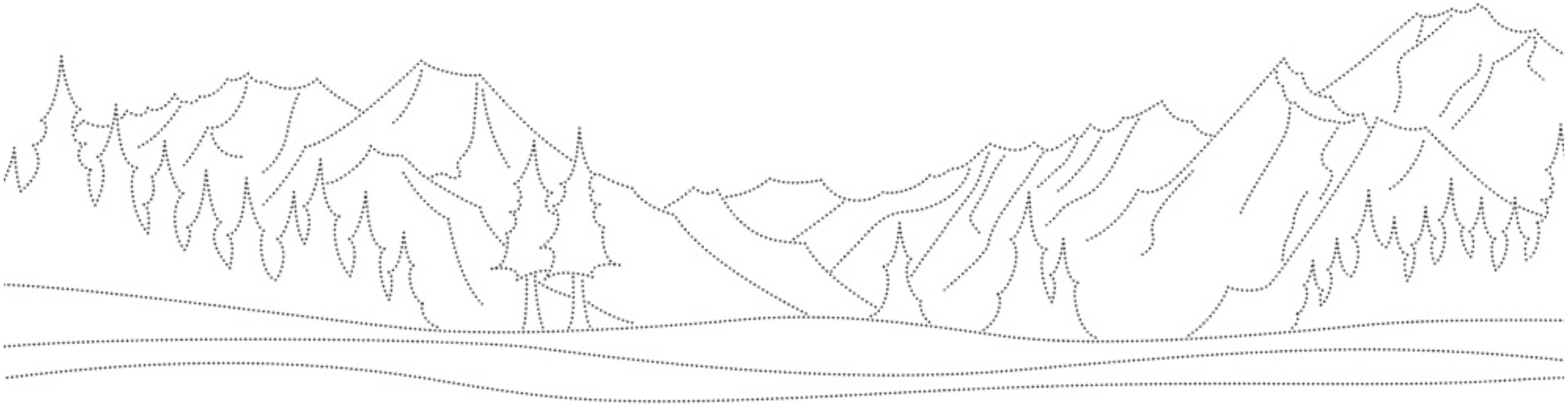
03 Gradual transition to 100% Class A- various technologies and strategies

04 King County Code change needed to allow Class A



Questions?

Erika Kinno
erika.kinno@kingcounty.gov



King County

Metropolitan King County Council
Regional Water Quality Committee

STAFF REPORT

Agenda Item:	8	**Name:**	Mike Reed
Proposed No.:	2020-0162	**Date:**	September 2, 2020

SUBJECT

Proposed Motion 2020-0162 acknowledges receipt of a report regarding the impacts of the Kenmore Interceptor, placed at the north end of Lake Washington, on sedimentation and on fish populations in the lake.

SUMMARY

Proviso P2, Section 108 of Ordinance 18835, requires an evaluation of the impact of a section of the Kenmore Interceptor, placed on the nearshore lakebed at the north end of Lake Washington, on silt accumulation and fisheries. The Wastewater Treatment Division, in responding to the requirements of the proviso, retained a consultant to evaluate the impacts of the Interceptor on siltation, and related fisheries impacts. The evaluation and report concluded, in sum, that the Kenmore Interceptor does not affect the processes that limit salmonid survival and migration, and does not contribute in a measureable way to other limiting factors to salmonids in Lake Washington.

Proposed Motion 2020-0162 acknowledges receipt of the report addressing the sedimentation and fisheries impacts of the Kenmore Interceptor.

BACKGROUND

In November, 2018, the Council adopted the 2019-2020 Biennial Budget that included a proviso requiring an evaluation of the impacts of a section of the Kenmore Interceptor on silt accumulation near the mouth of local creeks entering the north end of Lake Washington, and potential impacts on anadromous fish passage. Specifically, Proviso P2 in Section 108 of Ordinance 18835, reads:

> Of this appropriation, $250,000 shall not be expended or encumbered until the executive transmits a report on the Kenmore interceptor impacts to fish populations and a motion that acknowledges receipt of the report and the motion is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section and proviso number in both the title and body of the motion.

The report shall include, but not be limited to: (1) a discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna; (2) a characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction; (3) an analysis of the impacts of the silt accumulation on water fauna, with particular attention to the ability of the fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species; (4) an analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2. The report shall additionally address the impacts on the nearshore environment of effectively creating a barrier resulting in functionally separated lake areas. The report shall discuss options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps.

Proviso Response

In response to the requirements of the proviso, the Wastewater Treatment Division retained Environmental Science Associates (ESA) to evaluate sedimentation in the area of the subject pipeline segment, and associated impacts on fish populations. The study area was identified as that portion of the Kenmore Interceptor between Tracy Owen Station Park and Ballinger Way.

The Kenmore Interceptor conveys wastewater from Bothell, North Creek and Kenmore to the West Point Treatment Plant in Magnolia. The construction of the pipeline was an important element of the regional effort to keep wastewater out of Lake Washington undertaken by Metro as one of its primary regional responsibilities. Section 2 of the Kenmore Interceptor, which is the subject of the proviso language, is a 48-in pipeline that was constructed in the early 1960s, together with the remainder of the pipeline. In the construction process, the pipeline was built within a rectangular precast concrete casement, and placed in a trench excavated along the lakebed, between 75 and 200 feet offshore. The Interceptor is buried by sediment along 80 percent of the study area, and the remaining 20 percent is elevated from the lakebed by no more than ten inches. Recent inspections indicate that the pipe is in good condition, and is capable of providing service for years to come.

Study Methodology

The study methodology by ESA included review of the physical processes affecting sediment transport in the study area, an assessment of shoreline change over time, compilation of recent public works projects relevant to sediment transport, assessment of the constructed conditions of the lake line, and review of a 2011 report of an inspection and analysis of the area lakebed intended to address similar issues.

The ESA report identifies areas of the shoreline in the vicinity of Lyon and McAleer creeks where the shoreline appears to be dynamically filling and eroding, affecting sedimentation rates in the area. Historical survey data indicate that there has been substantial accumulation of sediment over the past 120 years; the nearshore has accumulated between one and four feet of sediment over that time, much of it in the late 1800s and early 1900s when logging around the lake and development activities resulted in

increased runoff and uncontrolled erosion. The analysis concludes that continued accumulation in the nearshore area has been primarily caused by physical processes, such as sediment transport by Lyon and McAleer creeks, nearshore erosion caused by wind, waves and boat propeller wash, and the trapping of sediment by stands of rooted aquatic vegetation, including Eurasian watermilfoil.

A variety of fish species are present in lake Washington, including several species of native salmon and trout. Species migrating through the Ship Canal and Lake Washington migratory corridor include Chinook, Sockeye, Chum, Coho and Steelhead as well as Bulltrout and Cutthroat Trout.

Study Conclusions

According to the ESA report, primary limiting factors to the successful growth and migration of salmonids in Lake Washington include shoreline armoring and development, lack of suitable lakeside vegetation, water quality concerns from stormwater runoff, and the presence of aquatic plants such as Eurasian watermilfoil. The extent of shoreline armoring and overwater structures around Lake Washington has limited natural erosion processes, leading to sediment transport, and has altered out-migrating salmon behavior and introduced cover for salmon predators. The resulting composition of shoreline substrates does not contain habitat suitable to most salmonids. Analysis by ESA indicates that, based on the location of the local segment of the Kenmore Interceptor, primarily below the substrate, and with adequate depth of water over exposed portions of the interceptor casement, the Kenmore Interceptor does not play a significant role in local sediment dynamics and does not represent a migration barrier to fish, which can swim over and across the pipeline unperturbed by any challenge presented by the pipeline. In summary, according to the report, the Kenmore Interceptor does not affect the processes that limit salmonid survival and migration, and does not contribute in a measureable way to other limiting factors to salmonids in Lake Washington.

Proposed Motion 2020-0162

Proposed Motion 2020-0162 has been transmitted to the Council and dually referred to the Regional Water Quality Committee and the Committee of the Whole. The proposed motion would acknowledge the receipt of the report addressing the design and placement of Section 2 of the Kenmore Interceptor, and its impacts on sedimentation and fish populations. Passage of the motion by Council would release the withheld $250,000 of the Wastewater Treatment Division's 2019-2020 biennial budget authorization.

INVITED

- Katherine Fischer, Environmental Programs Managing Supervisor, Wastewater Treatment Division

ATTACHMENTS

1. Proposed Motion 2020-0162
    a. Attachment A: Kenmore Interceptor Report, March 2020
2. Transmittal Letter dated March 26, 2020
3. Wastewater Treatment Division's Key Findings

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KING COUNTY

Signature Report

1200 King County Courthouse
516 Third Avenue
Seattle, WA 98104

Motion

Proposed No. 2020-0162.1 **Sponsors** Dembowski

A MOTION acknowledging receipt of a report providing information and analysis regarding the design and placement of Section 2 of the Kenmore interceptor and the impacts thereof on sedimentation and fish populations as required by the 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, Proviso P2.

WHEREAS, the 2019-2020 Biennial Budget Ordinance, Ordinance 18835, Section 108, Proviso P2, directs the executive to transmit, by March 31, 2020, a report addressing the design and placement of Section 2 of the Kenmore interceptor and the impacts thereof on sedimentation and fish populations along with a motion acknowledging receipt of the report, and

WHEREAS, the wastewater treatment division of the department of natural resources and parks retained Environmental Science Associates to analyze the Kenmore interceptor and its impacts on sedimentation and fish populations, and

WHEREAS, the consultant report concluded that the interceptor is buried throughout most of the Lyon Creek and McAleer Creek deltas and neither plays a significant role in sedimentation nor limits salmonid survival and migration, and

WHEREAS, the executive has transmitted to the council the requested report and motion;

NOW, THEREFORE, BE IT MOVED by the Council of King County:

The receipt of the report addressing the design and placement of Section 2 of the Kenmore interceptor and the impacts thereof on sedimentation and fish populations, Attachment A to this motion, is hereby acknowledged.

KING COUNTY COUNCIL
KING COUNTY, WASHINGTON

_____

Claudia Balducci, Chair

ATTEST:

_____

Melani Pedroza, Clerk of the Council

APPROVED this _____ day of _____, _____.

_____

Dow Constantine, County Executive

Attachments: A. Kenmore Interceptor Report March 2020

Kenmore Interceptor Report

March 2020

King County

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II. Executive Summary

Ordinance 18835, Section 108, Proviso P2 identified four areas of concern relative to the placement and presence of the Kenmore Interceptor Section 2 along the bed of Lake Washington. The Kenmore Interceptor Section 2 is a 48-inch pipeline that conveys wastewater from the Kenmore area to the Matthews Beach Pump Station and the West Point Treatment Plant. The concerns identified in the proviso relate to the interceptor's impact on sediment accumulation and, subsequently, water fauna in Lake Washington, particularly on species of fish that migrate from the ocean to rivers or streams known as "anadromous"[1] species. Lake Washington is an important habitat for a number of species of migrating salmon and trout.

To address the areas of concern identified in the proviso, the Wastewater Treatment Division (WTD) of the Department of Natural Resources and Parks retained Environmental Science Associates (ESA) to analyze sedimentation and impacts to fish populations in the vicinity of the pipeline. The study area for the analysis encompassed the area between approximately Tracy Owen Station Park and Ballinger Way. The analysis included a comprehensive review of the 2011 *Kenmore Lake Line Lakebed Sedimentation Analysis* conducted by SoundEarth Strategies, Inc., and Lally Consulting LLC (Appendix B) in response to similar concerns raised in the past. Appendix A presents ESA's complete 2020 report, *Kenmore Interceptor Proviso P2 Support: Sediment and Fish Population Study*.

ESA's report concluded that the Kenmore Interceptor, which is buried throughout most of the Lyon and McAleer creek deltas, does not play a significant role in sedimentation patterns in the study area. The analysis concluded that the Kenmore Interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor casement exposed by no more than 10 inches above the lakebed. No measurable differences in sediment accumulation were observed along near-shore and off-shore sides of the interceptor, with the exception of one area of approximately 500 square feet where localized effects of minor accumulation on the shore side have occurred in an area 10 to 20 feet wide.

Additionally, ESA's report determined the dominant physical processes that have influenced sediment accumulation in the study area and enhanced accretion[2] under and around docks, contributing to a perceived shallowing of recreational mooring areas, include the following:

- Deposition of sediment by McAleer and Lyon creeks
- The presence of dense stands of Eurasian watermilfoil[3]
- Nearshore erosion caused by wind and wave action

Lastly, although Lake Washington continues to provide important habitat for many species of fish, the quality and quantity of fish habitat in the study area have been degraded over the years by several factors that are generally present on a lake-wide basis. The extent of shoreline armoring[4] and overwater structures, or docks, around Lake Washington has effectively limited the natural erosion processes

[1] Anadromous fish are born in fresh water, spend most of their life in the sea, and then return to fresh water to spawn. Salmon are a type of anadromous fish.
[2] *Accretion* means a gradual buildup of sediment.
[3] Eurasian watermilfoil is an aquatic plant that can form thick mats in shallow areas of lakes and rivers.
[4] Armoring is the practice of using physical structures to protect shorelines from coastal erosion, such as a seawall.

leading to sediment transport, thereby altering out-migrating salmon behavior and introducing cover for salmon predators. ESA's report further determined that the resulting composition of most shoreline substrates does not contain habitat suitable to most salmonids.[5] However, the Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington.

III. Proviso Text

Of this appropriation, $250,000 shall not be expended or encumbered until the executive transmits a report on the Kenmore interceptor impacts to fish populations and a motion that acknowledges receipt of the report and the motion is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section and proviso number in both the title and body of the motion.

The report shall include, but not be limited to: (1) a discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna; (2) a characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction; (3) an analysis of the impacts of the silt accumulation on water fauna, with particular attention to the ability of the fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species; (4) an analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2. The report shall additionally address the impacts on the nearshore environment of effectively creating a barrier resulting in functionally separated lake areas. The report shall discuss options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps.[6]

IV. Background

Department Overview: The King County Department of Natural Resources and Parks (DNRP) works in support of sustainable and livable communities and a clean and healthy natural environment. Its mission is to foster environmental stewardship and strengthen communities by providing regional parks; protecting the region's water, air, land, and natural habitats; and reducing, safely disposing of, and creating resources from wastewater and solid waste. The Wastewater Treatment Division (WTD) of DNRP protects public health and enhances the environment by collecting and treating wastewater while recycling valuable resources for the Puget Sound region.

Current and Historical Context: Wastewater from the Bothell, North Creek, and Kenmore areas is conveyed by local sewer pipelines to the Kenmore Interceptor. The Kenmore Interceptor consists of five sections, for a total pipeline length of 16,031 linear feet. The 48-inch diameter Kenmore Interceptor Section 2 (also referred to as the "lake line") is the subject of Proviso P2. This section of the interceptor (traveling from north to south) begins at maintenance hole W11-39, entering Lake Washington at the

[5] *Salmonids* refers to fish of the salmon family (Salmonidae), including salmon, trout, chars, freshwater whitefishes, and graylings.
[6] Ordinance 18835, Section 108, Proviso P2

western end of Tracy Owen Station Park south of Bothell Way, and continues south to the Matthews Beach Pump Station at maintenance hole W11-01 (Appendix A, Figure 1). The pipeline transitions from Lake Washington to land at this location. From Matthews Beach, wastewater is pumped to West Point Treatment Plant in Magnolia.

Construction of the Kenmore Interceptor began in the early 1960s. Designed to convey 26 million gallons of wastewater per day, this pipeline was a critical piece of King County's new regional wastewater treatment system designed to keep wastewater out of Lake Washington. Design of the interceptor was per uniform building codes in effect at that time, and called for placement of the 48-inch pipe within a precast concrete rectangular casement set on piles driven into the lake bed. The entire casement was placed within a trench excavated along the lakebed, between 75 and 200 feet offshore. Backfill at the time of construction may have occurred through either mechanical means or natural processes. Today, the Kenmore Interceptor continues to function as a critical piece of the wastewater system in north King County. Recent inspections confirm the pipe is in good condition and will be able to remain in service for many years to come.

Residents in the Lake Forest Park area previously raised concerns about the placement of the interceptor as related to sediment deposition in the nearshore area of Lake Washington between Log Boom Park and the vicinity of Ballinger Way Northeast and Bothell Way Northeast. In 2011, WTD retained SoundEarth Strategies, Inc., and Lally Consulting LLC to conduct an inspection and analysis of the lakebed in the area referenced above. The 2011 report (Appendix B) concluded that there were no obvious indications that the interceptor was contributing, or had contributed, to sedimentation patterns in the study area. A review of the previous study was included in the scope of work for the current sedimentation and fish population study performed by ESA.

WTD staff visited the City of Lake Forest Park (City) in August 2019 to request information related to the proviso and current concerns by the City relative to the presence of the Kenmore Interceptor. The City described concerns that recently had been expressed by owners of the Lake Forest Park Community Center, where the boat launch requires dredging on a frequent basis to maintain a depth adequate for boat access.

Report Methodology: To address the concerns of Proviso P2, WTD retained ESA in September 2019. The analysis conducted by ESA focused on sedimentation and fish populations in the vicinity of the Kenmore Interceptor Section 2, in addition to a review of the 2011 study methods and conclusions. ESA compiled and reviewed recent public works projects in the City of Lake Forest Park relevant to sediment transport in the watershed, assessed the constructed conditions of the lake line, and reviewed the physical processes affecting sediment transport in the study area. ESA also conducted an assessment of shoreline and bathymetric[7] change over time using aerial orthophotos,[8] recent video inspection of the lakebed, and bathymetry from the National Oceanic and Atmospheric Administration (1902, 1975 and 2008), SoundEarth Strategies, and Gravity Marine. This report is attached as Appendix A.

[7] *Bathymetric or Bathymetry* refers to the measurement of the depth of water in oceans, seas, or lakes.
[8] Orthophotos are aerial photographs that have been geometrically corrected so that their scale is uniform and can be used in the same manner as a map.

V. Report Requirements

A. Discussion of the design and placement of Section 2 of the Kenmore Interceptor

Available information related to the design of the interceptor is limited to the engineer's approved design drawings dated August 1964 (Appendix A, Figures 5 and 6). No discussion or documents related to the placement of the interceptor to avoid the accumulation of silt or accommodate the movement of water fauna were discovered during background research efforts. Additionally, no documentation or historical photographs were discovered demonstrating the method of installation and backfill for the interceptor sections.

The design drawings specify three methods of installation that were allowed for interceptor placement on the lakebed, and it is reasonable to conclude that one or more of these methods was used by the construction contractor. The construction methods specified for the type of underwater topography in the study area would have likely been the method that completely buried or backfilled the pipe casement into an excavated trench or that partially buried the pipe casement into an excavated trench. Finally, given the design standards of the era, little consideration would likely have been given to the potential accumulation of silt or the movement of water fauna during design of the interceptor.

B. Characterization of the silt accumulation beneath and around the interceptor since its construction

Both the 2011 analysis (Appendix B) and the current analysis by ESA (Appendix A) showed that the interceptor is located in a net sediment depositional area. ESA determined that over the past 120 years, the nearshore within the study area has accumulated between one and four feet of sediment. Much of that occurred in the late 1800s and early 1900s, when logging around the lake and development activities resulted in increased runoff and uncontrolled erosion. The analysis concludes that continued accumulation in the nearshore area has been primarily caused by physical processes, such as sediment transport by Lyon and McAleer creeks, nearshore erosion caused by wind waves and boat propeller wash, and the trapping of sediment by dense stands of rooted aquatic vegetation, including Eurasian watermilfoil.

The most recent analysis by ESA included a review of the 2011 diving inspection of the interceptor, an October 2019 remotely operated vehicle (ROV) survey, and a January 2020 bathymetric survey using diving transects and single-beam sonar scans to characterize sediment accumulation nearby the interceptor in the study area. As of 2019, roughly 80 percent of the pipeline is covered in sediment within the study area. The remaining 20 percent includes areas where the casement is partially exposed to a maximum height of approximately 10 inches above the lakebed. Accumulation of sediment, as confirmed by recent ROV and bathymetric surveys, is similar on both sides of the interceptor, with the exception of one 500-foot section of pipeline where exposed casement appears to have had a minor influence on the downslope transport of sediment within 10 to 20 feet of the pipe (Appendix A, Figure 15). The section of the pipeline within the study area—even in locations where the pipe casing is exposed by up to 10 inches—is not acting as a sediment-trapping barrier.

C. Analysis of the impacts of silt accumulation on water fauna, including the ability of fauna to freely access the lake environment on both sides of the interceptor and potential Impacts on the migration of anadromous species

A variety of fish species inhabits Lake Washington, including several species of native salmon and trout. Species migrating through the Ship Canal and Lake Washington migratory corridor include Chinook, Sockeye, Chum, Coho, and Steelhead as well as Bulltrout and Cutthroat trout.

According to ESA's recent analysis, primary limiting factors to the successful growth and migration of salmonids in Lake Washington include shoreline armoring and development, lack of suitable lakeside vegetation, the presence of macrophytes[9] (especially non-native Eurasian watermilfoil), and water quality concerns from stormwater runoff. The Kenmore Interceptor is buried by sediment along 80 percent of the study area and, in the remaining 20 percent, is elevated from the lakebed by no more than 10 inches. Analysis conducted for this report finds that the presence of the interceptor in the study area is not a limiting factor to the successful survival or migration of salmonids. Based on its location primarily below the substrate and adequate depth of water over even exposed portions of the interceptor casement, ESA concluded that the Kenmore Interceptor does not play a significant role in local sediment dynamics and does not represent a migration barrier to fish as they can easily swim over and across it without stress.

D. Analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor, including impacts on the nearshore environment of creating a barrier, resulting in separated lake areas

The attached ESA report identifies areas of the shoreline in the vicinity of Lyon and McAleer creeks where the shoreline appears to be dynamically filling and eroding, affecting sedimentation rates in the immediate area. Bathymetric survey data from lake-wide surveying efforts in 1902, 1975, and 2008 overlap with the study area. As described previously, and verified by a comparison of the survey data, there was substantial accumulation of sediment in the lake between 1902 and 1975. A comparison of 1975 and 2008 elevations show that accumulation of plus/minus one foot of additional accumulation has occurred. Between 2008 and 2011, when sediment sampling occurred as part of the SoundEarth Strategies and Lally Consulting study, additional minor amounts of accumulation occurred. Based on the review of the data, the report concludes that the position of the lake line does not appear to influence a trend in accumulation or erosion. Accumulation of sediment during both time periods has occurred on both sides of the interceptor.

E. Options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps

The proviso requested options and subsequent steps to remedy identified impacts. Because the analysis finds that the Kenmore Interceptor is not causing negative impacts to sediment and water fauna in Lake Washington, no actions nor further steps are necessary at this time. However, WTD will continue to monitor the health and impact of the interceptor and address any identified impacts in the future.

---

[9] Macrophytes are aquatic plants growing in or near water.

VI. Conclusion

Ordinance 18835, Section 108, Proviso P2 identified four areas of concern relative to the Kenmore Interceptor's potential impact on sediment accumulation and migrating fish species and populations in Lake Washington. Lake Washington is an important habitat for many anadromous species of fish, including a number of species of migrating salmon and trout. To address the concerns identified in the proviso, WTD retained an environmental consultant, ESA, to analyze the design and placement of the interceptor in the study area, located between approximately Tracy Owen Station Park and Ballinger Way (Appendix A). ESA's analysis included a comprehensive review of the 2011 *Kenmore Lake Line Lakebed Sedimentation Analysis* (Appendix B) conducted by SoundEarth Strategies and Lally Consulting in response to similar concerns.

In its 2020 study and subsequent report, ESA compiled and reviewed recent public works projects in the City of Lake Forest Park relevant to sediment transport in the watershed, assessed the constructed conditions of the lake line, and reviewed the physical processes affecting sediment transport in the study area. ESA also conducted an assessment of shoreline and bathymetric change over time using aerial orthophotos, recent video inspection of the lakebed, and bathymetry from the National Oceanic and Atmospheric Administration (1902, 1975, and 2008), SoundEarth Strategies, and Gravity Marine.

ESA's analysis concluded that the Kenmore Interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor casement exposed by no more than 10 inches above the lakebed. No measurable differences in sediment accumulation were observed along near-shore and off-shore sides of the interceptor, with the exception of one area of approximately 500 square feet where localized effects of minor accumulation on the shore side have occurred in an area approximately 10 to 20 feet wide. Additionally, the dominant physical processes that have influenced sediment accumulation in the study area include the deposition of sediment by McAleer and Lyon creeks and the presence of dense stands of Eurasian watermilfoil. The Kenmore Interceptor, which is buried throughout most of the Lyon Creek and McAleer Creek deltas, does not play a significant role in how these processes affect sedimentation patterns in the study area.

The quality and quantity of fish habitat in the study area have been degraded over the years by several factors, which are generally present on a lake-wide basis. The extent of shoreline armoring and overwater structures around Lake Washington has effectively limited natural erosion processes, leading to sediment transport, and has altered out-migrating salmon behavior and introduced cover for salmon predators. The resulting composition of most shoreline substrates does not contain habitat suitable to most salmonids. The Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington. Finally, the nearly completely buried pipeline does not present a barrier to fish migration or passage in Lake Washington.

VII. Appendices

Appendix A: *Kenmore Interceptor Proviso P2 Support: Sediment and Fish Population Study*
Appendix B: *Kenmore Lake Line Lakebed Sedimentation Analysis (2011)*

KENMORE INTERCEPTOR PROVISO P2 SUPPORT

Sediment and Fish Population Study

Prepared for
King County
Wastewater Treatment Division

February 2020

KENMORE INTERCEPTOR PROVISO P2 SUPPORT

Sediment and Fish Population Study

Prepared for
King County
Wastewater Treatment Division

Contract No. P0019P16 WO39

February 2020

5309 Shilshole Avenue NW
Suite 200
Seattle, WA 98107
206.789.9658
esassoc.com

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Appendix A: Kenmore Interceptor Bathymetry and Dive Inspection Technical Memorandum

Acronyms and Abbreviations

cfs	cubic feet per second
Corps of Engineers	U.S. Army Corps of Engineers
DPS	distinct population segment
Ecology	Washington Department of Ecology
ESA	Environmental Science Associates, Inc.
ESU	evolutionarily significant unit
GPS	global positioning system
hp	horsepower
KCWTD	King County Wastewater Treatment Division
kg/m^3	Kilograms per square meter
NAVD	North American Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
RM	river mile
ROV	remotely operated vehicle
TSS	Total Suspended Solids
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife

Glossary

Accretion (n) or Accrete (v)	The accumulation of sediment material over time.
Allocthonous	Materials that originated or formed in locations away from where the materials are currently found.
Aquatic Macrophytes	A water-dwelling plant. Algae are not macrophytes.
Cyanobacteria	A type of aquatic photosynthetic bacteria. Also known as blue-green algae.
Downdrift	In the direction of alongshore transport of sediment.
Eutrophication (n) or Eutrophy (v)	The state of excessive nutrients in aquatic environments, often resulting in poor water quality.
Fluvial	Related to or from rivers.
Forcings	Phenomena that cause effects or act to generate an outcome.

1 EXECUTIVE SUMMARY

Environmental Science Associates, Inc. (ESA) was contracted by the King County Wastewater Treatment Division (KCWTD) to analyze the sedimentation and fish populations in the vicinity of the Kenmore Interceptor Section 2 lake line. The Kenmore Interceptor lake line is a 48-inch pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station and is the target of concern in the KCWTD Budget Proviso P2. The Proviso objectives included, but were not limited to, four areas of discussion, including aspects of design relating to silt accumulation and potential effects to in-water habitat. The Proviso in its entirety is included in Section 2. The study methods and topics of analysis are briefly summarized below.

1.1 Study Methods

The analysis described in this document did not include a site investigation, data collection, or numerical modeling by ESA. ESA relied on existing studies, available data, and expert judgement to conduct the work. ESA reviewed the *Kenmore Lake Line Lakebed Sedimentation Analysis* conducted in 2011 by SoundEarth Strategies and Lally Consulting and found the report to be a reasonably thorough summary of the physical processes occurring near the lake line. Standard data collection procedures and analysis were performed. ESA concurs with the overall findings of the 2011 report.

Recent public work projects in the City of Lake Forest Park relevant to sediment transport in the watershed were compiled and reviewed by ESA. Several significant flood control projects in Lyon and McAleer Creeks have removed anthropogenic barriers to the natural transport of coarse sediment from the upper watershed to the nearshore areas of Lake Washington.

ESA assessed the constructed conditions of the lake line to the extent possible using available pre- and post-construction information, and explained the uncertainties associated with installation options shown on the as-built construction drawings.

ESA conducted an assessment of shoreline and bathymetric change over time using publicly available aerial orthophotos, as-built construction drawings for the lake line, a video inspection of the lakebed from 2019 (King County 2019), and bathymetry from the National Oceanic and Atmospheric Administration (NOAA) (1902, 1975, and 2008), SoundEarth and Lally (2011), and Global Diving & Salvage, Inc. Gravity Marine Consulting (2020).

ESA reviewed the physical processes affecting sediment transport in the nearshore of the study area, including precipitation, streamflow, climate change, wind waves, boat wakes and propeller wash, lake circulation, downslope transport, and rooted aquatic vegetation.

1.2 Proviso P2 Topics

ESA's report focuses on the four main areas of discussion outline in Proviso P2, as summarized below.

Discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna.

The Kenmore Interceptor lake line was constructed in 1964 and has been in operation since that time. Section 2 of the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. The pipeline conduit is installed inside a rectangular concrete casement that is approximately 5 feet wide.

Based on inspection of 1964 design documents, the pipeline appears to have been installed well below the existing lakebed surface south of Lyon Creek, with the exception of a segment of elevated or trenched area south of McAleer Creek where the pipeline is farthest from shore. From Lyon Creek north, the pipeline is near, at, or slightly above the surface of the lakebed.

Final construction grades above and on either side of the lake line are not provided in the 1964 plans, nor are the method of installation and backfill recorded for each segment along the pipeline. The 1964 plans generally specify three allowable cases for how the pipeline may be constructed and backfilled, depending on the slope of the shoreline and the elevation of the existing lakebed relative to the design pipeline invert. However, the locations where each of the cases were utilized during construction are not provided. Because natural shorelines in the study area are quite flat, it is likely that a type Case II installation, which specifies backfilling the pipeline flat to existing grades, was used. This means that in some areas where the designed top of casement elevations exceeded existing grade, the concrete casement would have remained exposed on the lakebed. Steeper portions along the study area may have utilized a Case I installation, which specifies backfilling above the top of the pipeline casement. Because final installation grades to either side of the line were not provided, it is not possible to determine how the installed casement elevations relate to post-construction sediment elevations on either side of the line. This hinders the ability to assess changes in lakebed elevations on either side of the line in the years following construction.

In areas where the pipeline was fully buried below existing grade, there would be no anticipated impacts whatsoever to the movement of water fauna and sediment transport processes. Portions of the pipeline where the casement was installed partially exposed likely had little effect on sediment processes and negligible effect on the movement of water fauna, since the amount of exposed casing is small and located in already-degraded habitat.

Characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction.

As of 2019, roughly 80 percent of the pipeline is covered in sediment within the study area. The remaining 20 percent includes areas where the casement is partially exposed to a maximum

height of approximately 10 inches above the lakebed. As-built drawings indicate that one 500-foot stretch of the pipeline may have been elevated across a trench or depression, although recent surveys do not show the pipeline casement exposed in this area. This elevated or cantilever portion occurs in the far south end of the study area where typical water depths exceed 10 feet. It may have been partially backfilled following construction or has partially filled with sediment in the years following pipeline installation.

The assessment found that the lake line is located in an area of net sediment accumulation. Over the past nearly 120 years, the nearshore within the study area has accreted between 1 and 4 feet. This accretion has occurred on both sides of the current lake line. Areas under and around residential docks throughout the study area have likely experienced accretion since residential development began in the mid-1900s, especially in areas near Lyon and McAleer Creeks, although elevation data under docks are not available.

In its current state, the mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. The lake line is entirely buried along more than 80 percent of the study area. Exposed casement areas may have had minor, localized effects on sediment transport and accumulation on either side of the pipeline; however, historical data in this area are limited in coverage. It is not possible to determine specifically how bed elevations have changed in the immediate vicinity of the lake line because of limited as-built construction information. However, ESA estimates that the length of shoreline where minor localized effects may have occurred is approximately 500 feet, and the width over which effects could have occurred is on the order of 10 to 20 feet.

Analysis of the impacts of the silt accumulation of water fauna, with particular attention to the ability of fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species.

The presence of the Kenmore Interceptor lake line does not play a significant role in influencing aquatic flora or fish migration in and through the area. Fish habitat has been degraded over the years by several factors including shoreline armoring and overwater structures, changes to shoreline vegetation, stormwater inputs and historical industrial uses in the basin, and most notably the abundance of invasive Eurasian watermilfoil in much of the lake's littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth. The presence of Eurasian watermilfoil can affect the distribution of and habitat use by salmonids, pushing salmonids into deeper water along with prey fish. The presence of the Kenmore Interceptor lake line does not have an effect on the amount or distribution of watermilfoil in the area, as watermilfoil in Lake Washington can grow up to depths of 30 feet (Seattle Public Utilities n.d.) on both sides of the lake line.

Similarly, the installation and operation of the lake line have not significantly changed the quality or quantity of habitat for aquatic organisms, specifically salmonids. Although nearshore habitat conditions for salmonids in the area are substantially degraded from pre-contact conditions, the literature indicates that the degradation is a result of shoreline armoring and development, impacts on lake water quality, and the introduction of Eurasian watermilfoil into the lake. Several of these factors, as well as the presence of two stream deltas, directly contribute to the sediment

dynamics of the site, while the lake line does not significantly alter sediment dynamics or other processes that create and maintain salmonid habitat.

The presence of the exposed casement along limited portions of the study area is not a barrier to fish migration, as fish can easily swim over and across the short distance of casement.

Analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2.

Dominant physical processes affecting sediment transport in the nearshore include the deposition of fluvial material by McAleer and Lyon Creeks and sediment trapping and building by rooted aquatic vegetation. The mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. Exposed casement areas may have a minor influence on the downslope transport of sediment by physically obstructing moving offshore along steep slopes and possibly exacerbated wave scour for a limited distance offshore of the pipeline. However, much of the study area is relatively flat, such that downslope transport is not a dominant physical process and large waves are infrequent. Portions of the exposed casement are sufficiently deep such that only large waves may reflect or interact with the exposed casement. Offshore processes are limited in the study area, given the relatively flat slopes and dense colonization of rooted aquatic vegetation that inhibits the downslope transport of material into deeper areas.

The deposition of coarse and fine materials from nearby creeks does not appear to be impeded by the lake line, which is buried throughout most of the Lyon Creek and McAleer Creek deltas. The creeks are likely the dominant factor driving sediment accumulation on both sides of the lake line.

2 PROVISO TEXT

The section of King County Wastewater Treatment Division's Budget Proviso P2 related to the Interceptor reads:

> *"Of this appropriation, $250,000 shall not be expended or encumbered until the executive transmits a report on the Kenmore interceptor impacts to fish populations and a motion that acknowledges receipt of the report and the motion is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section and proviso number in both the title and body of the motion.*
>
> *The report shall include but not be limited to: (1) a discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna; (2) a characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction; (3) an analysis of the impacts of the silt accumulation of water fauna, with particular attention to the ability of fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species; (4) an analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2. The report shall additionally address the impacts on the nearshore environment of effectively creating a barrier resulting in functionally separated lake areas. The report shall discuss options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps."*
>
> (Ordinance 18835, Section 108, Wastewater Treatment Division, P2)

3 BACKGROUND

The purpose of this report is to address concerns identified in the King County Wastewater Treatment Division's Budget Proviso P2 related to the placement of the Kenmore Interceptor Section 2 lake line ("lake line" or "interceptor") on fish populations and sedimentation around the pipeline.

The Kenmore Interceptor lake line is a 48-inch pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station (Figure 1). The pipeline was constructed in 1964 and has been in operation since that time. Section 2 of the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. Environmental Science Associates, Inc. (ESA) was contracted by King County Wastewater Treatment Division (KCWTD) to analyze the sedimentation and fish populations in the vicinity of the pipeline.

In 2011, SoundEarth Strategies and Lally Consulting prepared the *Kenmore Lake Line Lakebed Sediment Analysis* for this same segment of pipeline. ESA performed a technical peer-review of the 2011 report for technical completeness and accuracy, as well as conducted further review of existing documents and information available as of December 2019. No field data collection, such as aquatic wildlife surveys, sediment sampling, or bathymetry collection, has been performed by ESA as part of this effort. Updated bathymetric data in the study area were collected by Global Diving & Salvage, Inc. and Gravity Marine Consulting as part of a separate contract with King County in January 2020. The recent bathymetric data are presented herein, and a copy of the bathymetry report is included in Appendix A.

The target of this assessment was to further consider if the location and condition of the Kenmore Interceptor lake line could have potential impacts on aquatic organisms that use the nearshore of Lake Washington, including direct impacts on habitat, feeding, migration, and predation. The report also includes a qualitative analysis characterizing sediment accumulation trends over time in the vicinity of the interceptor and identifies the driving factors behind the trends.

SOURCE: King County, USGS

Kenmore Interceptor Proviso P2 Support

Figure 1
Study Area

3.1 Technical Review of 2011 Analysis

A *Sediment Analysis Report for the Kenmore Lake Line Lakebed* was prepared in 2011 by SoundEarth Strategies, Inc. and Lally Consulting LLC. That study conducted an investigation of the sediment transport mechanisms and depositional environment along the lake line to evaluate whether its position has influenced the accumulation of sediment in the study area. Dive observations conducted in 2011 indicated that the study area appeared to be a depositional environment. The surface sediments appeared to result from numerous potential sources including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees, and potentially historic or current mill and plywood operations. Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion noted. Erosion was noted in several areas along the shoreline, particularly adjacent to shore landings or dock structures and along the downdrift side of armored beaches. No significant differences were noted in the surface sediment composition or vegetation density on either side of the lake line. The 2011study concluded that there were no obvious indications that the lake line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects in one 10-foot section near a manhole (Manhole 37) where the lakeward bed elevation dropped approximately 0.5-foot relative to the top of the lake line. The lakebed was flush with the top of this conduit section in 2011.

ESA concluded that SoundEarth and Lally used standard practices throughout their assessment. The 2011 summary of nearshore sedimentation processes is technically accurate and reasonably thorough. Data collection methods for sediment sampling and depth measurements were standard, although, as the 2011 report discusses, the sampling was significantly limited in scope and spatial extent. The 2011 data and technical analyses are valuable for this current investigation and have been included and cited throughout this report.

As part of this renewed investigation, ESA has identified additional publically available data relevant to nearshore sedimentation processes that supplement the 2011 data. ESA has also provided a more detailed analysis of certain processes that were only briefly mentioned in the 2011 study, as well as a habitat impact assessment for the pipeline. However, this current study reaches the same overall conclusion as the 2011 effort; the area through which the interceptor passes is an area of net sediment accumulation regardless of the presence of the pipeline and that any effects on sediment transport are localized.

3.2 Study Area Characteristics

This section presents an overview of the study area and geographic context for the sedimentation and habitat concerns around the Kenmore Interceptor lake line in Lake Washington. Figure 1 outlines the study area in relation to the Kenmore Interceptor lake line, other King County Wastewater facilities, and Lyon and McAleer Creeks. Also shown on Figure 1 is the approximate

extent of property owners that reportedly expressed sedimentation concerns, leading up the 2011 sedimentation study (Sound Earth Strategies, Lally Consulting 2011).

3.2.1 Lake Washington

Lake Washington is the second largest natural lake in the state of Washington with 80 miles of shoreline. The lake is approximately 20 miles long with a mean width of approximately 1.5 miles, has a circumference of 50 miles, covers 22,138 surface acres, has a mean depth of approximately 100 feet, and has a maximum depth of approximately 200 feet (Jones and Stokes 2005). Construction of the Lake Washington Ship Canal lowered the level of Lake Washington to its current elevation, and development has significantly altered the natural configuration of the lakeshore. Much of the shoreline adjacent to the lake has been developed with water-dependent industries, houses, bulkheads, docks, boat launches, and landscaped lawns.

3.2.1.1 History and Hydrology

The Lake Washington watershed has been dramatically altered from its pre-settlement conditions, primarily due to removal of the surrounding forest and urban development, as well as lowering of the lake elevation and rerouting of the outlet through the Ship Canal. As a result, the Cedar River is now the major source of freshwater to Lake Washington, providing about 50 percent (663 cubic feet per second [cfs]) of the mean annual flow entering the lake (NMFS 2008). The Cedar River drainage area is approximately 184 square miles, which represents about 30 percent of the Lake Washington watershed area. The Lake Sammamish basin is also a substantial freshwater source, providing about 25 percent (307 cfs) of the mean freshwater flow into Lake Washington.

The remainder of freshwater flow into Lake Washington originates from a variety of small creeks located primarily along the northern and eastern shores, including McAleer and Lyon Creeks. Within Lake Washington, the natural hydrologic cycle has been altered. Historically, lake elevations peaked in winter and declined in summer. Operation of the Government Locks now produces peak elevations throughout most of the summer.

The U.S. Army Corps of Engineers (Corps of Engineers) is mandated by Congress (Public Law 74-409, August 30, 1935) to maintain the level of Lake Washington between 20 and 22 feet Corps of Engineers datum or 16.75 to 18.75 feet NAVD88 datum, as measured at the Government Locks. The Corps of Engineers operates this facility to systematically manage the water level in Lake Washington over four distinct management periods, using various forecasts of water availability and use.

The four management periods are:

- **Spring Refill:** Lake level increases between February 15 and May 1 to 22 feet (Corps of Engineers datum).
- **Summer Conservation:** Lake level maintained at about 22 feet for as long as possible, with involuntary drawdown typically beginning in late June or early July.

- **Fall Drawdown:** Lake level decreases to about 20 feet from the onset of the fall rains until December 1.
- **Winter Holding:** Lake level maintained at 20 feet between December 1 and February 15.

Operation of the Government Locks and other habitat changes throughout the Lake Washington basin have substantially altered the frequency and magnitude of flood events in Lake Washington and its tributary rivers and streams. Historically, Lake Washington surface elevation was nearly 9 feet higher than it is today, and the seasonal fluctuations further increased that elevation by an additional 7 feet annually (Williams 2000). In 1903, the average lake elevation was recorded at approximately 32 feet (Corps of Engineers Datum) (NMFS 2008).

Development and urbanization have altered base flow in many of the tributary systems (Horner et al. 1997). Increases in impervious and semi-impervious surfaces increase runoff during storm events and reduce infiltration and groundwater discharge into streams and rivers. A substantial amount of surface water and groundwater is also diverted into the City of Seattle and King County wastewater treatment system and eventually discharged to Puget Sound.

Although the frequency and magnitude of flooding in the lake and the lower reaches of tributary streams have declined due to the operation of the Government Locks, flooding has generally increased in the upstream reaches of tributary rivers and streams. This change is largely because of the extensive development that has occurred within the basin over the last several decades (Moscrip and Montgomery 1997).

3.2.1.2 Shoreline Habitat

Lowering the lake elevation after completion of the Ship Canal transformed about 1,334 acres of shallow water habitat into upland areas, reducing the lake surface area by 7 percent, and decreasing the shoreline length by about 13 percent (10.5 miles) (Chrzastowski 1981). The most extensive changes occurred in the sloughs, tributary delta areas, and shallow portions of the lake. The area of freshwater marshes decreased about 93 percent, from about 1,136 acres, to about 74 acres (Chrzastowski 1981). Essentially all of the existing wetlands and riparian zone habitat were developed after the lake elevation was lowered. Currently, this habitat occurs primarily in Union Bay, Portage Bay, Juanita Bay, and Mercer Slough (Dillon et al. 2000).

Lake level regulation by the Corps of Engineers has eliminated the seasonal inundation of the shoreline that historically shaped the structure of the riparian vegetation community. This, together with urban development, has replaced much of the hardstem bulrush- and willow-dominated community with developed shorelines and landscaped yards. The current lake level regulation affects the growth of many species of native terrestrial and emergent vegetation. This hydrograph indirectly buffers the shorelines from potential wave impacts from winter storms. The loss of natural shoreline has also reduced the historic complex shoreline features such as overhanging and emergent vegetation, woody debris (especially fallen trees with branches and/or rootwads intact), and gravel/cobble beaches. The loss of native shoreline vegetation and wetlands has reduced the input of terrestrial detritus and insects to support the aquatic food web.

In addition to the loss of native shoreline due to lowering of the lake elevation, the remaining natural shoreline features have been largely replaced with armored banks, piers and floats, and limited riparian vegetation. A survey of 1991 aerial photos estimated that 4 percent of the shallow-water habitat within 100 feet of the shore was covered by residential piers (ignoring coverage by commercial structures and vessels) (USFWS 2008). Later studies report about 2,700 docks in Lake Washington and approximately 71 to 81 percent of the shoreline armored (Warner and Fresh 1999; City of Seattle 2000; Toft 2001).

3.2.1.3 Sedimentation Rates

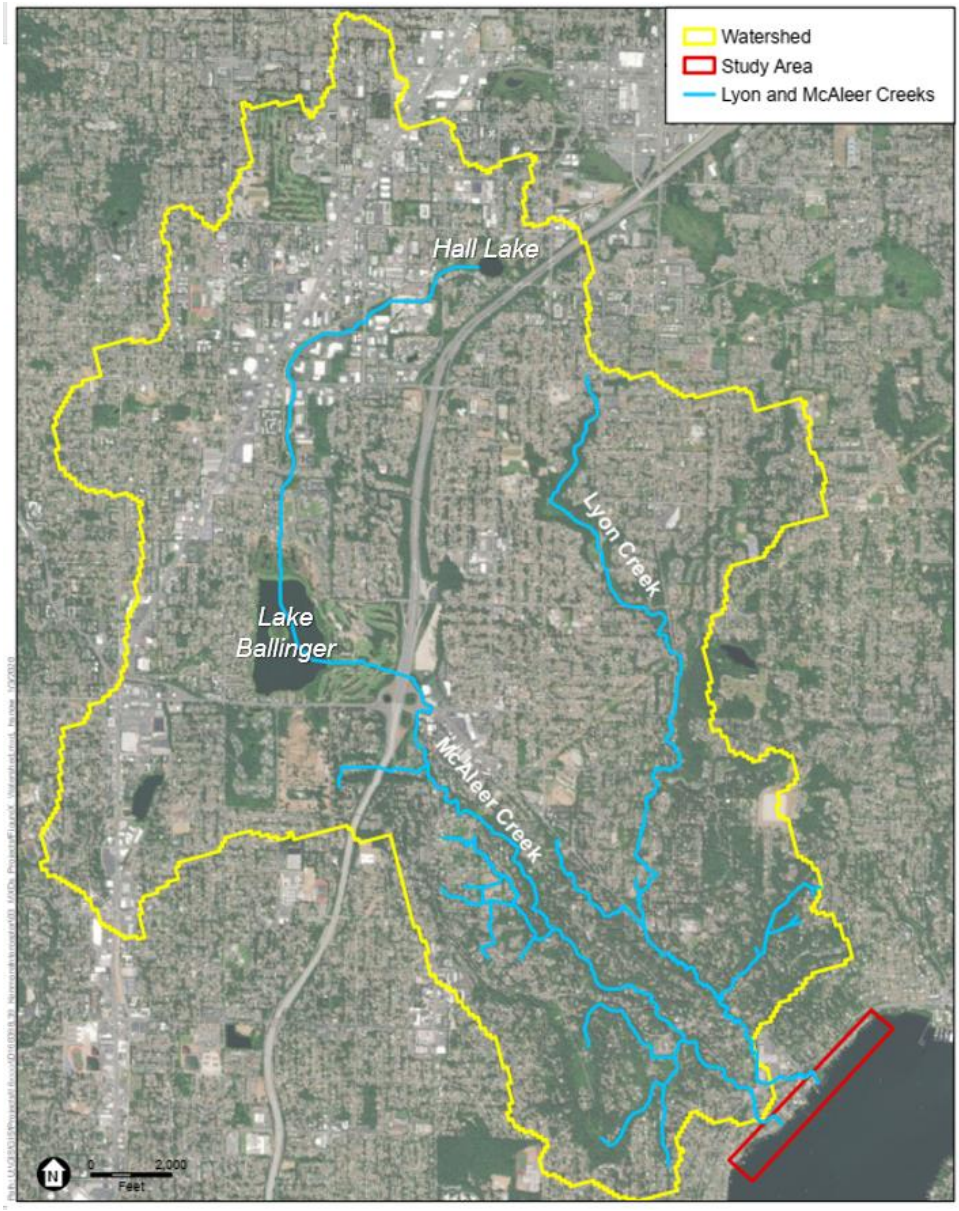
Rates of sedimentation in Lake Washington reflect the changing land uses in the watershed over time. Before the arrival of European settlers, Lake Washington was surrounded by dense stands of mixed coniferous forests and likely received little sediment and nutrient inputs. Pre-settlement sedimentation rates have been estimated between 0.73 and 1 mm/year (Birch et al. 1980, Wakeham et al. 2004). As the forests around the lake were logged in the late 1800s and early 1900s, the rates of sediment transport to the lake increased due to runoff from uncontrolled erosion. Sediment accumulation rates during this period were estimated to be between 4 and 5 mm/year (Birch et al. 1980).

In the early to mid-1900s, residential development near the lake grew considerably. During this time, secondary-treated sewage from nearby residences was discharged directly into the lake, delivering very high levels of nutrients. By 1922, sewage from 50,000 people was reaching the lake. Excessive nutrient delivery began to eutrophy the lake. Population growth continued, and by the 1950s, eutrophication in the lake was severe. Toxic cyanobacteria blooms and other nuisance algae growth seriously degraded both water quality and lake aesthetics. Periodic die-off of algal blooms contributed to increased sedimentation in the lake. During this highly eutrophic period, sedimentation rates were estimated between 2.2 and 5mm/year (Birch et al. 1980, Wakeham et al. 2004).

Efforts to restore the lake began in the early 1960s. Sewer trunk lines such as the Kenmore Interceptor lake line were installed to collect and reroute sewer discharges to the lake, and by 1968 all effluent was diverted. With these restoration efforts, the lake recovered rapidly. Sedimentation rates in the 1970s were between 2.5 and 3.1 mm/year. Today, the lake likely receives less sediment following the control on eutrophication, although little specific data on modern sedimentation rates are available (Ecology 2017).

3.2.2 Lyon Creek and McAleer Creek Watershed

Two major urban streams, Lyon and McAleer Creeks, flow through the City of Lake Forest Park and discharge directly to Lake Washington in the study area, near the north end of the lake (Figure 2). Both creeks naturally deliver sediment from the watershed into the nearshore areas of Lake Washington. Sediment deltas are found at the mouth of each stream where it enters Lake Washington.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 2
Lyon and McAleer Watershed

3.2.2.1 Lyon Creek

The headwaters of Lyon Creek begin in wetlands in south Snohomish County and flow 3.8 miles through Lake Forest Park before draining into the northwest corner of Lake Washington. The drainage basin is approximately 2,600 acres in size, one of the smallest of the Lake Washington tributary systems. Land use in the basin is predominantly developed (86 percent) as much of the land was developed in the late 1970s (Kerwin 2001). Forest land cover represents only 13 percent of the basin, while wetlands represent less than 1 percent (King County 2020).

Based on aerial photo interpretation of the lake deltas, Otak et al. (2009) indicates that Lyon Creek may have more severe erosion and sedimentation issues than McAleer Creek, which has also experienced flooding and erosion, but appears to benefit from the management of Lake Ballinger as an effective detention basin for the upper reaches of this subwatershed. Details on sediment deposition from Lyon Creek are provided in Section 5.1.1.1.

According to WDFW (2020), Lyon Creek has documented coho use to the Snohomish-King County line and sockeye salmon spawning and winter steelhead presence upstream to approximately SR 504, as well as cutthroat trout in the lower reaches. However, no use by Chinook salmon has been documented. From 2000 to 2015, volunteers with the King County Salmon Watcher Program recorded salmon observations at river mile (RM) 0.1 (King County 2020). Several sockeye and coho salmon were observed in the lower reaches of Lyon Creek although coho sightings were very rare. The suitability of Lyon Creek as salmonid habitat has been impacted by high storm flows, which have resulted in degraded substrate and lack of spawning habitat.

3.2.2.2 McAleer Creek

The McAleer Creek drainage basin is approximately 5,700 acres in size and includes portions of Mountlake Terrace, Shoreline, and Lake Forest Park. McAleer Creek originates at Lake Ballinger and flows roughly 6 miles before draining into the northwest corner of Lake Washington just south of Lyon Creek. Land use in the basin is predominantly developed (92 percent), and forest land cover represents only 6 percent of the basin, while wetlands represent less than 1 percent (King County 2020).

The middle portion of the drainage basin consists primarily of low-density residential land use with deep ravines and eroded soils, while the lower basin flattens and fans into a floodplain across what is now the Lake Forest Park Mall and Bothell Way. Building density increases and encroaches into the stream corridor.

WDFW (2020) reports both Chinook and steelhead presence upstream to near I-5, and coho salmon distribution extends upstream of I-5. Cutthroat trout and sockeye spawning occur in the lower 1.7 miles of McAleer Creek. Several tributaries to McAleer Creek, including Brookside and Whisper Creeks, are also known to support salmonids (Lake Forest Park Stewardship Foundation 2001). From 1997 to 2015, volunteers with the King County Salmon Watcher Program recorded salmon observations in McAleer Creek (King County 2020). Volunteers consistently saw Chinook, coho, and sockeye in the creek. No kokanee salmon or cutthroat trout were seen.

Details on sediment deposition from McAleer Creek are provided in Section 5.1.1.1.

3.2.2.3 Restoration and Flood Control Projects

Both Lyon and McAleer Creeks have been subject to flooding over the years, and a number of projects have been undertaken in the drainage basin to alleviate localized flooding. Because these projects were implemented within the streams, they have the potential to influence sediment transport to the lake. The following tables focus on projects undertaken to reduce flooding and improve streamflows.

Table 1 summarizes two projects that have been undertaken on Lyon Creek since 2015. Both of these projects included replacing undersized culverts that were contributing to flooding, and/or were fish barriers. Replacement of these culverts allowed for improved water flow during high-flow events and allowed fish to migrate up the creek past the former culvert site. Replacing the former undersized culverts also removed anthropogenic barriers to the natural transport of coarse sediments from the watershed to Lake Washington, thus restoring or partially restoring the natural sediment processes within the lower reaches of the creeks. Evaluating the extent to which the former culverts blocked or trapped sediment transport was not within the scope of this study.

Table 2 summarizes seven projects that have occurred along McAleer Creek since 2012, with one project dating back to 1994. These projects were undertaken to reduce downstream flooding, replace deficient culverts, and stabilize eroding areas.

Table 3 summarizes a variety of projects that have occurred along the shoreline within the study area. These projects included multiple minor installations and repairs of lakeside structures, and a dredging project near the mouth of Lyon Creek.

Table 1
PROJECTS ON LYON CREEK & TRIBUTARIES

Project Name	Project Years	Project Location (Creek Miles)	Project Description	Likely Effects on Nearshore Sediment Processes
Lyon Creek Town Center Flood Mitigation Project	2015	0.05	Replaced the three private culverts and one public culvert on Lyon Creek under SR 522 to address repeated flooding of Lyon Creek near the Lake Forest Park Town Center. Culverts are 20-foot-wide four-sided box culverts with 100-yr storm capacity. Work included over 1,100 feet of stream channel widening and large woody debris placement.	Increase in downstream transport of coarse sediment, previously trapped by undersized culverts. Possible reduction in transport from periodic overbank flooding and subsequent erosion.
Lyon Creek L60 Culvert Replacement	2019	0.6	Replaced and upgraded a structurally deficient and partial fish barrier culvert with a 70-foot-long concrete box culvert. Located at the Lyon Creek crossing of NE 178th Street & 44th Avenue NE.	Increase in downstream transport of coarse sediment, previous trapped by undersized culvert.

Table 2
PROJECTS ON MCALEER CREEK & TRIBUTARIES

Project Name	Project Years	Project Location (Creek Miles)	Project Description	Likely Effects on Nearshore Sediment Processes
McAleer Creek Bypass	1994	0.1	Installation of 48" bypass pipe to divert flood flows in McAleer Creek in response to flooding of Sheridan Beach neighborhood. Pipe inlet is between the Burke Gilman Trail and discharges under the Shore Drive NE bridge.	Redirection of flood flows likely reduces scour and downstream transport of material in lower reach of creek.
McAleer Creek Bypass Retrofit	2012	0.1	Retrofit of McAleer Bypass System to optimize flood reduction benefits. Work included adjusting inlet control, smoothing pipe, and enhancing maintenance facilities.	See McAleer Creek Bypass.
McAleer Creek Culvert Replacement at 178th Street	2015	0.75	Replaced undersized/structurally deficient culvert on McAleer Creek at NE 178th Street. New culvert is 21-foot-wide box culvert that allows for natural stream channel. Project included channel restoration upstream and downstream of culvert.	Increase in downstream transport of coarse sediment, previously trapped by undersized culvert.
McAleer Creek Emergency Stream Bank Protection	2016	1.5	Installed bank protection rock along approx. 30 feet of McAleer Creek to protect public/private safety and infrastructure. A 15-foot vertical bank had eroded during a storm event along NE Perkins Way, threatening the road. Work included bank protection, relocation of large woody material, and restoration planting.	Reduction in sediment supply from eroding back; possible decrease in downstream transport.
McAleer Creek Culvert Replacements	2014	3.25	Replaced undersized culverts along McAleer Creek between Lake Ballinger and I-5 to reduce flooding of lakefront property.	Possible increase in downstream transport of coarse sediment previously trapped by undersized culverts.
Hillside Creek Stream Regrading south of Brookside Elementary	2015	On Hillside Creek, tributary to McAleer with confluence at creek mile 0.75	Regrading of 330 LF of stream channel along Hillside Creek, including removal of accumulated sediment and woody debris, and cleaning/inspection of nearby culverts. Large sediment deposits had shifted base flows from primary stream channel to a high flow bypass pipe, creating fish stranding/barrier concerns	Grading likely increased sediment storage capacity, possibly reducing downstream transport.
Hillside Creek Bank Stabilization near 2800 Blk of 178th Street	2014	On Hillside Creek, tributary to McAleer with confluence at creek mile 0.75.	Stabilization of two erosion areas (approx. 30-feet-long) and enhancement of 80 LF streambank along Hillside Creek. Work included bioengineered streambank stabilization, sediment removal, and a native planting plan.	Reduction in sediment supply from eroding back; possible decrease in downstream transport.

Table 3
PROJECTS ON MCALEER CREEK & TRIBUTARIES

Project Name	Project Years	Project Location	Project Description	Likely Effects on Nearshore Sediment Processes
Lyon Creek Waterfront Preserve Buoy Project	2015	17337 Beach Dr, NE, Lake Forest Park, WA 98155	Installed a navigational buoy attached to a 1½-inch galvanized steel pipe to demarcate the location of the Lyon Creek Waterfront Preserve and prohibit watercraft from entering the area adjacent to the site and dock.	Minor bed disturbance during installation. Preventing of vessels from accessing the area reduces propeller-wash & wake effects in Lyon Creek delta depositional area.
Lake Forest Park Civic Club Boat Ramp Dredging	2016-2019	17301 Beach Dr NE, Lake Forest Park, WA 98155	Removed fine sediment that had accumulated near the Lake Forest Park Civic Club boat ramp. Approximately 20 cubic yards of material removed from 770-square-foot area. Work included lakeside native planting.	Reduced lakebed elevations within dredging area. Possible disruption and redistribution of nearshore sediments within the surrounding area outside of dredging limits.
Various projects constructed on private residential properties	2014-2019	Shoreline properties: 16524 and 16560 Shore Dr NE, 17767, 17350, 17356, 17417, 17733, 17759, 17763, and 17767 Beach Dr NE	Various minor projects consisting of the repair and replacement of piles, piers, boatlifts, and bulkheads. One project was corrective action for unauthorized hydraulic work along the shoreline of Lake Washington.	Minor localized bed disturbances during construction activities.

3.2.3 Sheridan Beach and Beach Drive NE

The Sheridan Beach neighborhood was platted in 1927 and 1930. Although property development was slow in the 1930s, following World War II shoreline development boomed (City of Lake Forest Park n.d.). Inspection of aerial photos from the U.S. Geological Survey (USGS) and Google Earth shows that as of 1936, very few docks and other shoreline modifications (such as groins or bulkheads) existed along the shore of the study area. By 1954, more docks were present, although only a relatively small percentage of the platted properties included docks. In the subsequent 12 years, aerial photos show that many docks and shoreline developments were implemented such that in 1964, most properties along the shore had docks and in 1968, shoreline build-out was similar to current conditions.

Today, shoreline conditions along Sheridan Beach and Beach Drive NE generally consist of managed grass lawns, few to no trees or other overhanging vegetation, docks (which vary in length from 50 feet to 375 feet), and small overwater structures such as boat houses. Nearly every property adjacent to the shore has a private dock. In total, 56 docks span the 4,700 feet of shoreline in the study area, which corresponds to a dock density of one structure per 80 feet. The shoreline is also heavily armored by revetments and bulkhead walls, occasionally punctuated by managed sandy pocket beaches. Figure 3 shows the typical shoreline conditions along Beach Drive NE.

SOURCE: WA Ecology Kenmore Interceptor Proviso P2 Support

Figure 3
Study Area Typical Shoreline Condition

3.3 Constructed Conditions of the Lake Line

The Kenmore Interceptor lake line is a 48-inch concrete conduit pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station (Figure 1). The Section 2 lake line is connected to the Kenmore Interceptor land section via a connection line near Log

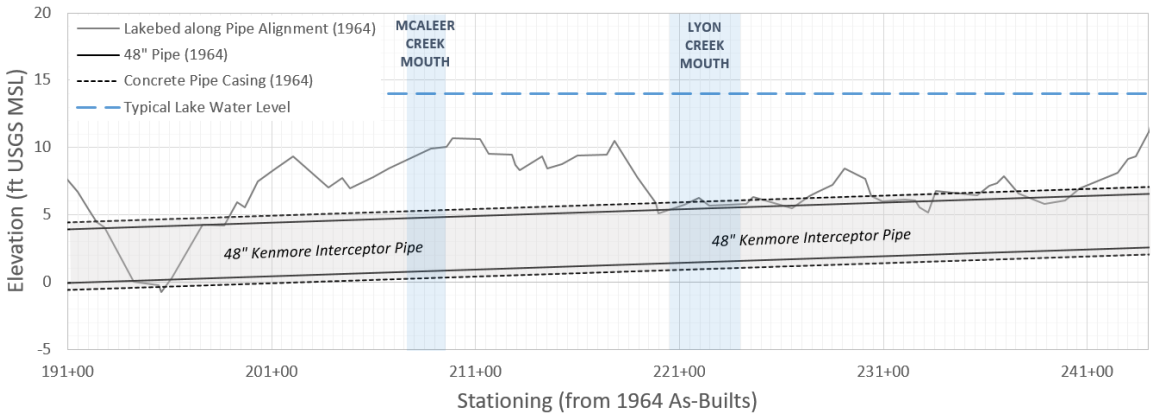
Boom Park in Kenmore. Within the lake, the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. The typical depth of installation of the pipeline is 8–12 feet below the lake water level, which varies up to 2 feet seasonally.

Elevations for lake line are provided in the 1964 engineering drawings for the Kenmore Interceptor Section 2 Contract (Municipality of Metropolitan Seattle 1964) and are reproduced in Figure 4, which shows the 48-inch pipeline and concrete casing in profile view. The casing extends 6 inches above the crown and below the invert of the pipeline. The existing grade along the alignment from the 1964 plans is also shown. The existing grade is assumed to be the elevation of the lakebed along the pipe centerline prior to installation, as it is not marked as a finished elevation. South of Lyon Creek, the pipeline appears to have been installed well below the existing lakebed surface. From Lyon Creek north, the pipeline is near, at, or slightly above the surface of the lakebed.

It is not clear if the 1964 drawings represent the as-built condition of the pipeline, which would reflect any changes or conditions observed in the field, or are a copy of the permitted design set. Some minor discrepancies appear to exist between the installed conduit section geometry observed in a 2019 video inspection of the lake line and the 1964 drawings. It is possible that design geometry changes were made following the permit drawings that are not reflected in the plans. See Section 4.2.2 for more details on the visual observations. Additional construction notes or specifications were not available beyond those provided in the 1964 drawings. For the purposes of this study, ESA assumes that the elevations and sections shown in the drawings reflect the 1964 conditions, as-installed.

Final construction grades above and on either side of the lake line are not provided in the 1964 plans; however, Figure 5 provides a typical cross-section detail from the 1964 plans showing three typical installation grading cases. Within the study area, Case I or Case II installation likely occurred, with Case I installation intended for more steeply sloping banks, and Case II installation intended for relatively flat slopes. The 1964 plans do not specify where along the alignment Case I or Case II installation occurred or was anticipated to occur, nor is the anticipated limit of excavation specified. Natural shoreline slopes in the study area range from nearly flat to slopes up to 13 percent (see Section 4.2.1). In nearly flat areas of the shoreline, Case I installation likely occurred, and is evident in some areas from the 2019 visual inspection (see Section 4.2.2). In the steeper areas of the shoreline, natural slopes fall between the schematic Case I and Case II installation cases, as shown schematically on Figure 6. Thus, it is not possible to determine specifically where Case II installation occurred within the lake, or if some condition between Case I and Case II was implemented in 1964.

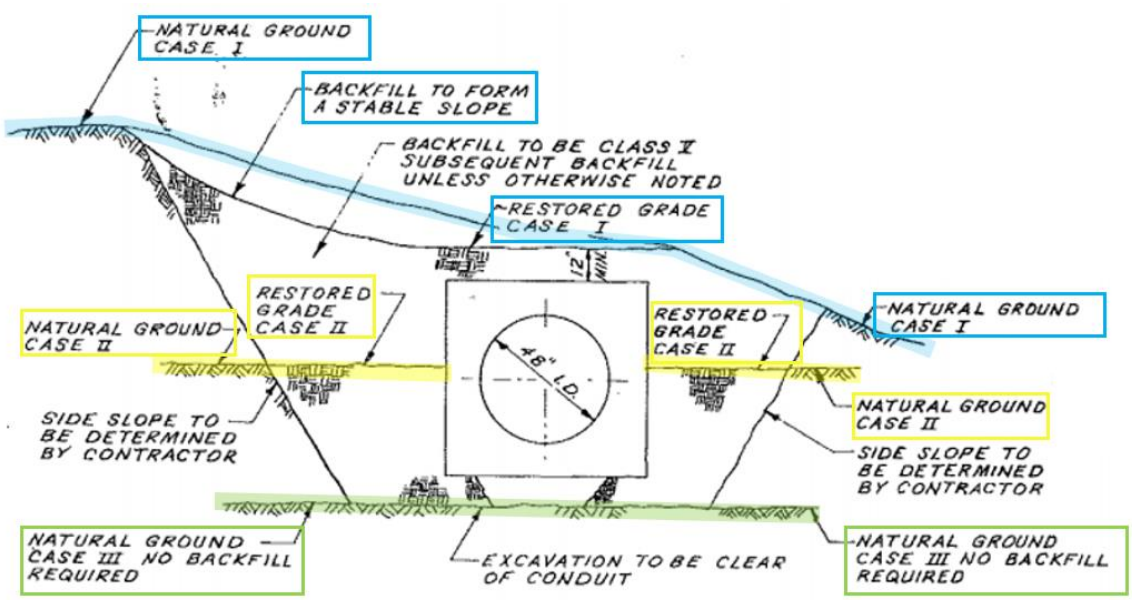
The 1964 plans indicate that a stretch of the pipeline at the southern end of the study area appears to be installed in a depression or trench. It is unclear if the pipe was backfilled following installation in this low area. This stretch is about 500 feet in length and is located in deeper water where the pipeline is farthest from shore.



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

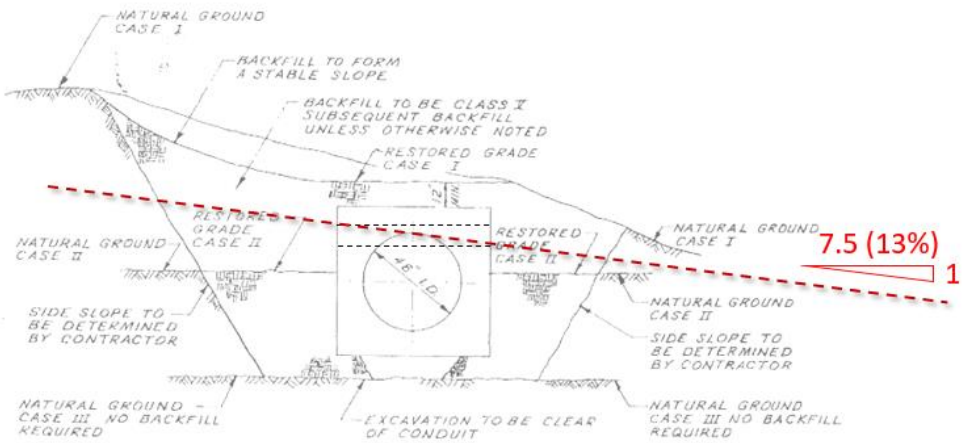
Figure 4
Typical Section of Kenmore Interceptor Lake Line



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

Figure 5
Typical Section of Kenmore Interceptor Lake Line
Case II Highlighted in Yellow



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

Figure 6
Schematic 13% Slope on Typical Section Detail

4 BATHYMETRIC ANALYSIS

This section analyzes changes to the shoreline position and nearshore elevations over time with respect to the installation of the Kenmore Interceptor lake line.

4.1 Shoreline Analysis

Aerial images of the study area were analyzed from 1954 to 2018 to determine changes in the position of the shore-water interface over time. Image sources include Google Earth and USGS. Figure 7 compiles the traced historical shorelines from a selection of years onto one image (2018 Google Earth imagery).

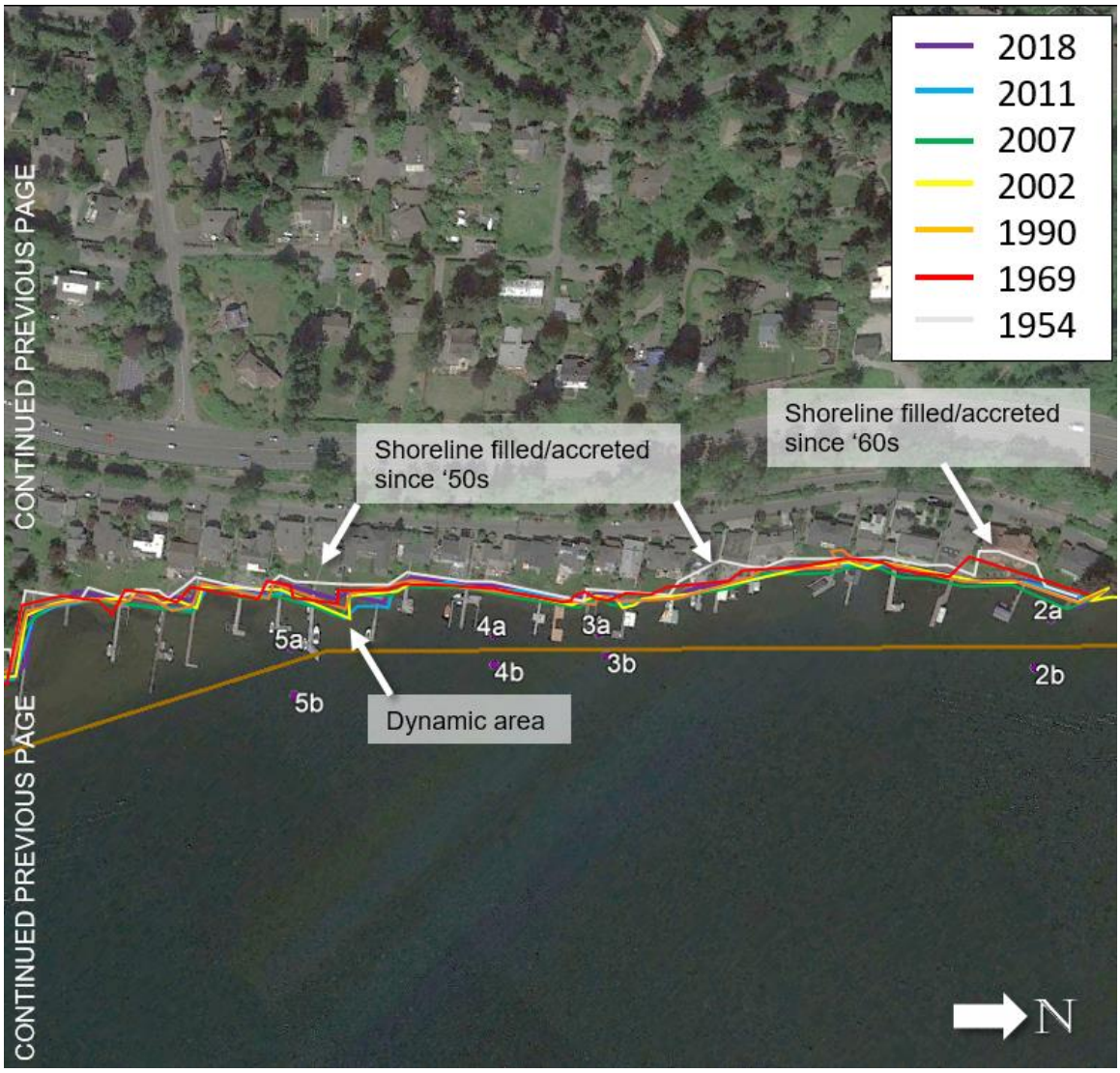
The aerial images show several areas that appear to be dynamically filling and eroding. Most of these areas occur downdrift of the mouths of McAleer and Lyon Creeks (sediment drift is south to north in this stretch of shoreline; see Section 5.1.1.2 for more details). Because fluvial sediment transport occurs periodically and unevenly, observing variability over time along a downdrift shoreline is common. Another dynamic area is observed farther north of Lyon Creek. The shoreline structures and armoring in this area appear to have been manipulated several times since the early 2000s, resulting in a variable shoreline.

A few areas appear to have been filled since the 1950s or 1960s. The area near the mouth of Lyon Creek may have naturally accreted, or human modifications may be responsible for fill in the areas indicated. Slight variability between years, especially in armored stretches, is likely attributed to changes in water level between photos and variability in aerial photo rectification.

SOURCE: Google Earth, USGS

Kenmore Interceptor Proviso P2 Support

Figure 7a
Shoreline Trends
1954–2018



SOURCE: Google Earth, USGS

Kenmore Interceptor Proviso P2 Support

Figure 7b
Shoreline Trends
1954–2018

4.2 Existing Bathymetric Data

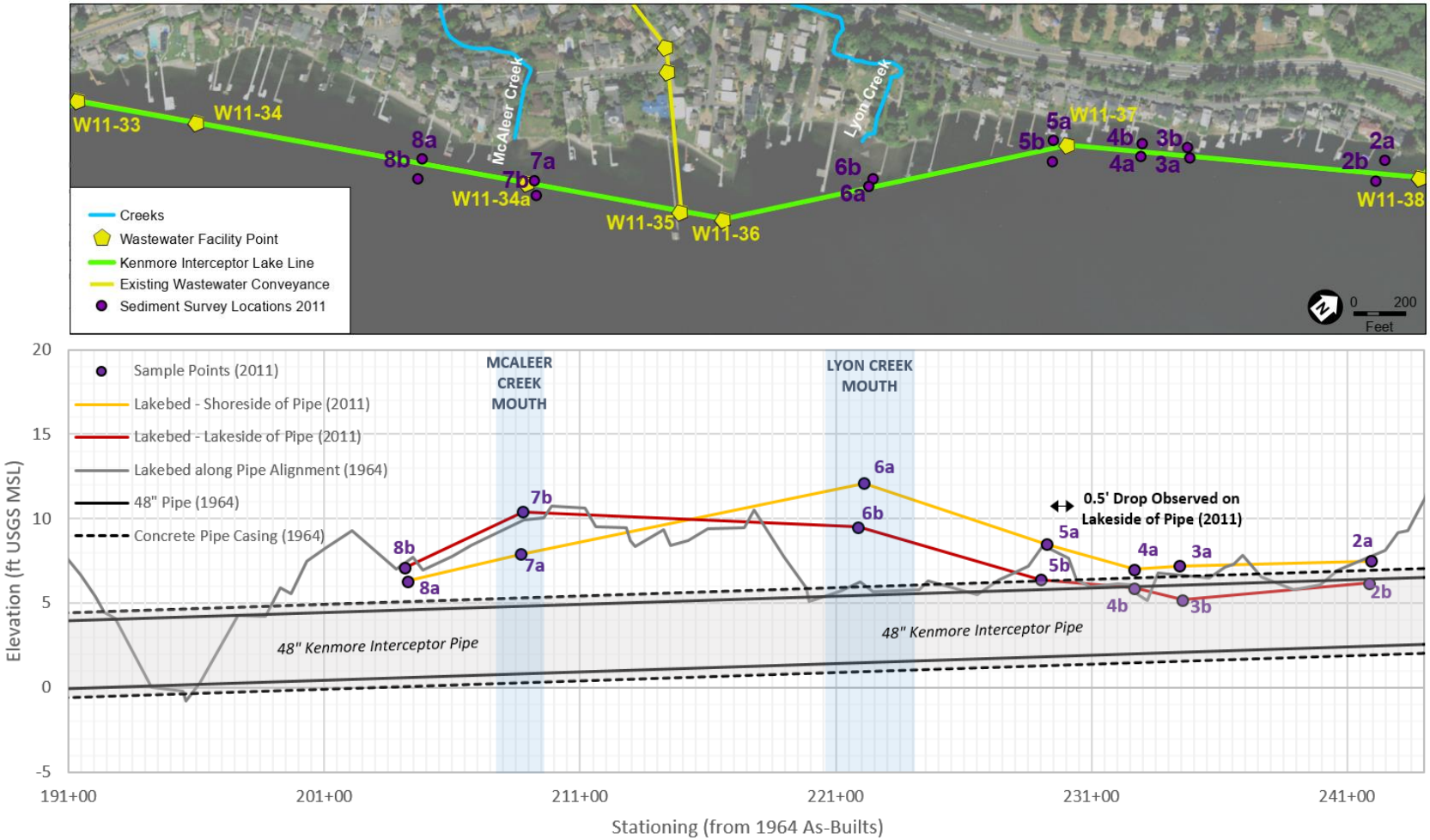
Available bathymetric data for the study area are limited. As of January 2020, datasets specifically related to pipeline elevations include the 1964 plan set elevations, the 2011 diving survey performed by Sound Earth Strategies and Lally Consulting, and the 2019 remotely operated vehicle (ROV) video images. Bathymetric points collected by NOAA during lakewide surveying operations in 1902, 1975, and 2008 also overlap with the study area and were included in this assessment.

4.2.1 Diving Survey, 2011

In June 2011, Sound Earth Strategies and Lally staff conducted a diving inspection of the lake line to support their sedimentation analysis. The inspection included depth and sediment sampling on either side of the Kenmore Interceptor lake line at eight different points along the alignment. Additional details on the diving methodology and observations are provided in Sound Earth Strategies and Lally (2011).

Figure 8 plots the results of the 2011 diving elevation measurements at paired points 2 through 8 along the alignment with the 1964 elevation data from Figure 4. Sample points were not taken directly over the top of the pipeline alignment, and instead are located between 10 and 40 feet offset from the centerline, thus capturing changes in elevations associated with natural cross-shore slopes. Figure 9 illustrates the approximate nearshore lakebed slopes, calculated between the shoreline and the “a” sample points. Slopes are generally flat, consistent with the 2011 diving observations (Sound Earth Strategies and Lally 2011). Sample sites 2, 3, and 4 were the steepest and are located where the pipeline is closest to the shore. Given the downward slopes, the “a” sample elevations would be expected to be higher than the “b” elevations. Refer to Figure 4 for a schematic example of how slopes may influence elevations in the vicinity of the lake line.

Direct comparison between the 2011 and 1964 elevations is not possible because of the uncertainty in installation grading conditions (Case I vs. Case II) and the inconsistent measurement locations (directly along the pipe centerline vs. horizontal offset of 10 to 40 feet). In areas where 2011 measurements are dramatically different than the 1964 existing grade, accretion or erosion has likely occurred over time. Near the mouth of Lyon Creek, accretion is clearly present on both sides of the lake line. However, in areas where the depth points are similar to the original existing grade (such as near sample sites 2, 3, 4, and 5), it is not possible to make a conclusion on accretion or erosion trends because of the uncertainty associated with comparing measurements at inconsistent locations. Also, individual spot measurements of elevation do not capture the natural variability within a localized area, making comparisons of small differences (less than 1 foot) difficult. In addition to the depth measurements, the 2011 diving survey indicated that a 10-foot-long stretch of the pipeline exhibited a 6-inch change in elevation between the shoreside and lakeside of the pipe. The report authors concluded that the lake line may have had localized effects on sediment accumulation in this isolated area. While this is possible, it is also difficult to determine based on the uncertainty of the originally constructed backfill grades on either side of the lake line.



SOURCE: Municipality of Metro Seattle (1964); Sound Earth Strategies and Lally (2011)

Kenmore Interceptor Proviso P2 Support

Figure 8
Change in Lakebed Elevation 1964–2011

Sampling Site	Nearshore Slope
1	9%
2	11%
3	13%
4	12%
5	7%
6	2%
7	5%
8	6%

SOURCE: SoundEarth and Lally 2011

Kenmore Interceptor Proviso P2 Support

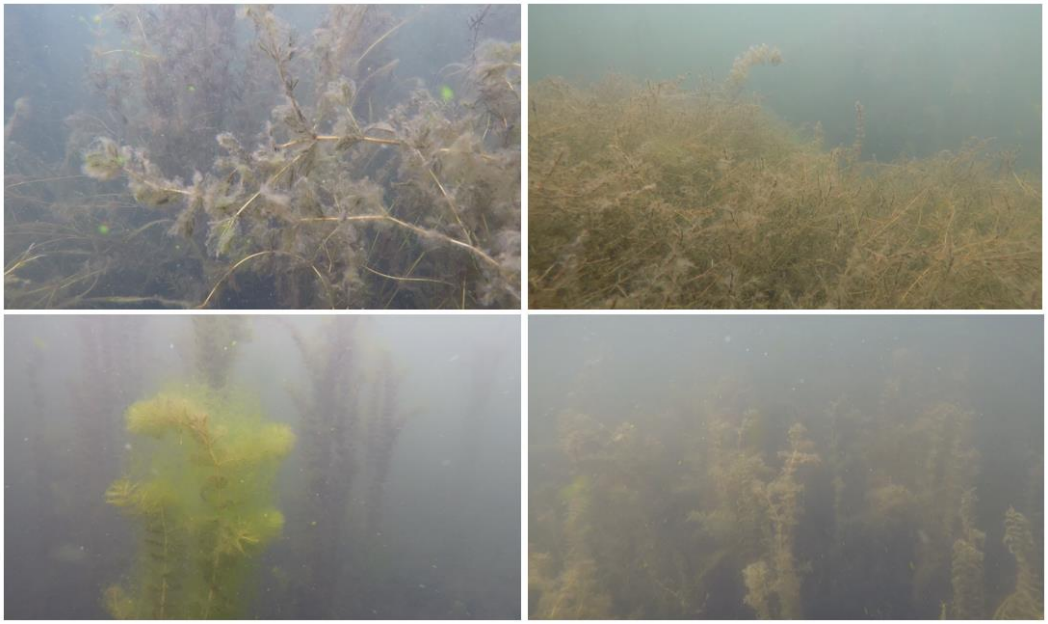
Figure 9
Nearshore Bed Slopes
Shoreward of Pipe Centerline

4.2.2 ROV Inspection, October 2019

On October 2, 2019, the King County Environmental Lab performed a remotely operated vehicle (ROV) survey of the lake line from near manhole W11-38 to W11-34a. Video from the ROV along with survey notes were provided to ESA.

Visual observation along much of the lake line is obscured by thick vegetation, high turbidity, propeller wash, and the uneven flight path of the ROV. ESA determined approximate location of the ROV based on nearby landmarks and properties shown when the ROV periodically surfaced. Figures 10 through 14 illustrate typical images from the ROV inspection along various segments of the survey.

Rooted aquatic vegetation occurs along most of the survey on both sides of the lake line. Figure 10 shows typical vegetation conditions, which is dominated by invasive European watermilfoil. The bed appears to be silty with organic debris where sediment is visible. In many locations, the vegetation completely obscures the lakebed and makes determination of bottom conditions impossible. Near the mouth of McAleer Creek, ROV images show a shallow, sandy lakebed with sand waves and limited aquatic vegetation (Figure 11). The creek mouths are more dynamic regions along the shore, with coarse bed materials and higher rates of sediment transport that likely inhibit vegetation establishment.



SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

Figure 10
Dense Vegetation along Pipeline

SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

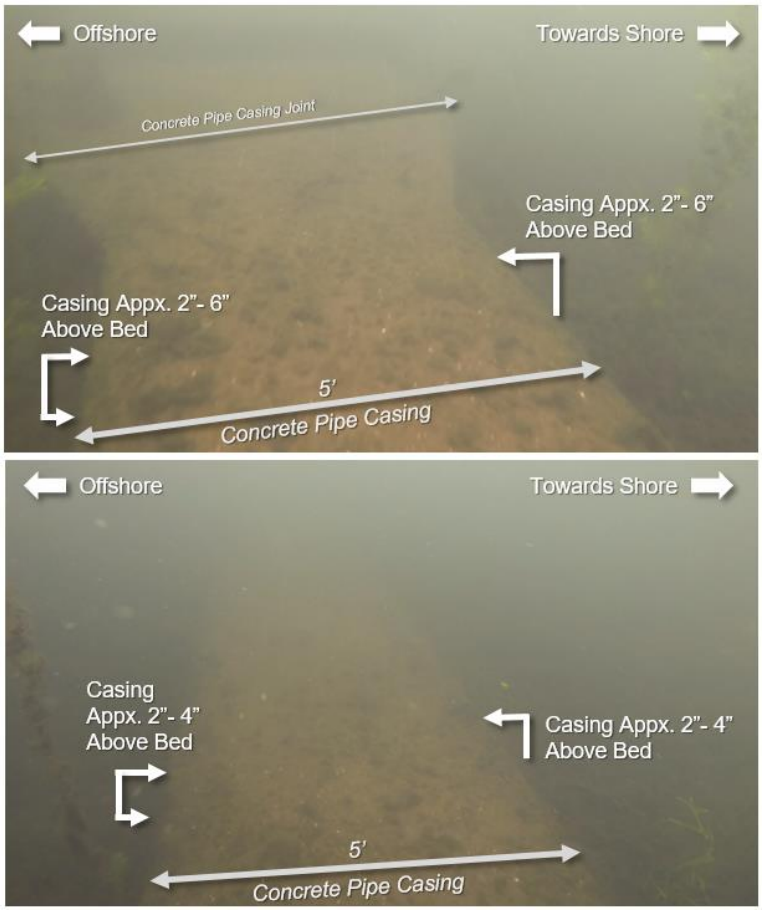
Figure 11
Sandy Bed near McAleer Creek Mouth

Figure 12 shows manhole W11-38 at the north end of the study area. Moving south from W11-38, Figure 13 shows the top of the lake line's 5-foot-wide concrete casing emerging from the sediment. The casing appears to stick up from the lakebed sediments several inches on both sides of the line. Farther south, Figure 14 shows images of the casing, which is partially covered by sediment on the shoreside of the pipeline and exposed up to an estimated 10 inches on the offshore side of the line. Video images and survey notes indicate that the casing is entirely covered in sediment south of approximately 17700 Beach Drive NW.

SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

Figure 12
Manhole W11-38

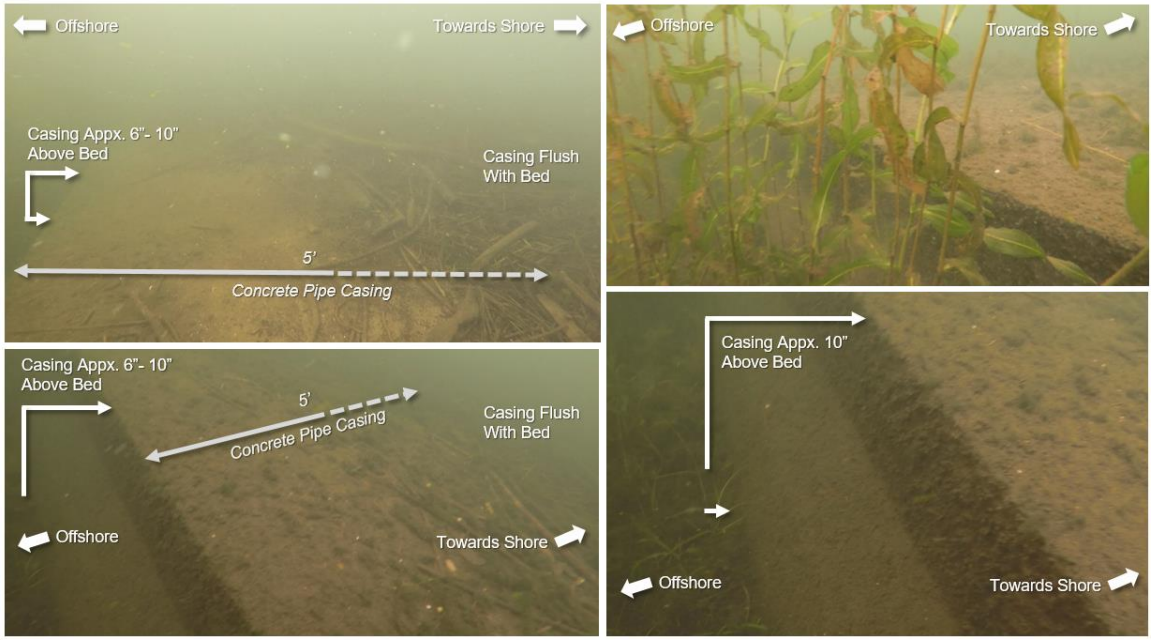


SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

Figure 13
Pipe Casing Near 17762 Beach Dr N
ROV Inspection – Oct. 2, 2019

The bottom panels of Figure 14 show what appears to be a beveled edge along some stretches of the lake line casing on the offshore side. This extends for some distance along the line, although it is difficult to estimate given the unknown speed of the ROV.



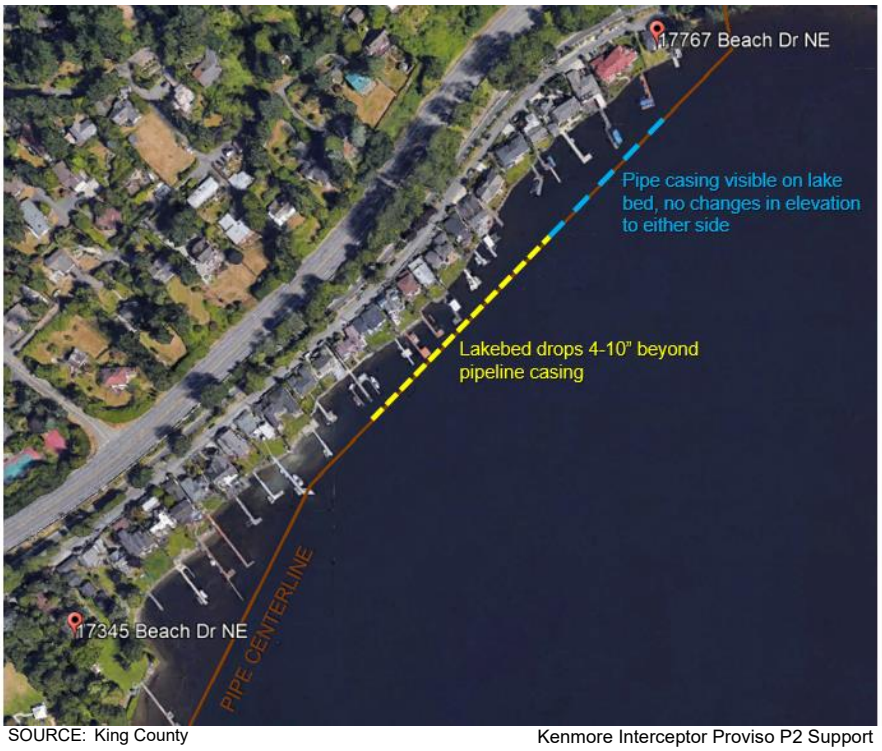
SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

Figure 14
Pipe Casing Near 17718 Beach Dr N
ROV Inspection – Oct. 2, 2019

Figure 15 summarizes observations of the pipeline casing in the north end of the study area. The regions shown in Figure 15 are approximate based on sparse visual references from the ROV footage and survey.

The conditions observed during the ROV survey are somewhat different than the previous observations from 2011. While the 2011 survey observed an approximate 10-foot stretch of pipeline with a drop to the offshore side, the 2019 ROV inspection appears to show a roughly 500-foot stretch with some visible drop on the offshore side.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 15
ROV Inspection Observations
King County Environmental Lab – Oct. 2, 2019

4.2.3 Hydrographic Survey, January 2020

On January 15, 2020, Global Diving LLC and Gravity Marine Consulting performed a bathymetry survey in the study area. The survey consisted of diving transects and single-beam sonar scans. The approximately 1-mile-long study area was mapped from the outermost extent of docks within the study area to approximately 600 feet offshore. The full technical memorandum describing the hydrography methods and results is included in Appendix A. Also included in Appendix A are figures showing the spatial extent of data collection and elevations of the survey points (Appendix A Figures 3 and 4). Bed elevations along the pipeline range from approximately 9 feet NAVD88 to 12 feet NAVD88. Elevations near the Lyon and McAleer Creek deltas are generally higher than in other areas. In the south end of the site, elevations are deeper closer to shore.

Extensive aquatic vegetation in the survey area affected the quality of some data points, despite the hydrographers use of state-of-the-art technology to penetrate the vegetation. Some of the sonar beams are reflected off of the dense vegetation before reaching the lake bed surface, producing final elevations that are higher than the anticipated actual bed surface. The cross-shore transects were affected more than the alongshore transects because of the motion of the surveying vessel (Gravity Marine, pers. Communication, 2020). These issues are described further in Section 4.2.4.

4.2.4 NOAA Surveys from 1902, 1975, and 2008

Bathymetric data from lakewide surveying efforts in 1902, 1975, and 2008 overlap with the study area. The 1902 and 1975 surveys captured a limited number of individual depth points near the lake line, while the 2008 single-beam bathymetry survey provided high resolution coverage across the study area. Original survey data were provided as points in meters, Lake Washington Low Water Datum. ESA converted these datasets to feet, NAVD88 and, when the density of points was sufficient (2008 survey), converted the points into an interpolated elevation surface. The 2008 survey is used as a comparison surface for the other surveys because it is the highest resolution and NOAA performed an extensive quality control assessment for the survey.

Figure 16 shows the lakebed elevations in 2008. Visible in this chart area is the substantial delta landforms around Lyon and McAleer Creeks. The shoreline toward the north end of the study area is narrower than in areas within the deltas and farther south. South of McAleer Creek, a trench is visible in the bathymetry overlapping with the location of the lake line. This depression is not clearly apparent in the 2020 survey (Appendix A, Figure 4), although the density of points in this portion of the survey is low. Other than this feature, there is no observable spatial trend associated with the position of the lake line in 2008.

4.2.5 Hydrographic Survey Comparison

This section compares the results of hydrographic surveys from 1902 to 2020 collected by NOAA and Global Diving & Gravity Marine (2020).

Figure 17 shows the change in bed elevations between the 2008 survey, and the 1902 or 1975 survey, respectively. Warm colors indicate an increase between 1902 and 1975, respectively, and 2008, while cool colors indicate a decrease. The top panel of Figure 17 indicates that between 1902 and 2008, substantial accretion throughout the nearshore area has occurred on both sides of the lake line. This figure is representative of relatively long-term processes at the site. Erosion is observed in a few limited spots, but the general trend is accumulation, especially in the delta areas of Lyon and McAleer Creeks.

The lower panel of Figure 17 shows the difference between 1975 elevations and 2008 elevations. No identifiable spatial trend is present. Most 2008 elevations are within +/- 1 foot of their 1975 elevations. The position of the lake line does not appear to influence a trend in accumulation or erosion. The delta area near Lyon Creek appears to have experienced the most variability between 1975 and 2008.

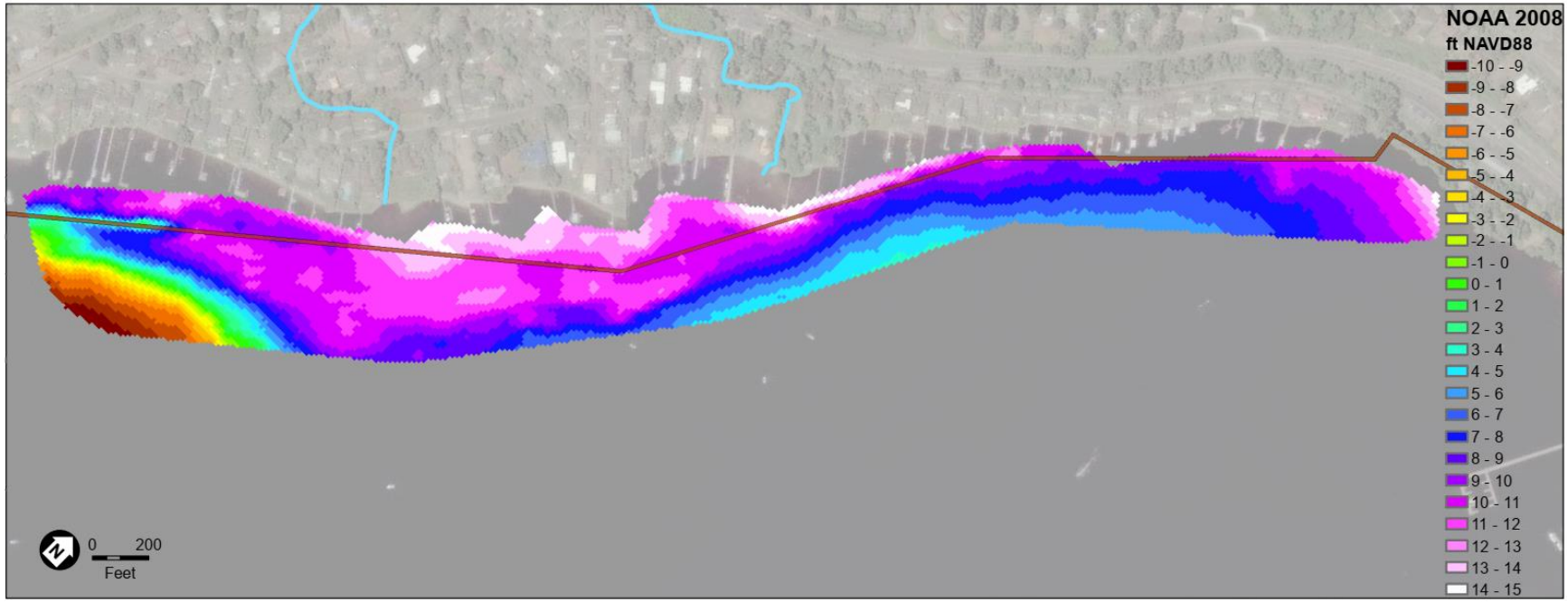
Figure 18 shows how the 2008 survey compares with the 2020 survey. Warm colors indicate an increase between 2008 and 2020, while cool colors indicate a decrease. These surveys, spaced 12 years apart, show some change in the bed elevations along the pipe centerline and to either side of the pipe. Most differences are +/- 1 foot, which is within the limit of accuracy for the surveys (Section 4.3). However, accretion greater than 1 foot is apparent on both sides of the pipeline, as is erosion. There are not clear spatial trends in erosion or accretion relative to the pipe centerline.

As described previously, the cross-shore transects for the 2020 survey were affected by dense vegetation, which skews reported elevations high (Gravity Marine, pers. communication, 2020). A typical transect that experienced vegetation effects is noted in Figure 18. These transects show a notable increase in elevation between 2008 and 2020. However, this apparent increase is likely exaggerated because of the effects of vegetation.

Erosion is seen along and shoreward of the pipe centerline near the north end of the site. This is consistent with the fact that the pipe casement was not observed exposed on the lakebed in 2011 in this area, but was observed in 2019 inspections. In the Lyon Creek delta, there are patches of localized erosion and accretion, which likely reflects the dynamic nature of the delta landforms, which change over time.

In the south end of the site, patterns of erosion and deposition are apparent near the trench-like feature observed in the 2008 survey. The feature appears to be mostly filled-in as of 2020. The densities of points in this area in 2020 are low and potentially affected by vegetation. It is difficult to assess what is happening in this region between 2008 and 2020, especially as it was not captured in the 2019 ROV survey. However, most of the change appears to occur in water deeper than 10 feet.

Figure 19 reproduces Figure 8 and includes elevations from the NOAA 1902, 1975, and 2008 surveys and the 2020 survey at locations similar to the 2011 sediment sample locations. Not all of the datasets had points near the 2011 sampling locations. In general, elevations from 1964, 1975, 2008, 2011, and 2020 are similar, except in the dynamic areas near the creek mouths. In some places, there appears to have been accretion on both sides of the lake line between 2008 and 2011 (e.g., sample sites 4, 5, and 8), where at other sites the bed elevations are nearly identical (e.g., sample site 2). At sites 4 and 5, there appears to be minor accretion (around 0.5 foot) between 2008 and 2011 on both sites of the line, but by 2020 elevations at these sites had returned to values similar to 2008. Data from 1975 to 2020 are similar, although fluctuations up and down are seen across all sites. At and south of McAleer Creek, there has been substantial accretion from 1902 to 1964. The most variability is seen near the creek mouths.



SOURCE: NOAA, 2008

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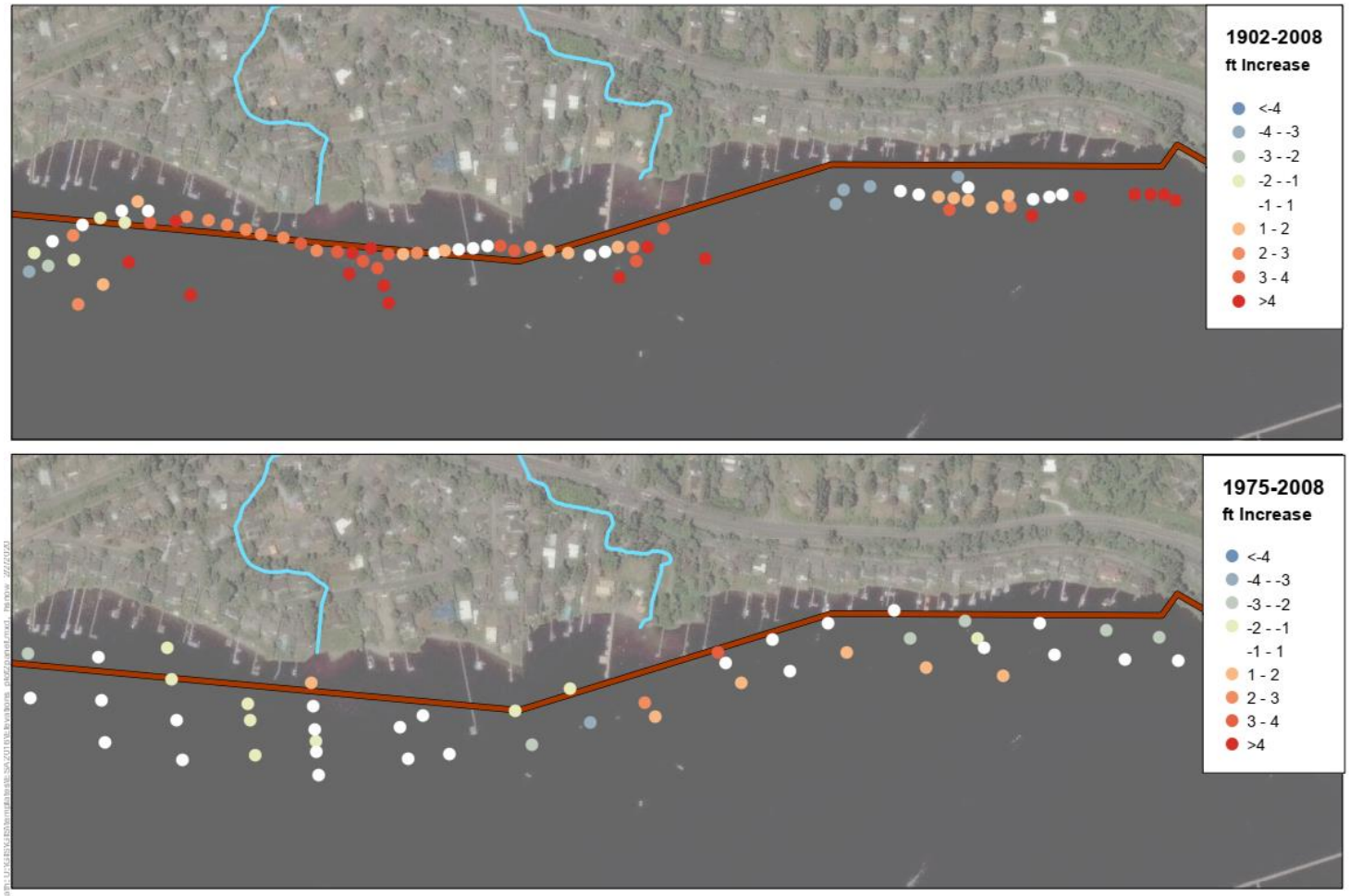
Figure 16
2008 NOAA Survey



SOURCE: NOAA 1902, 1975

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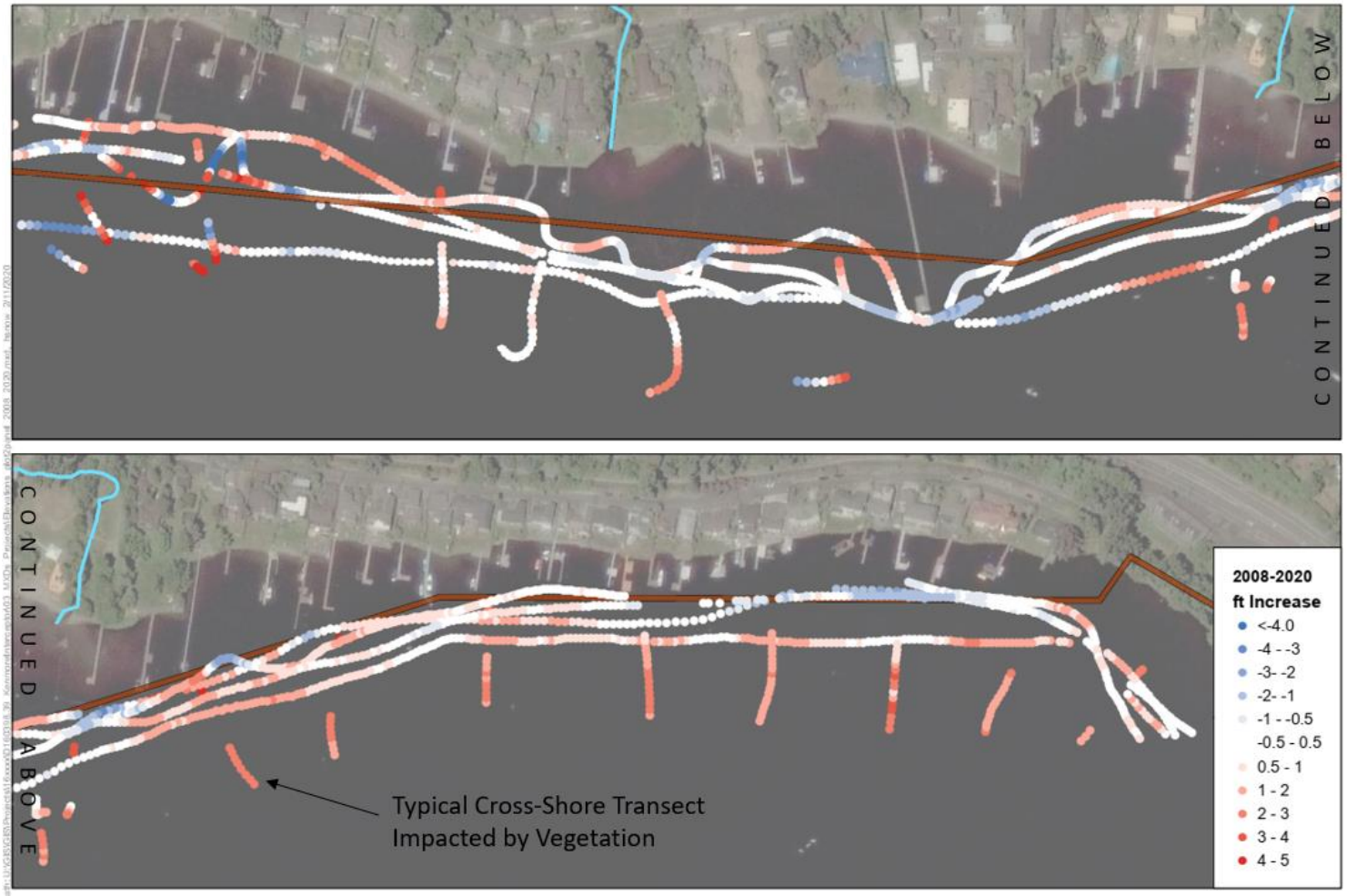
Figure 17
Change in Lakebed Elevation from 1902 to 2008 (top) and from 1975 to 2008 (bottom)



SOURCE: Global Diving & Gravity Marine (2020)

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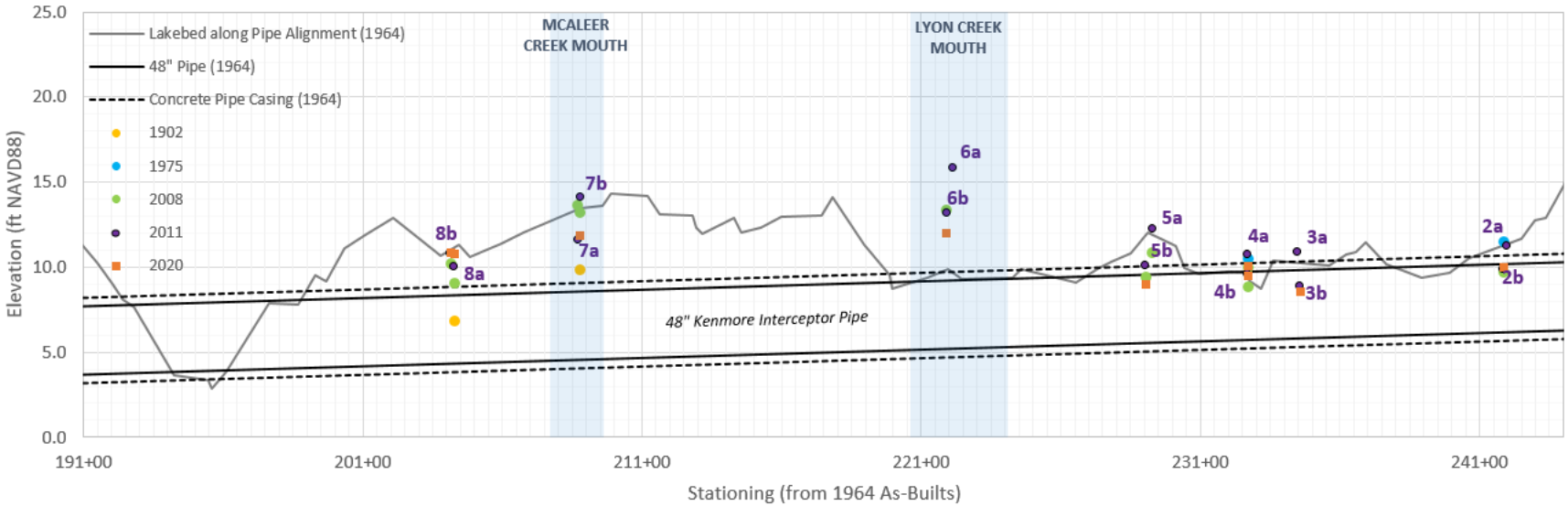
Figure 18
2020 Global Diving & Gravity Marine Survey versus 2008 NOAA Survey



SOURCE: Municipality of Metro Seattle 1964; NOAA, 1902, 1975 & 2008; SoundEarth and Lally 2011, Global Diving & Gravity Marine (2020)

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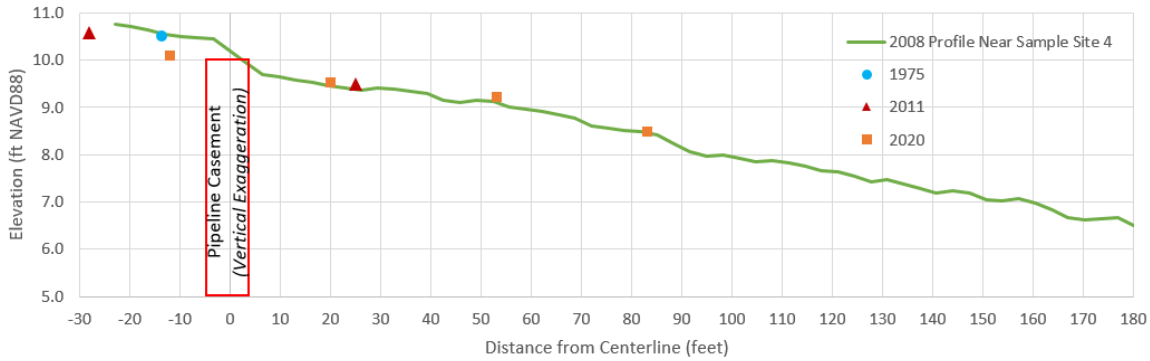
Figure 19
Data Points Near Interceptor Lake Line

Figure 20 plots an example profile near Profile 4 where a change in elevation across the pipeline is evident from the high resolution 2008 survey. The elevations of the pipeline casement are approximate and are shown vertically exaggerated on Figure 20. Elevations shoreside of the lake line have been relatively consistent since 1975 (within the range of uncertainty described in Section 4.3). A small step down occurs to the offshore side of the casement in the 2008 profile. Note that most of the profiles across the study area in 2008 show no grade breaks near the pipeline.



SOURCE: NOAA 2008; King County; SoundEarth and Lally 2011, Global Diving & Gravity Marine (2020)

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Figure 20
Example Profile near Sample Site 4
Lakebed Elevation Relative to Pipeline
Casement Elevations Approximate

4.3 Uncertainty

The process of surveying precise elevations underwater is challenging, making the comparison of small-scale accumulation and erosion difficult. Bathymetric data are often noisy and contain many sources of uncertainty. Sources of error within the bathymetry measurements described in this section include but are not limited to:

- Inconsistent measurement methods (e.g., sonar, diver, lead line).
- Inconsistent datums and conversions from historical datums.
- Seasonal lake water level corrections.
- Dense vegetation that reflects sonar and inconsistent surveying seasons resulting in variable density of vegetation.
- Variations in post-processing or correction for vegetation by surveyors.
- Soft sediments that allow for variable penetration by divers and lead lines.
- Inconsistent spatial location of measurements.
- Limited number of data points collected per survey.
- Limited number of total surveys.

- Inherent uncertainty with sonar, global positioning system (GPS), and other surveying methods.
- Disturbance of sediments by surveying vessel or divers causing temporary sediment redistribution and poor visibility.

This study did not include a quantitative uncertainty analysis. However, personal communication with dive teams, review of datum conversions, and professional experience with various surveying methods indicate that bed elevations reported in this section likely contain at least +/- 4 inches of uncertainty at a minimum. Reported variability for certain surveying methods is closer to +/- 1 foot. When comparing changes in elevation between the various surveys described in this section, this uncertainty should be considered.

4.4 Summary of Bathymetric Changes

Within the Lyon Creek delta area and extending across sample sites 6 and 5, sediment has apparently accumulated on both sides of the pipeline since its installation. Near the mouth of Lyon Creek, this accumulation has been significant on both sites of the pipeline (upwards of 4 feet) since installation of the lake line. Some accumulation (around 6 inches) appears to have occurred on both sides of the pipeline near site 4 and 5 between 2008 and 2011, although by 2020 the elevations had returned to similar to 2008 conditions. As described in Section 4.3, small-scale changes on the order of inches cannot be reported with confidence due to the uncertainty with bathymetry surveys in the study area. At sites 2 through 6, data points since 1975 fluctuated slightly up and down, generally staying +/- 1.5 feet. Historically since 1902, McAleer and Lyon Creek deltas have experienced significant accretion (greater than 4 feet of accretion).

In areas where visual observations indicate a differential drop-off on the offshore side of the pipeline, the presence of the lake line casing may have had localized effects on sediment trapping by obstructing downslope transport within several feet closest to the pipeline, or by exacerbating the effects of wave- or vessel wake-driven erosion immediately offshore of the pipeline within a distance of about 15 feet. This is apparent near site 4. Near the south end of the site, an apparent trench may be associated with the construction of the lake line, although reported existing grades in 1964 are also low. As of 2020, the trench feature was not clearly evident in the survey.

It is not possible to make a clear determination on how much, if any, the grades have changed since 1964 on either side of the lake line due to uncertainty in original construction conditions and lack of high-resolution historical bathymetry data during and prior to construction of the lake line.

5 SEDIMENT PROCESSES

Because of the limited availability of historical bathymetric data, it is not possible to determine specifically how the lakebed has changed over time. However, one can draw conclusions on likely changes based on measured or observed changes in the main physical factors that influence both deposition and erosion. This section describes the mechanisms and effects of various nearshore sediment processes in lakes and compares the relative magnitude of these processes in the study area.

5.1 Lacustrine Sediment Processes

After its formation, a lake accumulates inorganic and organic materials throughout its geological lifespan. These materials arrive at or are formed in the lake via a variety of mechanisms, and are distributed within different regions of the lake. Sources of sediments transported into lakes include:

- Inflowing water from the catchment watershed in the form of sediment-laden streams and urban runoff.
- Erosion from lake shorelines caused by wind wave or boat wake action, landslides, and human activities that may disrupt shoreline banks.
- Wind-blown dust.

Some sediments are also generated within the water column of the lake itself. These include:

- Organic material from the decay of algae and aquatic vegetation.
- Chemical precipitates.

Fine sediment generally accumulates in the deep, offshore region of lakes, called the profundal zone. Most measurements of sediment accumulation rates in lakes are calculated by corings from deep-water accumulation regions. Sediment also accumulates in flat (less than 15 percent slope) regions of the shoreline littoral zone that are colonized by aquatic macrophytes. These still, lower energy areas are ideal for settlement of even extremely fine class particles.

High-energy, shallow regions along beaches and near the mouths of rivers experience higher rates of sediment mobility and transport. At the shore-water interface, breaking waves and boat wakes erode materials from the shoreline. Near river mouths, sediment-laden flows deposit and rework material in their deltas. These regions are typically dominated by coarse sediments such as gravel and sand, although near river mouths, interrupted patterns of fine and coarse deposition may be observed.

5.1.1 Physical Processes

This section describes the physical processes by which sediment arrives at and moves within Lake Washington.

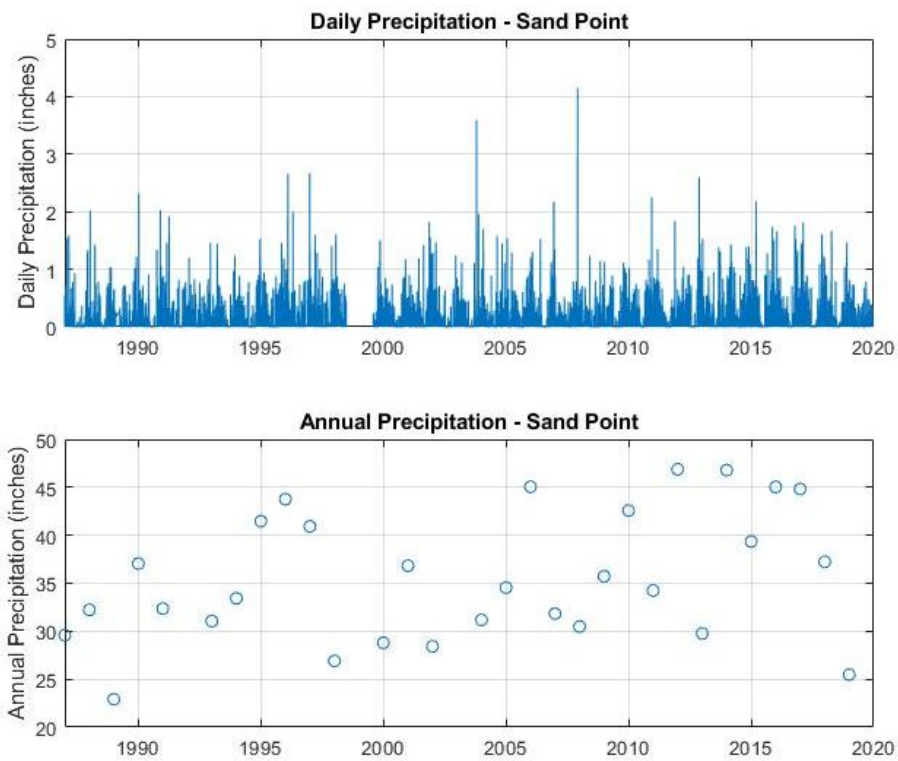
5.1.1.1 Precipitation and Streamflow

In the lowland areas of western Washington, small stream systems such as McAleer Creek and Lyon Creek are rain-fed. The water carried by these streams erodes sediment and transports it downstream. The main source of sediment to Lake Washington is material delivered by inflowing rivers (the Sammamish and Cedar) and smaller streams.

Precipitation

Precipitation data from 1987 to the present are available from the National Climate Data Center weather station at Sand Point on Lake Washington. The station is approximately 5 miles south of the study area. Precipitation data prior to 1987 are not available at Sand Point.

Figure 21 plots daily precipitation (top) and annual total precipitation (bottom) at Sand Point. No clear trends in precipitation occur from 1987 to 2020. The mid 2010s experienced several years of very high precipitation; however, interannual variability is high throughout the time period observed. Years of high precipitation may be correlated with increased streamflows and urban runoff directly into the lake from nearshore areas.



SOURCE: NOAA 2020

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Figure 21
Precipitation 1987–2019
Sand Point

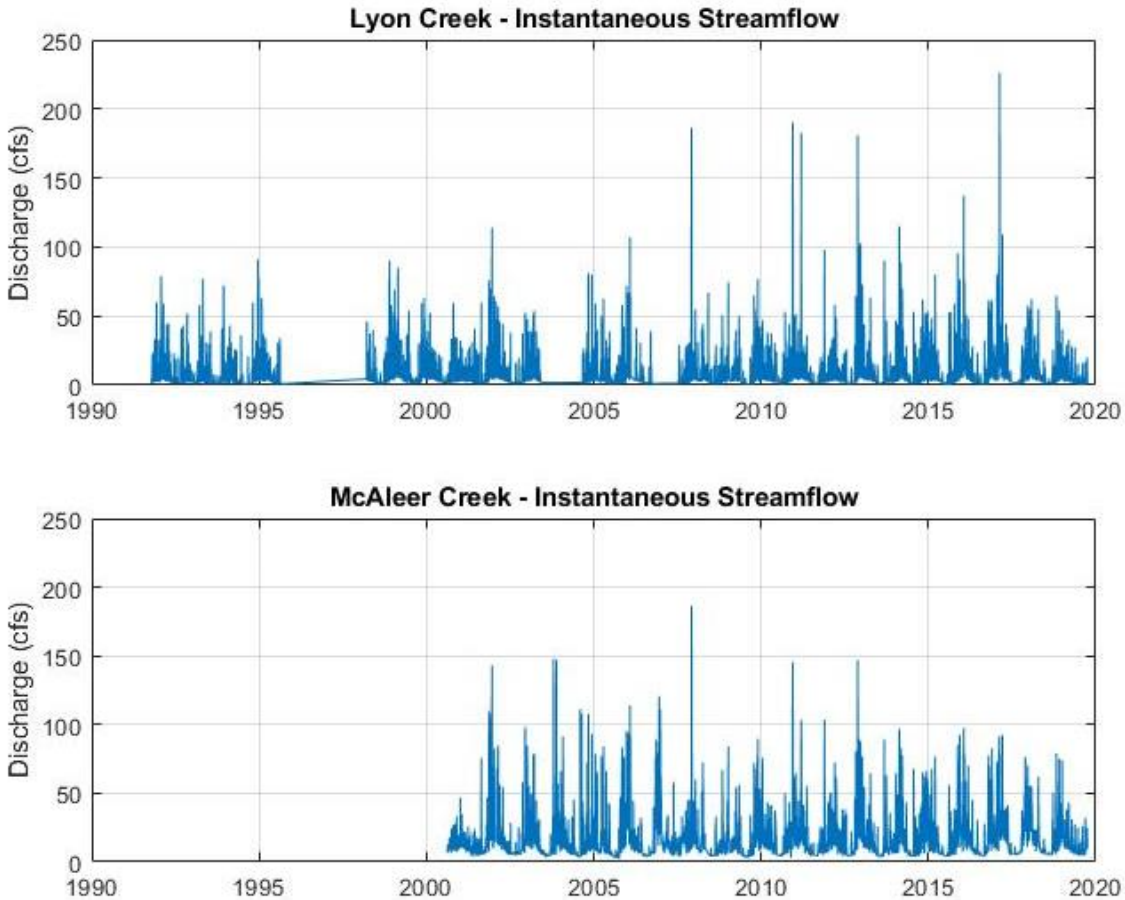
Streamflows in McAleer Creek and Lyon Creek

Streamflow and water quality parameters are monitored by the USGS and King County at stream gauges on Lyon and McAleer Creeks (Figure 22). A record of 15-minute streamflow is available for both creeks and is shown for each creek's respective length of record in Figure 23. Figure 24 summarizes the peak annual discharge in each stream.

SOURCE: King County

Kenmore Interceptor Proviso P2 Support

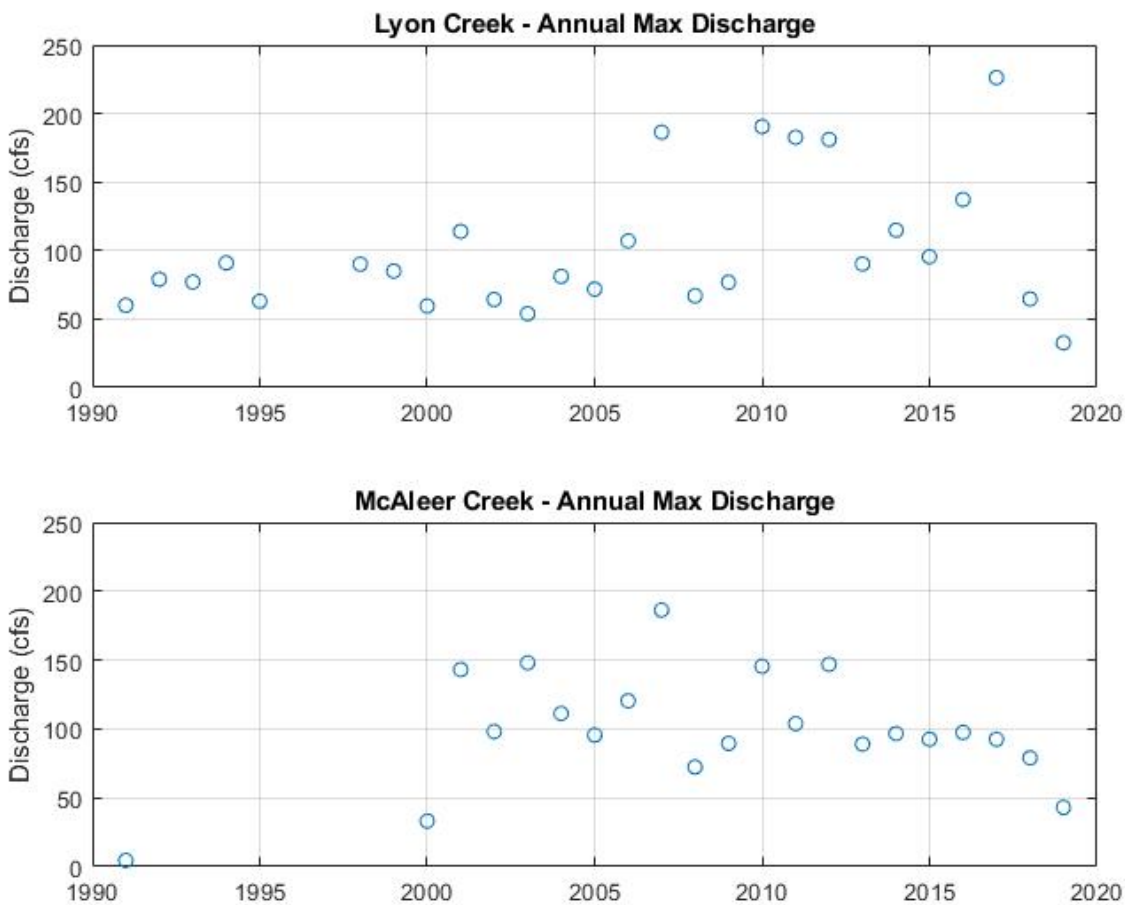
Figure 22
Stream Gauge Locations



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 23
Instantaneous Streamflow 1990–2019
Lyon and McAleer Creeks



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 24
Annual Maximum Discharge 1990–2019
Lyon and McAleer Creeks

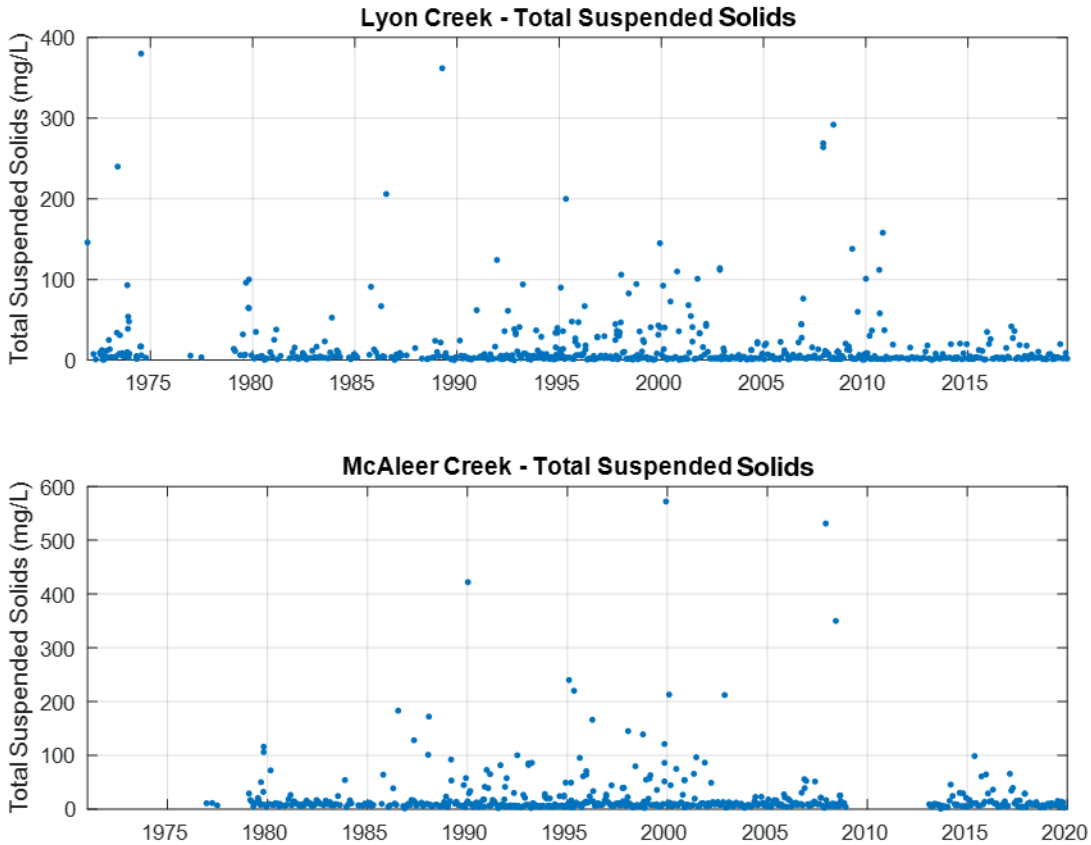
While the instantaneous rates are generally similar, McAleer Creek has higher baseflows year round when compared to Lyon Creek, which appears to be more variable. McAleer Creek may be less influenced by intense precipitation events because of the storage capacity of Lake Ballinger. Discharge from the lake also likely stabilizes base flows.

McAleer Creek exhibited the highest streamflows in the 2000s, while Lyon Creek had high flows in the 2010s. Since 2013, annual maximum discharges in McAleer Creek peaked at near 100 cfs.

High streamflows correspond to increased channel flow velocities, which can scour and mobilize sediment from the creek bed and bank areas. Mobilized sediment, transported as bedload or as suspended sediment, is deposited downstream, typically ending up in Lake Washington. Transported material generally settles in the delta area of each creek. Fine suspended sediments may remain suspended in the water column for longer, and may eventually settle in deeper areas.

Suspended sediment concentration is measured for water quality assessments as Total Suspended Solids (TSS). TSS provides an estimate of the rate of sediment transport in a stream, although it underestimates the actual transport amount by neglecting mobilized material that travels as

bedload (non-suspended). Figure 25 plots TSS for Lyon and McAleer Creeks from the 1970s to the present.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 25
Total Suspended Solids 1971–2019
Lyon and McAleer Creeks

TSS measurements at the Lyon and McAleer Creek gauges are taken periodically (generally monthly) and provide only a snapshot of sediment transport rates at one instance in time, which may vary dramatically over the course of a storm event. It is difficult to determine trends from such infrequent sampling; however, since 2011, TSS concentrations have been low in both creeks.

The total rate of sediment delivery from each creek is estimated by summing the product of the TSS concentration and flow rate over time. The rate of sediment mass delivery per second is converted into a volume rate by assuming a typical bulk density for sand of 1,400 kg/m^3. As a rough approximation, suspended material delivered by the creek is assumed to deposit uniformly in a plane across the delta area of the creek. Review of aerial photos indicates the approximate extents of the deltas, which appear as areas of deposited coarse materials (sand) that are generally free of vegetation (Figures 26 and 27). Lyon Creek has a maximum delta extent of approximately 4 acres, while the McAleer Creek delta covers about 4.4 acres.

Using these assumptions, ESA calculated the rate of sediment accumulation over years when TSS and streamflow data were available for each creek. The estimated deposition rate in Lyon Creek varies from near zero to 0.5 inch/year (13mm/yr) with an average of 0.1 inch/year (3mm/year). Deposition rates in McAleer Creek were similar, ranging from near zero to 0.6 inch/year (15mm/year) with an average of 0.2 inch/year (5mm/year). No clear interannual trend was observed. This could lead to a deposition of up to 2.3 feet of fine sediment across the delta areas between 1964 and 2011.

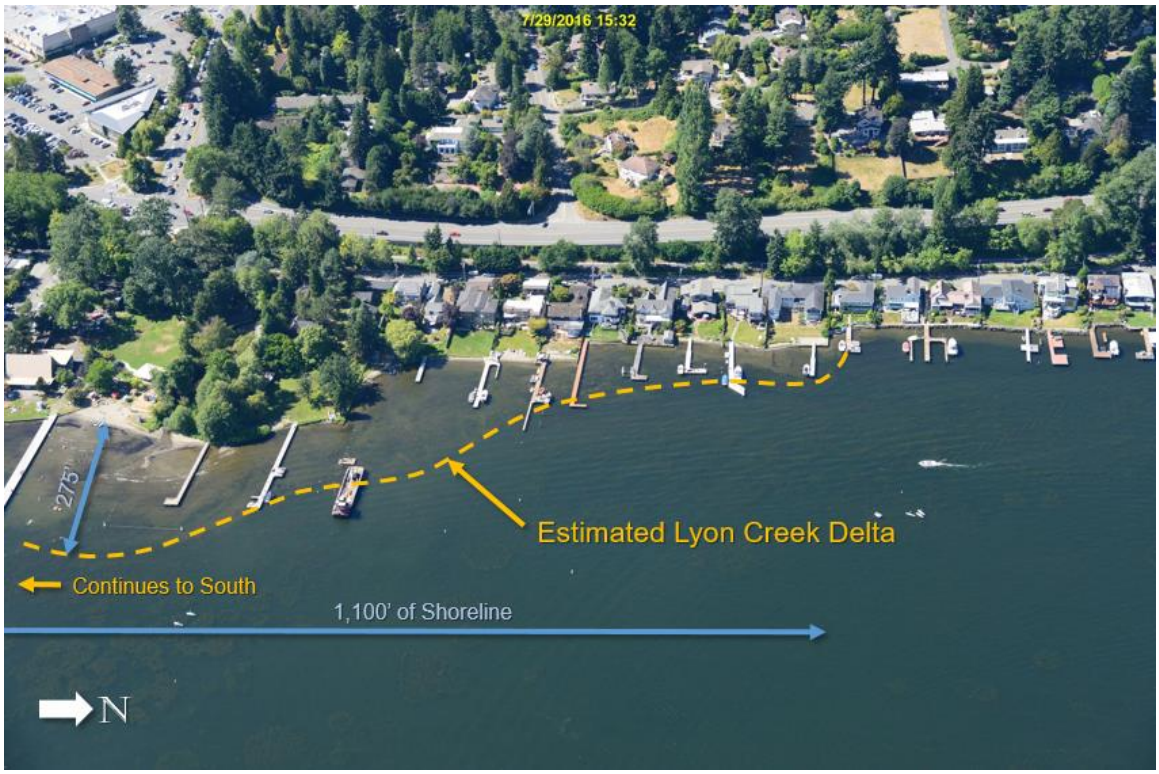
Note that these estimates based on TSS do not capture coarse sediment transported along the streambed as non-suspended bedload. Observed changes of approximately 4 feet in the delta areas since 1964 likely consist of fine sediments and coarse sediments, which are not included in the deposition rates described above. In reality, accumulation of material does not occur uniformly across the delta in an even plane, and variability in accretion amounts are expected.

Culvert replacement projects described in Section 3.2.2.3 have likely further increased the amount of coarse material reaching the creek deltas in the years since the replacements, which occurred in 2014–2019.

SOURCE: Google Earth

Kenmore Interceptor Proviso P2 Support

Figure 26
Extents of Lyon and McAleer Creek Deltas
Estimated from Aerial Images



SOURCE: WA Ecology

Kenmore Interceptor Proviso P2 Support

Figure 27
McAleer (top) & Lyon (bottom) Creeks Delta Extent
Estimated from 2016 Aerial Oblique Images

Sammamish River Flow

The Sammamish River, which drains Lake Sammamish, enters Lake Washington to the east of the study area (Figure 28). The Sammamish River represents 27 percent of the total flow input to Lake Washington, second only to the Cedar River contribution in the south of the lake (King County 2016). The mouth of the Sammamish River forms a bar-mouth type delta, comprised mainly of sand. The active area of deposition is approximately 2.3 acres, although it is heavily influenced by managed dredging activity. Sand deposits from the delta cover 30 acers of historically deposited materials, estimated to have been deposited at an average rate of 1.5 inches/year in the 1900s (Northwest Hydraulic Consultants Inc. and The Watershed Company 1991).

The western-most extent of the Sammamish River delta is about 0.5 mile east of the study area, most of which spans a deep-water area of the lake. Sediment delivered by the Sammamish River is not expected to reach the study area in any significant amounts.

SOURCE: Google Earth

Kenmore Interceptor Proviso P2 Support

Figure 28
Mouth of the Sammamish River

Climate Change

Global climate models for the Puget Sound region project an increase in the intensity of storms (Mauger, et al. 2015). Heavier, more intense rainfalls will increase the risk of urban flooding in small stream systems with limited storage capacity, such as the Lyon-McAleer Creek basin. Increased streamflows and overbank flooding will likely deposit additional sediment within the study area from bank and urban floodplain erosion. The University of Washington Climate Impact Group predicts that the rates of erosion and sediment transport will increase in fluvial

systems, especially in the winter and spring (Mauger, et al. 2015), while summertime streamflows and subsequent sediment transport rates will decrease.

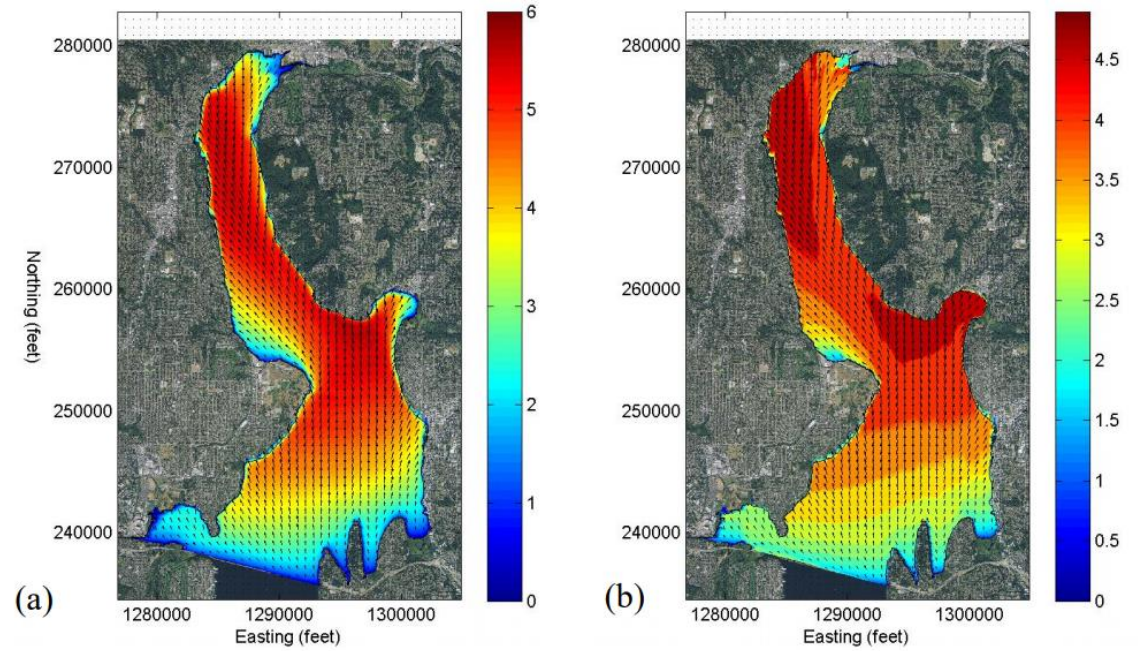
5.1.1.2 Waves and Propeller Wash

Wind waves, boat wakes, and propeller wash introduce turbulence to the nearshore environment and disturb sediments. The zone of influence of these forces is limited by the depth of water in which they occur, with shallow areas most affected by waves and propeller wash. The regular pattern of wind waves arriving at the study area causes a net transport in sediment along the shore from south to north. Propeller wash and boat wakes are periodic and irregular, causing the resuspension and scour of sediments depending on the location of passing vessels.

Wind Waves

SoundEarth and Lally (2011) assessed typical wind regimes in Lake Washington and found that the dominant wind direction along Lake Washington is from the southeast to northwest. This wind direction occurs approximately 45 percent of the time and is associated with strong winds. These winds generate waves that grow in wave height and period as they travel from the south to the north and reach the study area.

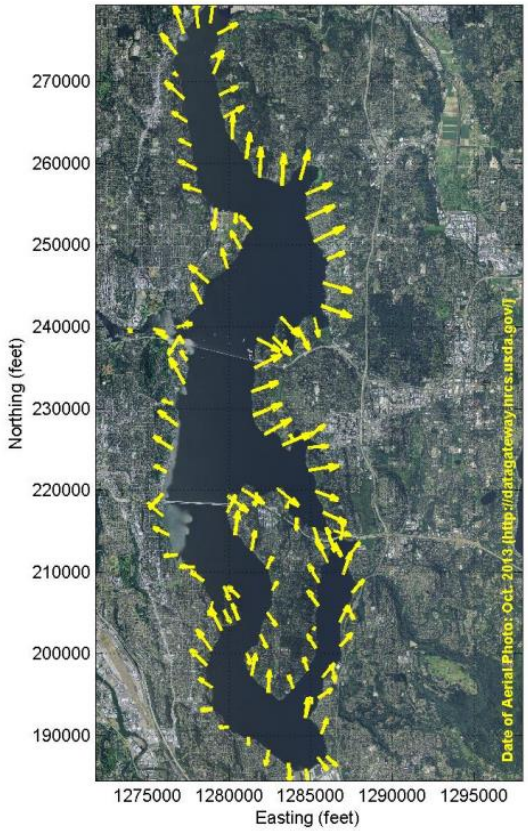
In addition to the information provided in SoundEarth and Lally (2011), Mott McDonald performed detailed wave modeling throughout Lake Washington on behalf of Washington Sea Grant and the City of Seattle in 2015. This work found that in the study area, a 100-year wind storm can generate waves with significant wave heights of approximately 5 feet and wave periods of 4.5 seconds (Figure 29, Mott McDonald 2015). Figure 30 shows the wave directions associated with the maximum nearshore wave heights over a series of model runs from the Mott McDonald report. Modeling confirms that in the study area, the nearshore wave directions associated with large waves from the south approach the shore in a northerly direction.



SOURCE: Mott McDonald, 2015

Kenmore Interceptor Proviso P2 Support

Figure 29
Reproduction of Figure10 from Mott McDonald (2015)
Wave Model Results for a 100-year Wind Storm from 170°
Significant Wave Height (right) and Wave Period (left)



SOURCE: Mott McDonald, 2015

Kenmore Interceptor Proviso P2 Support

Figure 30
Reproduction of Figure17 from Mott McDonald (2015)
Wave Direction Associated with the Maximum Wave Height
from Series of Model Runs

Waves arriving at an oblique angle to the shoreline generate a longshore transport of sediment from southwest to northeast along the study area. The shoreline orientation in the study area is approximately 215° (SoundEarth and Lally 2011) and the dominant wave direction is approximately 170° (Mott McDonald 2015). This means that the dominant waves arrive at approximately 45° to the shore. The lake line is oriented in line with the direction of sediment transport, and thus likely does not interrupt the longshore flow of wind-generated sediment transport. Most of this transport occurs shoreward of the lake line, in depths shallower than 6 feet for typical wave conditions (SoundEarth and Lally 2011). For a detailed discussion on the mechanisms of wave-driven sediment transport, see SoundEarth and Lally (2011).

Boat Wakes

Recreational vessels traveling along the shore near the study area and accessing docks within the area generate wakes that travel toward the shoreline. Wakes within the study area are likely around 1 to 2 feet in amplitude. When reaching shallow water, vessel wakes interact with bed sediments and cause the resuspension of fine materials.

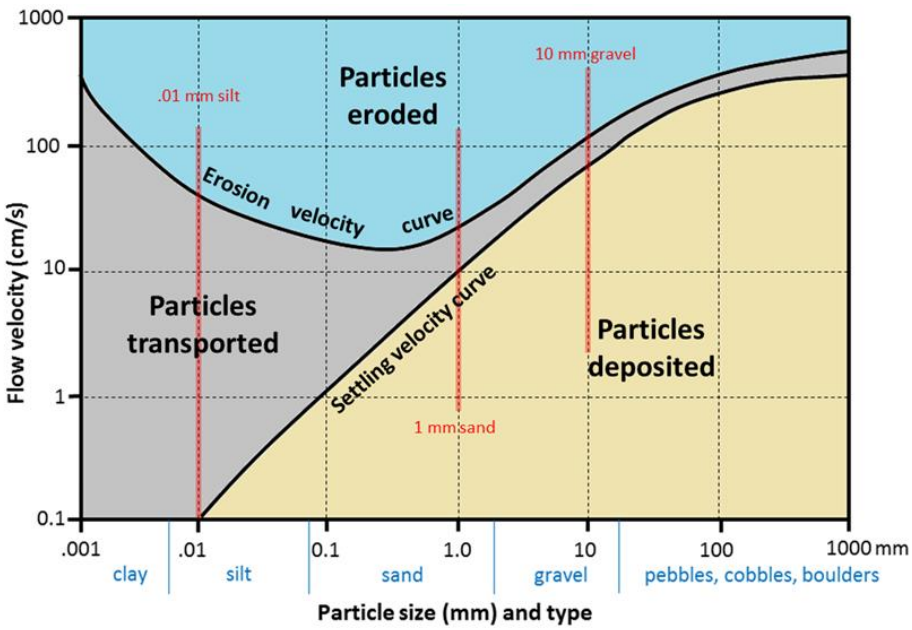
Unlike wind waves, wakes can arrive in the shallows at many angles, depending on the direction of travel of the passing vessels. Therefore, wakes in this area likely do not cause any alongshore trend in sediment transport. Instead, the periodic passing of vessels likely disrupts fine sediments in shallow parts of the lakebed in a chaotic manner and may erode sediment from beach or bank areas of the shoreline.

Propeller Wash

Use of propellers in shallow waters can erode and transport bottom sediments. The amount of transport depends on sediment grain size, the depth of water below the propeller, the size of the propeller and horsepower (hp) of the motor, and the length of time the propeller is operated.

Simplified estimates of propeller scour potential are given by Blaauw and van de Kaa (1978). To estimate typical scour potential, a typical small vessel berthed in the study area is assumed to have a 150-hp engine that is operated at 50 percent power when maneuvering nearshore. The vessel is assumed to have a 1-foot diameter non-ducted propeller. Using Blaauw and van de Kaa (1978), the lakebed would experience maximum velocities of 0.9 feet/sec (27 cm/sec) when the vessel is operated in 10 feet of water (below the propeller line). This velocity is sufficient to transport silts and sands, using a Hjulström-Sundborg diagram (Figure 31). The same vessel operated in 5 feet of water below the propeller can erode fine gravels.

Given the number of docks and the vessel traffic in the study area, propeller wash likely frequently disrupts and redistributes bottom sediments in shallow areas less than 15 feet-deep.



SOURCE: Earle (2019)

Kenmore Interceptor Proviso P2 Support

Figure 31
A Hjulström-Sundborg Diagram
Figure Reproduced from Earle (2019)

5.1.1.3 Lake Circulation

No public data are available on the horizontal circulation patterns in Lake Washington (Ecology 2017). Lake Washington does have documented seasonal patterns of vertical circulation and mixing typical of a deep, mid–high latitude lake; however, this vertical mixing likely has minimal effect on sediment in the littoral (near shore) zone as velocities are likely low and flows periodic.

5.1.1.4 Downslope Transport

The downslope transport of sediment from the shallow erosive zones of lakes to the deeper depositional areas of lakes is known as sediment focusing. Focusing is influenced by topographic controls (slopes) and hydraulic controls (waves and currents or changes in water levels). Turbulence near the bottom can resuspend particles in high-energy zones, which eventually deposit in low-energy zones, often in the deepest parts of lakes. Sediment can also move downslope in a thin, granular bed flow or in larger slumps (LaGarde 2018).

Sediment does not generally accumulate at angles greater than about 15 percent and is transported downslope. Slumping typically occurs on steeper slopes greater than 20 percent slope (Morales-Marin, et al. 2018).

Sediment can accumulate in areas <15 percent where erosive forces do not continually resuspend sediment. Because the study area is generally flat (0–13 percent) and heavily colonized by rooted vegetation, downslope transport does not likely occur at considerable rates. In steeper sections of the shoreline, sediment may have a stronger tendency to move downslope. Obstructions along the path of downslope transport could block transport occurring as granular bed flow or slumps.

Sediment focusing is a result of highly complex relationships between small-scale topography, wave dynamics, water level changes, and sediment properties. The use of sophisticated hydrodynamic models is needed to spatially predict sediment focusing.

5.1.1.5 Rooted Aquatic Vegetation

Rooted aquatic vegetation, also called rooted macrophytes, occurs in shallow areas of lake systems where sufficient light and nutrients are available. The root systems of such plants are anchored in the lakebed sediment, and the body of the plant extends upward toward the surface, in some instances reaching considerable length.

Macrophytes increase sedimentation rates in the littoral zone of lakes via two mechanisms: modifying the flow of water through the vegetation, which encourages settling and stabilization of fine sediments; and contributing organic material directly to the lakebed when vegetation senescences (dies).

Stands of rooted macrophytes decrease the flux of water through the vegetation and reduce turbulence in vegetated areas. The reduced water velocities in the vegetation beds subsequently enhance the trapping of fine sediment and inhibit sediment transport that might otherwise move sediment away from the beds into other areas of the lake (Carpenter and Lodge 1986). In lakes,

shallow and mid-water zones are typically characterized as regions of sediment erosion, resuspension, and transport; however, this characterization does not reflect conditions where the littoral zone is colonized by vegetation (Rooney, Kalff and Habel 2003). When vegetation senescences, the organic detritus accumulates within the vegetation bed, eventually breaking down and contributing to organic materials in the sediment. Because water flow is restricted through the bed, these accumulated sediments are less likely to be transported away from the vegetation beds, contributing to an overall increase in sedimentation. Sediment accumulation within macrophyte beds in North American lakes is documented to have localized accumulation rates up to double the average rate in the lake (Rooney, Kalff and Habel 2003). In Lake Washington, this could mean localized accumulation rates near 0.08 inch/year (2 mm/year).

The 2019 ROV survey of the Kenmore Interceptor lake line captured many images of dense Eurasian watermilfoil along the pipeline alignment, as shown in Figures 10–14. Even in areas where macrophytes are less dense, which occurs in some areas along the pipeline, moderate plant density sufficiently reduces turbulence for permanent sedimentation of fine particles (Rooney, Kalff and Habel 2003). Sedimentation rates in the study area have likely increased significantly since the introduction of invasive Eurasian watermilfoil in 1970. Areas previously free of vegetation on both sides of the lake line may have accumulated several inches of sediment as a result of vegetation growth since the 1970s.

5.2 Summary

Most of the physical processes described in this section contribute to accretion in the nearshore zone, namely fluvial and vegetation processes. Some factors, such as wind waves and propeller wash, act to resuspend and transport sediment generally within the nearshore zone. Offshore processes are limited in the study area, given the relatively flat slopes and dense colonization of rooted aquatic vegetation that inhibit the downslope transport of material into deeper areas. Table 4 summarizes the sources and physical forcings associated with sediment transport within the study area.

The presence of the Kenmore Interceptor lake line does not play a significant role in influencing nearshore sediment processes. In areas where the pipe casing was partially exposed above the lakebed after installation, the casing may have partially obstructed the downslope transport along the steepest slopes. However, as described in this section, downslope transport is not a significant mechanism in gently sloped nearshore lacustrine areas, and thus the overall net effect of any obstruction is minimal. The nearshore area along the lake line appears to be a net depositional zone, with the primary drivers being fluvial sediment deposition and trapping within rooted vegetation beds.

Table 4
Sediment Transport Sources and Forcings In the Study Area

Sources	Description	Magnitude in the Study Area	Effect in the Study Area
Fluvial Deposition	Materials transported into the nearshore via rivers and streams. Coarse materials are generally deposited within the delta area.	High	Estimated 3–6 mm/year of fine sediment deposition in delta zone of Lyon and McAleer Creeks (Figures 26–27) and additional unestimated volume of coarse sediment deposition. Little effect beyond the deltas.
Shoreline Erosion	Erosion of bank and beach sediments, caused by some of the forcings below.	Low	Minor added material to the study area in the shallow areas. Shoreline is heavily armored, with minimal material available to erode.
Aquatic Vegetation Decomposition	Senescence and decomposition of algae and rooted macrophytes contribute organic material that is incorporated into lakebed sediments.	High	Accretion of sediment in areas colonized by Eurasian watermilfoil could be up to 2 mm/year.
Riparian Vegetation Litter Decomposition	Organic debris accumulation from overhanging vegetation.	Low	Minor added material to the study area in the shallow areas. Minimal overhanging vegetation is present on shoreline.
Wind-blown Dust	Deposition of dust transported from nearby areas.	Low	Minor added materials uniformly across the lake. Wind-blown dust volumes are generally low in western Washington, especially around imperious surfaces.
Transport Forcings	**Description**	**Magnitude in the Study Area**	**Effect in the Study Area**
Fluvial Currents	High water velocities caused by existing rivers and streams.	Low–High	Carries coarse and fine materials into delta from watershed. Resuspends and transports settled fine sediments in nearshore areas. Effect is large closer to stream delta and low elsewhere.
Fluvial Obstructions	Thick woody debris and undersized culverts may trap sediments and prevent downstream transport to the creek delta. Properly sized box culverts should not obstruct sediments.	Low–High	Replacement of undersized culverts in the 2010s has likely increased downstream sediment transport of coarse material to McAleer and Lyon Creek deltas. Undersized culverts have likely artificially suppressed coarse sediment transport since the development of the Lake Forest Park area. Effect is large closer to stream delta and low elsewhere.
Wind Wave and Vessel Wake	Transport of sediment caused by wave orbital velocities and breaking wave impact.	Medium	Wind waves cause net longshore transport from south to north in the study area. Wind waves and wakes resuspend fine sediments in shallow areas and may erode unarmored beaches and banks.
Propeller Wash	Resuspension of sediment from wave orbital velocities and breaking wave impact.	Medium	A typical vessel in the study area will resuspend silt and likely sand when departing and docking.

Transport Forcings	Description	Magnitude in the Study Area	Effect in the Study Area
Water Level Changes	Annual fluctuations in lake levels controlled by the Corps of Engineers.	Low	Likely minimal effect. Can influence depth at which waves and wakes affect the lakebed.
Lake Circulation	Lakewide currents generated by seasonal changes and large scale wind patterns.	Unknown, likely low	No data available. Assumed periodic, minor effect on sediment resuspension.
Downslope Transport	Downslope sediment migration from shallow areas to deep areas.	Low	Study area is <15% slope, so accumulation dominates downslope transport. Likely minor amounts of sediment transported in the offshore direction in the steepest portions of the study area.
Lakebed Obstructions	Topographic obstructions can intercept downslope transport.	Low	Downslope transport estimated to be low, so interception of downslope transport likely minimal.
Rooted Aquatic Vegetation	Rooted macrophytes inhibit turbulence and the transport of sediments through vegetation beds. Decay of plant litter contributes additional organic materials to the sediment.	High	Significantly increased sediment accumulation rates in macrophyte beds.

6 AQUATIC FLORA & FAUNA

The Proviso includes objectives pertaining to aquatic flora and fauna, and in particular the potential for sediment accumulation around the Kenmore Interceptor lake line to affect anadromous fish migration, as noted in provision 3:

> *(3) an analysis of the impacts of the silt accumulation of water fauna, with particular attention to the ability of fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species;*

This section describes the fish species present in Lake Washington and several factors that limit salmonid habitat in the lake.

6.1 Fish Species in Lake Washington

A diverse group of fish species inhabit the Lake Washington watershed, including several species of native salmon and trout as well as introduced stocks. Most of these species likely occur at least occasionally in the study area. The more common of these species are listed in Table 5, which provides information on the general habitat used by the species of greatest concern within the watershed. Several other introduced (exotic) species also occur in Lake Washington, such as black crappie, carp, tench, and goldfish.

Table 5
Prevalent Fish Species in the Lake Washington Watershed and Their Ecological Roles

Species Scientific Name	Federal and State Status [a]	Native or Nonnative Species	Ecological Role and Population Characteristics
River lamprey *Lampetra ayresi*	FCo, SC	Native	Predator of salmonids observed in Lake Washington system. High predation rates measured for this species.
Bull trout *Salvelinus confluentus*	FT, SC	Native	Overlapping habitat with other salmonids, but very low numbers or nonexistent in most of watershed. Major fish predator.
Cutthroat trout *Oncorhynchus clarki* (formerly *Salmo clarki*)	None for Puget Sound ESU	Native	Young compete with other salmonids for prey. Adult cutthroat consume fish, including Chinook salmon and sockeye salmon. Population likely smaller than some other potential predators.
Steelhead/rainbow trout *O. mykiss* (resident and steelhead)	FT	Native	Overlapping habitat with other salmonids, consume similar prey. Some predation on young salmonids probable.
Chinook salmon *O. tshawytscha*	FT, SC	Native	Both wild and hatchery origin.

Species Scientific Name	Federal and State Status [a]	Native or Nonnative Species	Ecological Role and Population Characteristics
Coho salmon *O. kisutch*	FCo for Puget Sound	Native	Probably most abundant in north Lake Washington, primarily hatchery.
Sockeye salmon/ kokanee *O. nerka*	None for Lake Washington	Native [b]	Pelagic in open water areas.
Largemouth bass *Micropterus salmoides*	None	Nonnative	Major fish predator that occupies shoreline habitat. Young compete with young salmonids for some prey.
Smallmouth bass *Micropterus dolomieui*	None	Nonnative	Major fish predator that occupies salmonid fish habitat, resulting in some prey competition. Population size uncertain.
Brown bullhead *Ictalurus nebulosus*	None	Native	Competitor with young salmonids for some of same prey.
Longfin smelt *Spirinchus thaleichthys*	None	Native	Pelagic in open water areas. Little likelihood of salmonid prey competition.
Northern pikeminnow *Ptychocheilus oregonensis*	None	Native	Major fish predator that occupies salmonid fish habitat. Former common name was “northern squawfish.”
Peamouth chub *Mylochelius caurinus*	None	Native	Large numbers. Some occupy shallow benthic habitat, consume some of same prey as young salmonids.
Threespine stickleback *Gasterosteus aculeatus*	None	Native	Numerous, substrate-oriented, often near aquatic vegetation, provides prey for larger fish.
Pelagic sculpin *Cottus aleuticus*	None	Native	Also known as coast range sculpin. Pelagic in open water areas. Some overlap in prey with young salmonids. Sculpins represent 72 percent of Lake Washington biomass.
Prickly sculpin *Cottus asper*	None	Native	Benthic habitat from shorelines to deep water. Prey competition with young salmonids. Sculpins represent 72 percent of Lake Washington biomass. Larger sculpins prey on small fish.
Yellow perch *Perca flavescens*	None	Nonnative	Prey overlap with young salmonids. Abundant but substantially less than peamouth (introduced).

[a] FCo=Federal Species of Concern, FT=Federally Threatened, SC=State Candidate Species, ESU=evolutionarily significant unit.
[b] Introduced stock, uncertain whether there was originally a native stock inhabiting this watershed.
Source: Summarized from Wydoski and Whitney 2003

Lake Washington tributaries provide spawning and early rearing habitat for anadromous Chinook, coho, and sockeye salmon and steelhead trout. Cutthroat trout are also present in many of the tributaries and the lake. Rainbow trout were commonly planted in Lake Washington in the past and are still present in the lake.

Recent evidence for sockeye salmon indicates that spawners in the Cedar River and Issaquah Creek are likely descendants of introduced fish (Baker Lake stock), while those spawning in Bear Creek may be native fish (Hendry et al. 1996). All sockeye tend to have similar life-history patterns in the Lake Washington watershed, but the Cedar River sockeye tend to be larger and older than the Bear Creek spawners (Hendry and Quinn 1997). Chinook salmon naturally reproduce in many of the watershed streams and are supplemented by hatchery production of fish originally from the Green River (Weitkamp and Ruggerone 2000). Steelhead/rainbow trout are a

mix of introduced hatchery and native stocks. Cutthroat trout are assumed to be native coastal cutthroat.

Lake Washington and the Ship Canal provide a migratory corridor and juvenile-rearing area for all salmonids produced in the Lake Washington watershed. Juvenile salmonids migrating and rearing in the study area include subyearling Chinook and chum salmon. Yearling sockeye, coho, and steelhead salmon, along with a few Chinook salmon, also migrate to Puget Sound through Lake Washington. Adults of each salmon species migrate upstream through the Ship Canal to Lake Washington tributaries. Subadult and adult bull trout and cutthroat trout also most likely migrate in both directions through the Ship Canal.

6.1.1 Endangered Species Act Listed Species

Salmonid species that are listed as threatened or endangered under the federal Endangered Species Act that potentially occur in Lake Washington include Chinook salmon, steelhead trout, and bull trout (Table 5). Lake Washington supports one or more life stages of Chinook salmon, steelhead, and bull trout, which are currently listed as threatened under the Endangered Species Act (NMFS 1999, 2007; USFWS 1999). Lake Washington Chinook salmon are a part of the Puget Sound evolutionarily significant unit (ESU). NOAA Fisheries has also designated critical habitat for the Puget Sound ESU of Chinook salmon (NMFS 2005). This critical habitat includes Lake Washington, as well as the Ship Canal and Lake Union between the Ballard Locks and Lake Washington. The designation identified Lake Washington as high conservation value habitat because of its connectivity with the high-value Cedar River watershed and its support of rearing and migration habitat for fish from all four watersheds in the subbasin (Lake Washington, Sammamish River, Lake Sammamish/Issaquah Creek, and the Cedar River). Chinook salmon fry tend to use shallow shoreline area with finer gravel and sand substrates. They use woody debris for cover during the day and tend to avoid armored shorelines. Juveniles avoid overwater structures and are attracted to non-natal tributaries, and larger Chinook fingerlings move into deeper water and avoid overwater structures. Adult Chinook returning to freshwater spend 2 to 5 days in Lake Washington before staging near the Cedar or Sammamish rivers.

Lake Washington steelhead are part of the Puget Sound distinct population segment (DPS), also listed by the National Marine Fisheries Service (NMFS) as threatened (NMFS 2007). The listing indicated that Lake Washington steelhead include spawning populations in the Cedar River, Issaquah Creek, and Bear Creek, with the Cedar River contributing most of the escapement (the number of adults that return to the spawning grounds). While the Lake Washington population also appears to include a substantial number of rainbow trout (the resident form of steelhead), there is insufficient information to evaluate whether, under what circumstances, and to what extent the resident form may contribute to the viability of steelhead over the long term (NMFS 2007). Critical habitat has not yet been designated for Puget Sound steelhead. Juvenile steelhead are found in both littoral and limnetic areas, and steelhead in limnetic areas consume zooplankton.

USFWS listed the Coastal-Puget Sound DPS of bull trout as federal threatened, which includes the population in the Lake Washington watershed (USFWS 1999). Distribution of bull trout in the

Lake Washington watershed is uncertain, but individuals have been occasionally observed in recent years at the Ballard Locks and at several other locations in the watershed. USFWS also designated bull trout critical habitat in Lake Washington, in the Ship Canal, and Lake Union (USFWS 2005). These areas provide foraging, migratory, and overwintering habitat for bull trout outside of currently delineated core areas in the Puget Sound Recovery Unit. No bull trout critical habitat is designated in any Lake Washington tributaries.

6.2 Salmonid Habitat Limiting Factors in Lake Washington

The City of Seattle (2010) characterized human-caused stressors on lake, marine, and estuarine watershed processes as a part of the Shoreline Characterization Report. Sediment delivery stressors include in-water structures such as jetties, breakwaters, groins, log booms and rafts, dredging, armoring fill and dikes, native vegetation removal, boat wakes and propeller wash, and boat launches and rails.

Because of the extent of shoreline armoring around Lake Washington, which as described above in Section 3.2.1 effectively limits the natural erosion processes leading to sediment transport, most shoreline substrates do not contain habitat suitable for most salmonids. The extensive armoring also results in a lack of habitat structure used for rearing and allocthonous inputs necessary to support foraging. Juvenile salmonids feed primarily on aquatic and terrestrial invertebrates. The lack of overhanging and emergent vegetation limits allocthonous input of both detritus and invertebrates.

Limiting factors identified in McAleer and Lyon Creeks include large volumes of stormwater runoff from development. Stormwater carries toxic substances from streets, homes, lawns, and other sources, and, in the volumes frequently occurring in the basin, causes physical damage to streambanks and beds. Low impact development measures are important ways to reduce runoff from developed sites into streams. Installing rain gardens and replacing hard surfaces with permeable surfaces are steps that residents can take to reduce stormwater runoff from their properties.

6.2.1 Eurasian Watermilfoil

As described above under *Rooted Aquatic Vegetation,* invasive species such as Eurasian watermilfoil are concerns in the littoral zone of Lake Washington, in addition to other concerns such as shoreline armoring, overwater structures, and lighting (City of Seattle and U.S. Army Corps of Engineers 2008).

Shoreline vegetation in Lake Washington has changed substantially from historic conditions. Vegetation was reported as a dense undergrowth of small trees, brush, and Tule grass, but is now primarily landscaped residential properties with bulkheads. Shallow-water habitats are dominated by Eurasian watermilfoil (*Myriophyllum spicatum*), a non-native invasive aquatic plant

introduced into the lake in the 1970s. Despite reversing the eutrophication trend in the lake, the introduction of Eurasian watermilfoil to Lake Washington in the 1970s has caused additional water quality problems, as it has displaced native aquatic vegetation and changed substrate characteristics (Patmont et al. 1981).

Watermilfoil is present in much of the lake's littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth (Frodge et al. 1995). Watermilfoil contributes to phosphorus loading in the lake sediments through its release of phosphorus during decomposition, decreasing the effectiveness of alum treatments. Dense communities can reduce dissolved oxygen to below 5 parts per million (less than the minimum requirements for salmonids) through oxygen consumption during respiration at night (WDFW 2001). In addition, the decomposition of dead plant material increases the biological oxygen demand, further reducing dissolved oxygen and pH levels. In summary, dense communities of aquatic vegetation, or floating mats of detached plants, can adversely affect localized water quality conditions. Under extreme conditions, these situations can become anoxic.

In addition, the excessive accumulation and decomposition of organic material has transformed areas of natural sand or gravel substrate to fine silt and mud. Substantial shoreline areas of Lake Washington, including the study area, have soft substrate, with substantial accumulations of organic material from the decomposition of watermilfoil and other aquatic vegetation. The dense vegetation reduces the currents and wave energy in these areas, encouraging the accumulation of fine sediment material. Accumulated material and dense stands of vegetation cause aesthetic, recreational, and navigational concerns. Section 5.1.1.5 provides additional discussion of the effects of rooted vegetation on sediment accumulation.

The presence of Eurasian watermilfoil can also affect the distribution of and habitat use by salmonids. Tabor et al. (2006) found that the presence of Eurasian watermilfoil in Lake Washington appeared to cause juvenile Chinook salmon to be farther offshore in deeper water. The top of the watermilfoil appeared to act as the bottom of the water column for Chinook salmon. At some piers with extensive watermilfoil growth, Chinook salmon were located on the outside edge of the pier and the pier had little effect on their behavior. For example, at locations where the top of the watermilfoil was close to the water surface along the entire length of the dock, few Chinook salmon were observed; in contrast, at sites where watermilfoil was close to the water surface along the length of the dock except at the offshore end of the pier, Chinook salmon were only seen at the end of the dock and did not appear to change their behavior in response to the pier.

Alterations in fish distribution also appear to affect fish that prey on juvenile salmonids. Most bass used docks and other artificial structures (Celedonia et al. 2008), but distribution shifts to the deeper littoral zones in later summer were theorized to reflect watermilfoil growth.

6.2.2 Water and Sediment Quality in Lake Washington

The water and sediment quality in the Lake Washington basin is degraded from a variety of current and historic sources of both point and non-point pollution. Historically, Lake Washington,

Lake Union, and the Ship Canal were the receiving waters for municipal sewage, with numerous outfalls located along the shorelines that discharged untreated or only partially treated sewage directly into these waterways. Cleanup efforts in the 1960s and 1970s included expanding the area of wastewater treatment facilities (including the Kenmore Interceptor lake line), and eliminating most untreated effluent discharges into Lake Washington. However, some untreated discharges occasionally still enter these waterways during periods of high precipitation through discharge from combined sewer overflows (NMFS 2008).

In addition to point source pollution, a variety of non-point sources continue to contribute to the degradation of water and sediment quality. Non-point sources include stormwater and subsurface runoff containing pollutants from road runoff, failing septic systems, underground petroleum storage tanks, gravel pits/quarries, landfills and solid waste management facilities, sites with improper hazardous waste storage, and commercial and residential sites treated with fertilizers and pesticides.

Historical industrial uses in the basin, such as around Lake Union and the southern Lake Washington, Newcastle, Kirkland, and Kenmore areas, have contaminated sediments with persistent toxins, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals (King County 1995). The expanding urbanization in the basin has also increased sediment input into the Lake Washington system water bodies.

Along with these physical changes to the basin, substantial biological changes have occurred. Non-native plant species such as Eurasian watermilfoil have been introduced into Lake Washington, and years of sewage discharge into the lake increased phosphorus concentrations and subsequently led to extensive eutrophication. Blue-green algae dominated the phytoplankton community and suppressed the production of zooplankton, which reduced the available prey for salmonids and other species. However, water quality improved dramatically in the mid-1960s as sewage was diverted from Lake Washington to Puget Sound, and the dominance by blue-green algae subsided and zooplankton populations rebounded.

The thermal stratification of Lake Washington and Lake Union can produce surface water temperatures in excess of 68° F for extended periods during the summer. In addition, there is a long-term trend of increasing summer and early fall water temperatures (Newell and Quinn 2005). From 1932 to 2000, there has been a significant increase in mean August water temperature at a depth of 15 feet from about 66° F to 70° F (Shared Strategy 2007). If this trend continues, surface water temperatures could exceed the lethal threshold for returning adult Chinook salmon in some years. However, steelhead and bull trout migrate through the lake in the spring and early summer, so they are less likely to be substantially affected by the increasing summer water temperatures.

6.3 Summary

Primary limiting factors to salmonids in Lake Washington include shoreline armoring and development, lack of suitable lakeside vegetation, the presence of aquatic macrophytes

(especially non-native Eurasian watermilfoil), and water quality concerns from stormwater runoff. The presence of the Kenmore Interceptor lake line does not play a significant role as a limiting factor to salmonids and has minimal influence on aquatic flora or fish migration within and through the study area. As described above, the Kenmore Interceptor lake line does not play a significant role in local sediment dynamics and does not represent a migration barrier to fish, as the structure is buried along most of its length and, where exposed, extends an estimated 10 inches above the lakebed. Fish can easily swim over and across it without stress.

The quality and quantity of fish habitat in the study area have been degraded over the years by several factors, which are generally present on a lake-wide basis. The extent of shoreline armoring and overwater structures (docks) around Lake Washington has effectively limited the natural erosion processes leading to sediment transport and has altered outmigrating salmon behavior, as well as introducing cover for salmon predators. The resulting shoreline substrates do not contain habitat suitable for most salmonids. Historically, shoreline vegetation was reported as a dense undergrowth of small trees, brush, and Tule grass, but is now primarily landscaped residential properties with bulkheads. The lack of overhanging trees and vegetation limits the food sources (invertebrates) available to fish in the nearshore. Stormwater inputs carry toxic substances from streets, homes, lawns, and other sources, and, in the volumes frequently occurring in the basin, causes physical damage to streambanks and beds and degrades water quality. Historical industrial uses in the basin have contaminated sediments with persistent toxins, degrading fish habitat.

Invasive Eurasian watermilfoil is present in much of the lake's littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth. Watermilfoil contributes to phosphorus loading in the lake sediments through its release of phosphorus during decomposition, and dense communities can reduce dissolved oxygen to levels below the minimum requirements for salmonids. As described above, the decomposition of dead plant material increases the biological oxygen demand, further reducing dissolved oxygen and pH levels. Dense communities of aquatic vegetation, or floating mats of detached plants, can also adversely affect localized water quality conditions. The presence of Eurasian watermilfoil can also affect the distribution and habitat usage of salmonids, pushing salmonids into deeper water along with prey fish. The large amount and wide distribution of watermilfoil in the study area is a significant contributor to the increased rates of sedimentation in the study area, as are the alluvial fans from McAleer and Lyon Creeks. The Kenmore Interceptor lake line neither affects these processes, nor contributes in a measurable way to the other identified limiting factors to salmonids in Lake Washington.

7 CONCLUSIONS AND RECOMMENDATIONS

Physical sedimentation processes in the nearshore are not significantly affected by the presence of the Kenmore Interceptor Section 2 lake line, which is covered in sediment along more than 80 percent of its length in the study area.

The lake line is located in an area of net sediment accumulation, as is typical in the nearshore area of most lakes with gently sloping lakebeds. Over the past nearly 120 years, the nearshore within the study area has generally accreted between 1 and 4 feet. This accretion has occurred on both sides of the present lake line. Much of the accumulation likely occurred during periods of intensive logging and eutrophication in Lake Washington. The accumulation of 1 to 4 feet is consistent with 120 years of lakewide sediment accumulation ranging from 0.08 to 02 inch/year cited in literature and calculated creek deposition rates of 0.1 to 0.6 inch/year in the Lyon and McAleer Creek deltas. Areas under and around residential docks throughout the study area have likely experienced accretion since residential development began in the mid-1900s, especially in areas near Lyon and McAleer Creeks. The introduction and growth of invasive Eurasian watermilfoil since 1970 have likely enhanced accretion under and around docks and, in addition to causing actual increase in sedimentation rates, have likely contributed to a perceived shallowing of recreational mooring areas.

ESA did not observe significant changes to nearshore lakebed elevations that appear to be related to the lake line. Possible localized scour on the offshore side of the lake line and minor accumulation on the shore side of the line may have occurred in limited stretches. The length of shoreline where localized effects may have occurred is approximately 500 feet, and the width over which effects could have occurred is on the order of 10 to 20 feet. It is not possible to determine with certainty how bed elevations have changed immediately above and around the lake line following its installation because of limited as-built construction information.

Dominant physical processes affecting sediment transport in the nearshore include the deposition of fluvial material by both McAleer and Lyon Creeks and sediment trapping and building by rooted aquatic vegetation. The mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. Exposed casement areas may have had a minor influence on the downslope transport of sediment by physically obstructing movement offshore along steep slopes and possibly exacerbated wave scour for a limited distance offshore of the pipeline. However, much of the study area is relatively flat, such that downslope transport is not a dominant physical process. Portions of the exposed casement are sufficiently deep such that only extreme waves may reflect or interact with the exposed casement.

Based on the sediment analysis, there are no significant changes to the quality and quantity of habitat for aquatic organisms, specifically salmonids, that have resulted from installation or operation of the lake line. Although nearshore habitat conditions for salmonids in the area are substantially degraded from pre-contact conditions, the literature indicates that the degradation is a result of shoreline armoring and development, impacts on lake water quality, and the introduction of Eurasian watermilfoil into the lake. Several of these factors, as well as the presence of two stream deltas, directly contribute to the sediment dynamics of the site, while the

lake line does not significantly alter sediment dynamics or other processes that create and maintain salmonid habitat. In areas where the pipeline casement is exposed, fish can easily swim over the low and relatively short obstruction.

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Appendix A

Kenmore Interceptor Bathymetry and Dive Inspection Technical Memorandum

To: King County Wastewater Division

From: Global Diving & Salvage, Inc.

Date: January 31, 2020

Subject: *C01298C18 – Work Order 02*

Project: Kenmore Interceptor Bathymetry and Dive Inspection

Overview

On January 15, 2020 Global Diving & Salvage, Inc. (Global) was issued Work Order 02 under contract C01298C18. The scope of work was to conduct a bathymetric survey and dive inspection of a section of the Kenmore Interceptor wastewater conveyance pipeline pathway in the northwestern portion of Lake Washington. Gravity Marine Consulting (Gravity) was subcontracted by Global to conduct the bathymetric survey and establish transect coordinates for detailed inspection by diver. This report details the survey methodology and findings for both phases of work.

Divers walked four transects perpendicular to the pipeline. The pipe was not exposed in any of these locations. Substrate was variable but consisted of mud and clay or hard packed sand. There was heavy milfoil growth in several locations.

SBES Hydrographic Survey

SURVEY METHODOLOGY

Survey Coverage

The SBES survey was conducted in the Northwestern extent of Lake Washington, near Kenmore, WA. The survey area was concentrated around an existing buried pipeline used by King County for wastewater conveyance. Pipeline and requested survey area are shown in Figure 1.

The survey area was concentrated within a hydrographic polygon supplied by King County representatives. The hydrographic survey area extended along a section of the pipeline, approximately one-mile long. The area was surveyed within the polygon as close to shore as possible given depth and obstruction limitations. Attention was also given to requested diver transects, so that sonar data could also be collected directly over these same locations.

Survey Vessel and Crew

The MBES survey was conducted on R/V Discovery, a 26-ft aluminum survey vessel owned and operated by Gravity Marine, LLC. Lead surveyor for the data acquisition was Gravity's Senior Engineer, Jeff Wilson MSc, with assistance from Gravity's USCG Captain and Sonar Technician, Edward Sloan

Survey Equipment

Acoustic surveys in moderate to heavy vegetated areas is a constant problem for reliable and accurate data acquisition. The aquatic vegetation tissue acts as an excellent reflector of acoustic energy, thus skewing the absorption and reflection of the sonar beam. Given that this location had a significant amount of aquatic vegetation, a special SBES specifically designed for aquatic vegetation was used for data acquisition.

The BioSonics MX sonar was used for this survey. It is a single beam sonar platform specifically designed for the mapping of aquatic vegetation and the seafloor beneath. Through a proprietary developed filtering algorithm, the BioSonics MX sonar is able to filter through the backscatter created by heavily vegetative area, and delineate both the top of vegetation, and the mudline beneath.

The BioSonics MX sonar was outfitted on a Gravity Survey vessel and attached to a custom designed survey pole. The sonar was used in unison with a Trimble R8 GNSS and GLONASS receiver. The GPS receiver sent accurate position data and information to the data acquisition platform to create precise position data for each sonar sounding.

Figure 1. Survey Transects and Pipeline

Accurate tidal data was measured using a Trimble R8 GNSS Rover. The R8 collects highly accurate elevation data using RTK positioning. RTK corrections were transmitted to the R8 from the Washington State Reference Network (WSRN) via an NTRIP communication configuration. The Puget Sound subnet (PRSN) was used for real-time RTK corrections. Each subnet is a combination of approximately 22 base stations collecting and transmitting position correction data real time. The combination of all these base stations allows for an extremely accurate position correction. The subnet was monitored real time to ensure stations were transmitting properly and in real time.

The following survey equipment was used to conduct the SBES survey;

- Echosounder
  - BioSonics MX Aquatic Habitat Echosounder
  - 204.8 kHz / 8.4-degree SBES
- GPS Receiver
  - Trimble R8 GNSS and GLONASS Receiver
  - Positioning Set to 20 Hz
  - Receiving Real Time Kinematics (RTK) Corrections
- Sound Velocity Profiler
  - YSI/Sontek Castaway CTD Sound Velocity Profiler

Data Acquisition

Survey data was acquired on two separate platforms during the survey. The sonar data was acquired using the BioSonics proprietary data acquisition software Visual Acquisition. The program receives the sonar data, and GPS navigation data and combines them to create a time synced and georeferenced position for each sonar sounding. The program saves all sonar and navigation data to a connected PC as ".dt4" files, a proprietary format developed by BioSonics.

Visual Acquisition also shows a full echogram and performs real-time filtering of the acoustic amplitudes for observation during survey acquisition. This helps the surveyor identify mudlines, presence of vegetation, and the sediment/vegetation interface.

Simultaneously, vessel navigation data was acquired through the survey software platform HYPACK SURVEY. This software is used for vessel navigation, allows the vessel to follow predetermined transect lines, and logs all raw GPS data. Files were recorded as ".RAW" files and saved to a connected PC.

SBES QA/QC

System Assessment

Prior to commencing SBES survey activities, a full system assessment was conducted to ensure all proper checks and procedures were in place to execute a successful SBES survey. This includes assessment of the following items;

- Confirm SBES system is powered and transmitting/receiving data
- Confirm GPS system is powered and transmitting/receiving position data, and position data seems reasonable given the geographic location
- Check survey acquisition software is running properly, and all sensors are communicating properly with software
- Check survey computer that it has sufficient hard drive space and memory to conduct survey and run current version of acquisition software.

SBES Bar Check

A bar check is conducted by placing a static object below the transducer at a specified depth, and recording the sonars measurement of the object's depth. This is done by placing a flat plate or solid lead weight below the transducer.

Both the depth of the object and the sonar draft are included in the depth calculations and should be confirmed during the bar check.

Sound Velocity Profiles

Sound velocity profiles are vital to acoustic data collection, and dictate the angles of acoustic beam transmission and return. Sound velocity data were used in final SBES processing to calculate accurate sounding data.

The BioSonics proprietary acquisition software Visual Acquisition was used for sonar data acquisition, and real time adjustments of sonar data with sound velocity. While other survey acquisition programs require a full depth sound velocity profile, Visual Acquisition only requires an average temperature and salinity to compute a bulk sound velocity value. Therefore, a salinity value of zero (freshwater), and a temperature of 7.8 Celsius was used.

Position Accuracy Verification

Horizontal and vertical positions were corrected via a Real-Time Kinematic (RTK) broadcast to the GPS receiver. The Trimble R8 receiver board receives the RTK corrections and processes position data in real time. With an RTK broadcast less than 30 km from the receiving antennas, the Trimble R8 specifications allow for a horizontal accuracy of approximately 1 cm, and a vertical accuracy of approximately 1.5 cm.

RTK corrections were transmitted to the INS via the Washington State Reference Network (WSRN) via an NTRIP communication configuration. The PRSN subnet was used for real-time RTK corrections. The PRSN is a combination of 22 base stations collecting and transmitting position correction data real time. The combination of all these base stations allows for an extremely accurate position correction. The subnet was monitored real time to ensure stations were transmitting properly and in real time.

SBES PROCESSING

Sonar data from the BioSonics MX sonar was processed in the manufacturers proprietary processing software Visual Habitat. In this software the raw .dt4 files are processed to extract the several available products from the dataset.

Data processing was conducting in a three-stage process. This process takes the data from its raw form to a processed state for analysis and creation of geospatial products. The data processing stages are as follows:

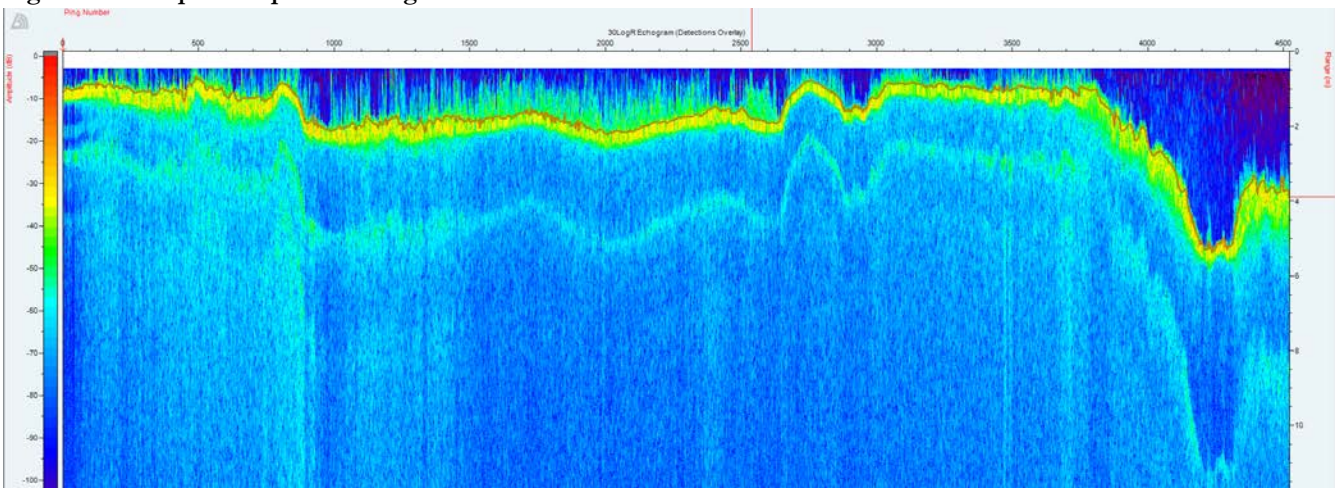
- Stage 1: Process all raw .dt4 files in Visual Habitat through auto filters for desired features extractions (i.e. Bottom detection, Plant detection, Feature Extraction, Bottom typing)
- Stage 2: Manually edit all transect lines to correct for any erroneous sonar soundings
- Stage 3: Export processed data matrix into ArcGIS for geospatial analysis and deliverable creation.

The raw data was initially processed in Visual Habitat for bottom detection only. This is because the actual mudline elevation of the survey area is of greatest interest compared to plant coverage and height of the area. Plant and bottom typing data is also possible to extract from the acoustic data if desired. Bottom detection was initially conducted through some auto filtering and processing tools created by BioSonics. These algorithms run through each sounding and attempt to delineate the interface between water, vegetation, and sediment for each echogram. The following criteria were used for Stage 1 processing;

- Domain: 30LogR
- Rising Edge Threshold: -40dB
- Rising Edge Length: 10 cm
- Rising Edge Search Window: 100 cm
- Reset Search Window: 5 ensembles
- Rising Edge Min Detection Range: 0 m
- Rising Edge Max Detection Range: 1000 m

Given the extensive coverage of aquatic vegetation, all survey lines underwent manually editing to correct for biases due to extensive acoustic backscatter. Each line was manually editing to position the mudline surface in the most appropriate position, based on visual assessments of the full echogram from each sounding. An example echogram can be seen in Figure 2.

Figure 2. Example interpreted echogram



The solid brown line in Figure 2 indicates the interpreted mudline of the lake bottom in contrast to the water column (dark blue) and aquatic vegetation (turquoise). This is done by contrasting the return amplitude of the acoustic beam received by the sonar system. Typically, the strongest return (yellow-red) is the area where the density gradient is the greatest, such as the interface between water and sediment.

Following the processing of each survey line in Visual Habitat, all sonar data was exported into a matrix which included a lake bottom depth, a GPS time stamp, and GPS latitude and longitude. This data was then paired with the RTK elevation data captured by the Trimble R8 to compute a real time elevation of the data referenced to NAVD88. This was done by pairing the GPS synced time stamp between both data sets to arrive at a final and single elevation data point for each sounding.

Referenced data was then imported into ESRI's ArcMap to plot and interpolate the data sets. The bathymetric data was used to create a digital elevation model (DEM) and bathymetric contours for the survey area. These data were plotted on aerial imagery for visual reference of the information with the surrounding area.

Diver Inspection Survey

The subsea inspection was completed utilizing a three (3) person dive team working off of the Dive Support Vessel (DSV) “Titan”. The diver used surface supplied shallow water air diving gear with full (2) way communications and a laptop computer with video recording software. A helmet mounted camera and light was used to view and document the dive inspection as well as capture the video for recording to hard disk.

Each transect was inspected between two referenced points measured with a GPS. Inspection points were spaced equally between start and stop reference points for each transect. Inspection continued as close to shore as possible until either the end of transect was reached or lack of water no longer allowed for a diver inspected point. The below table outlines each diver inspected location, a Northing and Easting location, converted mud line elevations from water depths, and inspection notes. Station identification numbers follow the format “transect number (##)-point number (##)”. For example, the seventh inspection point on transect 9 would have a station identification of 09-07.

The following conditions were found to exist:

Table 1. Diver Inspection Notes

Station ID	X	Y	Elevation (NAVD88)	Notes
08-01	1286076.186	277688.063	7.15	clay/mud
08-02	1286064.983	277704.8231	7.15	clay/mud
08-03	1286053.935	277720.7821	7.15	clay/mud
08-04	1286042.886	277737.3549	9.15	clay/mud, slight slope, hard pack
08-05	1286031.838	277753.9277	9.15	clay/mud
08-06	1286019.868	277770.1936	11.15	clay/mud. flat, hard pack
08-07	1286009.434	277787.3803	13.15	clay/mud. flat, hard pack
08-08	1285998.078	277803.6462	16.15	1' or less depth, Hard Pack
08-09	1285986.853	277818.988	16.15	1' or less depth, Hard Pack
09-01	1285951.716	277336.588	12.15	hard pack sand, slight marine growth, flat
09-02	1285935.347	277347.5255	12.15	heavy grass, hard pack sand, slight slope to beach
09-03	1285918.406	277358.2057	12.15	no growth, hard back sand with mud, slight slope
09-04	1285901.833	277368.886	12.15	mud/clay mix. Flat surface, no growth
09-05	1285884.708	277379.3821	12.15	mud/clay mix. Flat surface, no growth
09-06	1285867.828	277390.1851	13.15	muddy, light growth, slight up hill to beach
09-07	1285851.378	277400.7426	14.15	muddy, 4" top. hard pack below. slight slope
09-08	1285833.455	277412.2822	14.15	hard pack mud, moderate growth. slight uphill slope
11-01	1285225.549	276734.946	10.15	hard pack sand with milfoil, flat bottom

Station ID	X	Y	Elevation (NAVD88)	Notes
11-02	1285211.238	276748.2647	11.15	hard pack sand with milfoil, flat bottom
11-03	1285195.77	276761.1547	12.15	slight sand, slight slope up, milfoil
11-04	1285180.349	276775.022	11.15	hard pack sand, sloped up to shore
11-05	1285165.386	276787.1188	12.15	hard pack sand with mud mixed. slight slope to beach
11-06	1285150.103	276800.1929	12.15	hard pack sand with mud mixed. slight slope to beach
11-07	1285135.187	276812.8987	12.15	hard pack sand with mud. Milfoil, slight slope to beach
12-01	1284926.251	276407.353	14.15	hard pack sand slight slope to beach
12-02	1284912.832	276422.1107	15.15	no marine growth, sand, slight slope to beach
12-03	1284898.356	276435.6863	15.15	hard pack sand, no growth, slight slope
12-04	1284884.464	276449.5782	15.15	hard pack sand, no growth, slight slope
12-05	1284870.009	276463.2823	15.15	hard pack sand, no growth, no slope
12-06	1284855.742	276477.9251	16.15	gravel and hard pack sand, slope
12-07	1284841.662	276491.6293	17.15	on shore
12-08	1284804.357	276526.462	15.15	>2' depth to the beach

SURVEY DRAWINGS

Figure 3. Bathymetric contours at 1-foot intervals

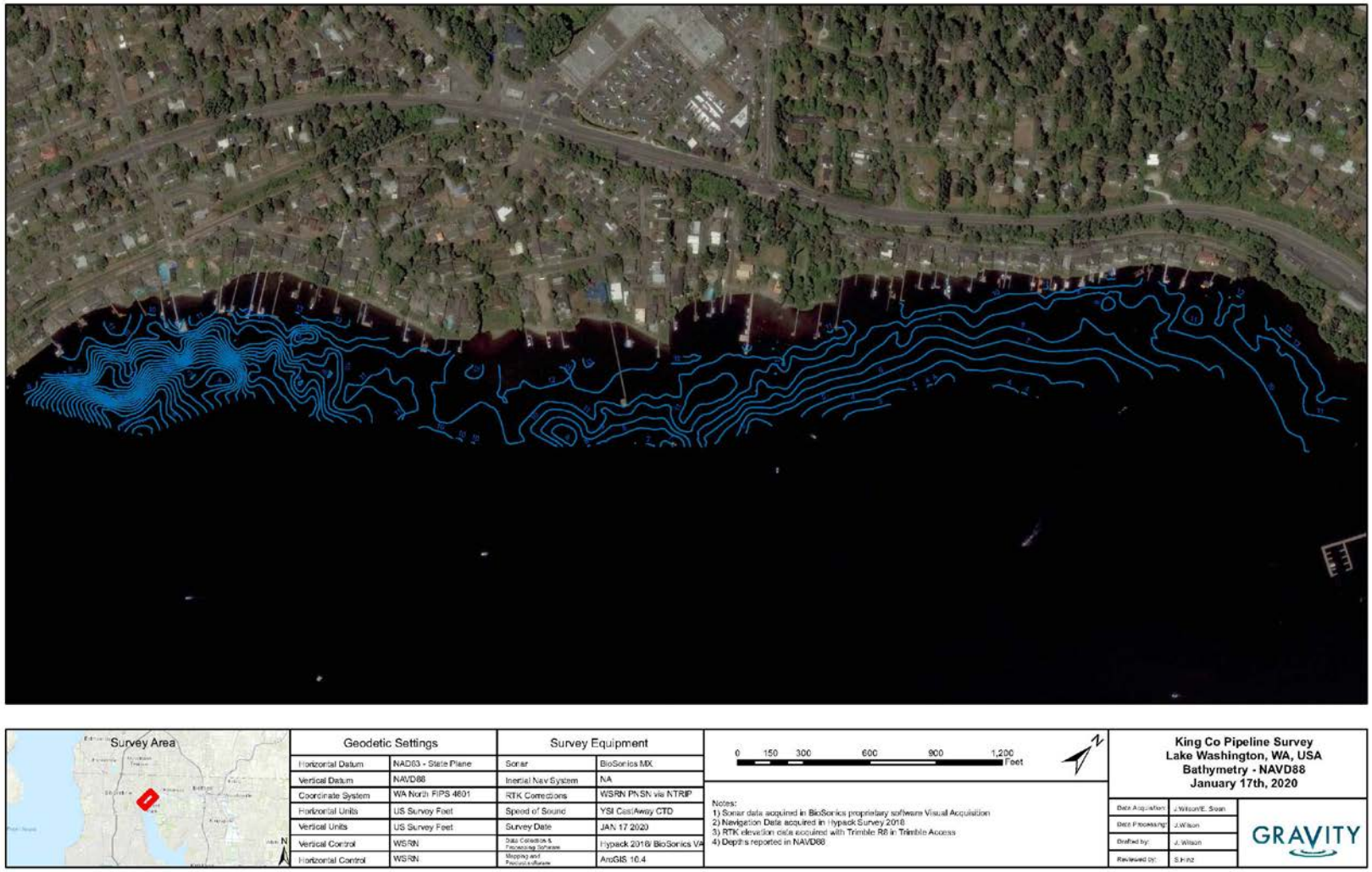


Figure 4. Digital Elevation Model (DEM)

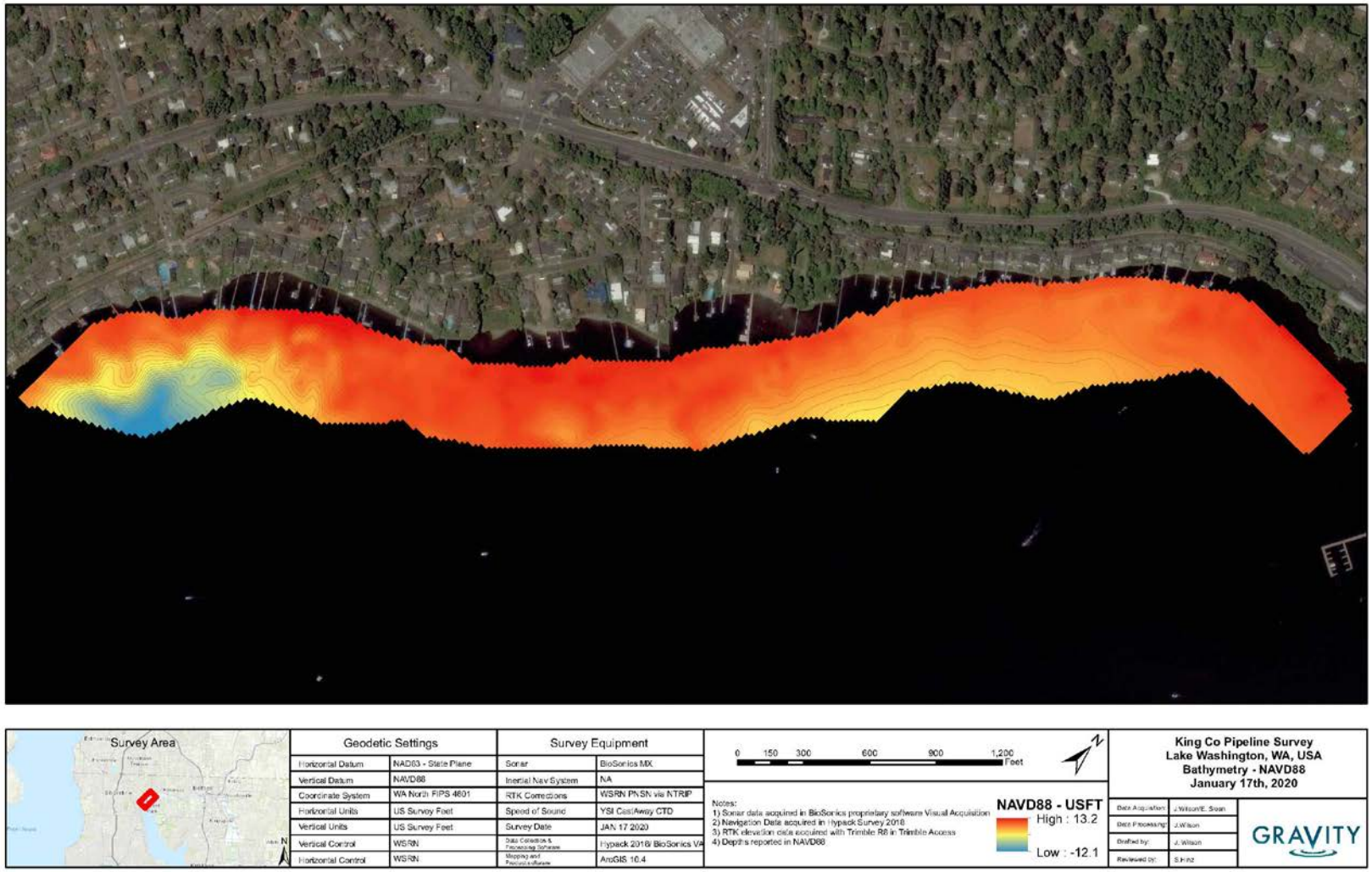
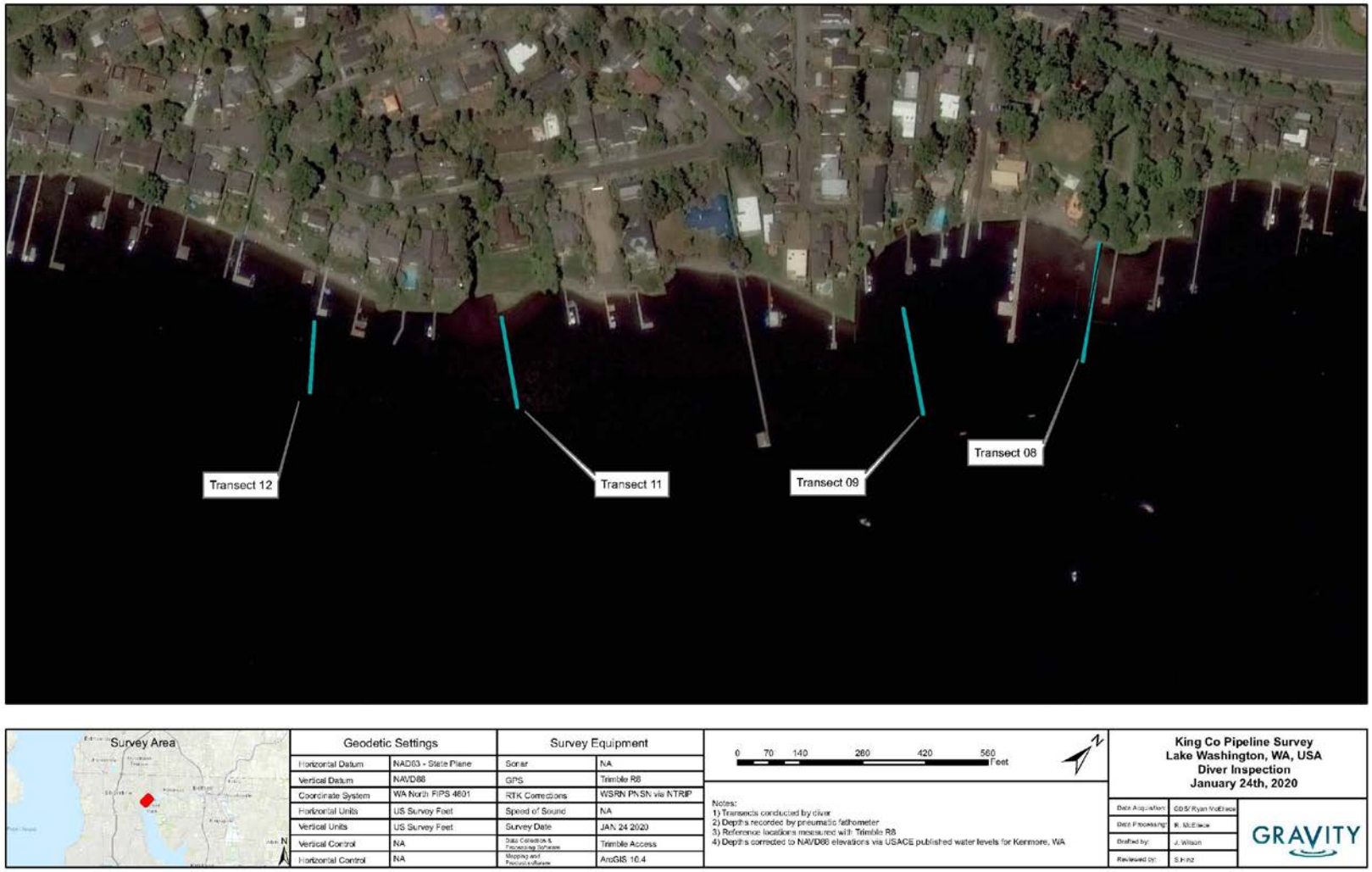


Figure 5. Diver Inspection Transects



KENMORE LAKE LINE LAKEBED SEDIMENTATION ANALYSIS

Property:
Kenmore Lake Line
Lakebed Sedimentation Analysis
Lake Washington
King County, Washington

Prepared for:
King County Wastewater Treatment Division
Department of Natural Resources and Parks
201 South Jackson Street
Seattle , Washington

Report Date:
October 6, 2011

Kenmore Lake Line Lakebed Sedimentation Analysis

Prepared for:

King County Wastewater Treatment Division
Department of Natural Resources and Parks
201 South Jackson Street
Seattle, Washington 98104

Project No.: 0773-001-01

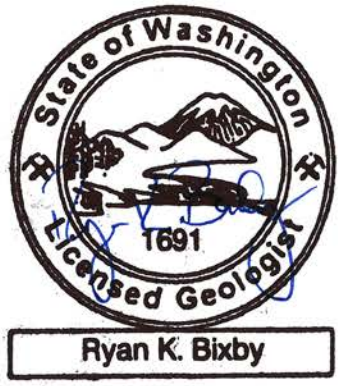
Prepared by:

John Lally, PE
Coastal Engineer, President
Lally Consulting LLC

Reviewed by:

Ryan K. Bixby, LG
President - Environmental Division
SoundEarth Strategies, Inc.

October 6, 2011



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EXECUTIVE SUMMARY

SoundEarth Strategies, Inc., and Lally Consulting LLC have prepared this Sedimentation Analysis Report for the Kenmore Lake Line Lakebed on behalf of King County Wastewater Treatment Division, Department of Natural Resources and Parks. King County owns and operates the Kenmore Lake Line Interceptor sewer pipeline located along the lakebed ranging approximately 75 to 200 feet offshore of the north Lake Washington shoreline between Kenmore and Matthews Beach Park. Shoreline residents along the study reach, between 17345 and 17767 Beach Drive Northeast, have reportedly expressed concerns that sediment deposition has occurred on the lakebed fronting their properties and that the deposition may be caused by the position of the Lake Line.

At King County's request, SoundEarth Strategies, Inc., and Lally Consulting LLC performed an investigation of the sediment transport mechanisms and depositional environment along the Lake Line to evaluate whether the position of the Lake Line has influenced accumulation of sediments in the study area.

Field investigations were performed at the study area on June 15 and 16, 2011. Dive observations yielded the following initial findings regarding the erosional and depositional environment in the vicinity of study area:

- The areas investigated, within and immediately to the southwest of the study area, appeared to be depositional, based on the presence of compressible fine sands, silts, and organics at the lakebed surface.
- The surface sediments appeared to result from numerous potential sources, including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees in a few locations, and perhaps anthropogenic influences from historical or current mill and plywood operations.
- The dense growth of Eurasian watermilfoil within the study area likely has an effect on sediment transport processes, as well as vessel navigation.
- Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion patterns noted by the pile alignments or moorings.
- Erosion was observed along several areas of the shoreline within the study area, particularly adjacent to shore landings for the dock structures and along the downdrift side of armored beaches. A close inspection of the shorelines was not within the scope of this investigation; however, it was observed that natural beaches and man-made beaches are present within and adjacent to the study area.
- No significant differences were noted in the surface sediment composition or vegetation density on either side of the Lake Line.
- There were no obvious indications that the Lake Line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects within a few feet of the emergent section of the Lake Line southwest of Manhole 37. At this location, the lakeward bed elevation dropped approximately 0.5 feet relative to the top of the Lake Line along an approximately 10-foot section of the conduit. The lakebed elevation was flush with the top of the conduit along this section.

EXECUTIVE SUMMARY (CONTINUED)

Results of the sediment sampling activities indicate that in areas other than the Lyons Creek and McAleer Creek outlet shoals, surface sediment generally consisted of fine sand with silt and organics, overlying a thicker layer of finer sediments consisting of organics and silt with some sand. It was noted that both the surface layer and substrate were comprised of shoaling materials, with the surface layer appearing to consist of fine sands, likely originating from the adjacent creek outlets and/or shoreline erosion. The fine sands overlay a more organic-rich layer, perhaps from in-place decomposition of aquatic vegetation or deposition from other sources. Detailed analyses of the geotechnical composition of the samples were performed by a geotechnical laboratory.

Supplemental to the field investigations, lacustrine sedimentation analyses of samples collected from outside the study area at the north end of Lake Washington were undertaken by SoundEarth Strategies, Inc., and Lally Consulting LLC. Site geomorphological, lake level, wind and wave regime, and sediment transport processes were evaluated and characterized for the study area.

The findings from the field investigation and sedimentation processes evaluation suggest that the study area is located in a net depositional area, regardless of the Lake Line. The following primary conclusions were made:

- Submerged aquatic vegetation appears to play a role in limiting both the initiation of sediment movement and deposition patterns within the Lake Line study area. The aquatic vegetation is of a significant density and height to potentially impact vessel navigation and create a perceived shoaling condition.
- The sediment depositional patterns on both sides of the Lake Line are essentially the same and appear to have reached a state of dynamic equilibrium with respect to uniform deposition across the Lake Line.
- Lyons and McAleer creeks and erosion of shoreline areas within and outside the study area appear to be the primary sources of sediment. The in-place decomposition of aquatic vegetation may also be a source of shoaling material.
- The north end of Lake Washington is in a “downdrift” littoral cell with respect to lacustrine sediment transport processes, which results from the predominant wind, wave, and current directions in the lake.
- The dominant southerly wind-wave direction produces a net longshore current from southwest to northeast. This finding was supported by analysis of aerial photography and observations in the field.

SoundEarth Strategies, Inc., and Lally Consulting LLC conclude that the study area is in a net depositional littoral cell of Lake Washington and will therefore continue to experience accretion of sediments. It is also our opinion that the Lake Line sewer pipeline, where originally emergent, likely had some localized effect on the sedimentation immediately within the vicinity of its alignment. However, the sedimentation volumes are overwhelmingly more attributable to the location of the study area being at the north end of the lake and to natural sedimentation processes in the study area.

1.0 INTRODUCTION

According to information provided by the King County Wastewater Treatment Division, Department of Natural Resources and Parks (DNRP), King County owns and operates the Kenmore Lake Line Interceptor sewer pipeline (Lake Line) located along the lakebed ranging approximately 75 to 200 feet offshore of the north Lake Washington shoreline between Kenmore and Matthews Beach Park, as shown on Figure 1. The top of the 48-inch-diameter sewer line, which was installed in 1966, is situated at a depth of approximately 8 feet beneath the lake surface in a shallow trench that was either backfilled to the top of the sewer pipe following its installation or allowed to backfill naturally. The sewer pipe is encased in a 66-inch-square concrete conduit. The study area, shown on Figure 1, is approximately 4,000 feet long. As-built drawings (Appendix A) show the pipeline between stations 190+00 and 245+00 (a length of approximately 5,500 feet), buried as much as 6 feet and exposed as much as 4 feet, at the time of installation.

Shoreline residents along the study reach, between 17345 and 17767 Beach Drive Northeast, have reportedly expressed concerns that sediment deposition has occurred on the lakebed fronting their properties, and they suspect it may be related to the position of the Lake Line. The span of 29 properties where sedimentation concerns have been expressed by the residents is located in the City of Lake Forest Park between Logboom Park, near the intersection of Northeast Bothell Way and 61st Avenue Northeast, and the shore area in the vicinity of Ballinger Way Northeast and Bothell Way Northeast.

DNRP contracted with SoundEarth Strategies, Inc. (SoundEarth) to conduct an inspection and analysis of the lakebed in the vicinity of Lake Line. SoundEarth and Lally Consulting LLC (Lally) prepared this report, which summarizes the results of our field investigation and analyses and provides observations on the sediment transport mechanisms at work in the vicinity of the project area, including the extent to which the Lake Line shows evidence of having a role in sediment deposition in this location.

SoundEarth and Lally attended a pre-dive meeting with DNRP on March 2, 2011. The pre-dive meeting discussion topics included local community relations, the Lake Line easement and access agreement, the field work schedule and weather contingencies, sediment sampling scope of work and sampling techniques, and the reporting schedule. The number and location of sediment samples were also discussed, and it was concluded that in order to more accurately evaluate whether the Lake Line is affecting the sediment accumulation patterns, additional sediment sample locations outside of the study area were warranted. These additional sample locations were intended to provide a baseline for the study because the sediment in these areas would not be affected by the position of the Lake Line. DNRP tentatively approved the additional sample locations if the samples could be collected within the allotted time frame of a 2-day field event.

The following documents and data were provided by King County to SoundEarth and Lally in support of the sedimentation analyses:

- Kenmore Interceptor Section 2B – Construction Drawings, Cross Sections, Plans, and Details
- Kenmore Interceptor Manhole Locations
- Utility Easement – Volume 4515, Pages 222 and 223

2.0 FIELD INVESTIGATION

Field investigations were performed at the study area by SoundEarth and Lally personnel June 15 and 16, 2011. A 20-foot-long, aluminum diving support vessel was employed and mobilized to the site, along with dive equipment, a piston core sampler system, an underwater camera, a global positioning system (GPS) unit, a laser rangefinder, and ancillary equipment. The vessel was operated by Global Diving & Salvage, Inc., and skippered by personnel having knowledge of the locations of the Lake Line and manholes through prior work at the site.

2.1 DIVING OBSERVATIONS

On June 15, 2011, SoundEarth and Lally personnel visually inspected the lakebed of the study area using scuba equipment. Observations commenced in the vicinity of Manhole 37, near the northeast end of the study area. In total, approximately 2,500 linear feet were covered by the dive investigation including between 17360 and 17731 Beach Drive Northeast, where the Lake Line is situated closest to the shoreline; between the Lake Line and the outlets of Lyons Creek and McAleer Creek; and between approximately 16726 and 16740 Shore Drive Northeast, outside and southwest of the original study area.

Numerous dive transects were performed, both shore-perpendicular across and shore-parallel along the Lake Line alignment. Observations made by the diver over the course of the investigations were relayed to personnel aboard the survey vessel and recorded. Appendix B provides a field record of observations and positions, as well as photos taken during the dive and field investigation activities. A summary of findings from the dive survey are provided below.

Visibility was less than approximately 5 feet, and submerged aquatic vegetation was very dense throughout the majority of the study area, making visual observations of the bottom conditions often difficult. Several underwater photos were taken; however, image quality was poor due to the poor visibility in the water column and vegetation density. Observations of bottom conditions were most often made by feel or, where vegetation was not overly dense, by viewing within inches of the lakebed. Care was taken to minimize fin movements to avoid resuspending bottom sediments, thereby further impairing visibility.

Although the Lake Line was not exposed throughout much of the study area, its position was established by identifying the locations of Manholes 35 and 36, which had been previously marked by buoys, and by using a mapping-grade GPS unit to identify the locations of Manholes 34A, 37, and 38, the coordinates of which had been provided by DNRP. The Lake Line was assumed to run in a direct line between the manhole locations, as depicted on the Lake Line as-built construction plans and drawing. Diving personnel were able to physically locate Manholes 35, 36, and 37, as well as a section of the Lake Line's concrete conduit that extends in a southerly direction from Manhole 37 throughout the study. Manholes 34A and 38, as well as the remaining sections of the concrete conduit, were covered by sediment and vegetation and were not physically identified in the course of the investigation.

Both shoreward and lakeward of the Lake Line, the lakebed surface sediments consisted predominantly of loose, silty, fine sand and/or sandy silt and organics. As noted and photographed during the dives, dense stands of Eurasian watermilfoil (*Myriophyllum spicatum L.*) were present within and outside of the study area, with the exceptions of areas with coarser sands and gravels in the nearshore to shoreline zones and outlets to McAleer and Lyons creeks.

The lakebed bathymetry was observed as gently sloping to flat, with no significant undulations along or across the Lake Line alignment or nearshore areas within the study area. Except in nearshore areas, generally shallower than 3 to 5 feet, the lakebed surface material was compressible and appeared to be shoaling material. At depths shallower than 3 to 5 feet, the lakebed was generally stiffer sands and gravels, with less vegetation.

Near the outlets of both Lyons and McAleer creeks, the lakebed consisted of fluvial deposits of coarser sands, and gravels approximately 2 inches in diameter and smaller. These materials were noted as visually similar to the sediments found in the creeks. The water depths over the creek offshore deposits were generally shallower than adjacent offshore areas. Deposits of coarser and stiffer sands appeared to extend approximately 100 to 300 feet on either side of the creek outlets, but generally trended in a net northeasterly direction within the study area.

Outside the original study area to the southwest, the materials also appeared to be coarser sands and gravels along the Lake Line alignment, as influenced by the McAleer Creek shoal, trending to more compressible, finer sands and organics within about 100 feet west of the creek outlet. In this area it was noted, by feel, that some form of geotextile fabric had been placed offshore of at least one property on the lakebed. The area of geotextile fabric placement was estimated to cover at least 1,000 square feet of the lakebed, and it was surmised that the fabric was installed for suppression of submerged vegetation.

The concrete conduit of the Lake Line was physically encountered offshore of the residence at 17364 Beach Drive Northeast. The Lake Line was covered with at least a 1-inch-thick layer of sediment in this area, but could be followed by running ones hands over the approximate 5-foot-wide concrete box conduit. About 200 feet south of Manhole 37, in front of 17360 Beach Drive Northeast, an approximately 10- to 15-degree southward turn was noted in the Lake Line concrete box conduit. In the vicinity of the turn, the lakebed was noted as dropping in elevation approximately 0.5 feet on the lakeward side of the Lake Line relative to the elevation of the sediment on top of the Lake Line conduit and the shoreward lakebed. The slight change in elevation extended a distance of approximately 10 feet; further south, the concrete box conduit was covered by sediment and could not be located by feel.

Manholes 35 and 36 were visually located since they had been previously marked with floats. The manholes were measured to be approximately 5 feet in diameter and had lifting eyes welded on the top plates. The manholes, like the Lake Line, were surrounded by dense Eurasian watermilfoil.

Dive observations yielded the following initial findings regarding the erosional and depositional environment in the vicinity of study area:

- The areas investigated, within and immediately to the southwest of the study area, appeared to be depositional, based on the presence of compressible fine sands, silts, and organics at the lakebed surface.
- The surface sediments appeared to result from numerous potential sources including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees in a few locations, and perhaps anthropogenic influences from historical or current mill and plywood operations.
- The dense growth of Eurasian watermilfoil within the study area likely has an effect on sediment transport processes, as well as vessel navigation.

- Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion patterns noted by the pile alignments or moorings.
- Erosion was observed along several areas of the shoreline within the study area, particularly adjacent to shore landings for the dock structures and along the downdrift side of armored beaches. A close inspection of the shorelines was not within the scope of this investigation; however, it was observed that natural beaches and man-made beaches are present within and adjacent to the study area.
- No significant differences were noted in the surface sediment composition or vegetation density on either side of the Lake Line.
- There were no obvious indications that the Lake Line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects within a few feet of the emergent section of the Lake Line southwest of Manhole 37. At this location, the lakeward bed elevation dropped approximately 0.5 feet relative to the top of the Lake Line along an approximately 10-foot section of the conduit. The lakebed elevation was flush with the top of the conduit along this section.

2.2 SEDIMENT SAMPLING

Additional investigations of lakebed sediments were conducted on June 16, 2011, by SoundEarth and Lally personnel from the sampling vessel. Sediment sampling was performed using a piston core system with a stainless steel, 1.5-inch-diameter, 6-foot core. Twelve samples at six paired stations were collected within the original study area (Stations 2 through 7), and an additional four samples were collected at two paired stations (Stations 1 and 8) located outside the study area to the northeast and southwest, respectively. Samples were collected in pairs along the Lake Line alignment both shoreward and lakeward of the Lake Line. Station 1 was located to the northeast of the point where the Lake Line intersects the shoreline; sediment samples from this station were collected at similar distances from the shore as those collected from the other stations. Sediment sample and station locations are depicted on Figures 2 and 3.

Refusal (i.e., the inability to further advance the sampler) was generally met within 3 feet of the lakebed surface. In the vicinity of Lyons Creek and McAleer Creek, the sampler met refusal at depths of less than 1 foot due to the presence of compacted sands and gravel in the surface layer. The core samples were extruded in a core tray on the deck of the survey vessel for preliminary analysis and cataloging. Several of the samples that exhibited distinct layers of sediment were partitioned. All samples were photographed and placed in individually labeled and sealed plastic bags for grain-size analysis at a geotechnical laboratory.

The depth to the sediment surface at each sample location was measured by lead line sounding and corrected to U.S. Army Corps of Engineering (Corps) datum. The lake elevation as measured at the Corps Kenmore gage was 22.13 feet on June 15, 2011, and 22.15 feet on June 16, 2011. Table 1 summarizes the sample locations and corrected depths for each sediment sample location.

The results of the sediment sampling activities indicate that in areas other than the Lyons Creek and McAleer Creek outlet shoals, surface sediment generally consisted of fine sand with silt and organics, overlying a thicker layer of finer sediments consisting of organics and silt with some sand. It was noted that both the surface layer and substrate were comprised of shoaling materials, with the surface layer

appearing to consist of fine sands, likely originating from the adjacent creek outlets and/or shoreline erosion. The fine sands overlay a more organic-rich layer, perhaps from in-place decomposition of aquatic vegetation or deposition from other sources. More detailed analyses of the geotechnical composition of the samples are described below and in Appendix C.

2.2.1 Geotechnical Analyses

Sediment samples were delivered to the HWA Geosciences Inc. laboratory in Bothell, Washington, on June 16, 2011, for testing and grain-size analysis. Moisture contents of the samples were determined in accordance with American Society for Testing and Materials (ASTM) D2216, and grain-size distributions were determined in accordance with ASTM D422. Standard sieve analysis was employed for the grain-size analysis, as well as a hydrometer analysis when a significant fines fraction was present. Particle-size distribution reports were generated for each sample; the reports provide grain-size curves and other information, including the percentages of fines, sand, and coarser fractions, as well as the moisture content of the samples. The complete geotechnical testing report is provided as Appendix C.

A summary of the laboratory testing results, including sample location, depths, and geotechnical characteristics, is provided in Table 1.

2.3 DEPTH MEASUREMENTS

Depth measurements were collected at each sample location by lead line sounding. Table 1 summarizes the locations and corrected depths of the soundings.

Figure 3 plots the sample depths, corrected to Mean Sea Level datum, along with the 1966 as-built depth profile. Lack of adequate data density and limited or unknown horizontal and vertical positioning accuracy between the two survey methods prevent a reliable comparison between the surveys to be made. However, it can be observed from the sample location depth measurements and from stations 7 and 8 that the shallowest depths are located over the shoals of McAleer and Lyons creeks. In general, there appear to be no significant deposition patterns along the Lake Line alignment in other than the creek areas. Although the lakebed depth increased with distance from shore in most portions of the study area, the depth decreased with distance from shore in the vicinity of stations 7 and 8, which are the two southwesternmost stations. The cause of this irregularity was not apparent. To evaluate the sedimentation depths and patterns by depth measurement, with any level of useful accuracy, both the historical and current surveys would need to encompass a wider study area, on either side of the Lake Line, and similar data density and sounding methods would need to be employed for all comparative surveys.

3.0 SEDIMENTATION ANALYSES

Supplemental to the field investigations, additional lacustrine sedimentation analyses of the north end of Lake Washington were undertaken by SoundEarth and Lally in the effort to assess the sedimentation conditions and the relative contributions that the Lake Line and other factors may have made toward the reported decrease in lakebed depth in the study area.

3.1 SITE GEOMORPHOLOGY

The study area is located at the north end of Lake Washington, which is a long, narrow ribbon lake, excavated by advancing glaciers. As the Puget lobe of the Cordilleran Ice Sheet flowed southward near

the end of the Late Pleistocene, it met bands of harder and softer rock. Erosion of the softer rock occurred more quickly than that of the harder rock and a linear depression was created in the flow direction. When the glacier melted, the lake filled with meltwater, which was retained by morainal deposits (Booth 1994).

Ribbon lakes such as Lake Washington commonly have rivers at each end; one river an inlet and one river an outlet. However, in the case of Lake Washington, both rivers (the Cedar River to the south and the Sammamish River to the north) are inlets. The outlet for Lake Washington is the Lake Washington Ship Canal, which empties into Puget Sound. There are also several creeks that feed Lake Washington. Two of the creeks, Lyons Creek and McAleer Creek, empty into and contribute sediment to the study area. The Sammamish River outlet is located approximately 4,000 feet to the east of the center of the study area and is likely not a significant source of sediment to the study area.

The shoreline of Lake Washington, including that of the study area, has been highly developed. Within and adjacent to the study area, large portions of the shoreline are hardened with vertical bulkheads of various composition, including large, keyed-in rock or sheet piles. Less frequently, the shoreline consists of native or man-made beach. Based on review of aerial photography of the study area, approximately 60 percent of the shoreline within the study area is hardened and 40 percent is soft native or beach shoreline. Approximately 35 of the 42 properties within the study area have docks. Docks vary in configuration and construction, but are generally built shore-perpendicular with timber piles and fixed pier decks. Based on review of historical aerial photographs, between 1963 and 2011, 15 or more docks appear to have been constructed within the study area.

A review of historical aerial photographs indicates that Lyons and McAleer creeks are significant sediment sources to the littoral system within the study area. As viewed during the field investigation and supported by analysis using aerial photography, the net longshore direction along the north shoreline of Lake Washington, including the study area, is to the northeast. This is evident based on the accretion of sediments on the updrift (southwest) side of structures and headlands, and erosion immediately downdrift (northeast).

3.2 SEDIMENTATION PROCESSES

The primary forces driving lacustrine sedimentation processes in nearshore areas are lake levels, winds, wind-waves, and currents. The following sections characterize these forces in the study area, based on prior work.

3.2.1 Lake Levels

Water surface elevations, or lake levels, control the depth or height to which sediment is eroded and transported along lake shorelines and nearshore zones. The water level of Lake Washington is controlled by the Corps at the dam adjacent to the Ballard Locks. The legislation authorizing the Corps to maintain the Lake Washington Ship Canal, established by Congress June 25, 1910, requires that the lake level in Lake Washington be maintained between 20.0 feet and 22.0 feet, Corps Locks datum.

To meet this requirement, the Corps starts each planned calendar year with the lake level at an elevation of 20.0 feet as part of the winter holding period. On or about February 15 of each year, the lake level is allowed to rise slowly during the spring refill period to elevation 22.0 feet on or about May 1. The lake is maintained at elevation 22.0 feet through the summer

conservation period and then allowed to recede during the fall drawdown period starting on or about November 1. By December 1, the lake level has typically returned to elevation 20.0 feet (Corps 2004). The actual Lake Washington water level cycle can deviate from the standard operating schedule depending on the amount of rainfall received during the year and other factors.

The Corps maintains water level gages on the Lake Washington Ship Canal at the Ballard Locks and at the north end of Lake Washington in Kenmore. The Ballard Locks gage data is available for the period 1999–present and can be accessed online at <http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=id:LKW>. The Kenmore gage data is available for the period 2004–present and can be accessed at <http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=id:LWKW>. Both gages report water level data to the Corps datum.

Data from both Ballard Locks and Kenmore gages were compiled and analyzed for the period 1999 through 2009. A summary hydrograph for the period 2004 through 2009 comparing the two gage locations is presented in Diagram 1.

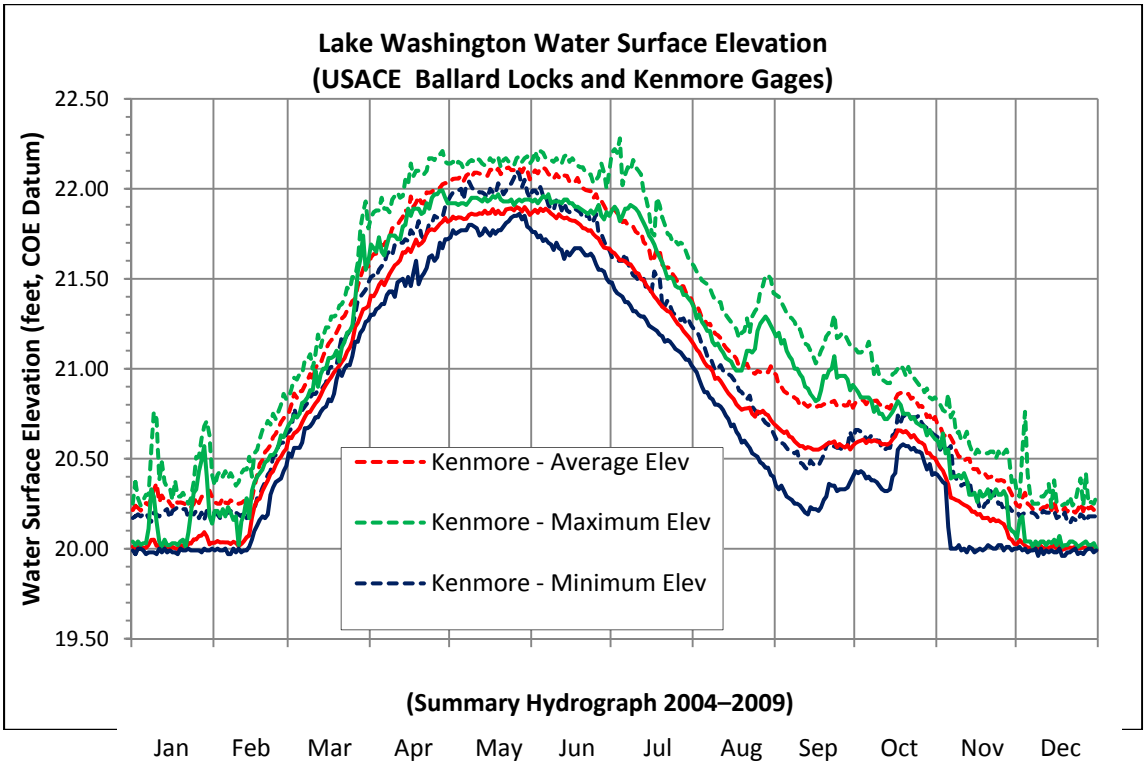

Diagram 1. Lake Washington Water Surface Elevation at Ballard Locks and Kenmore Gages, 2004–2009. (Lally 2010)

As shown in Diagram 1, the lake level at the Kenmore gage is consistently 0.15 feet to 0.30 feet above the elevation at the Ballard Locks gage. According to the Corps, this is at least in part attributable to water "stacking" at the north end of Lake Washington due to basin narrowing and the dominant southerly winds.

3.2.2 Wind Regime

The major axis of Lake Washington is approximately 23 miles long and lies in a north-south direction. The predominant weather systems of the Pacific Northwest from late fall to early spring generate winds from the southwest through the southeast. Northerly winds (from the north) accompany cold fronts that pass through occasionally during the winter. Light, northerly winds also occur during the summer season. The general meteorological conditions and site topography are not conducive to the formation of winds from either the west or east. The most severe storm winds over Lake Washington are southerly (from the south) and are associated with the strong, semipermanent low pressure system that exists over the Gulf of Alaska in winter (Glosten Associates 1993).

Wind analyses for Lake Washington were performed using Washington State Department of Transportation meteorological record files, including wind speed, direction, and frequency data, from the Evergreen Point Floating Bridge (SR-520) meteorological station (Lally 2010). The data generated from the SR-520 station, located approximately 45,000 feet south of Kenmore, appear to be the most representative of the wind conditions having an effect on the sedimentation processes in the study area.

The raw wind data, consisting of over 4,600 individual files and 8.1 million wind measurements, including date, time, and a number of wind speed and direction values, were statistically analyzed to develop 1-year and 10-year recurrence interval wind spectra as the basis for wave and sediment transport calculations. A wind rose was developed for the period 2000 through 2009 using the hourly wind data (Diagram 2). The wind rose illustrates how the wind speed and directions are typically distributed on Lake Washington.

As can be seen from Diagram 2, the wind spectra for the area are generally bimodal. The dominant mode is from the southeast through southwest (150 degrees [°] to 250° from north), a directional range that is also associated with the strongest winds. Winds in this directional range occur approximately 45 percent of the time. The second mode ranges northwest through northeast (330° to 40° from north) approximately 30 percent of the time. Winds in this range are more moderate than those from the south.

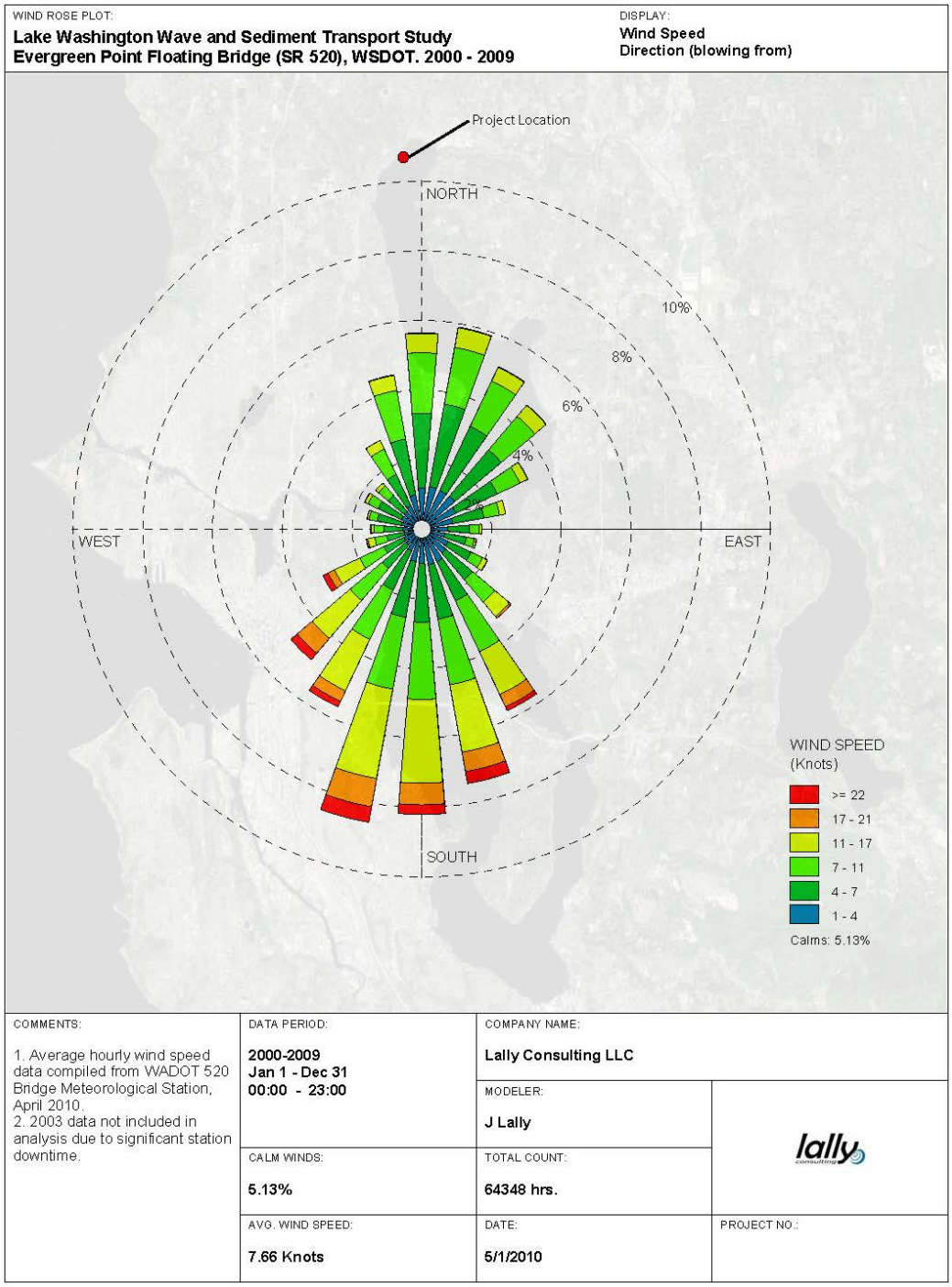

Diagram 2. Lake Washington Wind Rose 5-Min. Avg. Wind Speeds at SR-520 Bridge, 2000–2009.

A scatter plot for 1 year (Diagram 3) presents the directional distribution of winds, further showing that the strongest and most frequent winds are from the south. This characterization of the wind regime further suggests that the net longshore currents along Lake Washington shorelines and nearshore zones are generally toward the north.

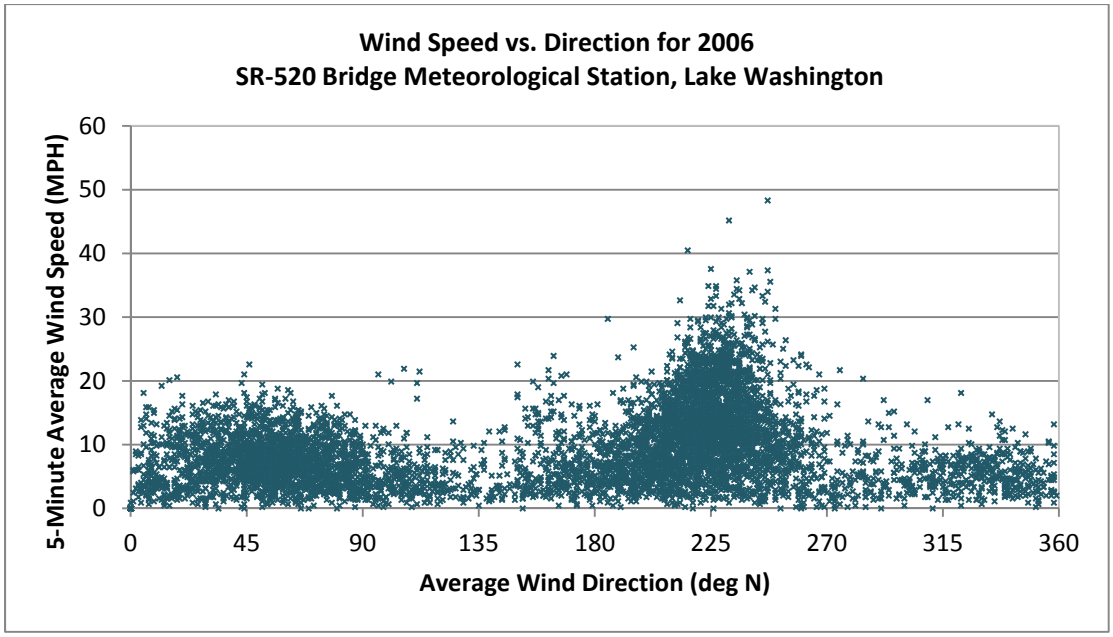

Diagram 3. Scatter Plot of Wind Speed vs. Wind Direction, SR-520 Bridge, 2006. (Lally 2010)

Considering the critical relationship between wind and wave generation, and the associated sediment transport regime in the Lake Line study area, it is important to recognize that the lake winds can be highly localized due to topography effects. Along the east and west shores of Lake Washington north of the SR-520 bridge, hills several hundred feet high exert a significant steering influence on the winds, in the case of southerly winds, to the northeast. The lake also narrows at its north end, which likely creates a Venturi effect and increases wind speed.

3.2.3 Wave Regime

When wind blows over water it exerts a stress on the surface, transferring some of its energy into the water and forming waves. As wind-waves travel across the water surface, orbital motions are created within the wave. In deep water, the motions approximate closed circular orbits. As the wave advances into intermediate water, the motions become more elliptic as the wave “feels” the bottom. In shallow water, the motions become a series of horizontal oscillatory movements capable of transporting sediment. A generalized wave orbital motion diagram is shown in Diagram 4.

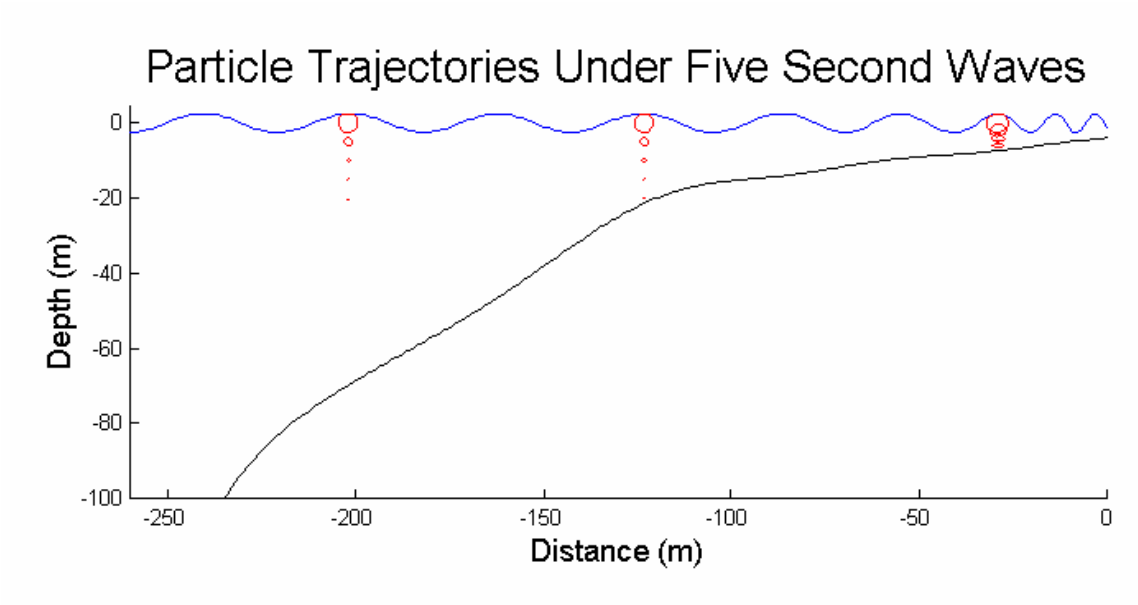

Diagram 4. Diagram of Water Orbital Motions under a Wave. (From TRDI 2006)

The wind-waves that are generated in Lake Washington are a function of the wind speed and duration, as well as the depth of the lake and the fetch (the distance the wind travels over the lake). The generation of wind-waves for a given wind speed is either limited by the duration of a storm event or by the fetch. Wave generation, therefore, is referred to as being either duration-limited or fetch-limited. For a smaller body of water, like Lake Washington, the generation of wind-waves is fetch-limited.

Due to the location of the Kenmore Lake Line project site on the north end of Lake Washington, only winds from approximately 110° (east-southeast) through 205° (southwest), can affect the formation of wind-waves incident to the site. The longest fetch for the study area is estimated at 7.3 nautical miles, or 8.4 statute miles, from 162° (south-southeast). This is a relatively long fetch for Lake Washington, which likely allows for the formation of some of the highest waves and shoreline currents on the lake.

3.2.4 Sediment Transport Processes

The two main littoral current systems that can develop in the nearshore forward of breaking waves are longshore currents and cross-shore currents. Longshore currents generally result from waves crests approaching the shoreline obliquely, while cross-shore currents form when waves approach with their crests approximately parallel to the shoreline. Both current types are capable of transporting large quantities of sediment within a nearshore shoreline system.

The major axis of the Kenmore Lake Line study area is oriented approximately 215° (N35°E), which suggests that, regardless of storm intensity, the angle of wave incidence along the study area is predominantly longshore, with likely a cross-shore component.

The sum of all the movements in longshore or cross-shore directions is known as the gross sediment transport rate. The term “littoral” accounts for movements in both longshore and cross-shore directions. The net littoral transport rate quantifies the sediment movement in a single direction.

From prior work, it has been estimated that net sediment transport rates within the nearshore zone with a more moderate wind regime in the central section of Lake Washington are 5 to 10 cubic yards per foot per year (Lally 2010). The nearshore zone extends from approximately the initiation of wave breaking, or approximately the 5- to 6-foot-depth contour in the case of Lake Washington, to the shoreline. Sediment transport rates can be affected by grain size, bathymetry, presence of structures, and other factors.

When current velocities reach a critical threshold, sediment is entrained (eroded) and transport is initiated. Once sediment is in motion it can generally be described as moving in one of two modes: bedload transport or suspended transport (Diagram 5). Bedload transport occurs when grains are in continual or frequent contact with the bed. Particles move by creeping or rolling in a zigzag pattern along the bed. Suspended transport occurs when particles leave the bed due to fluid turbulence and are predominantly transported in the water column. Particles settle out and deposit when current (settling) velocities fall beneath the critical transport threshold. Settling velocities of the particles will vary depending on their grain size.

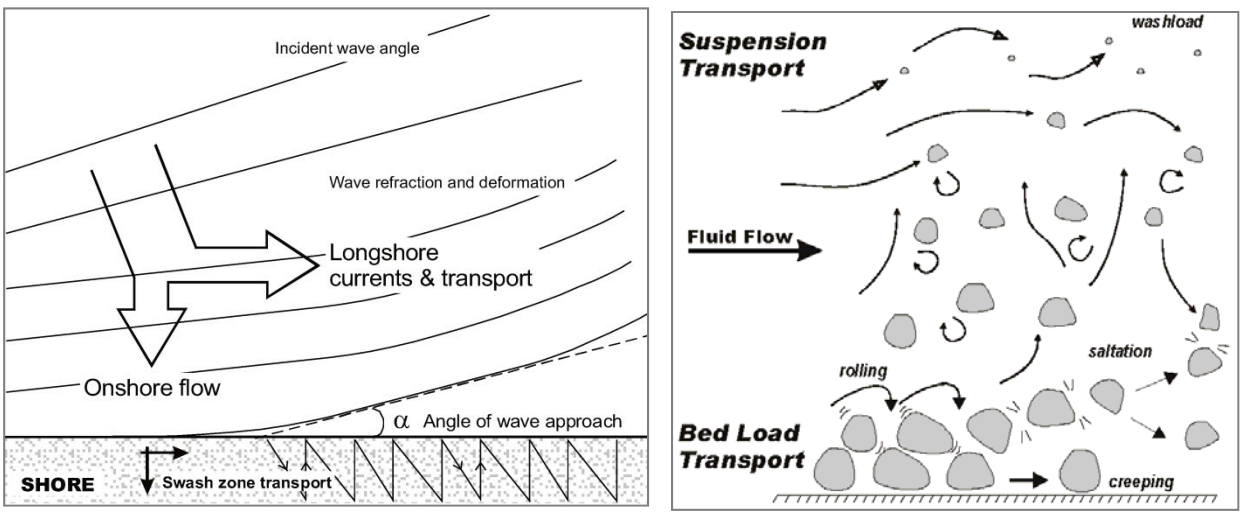

Diagram 5. Littoral Currents and Sediment Transport Mechanics. (Adapted from Dawe 2006)

Whether a particle is transported in suspension or by bedload is typically a function of the fluid velocity and the size, shape, and density of the grain. Fine particles have low critical threshold velocities and are more readily set into motion. Coarser particles are more resistant to moving and may require higher velocities to set in motion. It is generally accepted that gravel is transported as bedload, and that sands and finer material are transported through a combination of both bedload and suspension depending on the wave conditions (Dawe 2006). In most nearshore systems, including the Lake Line study area, both of these mechanisms play a role.

3.3 SEDIMENTATION ANALYSES

The findings from the field investigation and sedimentation processes evaluation suggest that the study area is in a net depositional area, regardless of whether the Lake Line is in place. The following primary conclusions were made based on our analyses:

- Submerged aquatic vegetation appears to play a role in limiting both the initiation of sediment movement and deposition patterns within the Lake Line study area. The aquatic vegetation is of significant density and height that it likely impacts vessel navigation and can create a perceived shoaling condition.
- The sediment depositional patterns on both sides of the Lake Line are essentially the same and appear to have reached a state of dynamic equilibrium with respect to uniform deposition across the Lake Line.
- Lyons and McAleer creeks and erosion of shoreline areas within and outside the study area appear to be the primary sources of sediment. The in-place decomposition of aquatic vegetation may also be a source of shoaling material.
- The north end of Lake Washington is in a "downdrift" littoral cell with respect to lacustrine sediment transport processes, which results from the predominant wind, wave, and current directions in the lake.
- The dominant southerly wind-wave direction produces a net longshore current from southwest to northeast. This is supported by analysis of aerial photography and observations in the field.
- Once set in motion, sediments migrate in the nearshore zone through a combination of bedload and suspension transport.

4.0 CONCLUSIONS AND RECOMMENDATIONS

It is our opinion that the study area is in a net depositional littoral cell of Lake Washington and will continue to experience accretion of sediments. It is also our opinion that the Lake Line sewer pipeline, where originally emergent, likely had some localized effect on the sedimentation immediately within the vicinity of its alignment. However, the sedimentation volumes are overwhelmingly more attributable to the location of the study area being at the north end of the lake and to natural sedimentation processes in the study area.

5.0 REFERENCES

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FIGURES

SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 07/07/11
DRAWN BY: ..... NAC
CHECKED BY: ..... RKB
GIS FILE: ..... 0773_2011_VM

PROJECT NAME: ..... KENMORE LAKEBED
PROJECT NUMBER: 0773-001
STREET ADDRESS: ..... NA
CITY, STATE: ..... KENMORE,WASHINGTON

0 0.25 0.5 0.75 1 Miles
APPROXIMATE SCALE IN MILES

FIGURE 1
STUDY AREA VICINITY MAP

11/16/2010

File: P:\0773 Kenmore Lakebed\Technical\GIS\MXDs\baseemap.mxd

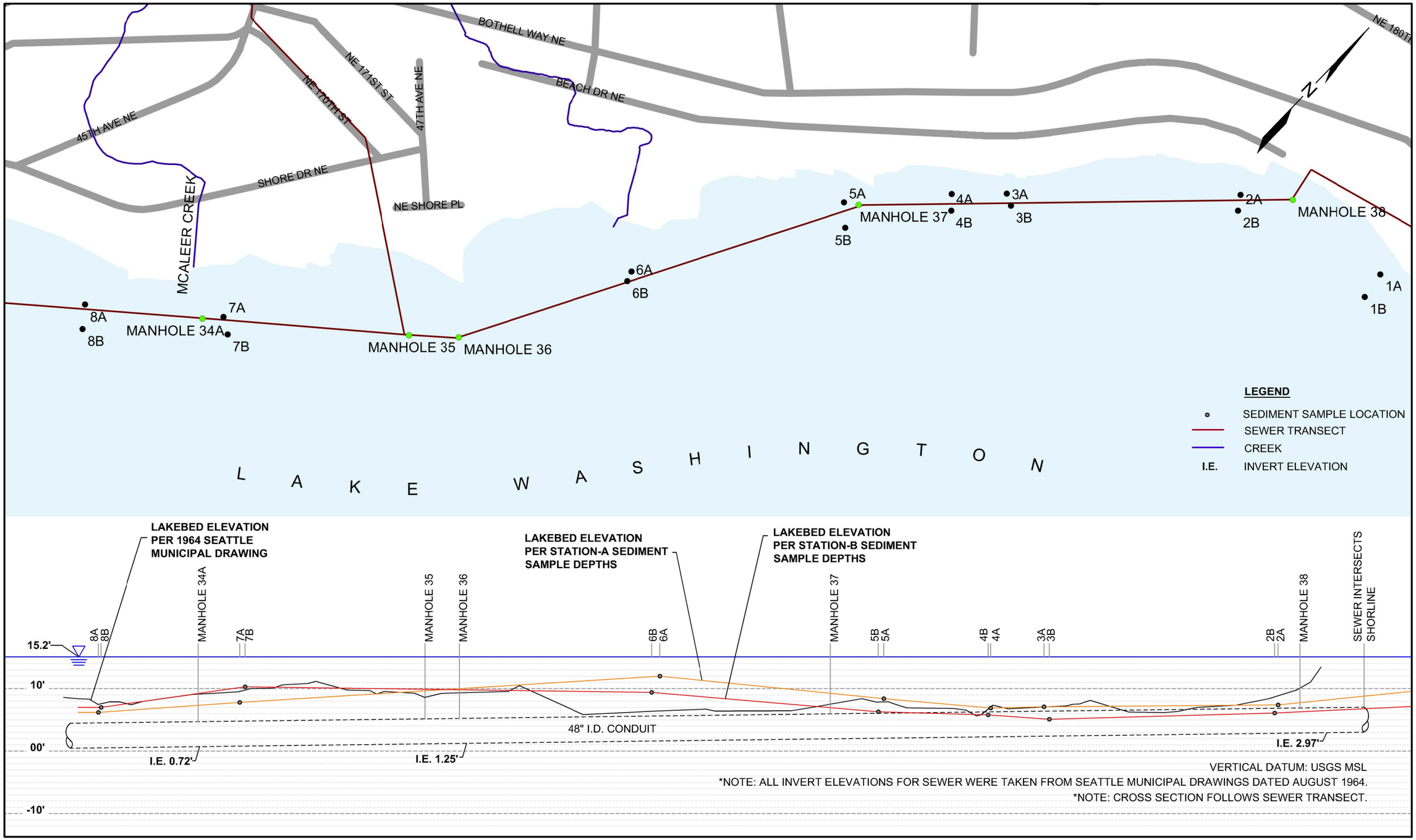
SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 07/07/11
DRAWN BY: ..... NAC
CHECKED BY: ..... RKB
GIS FILE: ..... 0773_2011_EL

PROJECT NAME: ..... KENMORE LAKEBED
PROJECT NUMBER: 0773-001
STREET ADDRESS: ..... NA
CITY, STATE: ..... KENMORE,WASHINGTON

0 200 400 600 800 Feet
APPROXIMATE SCALE IN FEET

FIGURE 2
EXPLORATION LOCATION PLAN



SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 7/12/2011
DRAWN BY: VPB
CHECKED BY: RKB
CAD FILE: 0773_2011_XS

PROJECT NAME: KENMORE LAKEBED
PROJECT NUMBER: 0773-001
STREET ADDRESS: NA
CITY, STATE: KENMORE, WASHINGTON

REGION:

0 150 300 600
APPROXIMATE SCALE IN FEET (HORIZONTAL)
20X VERTICAL EXAGGERATION

FIGURE 3
PROFILE SECTION ALONG SEWER TRANSECT

7/15/2011
P:\0773 KENMORE LAKEBED\TECHNICAL\CAD\BASEMAP\0773-001-01 XS.DWG

TABLE

SoundEarth Strategies

Table 1
Summary of Sediment Sampling and Analytical Results
Kenmore Lakebed
Kenmore, Washington

Sample ID	Sample Location		Sample Depth (feet)[1]	Corrected Lakebed Surface Elevation (feet)[1]			Sample Interval (Lakebed surface to bottom of boring in feet)	Sample Date	USCS Classification	Median Grain-Size Diameter D_{50} (mm)[2]	Moisture Content (% Dry Mass)[2]	Particle Distribution (%)[3]			
	Latitude	Longitude		Corps of Engineers Datum	MSL Datum	Metro Datum						Gravel	Sand	Silt	Clay
1-A	N 47° 45.425'	W 122° 16.028'	4.5	17.8	10.8	110.8	0.0	06/16/11	poorly graded SAND	0.19	27	0.0	97.0	3.0	
1-B	N 47° 45.411'	W 122° 16.024'	7.4	14.8	7.8	107.8	0.0	06/16/11	sandy SILT	0.07	57	0.0	48.4	51.6	0.0
2-A	N 47° 45.403'	W 122° 16.149'	7.7	14.5	7.5	107.5	0.0	06/16/11	silty SAND with organics	0.18	81	0.0	75.5	23.6	0.9
2-B	N 47° 45.396'	W 122° 16.142'	9.0	13.2	6.2	106.2	0.0 - 0.8	06/16/11	SILT with sand	0.04	103	0.0	23.4	74.2	2.4
3-A	N 47° 45.316'	W 122° 16.279'	8.0	14.2	7.2	107.2	0.0	06/16/11	silty SAND with organics	0.08	88	0.0	55.5	43.7	0.8
3-B	N 47° 45.313'	W 122° 16.270'	10.0	12.2	5.2	105.2	0.0	06/16/11	SILT with organics	0.03	157	0.0	8.6	88.9	2.5
4-A	N 47° 45.295'	W 122° 16.309'	8.2	14.0	7.0	107.0	0.0 - 0.3	06/16/11	silty SAND with organics	0.09	92	1.7	60.3	38.1	
							0.3-1.4	06/16/11	SILT	0.02	176	0.0	8.9	87.4	3.7
4-B	N 47° 45.289'	W 122° 16.300'	9.3	12.9	5.9	105.9	0.0 - 0.3	06/16/11	silty SAND with organics	0.11	84	0.0	63.2	36.8	
							0.3-1.19	06/16/11	SILT with organics	0.02	212	0.0	10.8	86.0	3.2
5-A	N 47° 45.252'	W 122° 16.364'	6.7	15.5	8.5	108.5	0.0	06/16/11	poorly graded SAND with silt	0.20	32	0.1	92.5	7.4	
5-B	N 47° 45.243'	W 122° 16.349'	8.8	13.4	6.4	106.4	0.0-0.8	06/16/11	silty SAND with organics	0.09	86	0.0	59.3	39.8	0.9
							0.8-2.3	06/16/11	SILT with organics	0.03	202	0.0	13.0	83.1	3.9
6-A	N 47° 45.147'	W 122° 16.443'	3.1	19.1	12.1	112.1	0.0	06/16/11	poorly graded SAND	0.39	22	12.8	86.4	0.8	
6-B	N 47° 45.142'	W 122° 16.440'	5.7	16.5	9.5	109.5	0.0	06/16/11	poorly graded SAND	0.34	30	3.8	94.4	1.8	
7-A	N 47° 44.978'	W 122° 16.643'	7.3	14.9	7.9	107.9	0.0	06/16/11	poorly graded SAND	0.31	28	10.9	88.0	1.1	
7-B	N 47° 44.973'	W 122° 16.631'	4.8	17.4	10.4	110.4	0.0	06/16/11	NO SAMPLE RECOVERY						
8-A	N 47° 44.931'	W 122° 16.726'	8.9	13.3	6.3	106.3	0.0	06/16/11	poorly graded SAND	0.33	27	7.6	89.1	3.3	
8-B	N 47° 44.921'	W 122° 16.714'	8.1	14.1	7.1	107.1	0.0-0.6	06/16/11	poorly graded SAND with silt	0.28	37	6.0	86.7	7.2	
							0.6-1.0	06/16/11	silty SAND	0.08	61	0.0	55.3	44.7	

NOTES:

Matrix for all samples was sediment.

Analyses conducted by HWA GeoSciences Inc., of Bothell, Washington.

[1]Lake Level on sample date, June 16, 2011, was 22.15 feet. (USACE datum), as recorded at Kenmore gage.

[2]Determined in general accordance with ASTM D2216.

[3]Determined in general accordance with ASTM D422.

% = percent

ASTM = American Society for Testing and Materials

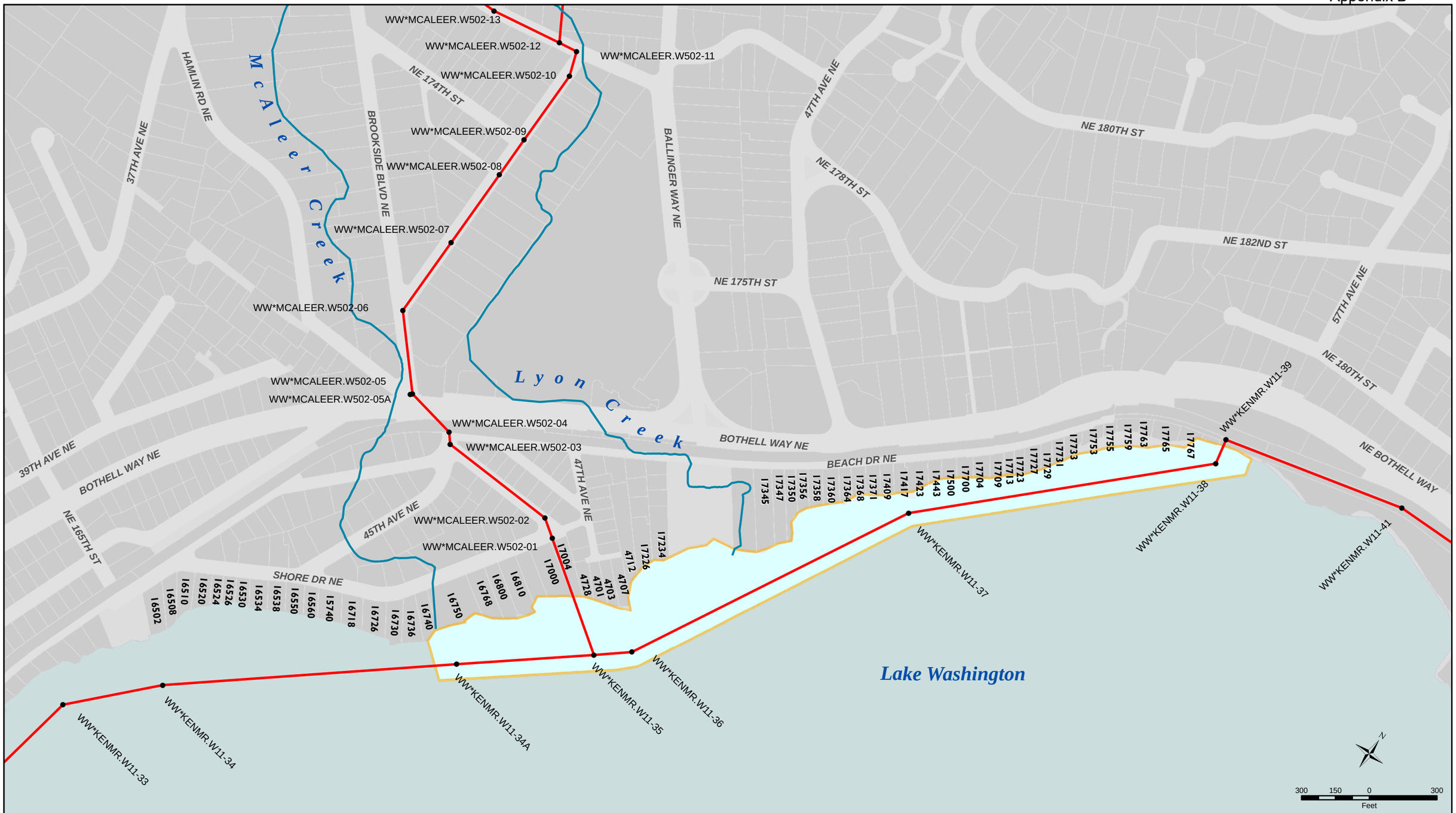
mm = millimeters

USACE = U.S. Army Corps of Engineers

USCS = Unified Soil Classification System

APPENDIX A

KING COUNTY MAPS/DRAWINGS



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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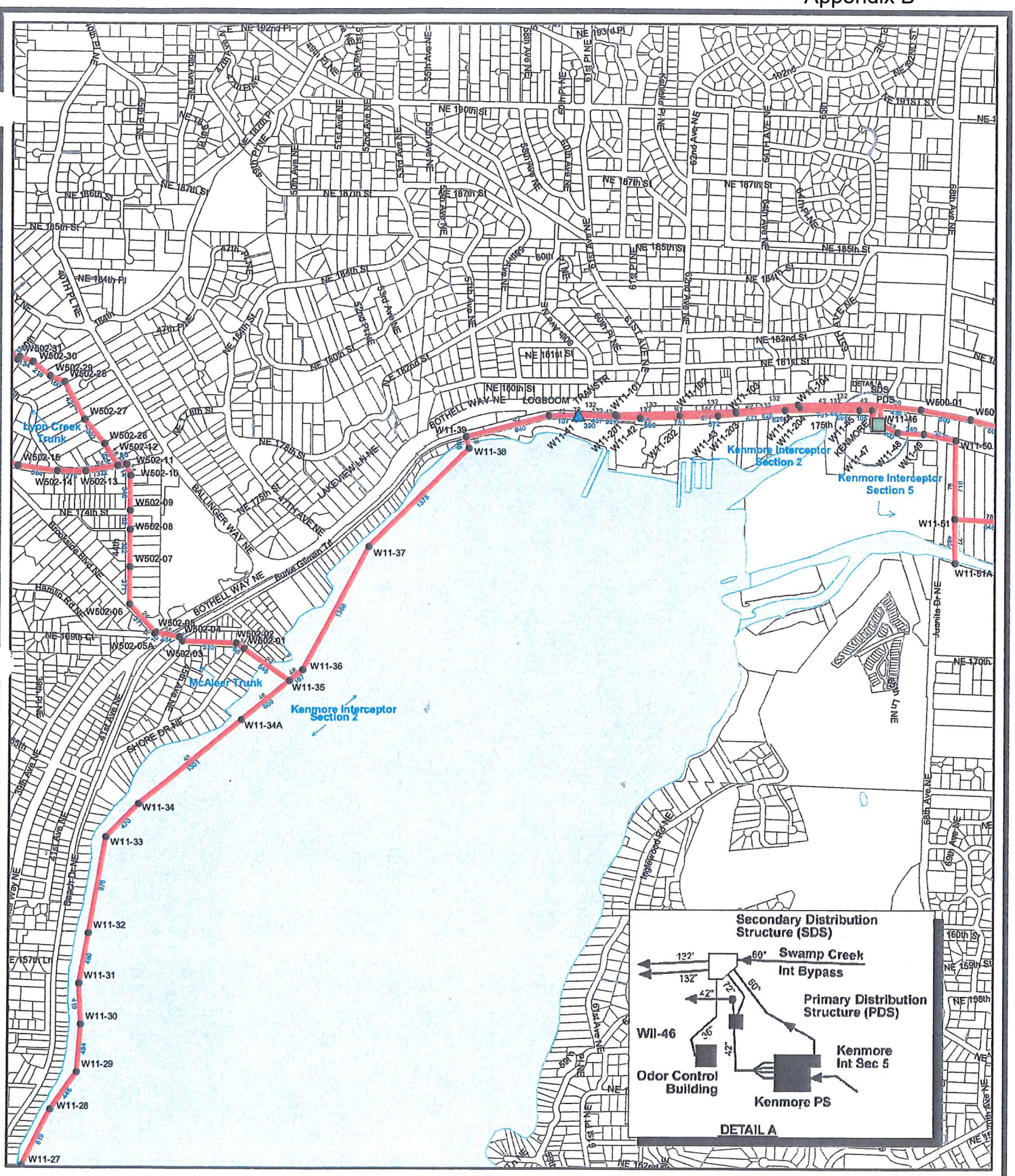
File Name: \\dnrp1\projects\wtd\projects\legal\projects\Lakeline_33to41_mailing.mxd
Shaun O'Neil 20100716

Creeks
KC_WTD Manholes
KC-WTD Conveyance
Project Area

Kenmore Lakeline Lakebed Analysis
August 2010



Kenmore Interceptor Section 2 B

WW*KENMR

500 0 500 1000 Feet

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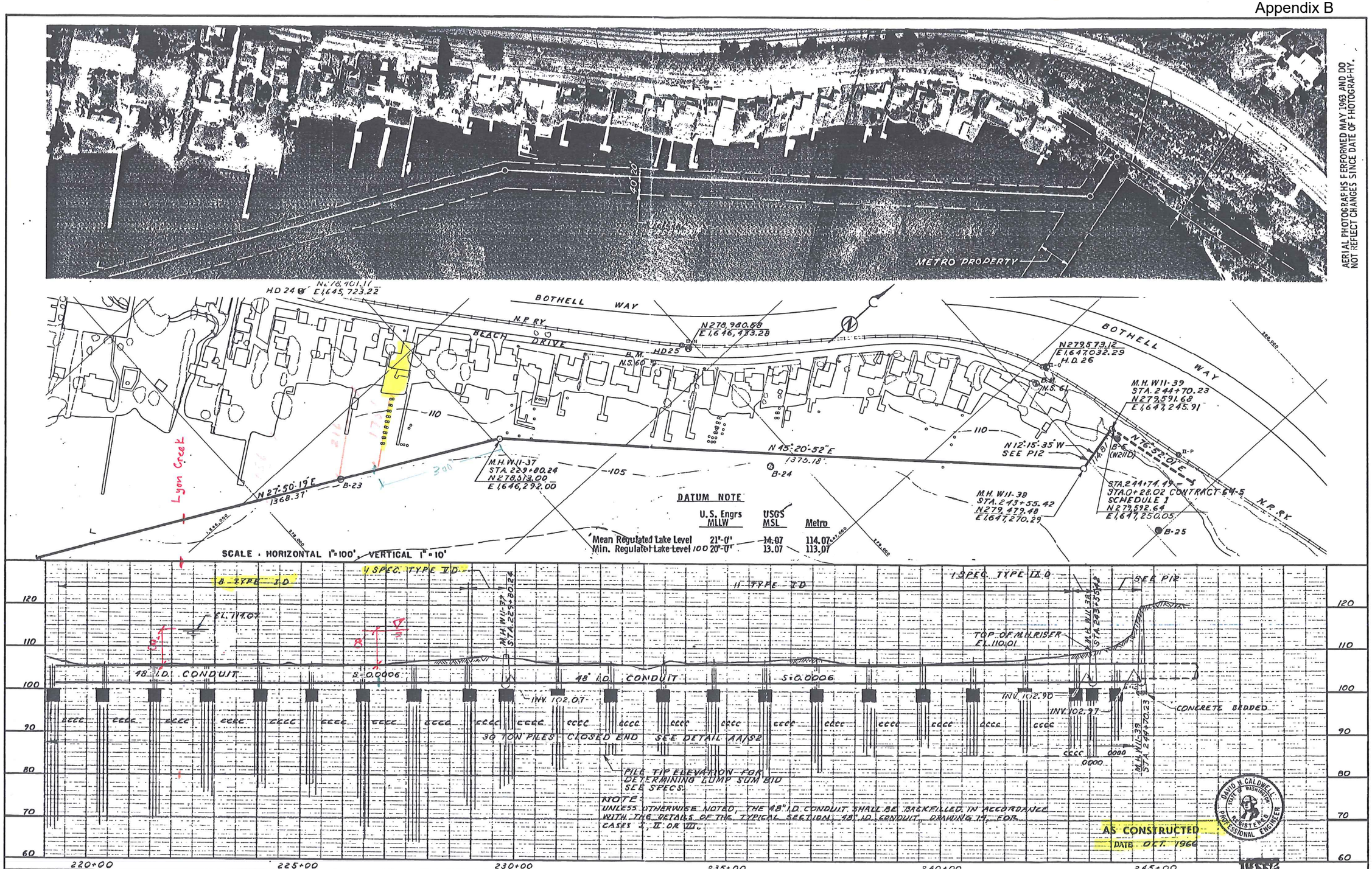
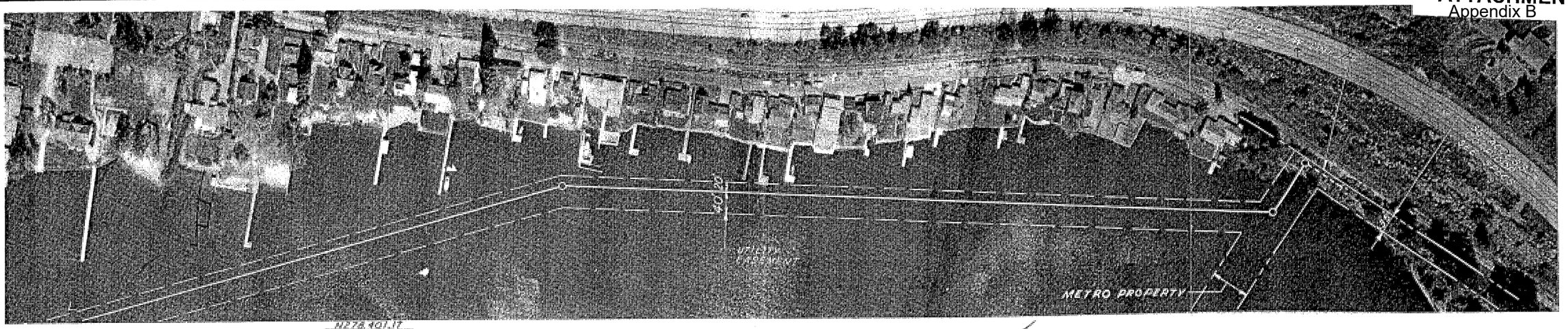
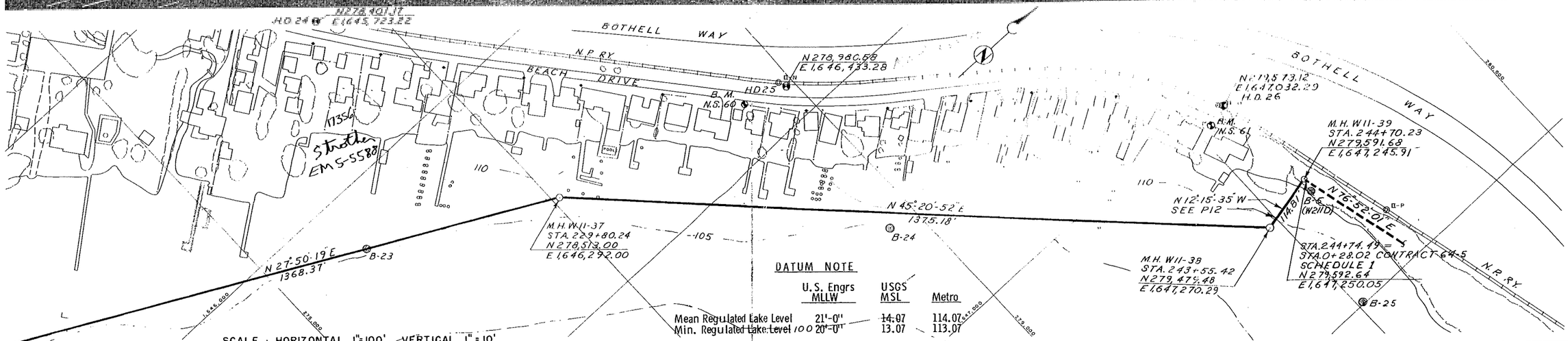

METRO PROPERTY
AERIAL PHOTOGRAPHS PERFORMED MAY 1963 AND DO NOT REFLECT CHANGES SINCE DATE OF PHOTOGRAPHY.
BOTHELL WAY
N.P. RY.
BEACH DRIVE
HD 24
N 278,901.11
E 1,645,723.22
N 278,980.66
E 1,646,433.28
B.M. HD25
N.S. 66
N279,573.12
E1,647,032.29
H.D. 26
N.S. 61
M.H. W11-39
STA. 244+70.23
N279,591.68
E1,647,245.91
N 45°-20'-52" E
1375.18'
N 12°-15'-35" W
SEE P12
N 76°-52'-01" E
B-6
(W211D)
STA. 244+74.49
STA. 0+28.02 CONTRACT 64-5
SCHEDULE 1
N 278,592.64
E 1,647,250.05
B-25
N.P. RY.
M.H. W11-38
STA. 243+55.42
N279,479.48
E1,647,270.29
B-24
M.H. W11-37
STA. 229+80.24
N278,513.00
E 1,646,292.00
N 27°-50'-19" E
1368.37'
B-23
Lyon Creek
110
105
DATUM NOTE
U.S. Engrs MLLW
USGS MSL
Metro
Mean Regulated Lake Level 21'-0" 14.07 114.07
Min. Regulated Lake Level 20'-0" 13.07 113.07
SCALE - HORIZONTAL 1" = 100', VERTICAL 1" = 10'
B TYPE I.D.
U SPEC. TYPE II.D.
II TYPE I.D.
I SPEC. TYPE II.D.
SEE P12
EL. 114.07
M.H. W11-37 STA. 229+80.24
M.H. W11-38 STA. 243+55.42
TOP OF M.H. RISER EL. 110.01
48" I.D. CONDUIT
S = 0.0006
INV. 102.07
INV. 102.90
INV. 102.97
CONCRETE BEDDED
M.H. W11-39 STA. 244+70.23
30 TON PILES CLOSED END SEE DETAIL AA/S2
PILE TIP ELEVATION FOR DETERMINING LUMP SUM BID SEE SPECS.
NOTE - UNLESS OTHERWISE NOTED, THE 48" I.D. CONDUIT SHALL BE BACKFILLED IN ACCORDANCE WITH THE DETAILS OF THE TYPICAL SECTION, 48" I.D. CONDUIT, DRAWING 14, FOR CASES I, II OR III.
AS CONSTRUCTED
DATE OCT. 1966
DAVID M. CALDWELL STATE OF WASHINGTON REGISTERED PROFESSIONAL ENGINEER
120
110
100
90
80
70
60
220+00
225+00
230+00
235+00
240+00
245+00
DESIGNED JFL
DRAWN DLO
CHECKED JFL
METROPOLITAN ENGINEERS
BROWN AND CALDWELL
CAREY AND KRAMER
HILL AND INGMAN
R.W BECK AND ASSOCIATES
MUNICIPALITY OF METROPOLITAN SEATTLE
SUBMITTED Design Engineer - Metropolitan Engineers
RECOMMENDED Project Engineer - Metropolitan Engineers
APPROVED Chief Engineer - Metropolitan Engineers
APPROVED For Metropolitan Engineers
APPROVED For Municipality of Metropolitan Seattle
SCALE AS NOTED
FILE W211C
DATE AUG. 1964
WEST POINT SYSTEM
KENMORE INTERCEPTOR SECTION 2
STA. 219+50 TO STA. 244+70.23 (END)
DRAWING NUMBER P9
SHEET NUMBER 22 OF 27

AERIAL PHOTOGRAPHS PERFORMED MAY 1963 AND DO NOT REFLECT CHANGES SINCE DATE OF PHOTOGRAPHY.

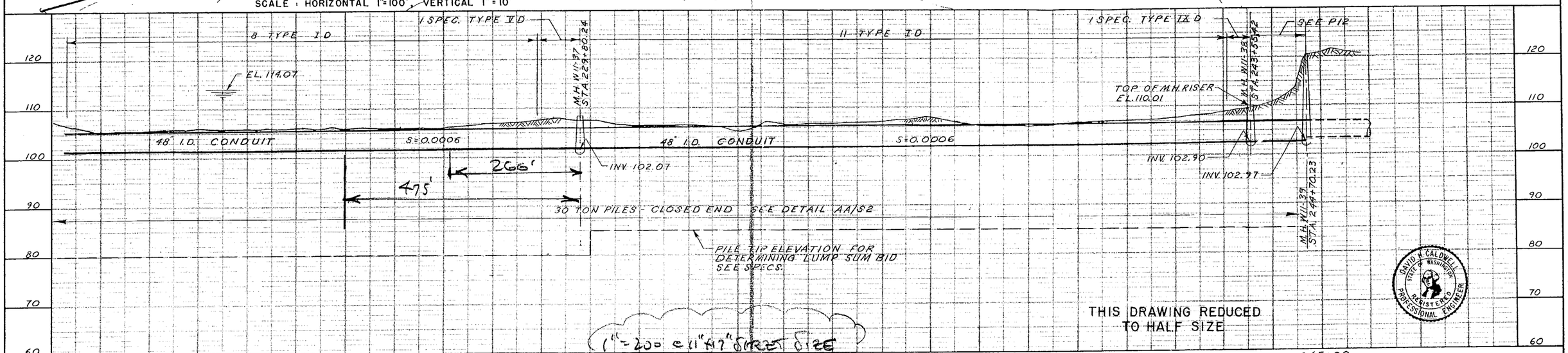




DATUM NOTE

	U.S. Engrs MLLW	USGS MSL	Metro
Mean Regulated Lake Level	21'-0"	~~14.07~~	114.07
Min. Regulated Lake Level	20'-0"	13.07	113.07

SCALE : HORIZONTAL 1" = 100', VERTICAL 1" = 10'



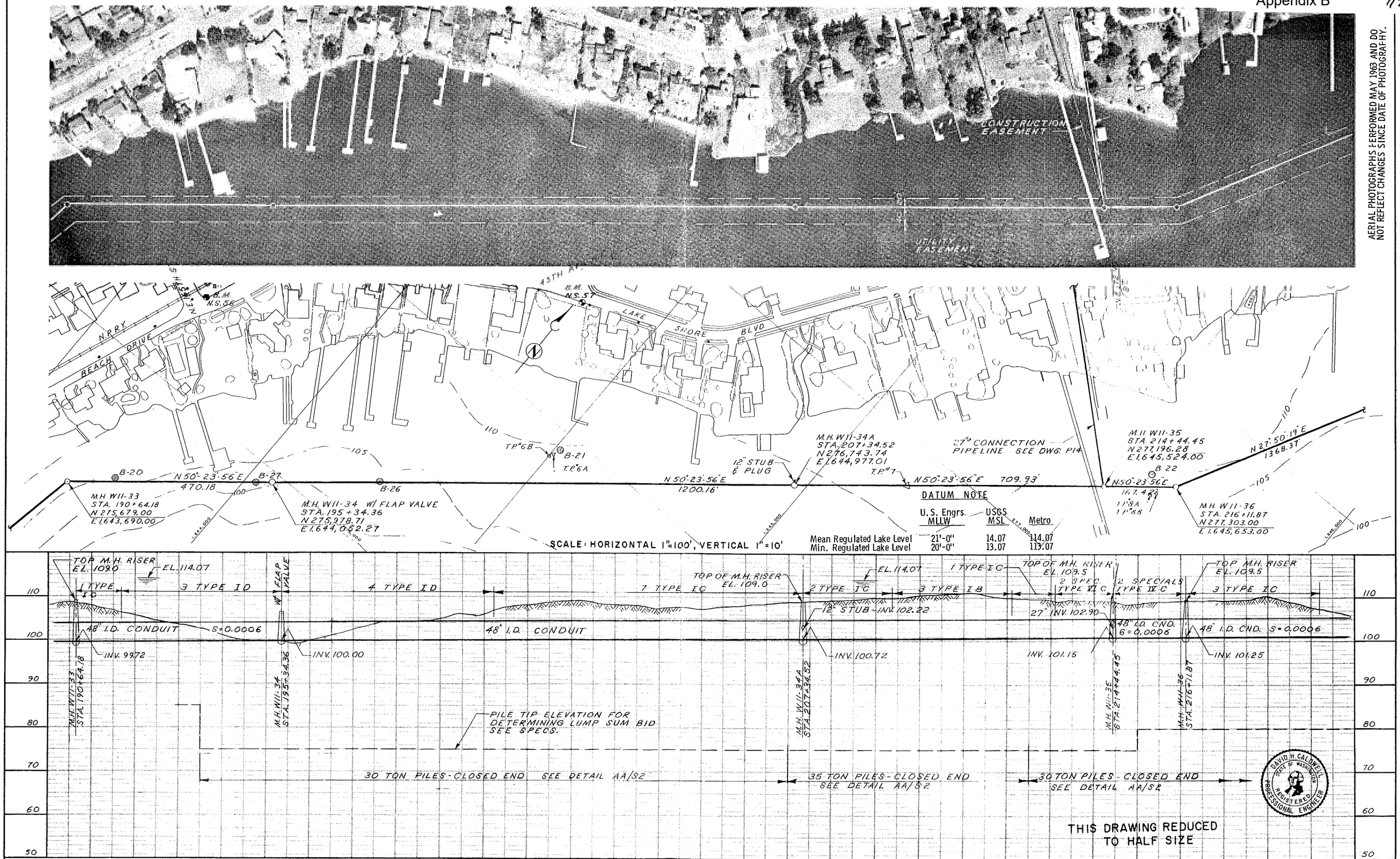
THIS DRAWING REDUCED TO HALF SIZE

1" = 20' = 11" x 17" SIZE

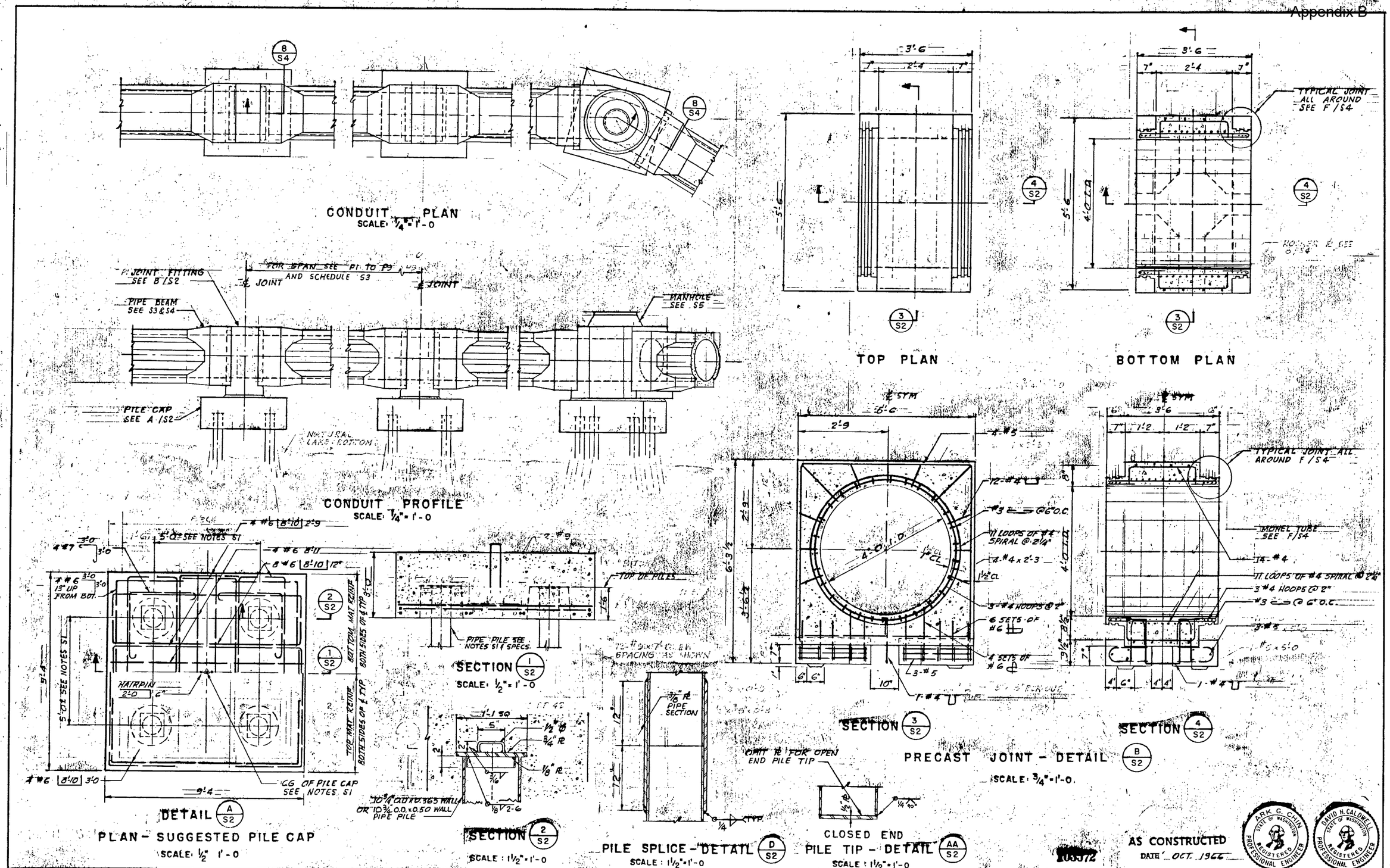
DAVID H. CALDWELL STATE OF WASHINGTON REGISTERED PROFESSIONAL ENGINEER

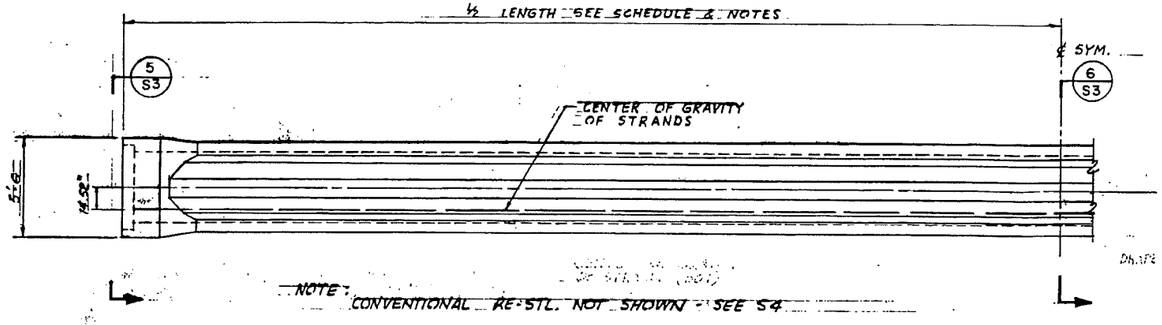
DESIGNED JFL DRAWN DLO CHECKED	METROPOLITAN ENGINEERS BROWN AND CALDWELL CAREY AND KRAMER LAWRENCE A. HARMAN JOHN W. BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED Design Engineer – Metropolitan Engineers RECOMMENDED Project Engineer – Metropolitan Engineers APPROVED Chief Engineer – Metropolitan Engineers APPROVED For Metropolitan Engineers APPROVED For Municipality of Metropolitan Seattle	SCALE AS NOTED DATE AUG. 1964	FILE W211C	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 STA. 219+50 TO STA. 244+70.23 (END)	DRAWING NUMBER P9 SHEET NUMBER 22 OF 27

AERIAL PHOTOGRAPHS PERFORMED MAY 1963 AND DO NOT REFLECT CHANGES SINCE DATE OF PHOTOGRAPHY.



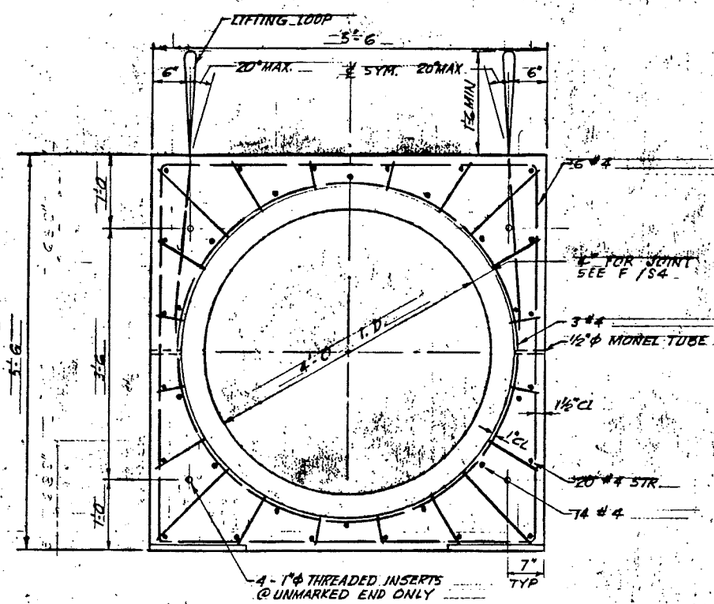
DESIGNED U.F.L. DRAWN D.L.C. CHECKED	METROPOLITAN ENGINEERS BROWN AND CALDWELL CAREY AND KRAMER PHILLIPS AND THOMAS W BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE				FILE W211C DATE AUG. 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 STA. 191+00 TO STA. 219+50
		SUBMITTED Design Engineer - Metropolitan Engineers	RECOMMENDED Project Engineer - Metropolitan Engineers	APPROVED Chief Engineer - Metropolitan Engineers	APPROVED For Metropolitan Engineers	APPROVED For Municipality of Metropolitan Seattle	SCALE AS NOTED	DRAWING NUMBER P 8 SHEET NUMBER 21 OF 27


CONDUIT PLAN
SCALE: 1/4" = 1'-0
TOP PLAN
BOTTOM PLAN
TYPICAL JOINT ALL AROUND SEE F/S4
CONDUIT PROFILE
SCALE: 1/4" = 1'-0
JOINT FITTING SEE B/S2
PIPE BEAM SEE S3 & S4
FOR SPAN SEE P1 TO P9 AND SCHEDULE S3
MANHOLE SEE S5
PILE CAP SEE A/S2
NATURAL LAKE BOTTOM
TOP OF PILES
PIPE PILE SEE NOTES S1 & SPECS.
SECTION 1/S2
SCALE: 1/2" = 1'-0
HAIRPIN
CG OF PILE CAP SEE NOTES S1
DETAIL A/S2
PLAN - SUGGESTED PILE CAP
SCALE: 1/2" = 1'-0
10 3/4" O.D. x 0.365 WALL OR 10 3/4" O.D. x 0.50 WALL PIPE PILE
SECTION 2/S2
SCALE: 1 1/2" = 1'-0
3/8" R PIPE SECTION
PILE SPLICE - DETAIL D/S2
SCALE: 1 1/2" = 1'-0
OMIT R FOR OPEN END PILE TIP
CLOSED END PILE TIP - DETAIL AA/S2
SCALE: 1 1/2" = 1'-0
SECTION 3/S2
SECTION 4/S2
PRECAST JOINT - DETAIL B/S2
SCALE: 3/4" = 1'-0
MONEL TUBE SEE F/S4
AS CONSTRUCTED
DATE OCT. 1966
DESIGNED MCD
DRAWN WG
CHECKED AGC
METROPOLITAN ENGINEERS
BROWN AND CALDWELL
CAREY AND KRAMER
HILL AND INGMAN
R.W. BECK AND ASSOCIATES
MUNICIPALITY OF METROPOLITAN SEATTLE
SUBMITTED Design Engineer - Metropolitan Engineers
RECOMMENDED Project Engineer - Metropolitan Engineers
APPROVED Chief Engineer - Metropolitan Engineers
APPROVED For Metropolitan Engineers
APPROVED For Municipality of Metropolitan Seattle
SCALE AS NOTED
FILE W.211C
DATE AUG 1964
WEST POINT SYSTEM
KENMORE INTERCEPTOR SECTION 2
PRECAST JOINT AND SUGGESTED PILE CAP
PLANS, SECTIONS AND DETAILS
DRAWING NUMBER S2
SHEET NUMBER 5 OF 27



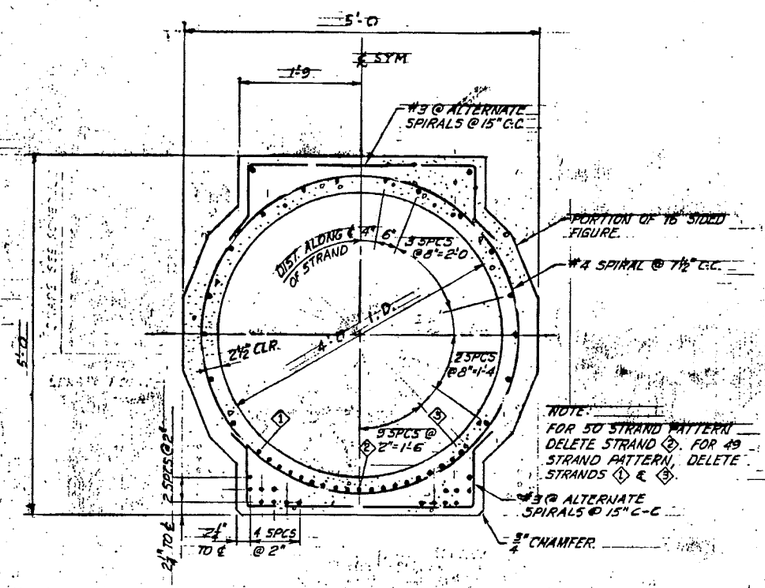
ELEVATION - PRESTRESSED PIPE BEAM - DETAIL (C / S3)

NO SCALE



END SECTION (5 / S3)

SCALE: 1" = 1'-0



CENTER SECTION (6 / S3)

SCALE: 1" = 1'-0

PRESTRESSED PIPE BEAM SCHEDULE

BEAM DATA			½ ϕ STRAND DATA														
				NUMBER OF STRANDS PER ROW													
TYPE	CLASS	LENGTH	TOTAL REQ'D	A	B	C	D	E	F	G	H	J	K	L	M	N	P	DRAPE AT ℄
I	A B C D	80.0' 90.0' 100.0' 120.0'	60		4	4	2			2			4	6	10	12	16	33"
II	A B C D	74.0' - 80.0' 82.0' - 90.0' 93.0 - 100.0' 110.0' - 120.0'	60		4	4	2			2			4	6	10	12	16	33"
III	A B C D	67.0' - 74.0' 75.0' - 82.0' 85.0' - 93.0' 100.0 - 110.0'	48			4		4	2				6		10	6	16	33"
IV	A B C D	61.0' - 67.0' 68.0' - 75.0' 77.0' - 85.0' 90.0' - 100.0'	40			4	4						4	4	8		16	33"
V	A B C D	54.0' - 61.0' 60.0' - 68.0' 68.0' - 77.0' 80.0' - 90.0'	32	2	4						2		4		4		16	32"
VI	A B C D	47.0' - 54.0' 52.0' - 60.0' 59.0' - 68.0' 70.0' - 80.0'	26			4	2								4		16	29"
VII	A B C D	41.0' - 47.0' 45.0' - 52.0' 51.0' - 59.0' 60.0' - 70.0'	20	4										2		6	8	28"
VIII	A B C D	33.0' - 41.0' 37.0' - 45.0' 42.0' - 51.0' 50.0' - 60.0'	14	2							2	2	2				6	38"
IX	A B C D	30.0' - 33.0' 30.0' - 37.0' 30.0' - 42.0' 50.0' - 50.0'	10	2										2			6	28"

NOTE:
STRAND DATA VOID

PRESTRESSED CONCRETE NOTES

CONCRETE DESIGN STRESSES:
f'c = 6000 PSI, ULTIMATE STRENGTH @ 28 DAYS
f'ci = 5000 PSI (AT TRANSFER)

PRESTRESSING STRANDS:
f's = 250,000 PSI, ULTIMATE
f'si = 180,000 PSI, INITIAL TENSION
fs = 150,000 PSI, AFTER LOSSES

GENERAL NOTES:

1. PLACE STRANDS SYMMETRICALLY ABOUT THE CENTER LINE BEGINNING AT THE EXTERIOR ROW.
2. TYPE I PIPE BEAM LENGTH SHALL BE AS SHOWN IN SCHEDULE.
3. TYPE II THROUGH TYPE IX PIPE BEAM LENGTHS SHALL BE DETERMINED BY THE CONTRACTOR.
4. LENGTHS AND DETAILS OF PIPE BEAMS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO FABRICATION.
5. IN PLACE JOINT TOLERANCE SHALL BE AS INDICATED ON F/S4. DETAILS, INCLUDING TOLERANCES, OF JOINT SHALL BE SUBMITTED TO THE ENGINEER FOR ACCEPTANCE.
6. ALL EXPOSED STRAND ENDS SHALL BE CUT FLUSH WITH THE CONCRETE SURFACE AND COATED WITH COAL TAR EPOXY. MINIMUM THICKNESS 25 MILS.

[redacted] AS CONSTRUCTED
DATE OCT. 1966

ARK G. CHIN — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER
DAVID H. CALDWELL — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

DESIGNED MCD DRAWN WG CHECKED KLW	METROPOLITAN ENGINEERS BROWN AND CALDWELL — CAREY AND KRAMER HILL AND INGMAN — R W BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED Design Engineer - Metropolitan Engineers; RECOMMENDED Project Engineer - Metropolitan Engineers; APPROVED Chief Engineer - Metropolitan Engineers; APPROVED For Metropolitan Engineers; APPROVED For Municipality of Metropolitan Seattle	SCALE AS NOTED	FILE W 211 C DATE AUG 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 PRESTRESSED PIPE BEAM SECTIONS, DETAIL AND SCHEDULE	DRAWING NUMBER S3 SHEET NUMBER 6 OF 27

5712668

Entered in System

UTILITY EASEMENT

THE UNDERSIGNED, hereinafter called Grantors, for themselves, their heirs, successors and assigns, and in consideration of Ninety and no/100 - - - - Dollars ($90.00) the receipt and sufficiency of which is hereby acknowledged, do by these presents convey and warrant unto the Municipality of Metropolitan Seattle, hereinafter called Municipality, its successors and assigns, a perpetual easement for the purpose of installing, constructing, operating, maintaining, repairing and replacing sewer trunk lines at a depth of more than *10* feet below the controlled low water elevation as established by the U. S. Corps of Engineers at the date of this grant over, above, across, in, along and under the following described tract of land situate in King County, State of Washington:

That portion of Lot 20 and 21, Block 5, Cedar Park Addition, Division No. 4, according to plat thereof recorded in Volume 33 of Plats, page 14, records of King County, included within a strip of land 60 feet in width lying 20 feet westerly (shoreward) and 40 feet easterly (lakeward) of the following described line:

Beginning at a point on the easterly extension of the northerly line of Section 27, Township 26 North, Range 4 East, W.M., distant South 88°11'43" East 357.19 feet along said northerly line and easterly extension thereof from the north quarter corner of said Section 27; thence North 15°16'14" West 26.97 feet; thence North 36°55'42" West 196.40 feet; thence North 58°25'07" West 286.42 feet; thence North 20°00'38" West 356.52 feet; thence North 01°18'25" West 263.07 feet; thence North 07°38'14" East 624.54 feet; thence North 17°15'00"East 657.58 feet; thence North 13°11'11" West 425.21 feet; thence North 17°24'03" West 1271.65 feet; thence North 16°27'59" East 589.16 feet; thence North 30°03'26" West 227.61 feet; thence North 42°06'59" West 857.39 feet; thence North 04°49'15" West 103.37 feet to point of terminus on the easterly extension of the northerly line of Section 22, Township 26 North, Range 4 East, W.M., said point being distant South 88°54'44" East 428.88 feet along said northerly line and easterly extension thereof from the northeast corner of the NW quarter of the NW quarter of said Section 22.

This easement is granted subject to the following terms and conditions:

1. All right, title and interest which may be used and enjoyed without interfering with the easement rights herein conveyed are reserved to the Grantors.

2. Municipality shall protect and save harmless Grantors from and against any and all claims, demands, loss, damage, expense and liability of every kind and description and for any damage to or loss or destruction of property whatsoever suffered by Grantors, their heirs, successors and assigns, or by any persons, firms or corporations, because of the installation, construction, operation, maintenance, repair and/or replacement of said sewer trunk lines.

DATED this 14th day of March, 1964.

Gladys Irene Allen

Page 1 of 2 pages

STATE OF WASHINGTON)
) ss.
COUNTY OF KING)

On this 14th day of March, 1964 before me the undersigned, a Notary Public in and for the State of Washington, duly commissioned and sworn, personally appeared

GLADYS PAINE ALLIN, a widow

to me known to be the individual__ described in and who executed the foregoing instrument, and acknowledged to me that she signed and sealed the said instrument as her free and voluntary act and deed for the uses and purposes therein mentioned.

WITNESS my hand and official seal hereto affixed the day and year in this certificate above written.

RICHARD F. MURRAY
NOTARY PUBLIC
COMMISSION EXPIRES JAN. 17, 1965
STATE OF WASHINGTON

Richard F. Murray
Notary Public in and for the State of Washington, residing at Seattle

STATE OF WASHINGTON)
) ss.
COUNTY OF KING)

On this ____ day of _____, 1964 before me the undersigned, a Notary Public in and for the State of Washington, duly commissioned and sworn, personally appeared

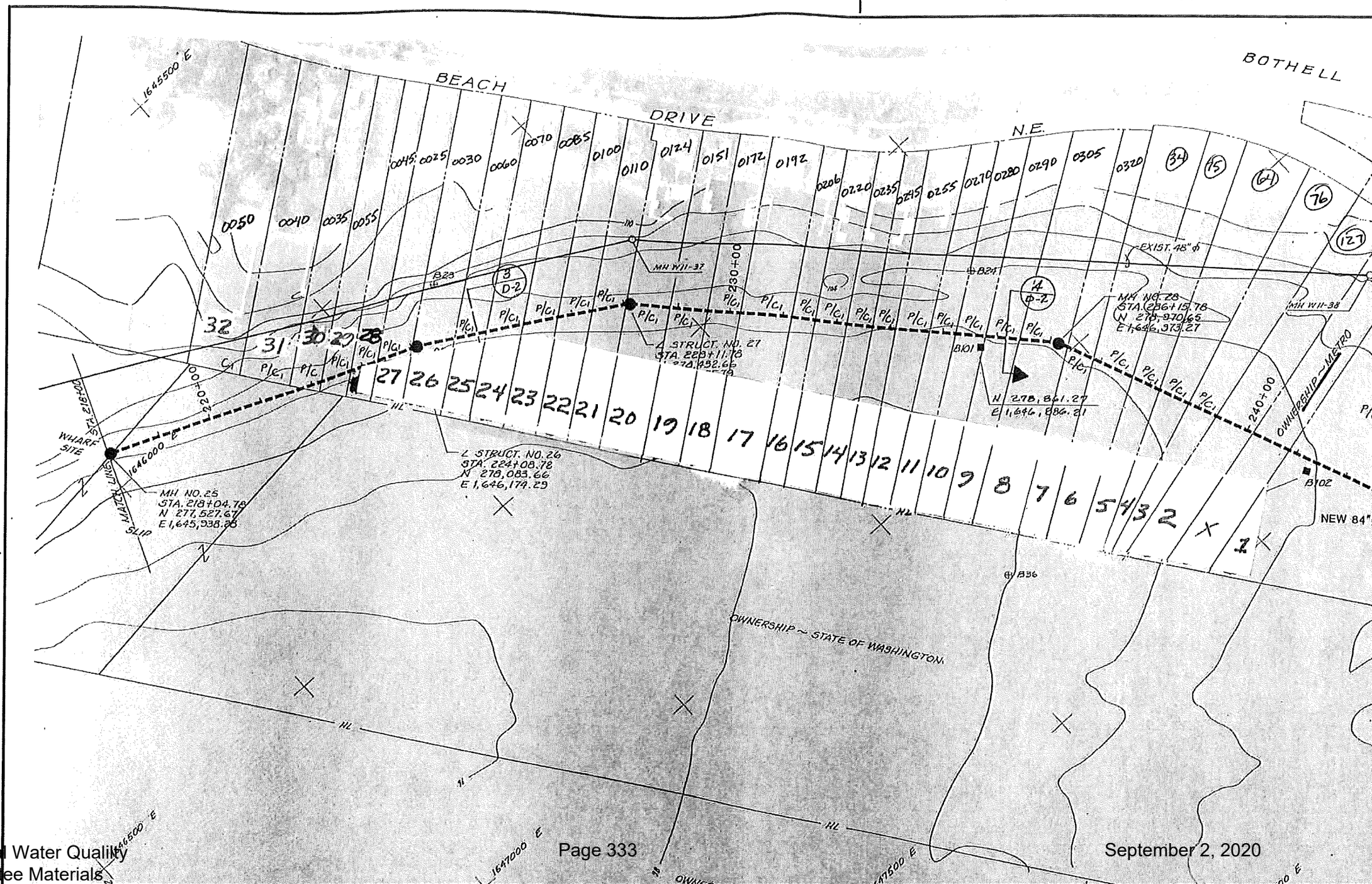
_____

to me known to be the individual__ described in and who executed the foregoing instrument, and acknowledged to me that _____ signed and sealed the said instrument as _____ free and voluntary act and deed for the uses and purposes therein mentioned.

WITNESS my hand and official seal hereto affixed the day and year in this certificate above written.

_____
Notary Public in and for the State of Washington, residing at _____

Filed for Record Mar. 19 1964 3:01 P.M.
Request of Metro

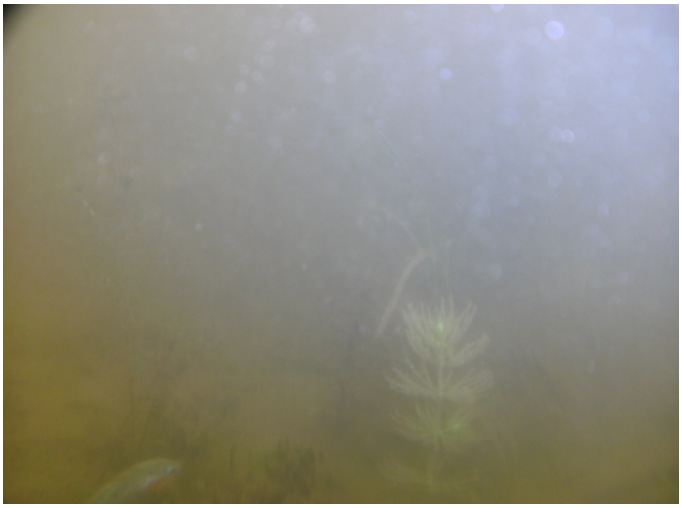

BEACH DRIVE N.E.
BOTHELL
1645500 E
1646000
1646500 E
1647000 E
1647500 E
WHARF SITE
STA. 212+00
STA. 220+00
STA. 230+00
STA. 240+00
MH NO. 25
STA. 218+04.78
N 277,527.67
E 1,645,938.38
L STRUCT. NO. 26
STA. 224+08.78
N 278,083.66
E 1,646,174.29
L STRUCT. NO. 27
STA. 229+11.78
MH NO. 28
STA. 236+15.78
N 278,970.65
E 1,646,373.27
N 278,861.27
E 1,646,886.21
MH W11-37
MH W11-38
EXIST. 48" Φ
NEW 84"
OWNERSHIP ~ METRO
OWNERSHIP ~ STATE OF WASHINGTON
HL
B23
B24
B101
B102
B36

APPENDIX B

FIELD INVESTIGATION PHOTOGRAPHS

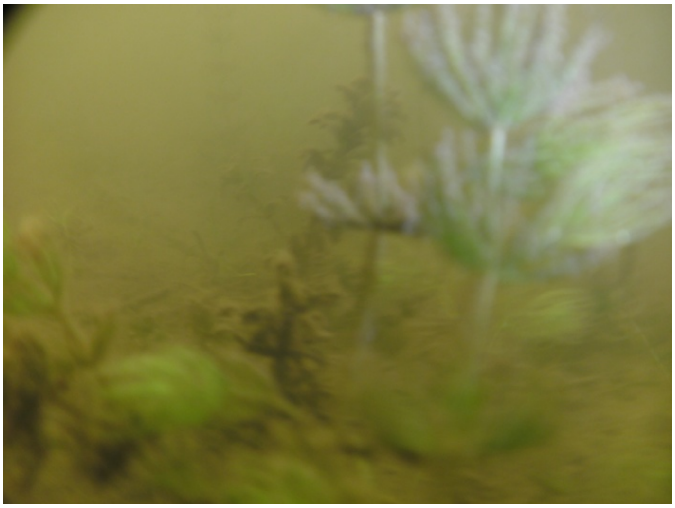
Photograph 1. Lake Line alignment, looking southwest.

Photograph 2. Survey vessel.

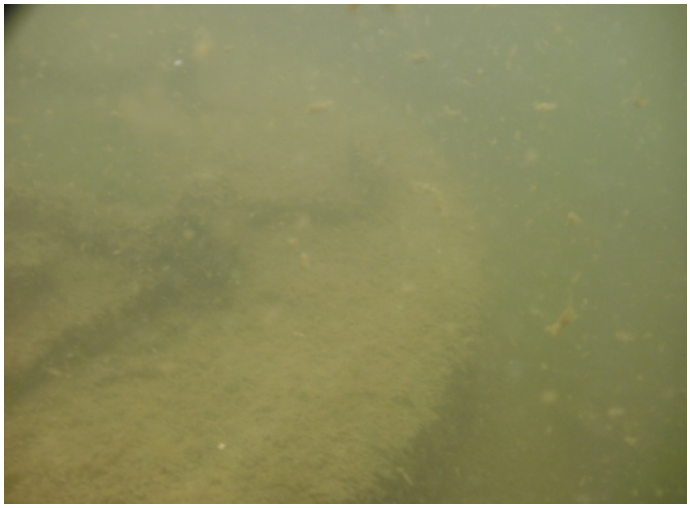


Photograph 3. Typical visibility while diving.

Photograph 4. Eurasian watermilfoil (*Myriophyllum spicatum L.*).



Photograph 5. Eurasian watermilfoil (*Myriophyllum spicatum L.*).



Photograph 6. Manhole 35.

SoundEarth Strategies	Project No.:	0773-001	**FIELD INVESTIGATION PHOTOGRAPHS**
	Date:	July 15, 2011	Kenmore Lake Line Lakebed
	Drawn By:	J. Lally	Sedimentation Analysis
	Chk By:	R. Bixby	Lake Washington
	File ID:	Site Photographs_.docx	King County, Washington

Photograph 7. Manhole 35 lifting eye.

Photograph 8. Facing northwest at 17364 Beach Drive Northeast residence.

Photograph 9. Facing south at Manhole 35.

Photograph 10. Representative core sample (Sample 2B). Top of core is at right.

Photograph 10. Representative core sample (Sample 4A, shoreward of Lake Line). Top of core is at right.

Photograph 11. Representative core sample (Sample 4B, lakeward of Lake Line). Top of core is at right.

SoundEarth Strategies	Project No.: 0773-001 Date: July 15, 2011 Drawn By: J. Lally Chk By: R. Bixby File ID: Site Photographs_.docx	**FIELD INVESTIGATION PHOTOGRAPHS** Kenmore Lake Line Lakebed Sedimentation Analysis Lake Washington King County, Washington

APPENDIX C

HWA GEOSCIENCES, INC. MATERIAL LABORATORY REPORT

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering · Hydrogeology · Geoenvironmental · Planning & Permitting · Inspection & Testing

September 15, 2011
HWA Project No. 2011-068-T100

Lally Consulting, Inc.
2811 Fairview Avenue East, Suite 1004
Seattle, Washington 98102

Attention: Mr. John Lally, P.E.

Subject: **Materials Laboratory Report**
Grain Size Testing
Lakeline Lakebed Analyses
Kenmore, Washington

Dear Mr. Lally;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached reports. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: The subject samples were delivered to our laboratory on June 17, 2011 by Lally Consulting personnel. The samples were delivered in small sealable plastic bags. Each bag was designated with a number and a letter depicting the sample location and few samples were also labeled with the depth of sampling.

MOISTURE CONTENT OF SOIL: The moisture content of the soil samples (percent by dry mass) were determined in general accordance with ASTM D 2216. Sample "*2-B 9-13in*" was composed of woody organics and did not contain enough material to conduct a grain size analysis. The moisture content of this sample was determined as **732.8%.** The results of the remaining samples are shown on the attached Figures.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle distribution of material in general accordance with ASTM D422. The results are summarized on the attached Grain Size Distribution reports, which also provide information regarding the classification of the sample and the moisture content at the time of testing.

21312 30th Drive SE
Suite 110
Bothell, WA 98021.7010

Tel: 425.774.0106
Fax: 425.774.2714
www.hwageo.com

September 15, 2011
HWA Project No. 2011-068-T100

CLOSURE: Experience has shown that test values on soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested samples may represent. HWA also makes no warranty as to how representative either the samples tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

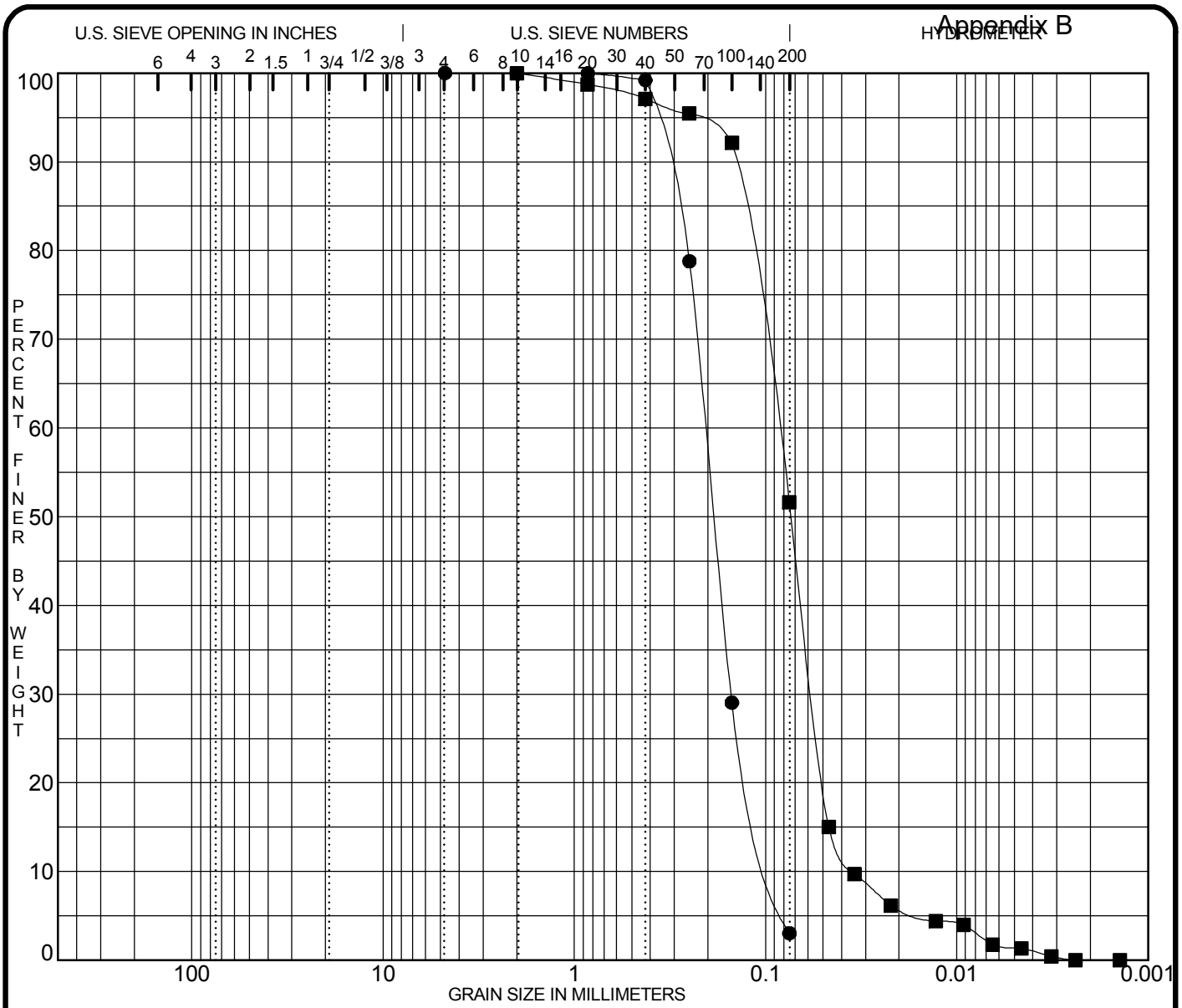
HWA GEOSCIENCES INC.

Harold Benny
Materials Laboratory Manager

Steven E. Greene, L.G., L.E.G.
Vice President

Attachments:

Figures 1-11 Gradation Curves



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**1-A**	**0.0 -**	**poorly graded SAND**	**27**				**1.23**	**2.3**
■	**1-B**	**0.0 -**	**sandy SILT**	**57**				**1.06**	**2.5**

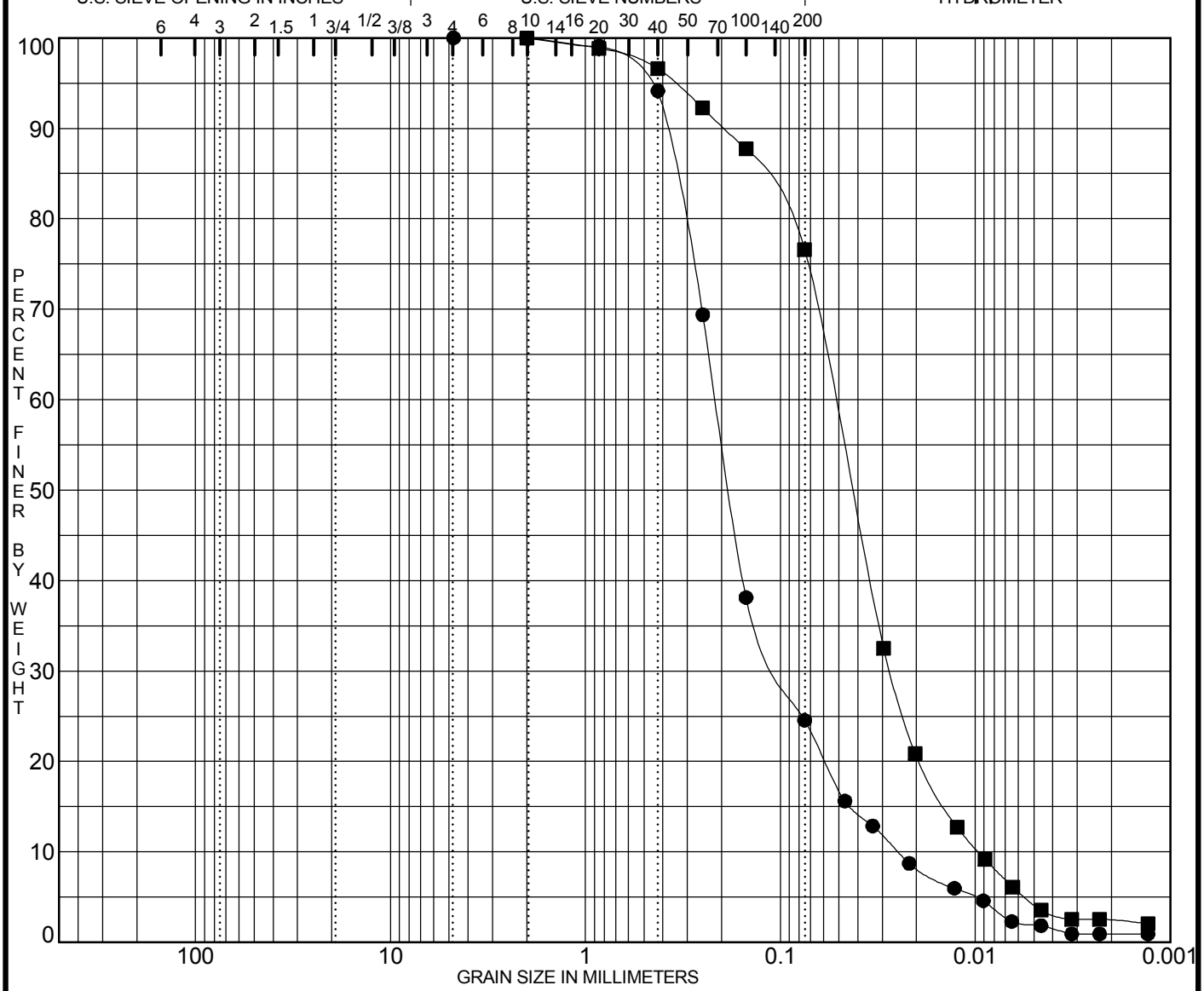
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**1-A**	**0.0**	**0.21**	**0.19**	**0.151**	**0.0903**	**0.0**	**97.0**	**3.0**	
■	**1-B**	**0.0**	**0.09**	**0.07**	**0.057**	**0.0348**	**0.0**	**48.4**	**51.6**	**0.0**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**2-A**	**0.0 -**	**silty SAND with organics**	**81**				**1.84**	**8.6**
■	**2-B**	**0.0 - 0.8**	**SILT with sand**	**103**				**1.46**	**5.5**

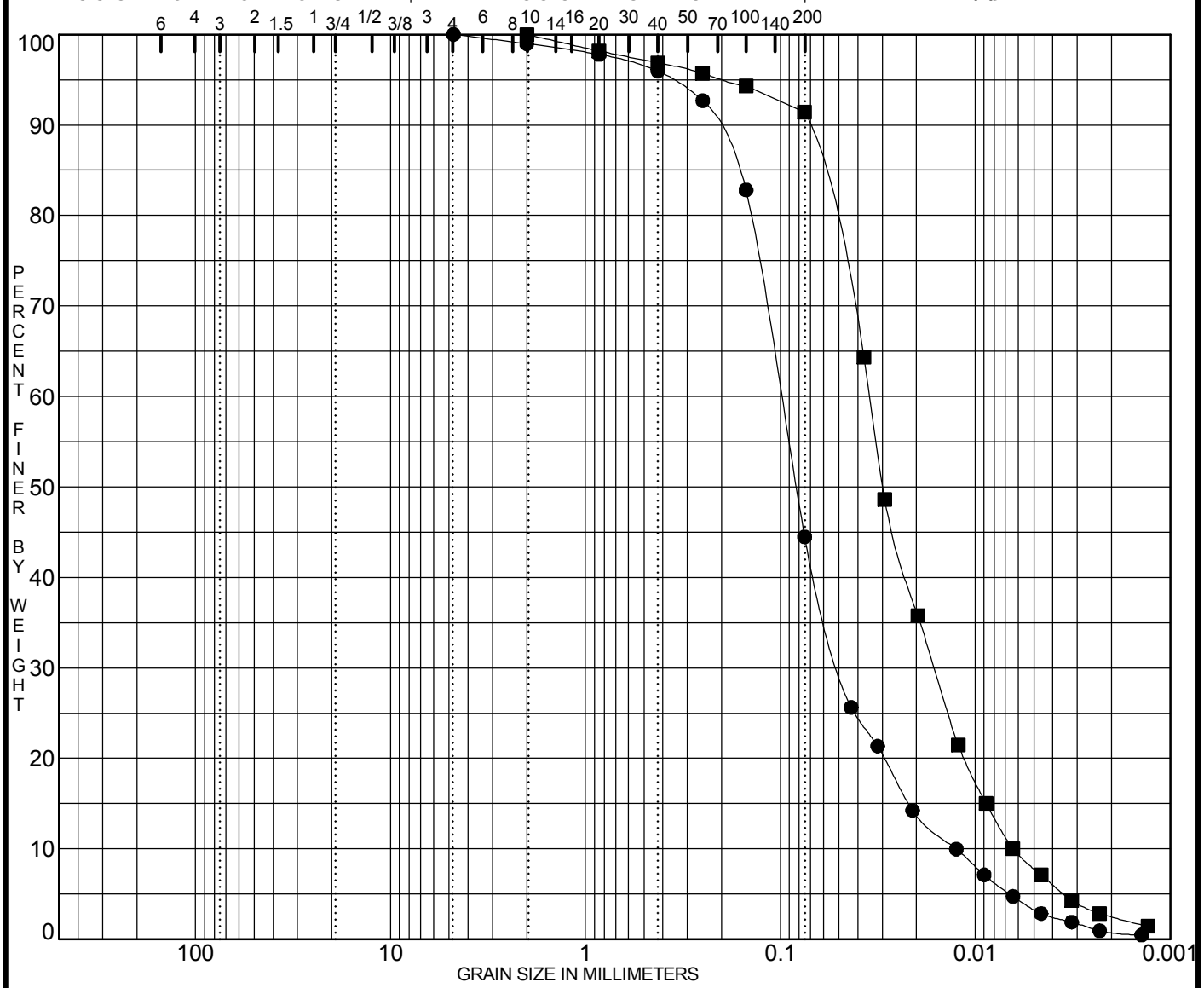
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**2-A**	**0.0**	**0.21**	**0.18**	**0.099**	**0.0249**	**0.0**	**75.5**	**23.6**	**0.9**
■	**2-B**	**0.0**	**0.05**	**0.04**	**0.027**	**0.0096**	**0.0**	**23.4**	**74.2**	**2.4**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**3-A**	**0.0 -**	**silty SAND with organics**	**88**				**1.94**	**7.9**
■	**3-B**	**0.0 -**	**SILT with organics**	**157**				**1.19**	**5.4**

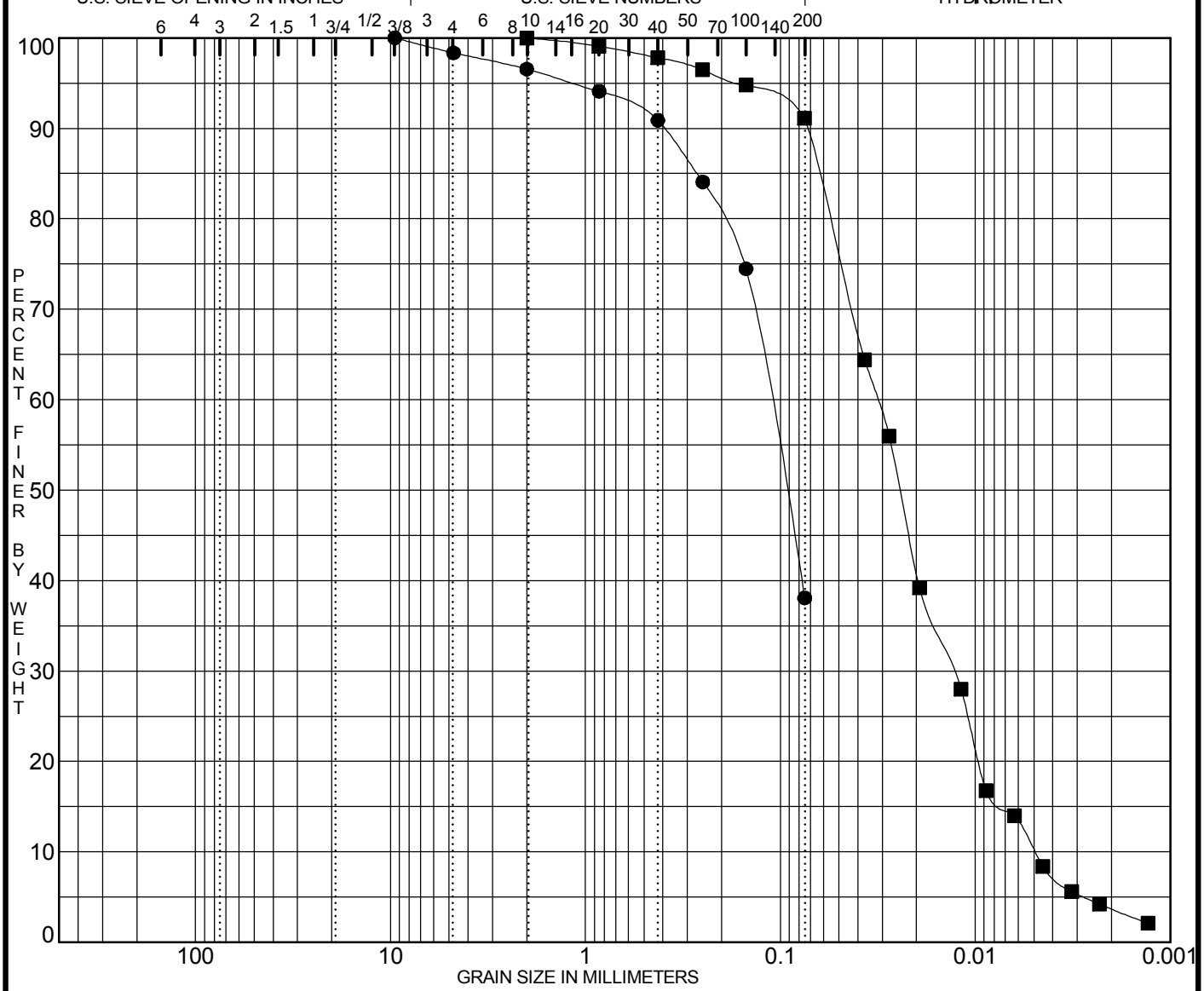
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**3-A**	**0.0**	**0.10**	**0.08**	**0.049**	**0.0126**	**0.0**	**55.5**	**43.7**	**0.8**
■	**3-B**	**0.0**	**0.03**	**0.03**	**0.016**	**0.0064**	**0.0**	**8.6**	**88.9**	**2.5**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**4-A**	**0.0 - 0.3**	**silty SAND with organics**	**92**					
■	**4-A**	**0.3 - 1.4**	**SILT**	**176**				**1.06**	**6.4**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**4-A**	**0.0**	**0.11**	**0.09**			**1.7**	**60.3**	**38.1**	
■	**4-A**	**0.3**	**0.03**	**0.02**	**0.013**	**0.0050**	**0.0**	**8.9**	**87.4**	**3.7**

PROJECT **Lakeline Lakebed Analyses -**

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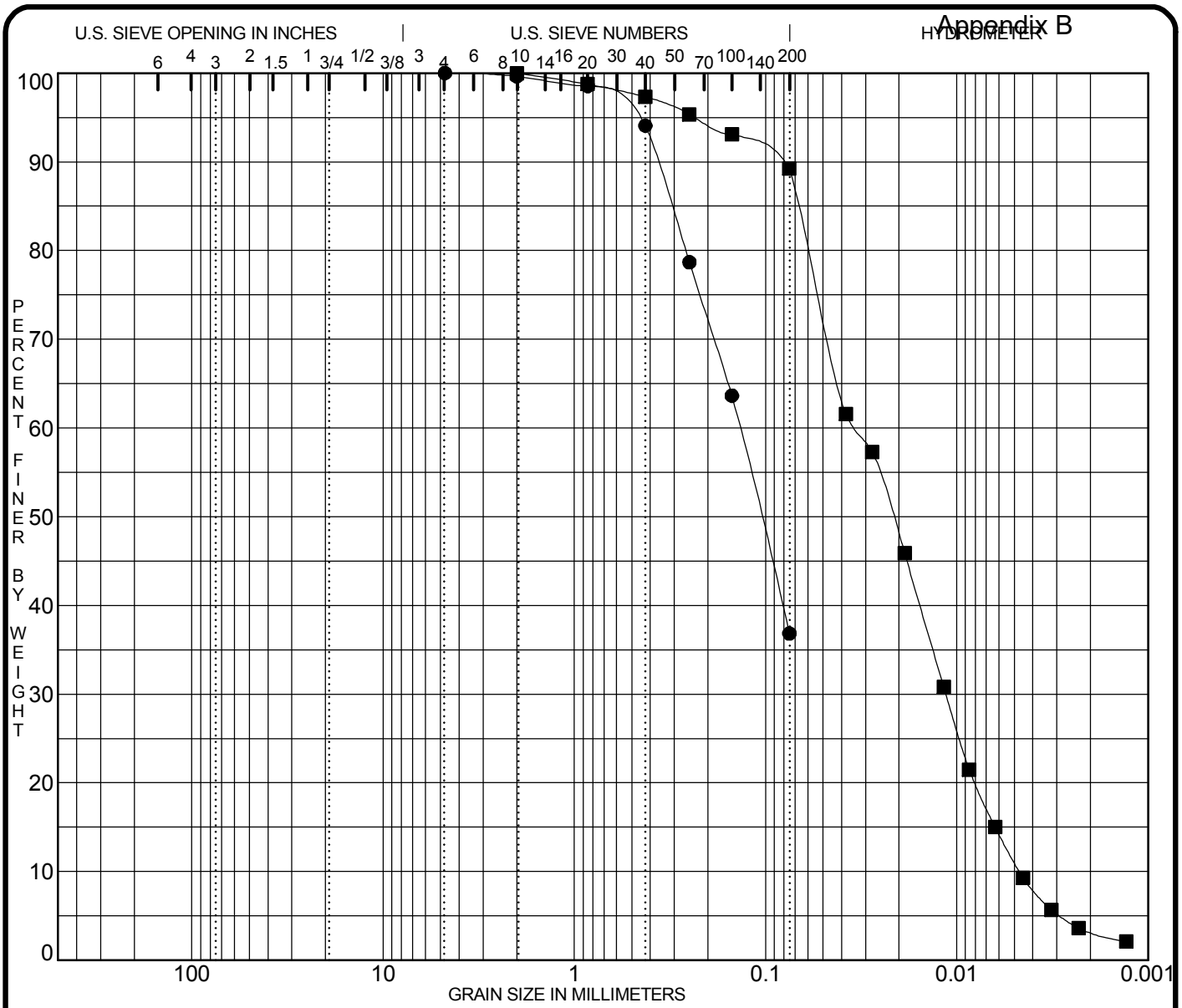
HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**4-B**	**0.0 - 0.3**	**silty SAND with organics**	**84**					
■	**4-B**	**0.3 - 1.9**	**SILT with organics**	**212**				**0.82**	**7.2**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**4-B**	**0.0**	**0.14**	**0.11**			**0.0**	**63.2**	**36.8**	
■	**4-B**	**0.3**	**0.03**	**0.02**	**0.011**	**0.0047**	**0.0**	**10.8**	**86.0**	**3.2**

PROJECT **Lakeline Lakebed Analyses -**

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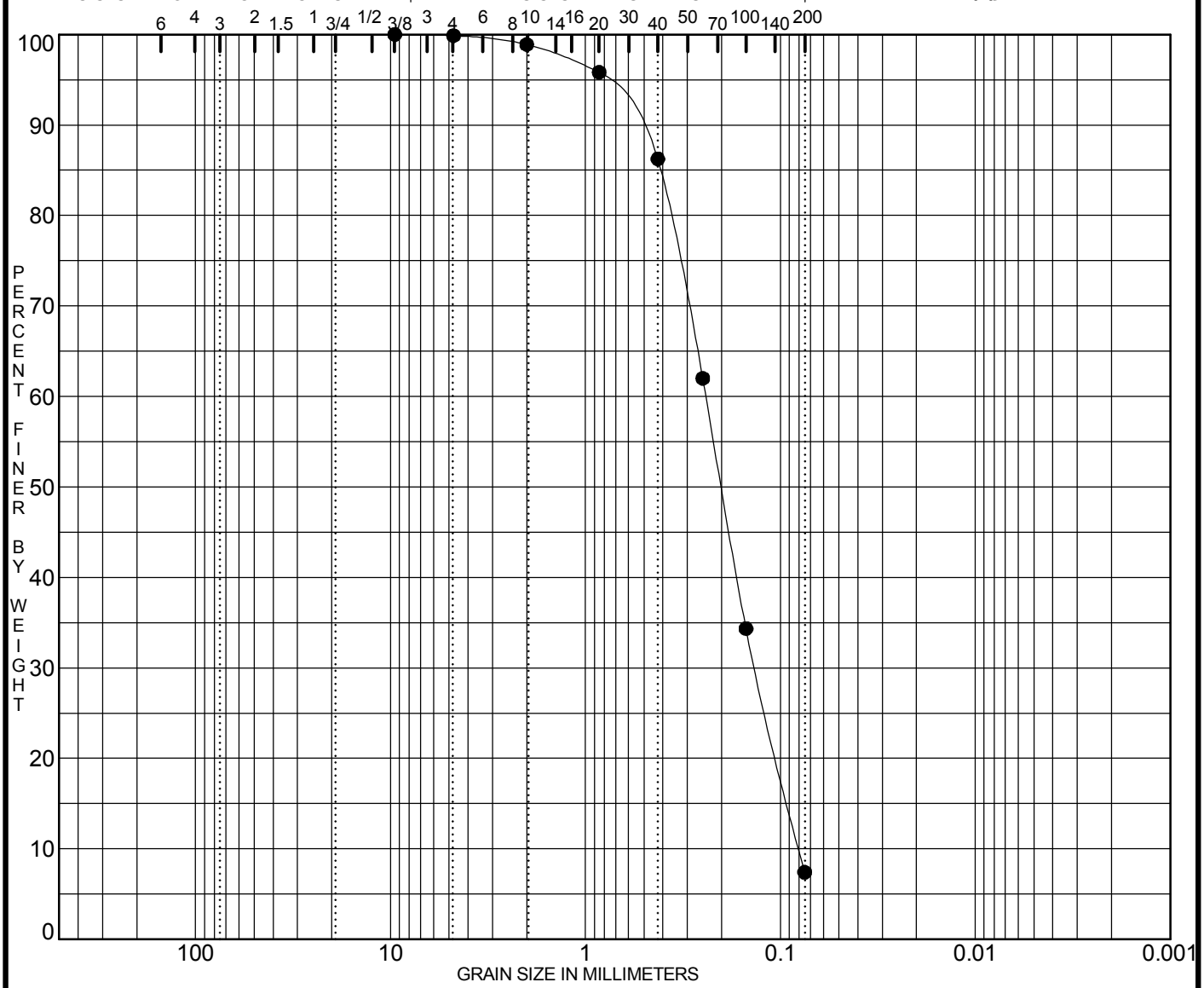

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**5-A**	**0.0 -**	**poorly graded SAND with silt**	**32**				**0.93**	**3.0**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**5-A**	**0.0**	**0.24**	**0.20**	**0.134**	**0.0802**	**0.1**	**92.5**	**7.4**	

PROJECT **Lakeline Lakebed Analyses -**

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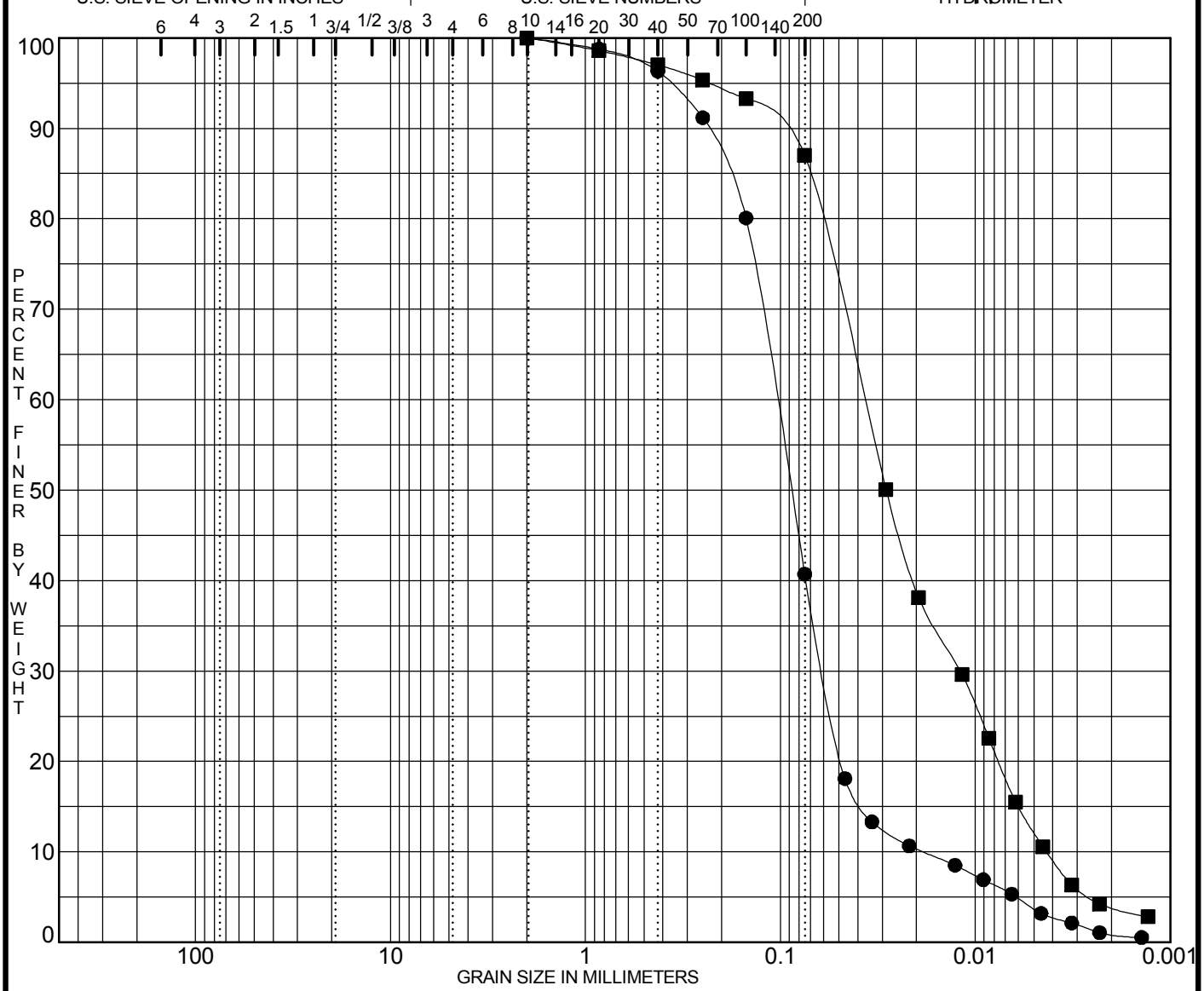

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**5-B**	**0.0 - 0.8**	**silty SAND with organics**	**86**				**1.84**	**5.7**
■	**5-B**	**0.8 - 2.3**	**SILT with organics**	**202**				**0.90**	**8.6**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**5-B**	**0.0**	**0.11**	**0.09**	**0.060**	**0.0185**	**0.0**	**59.3**	**39.8**	**0.9**
■	**5-B**	**0.8**	**0.04**	**0.03**	**0.012**	**0.0043**	**0.0**	**13.0**	**83.1**	**3.9**

PROJECT **Lakeline Lakebed Analyses -**

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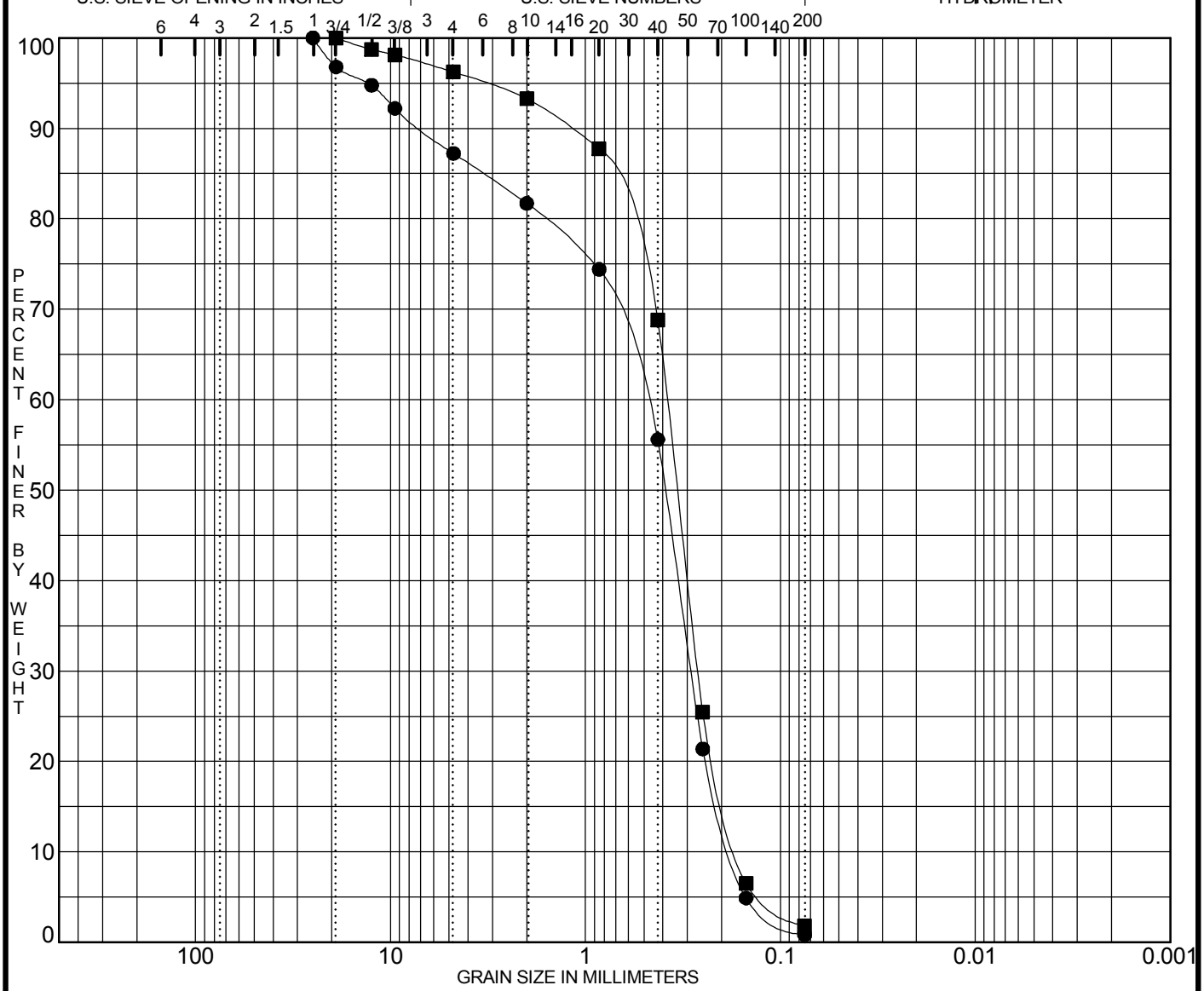

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**6-A**	**0.0 -**	**poorly graded SAND**	**22**				**0.93**	**2.8**
■	**6-B**	**0.0 -**	**poorly graded SAND**	**30**				**1.11**	**2.3**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**6-A**	**0.0**	**0.50**	**0.39**	**0.286**	**0.1757**	**12.8**	**86.4**	**0.8**	
■	**6-B**	**0.0**	**0.38**	**0.34**	**0.264**	**0.1647**	**3.8**	**94.4**	**1.8**	

PROJECT **Lakeline Lakebed Analyses -**

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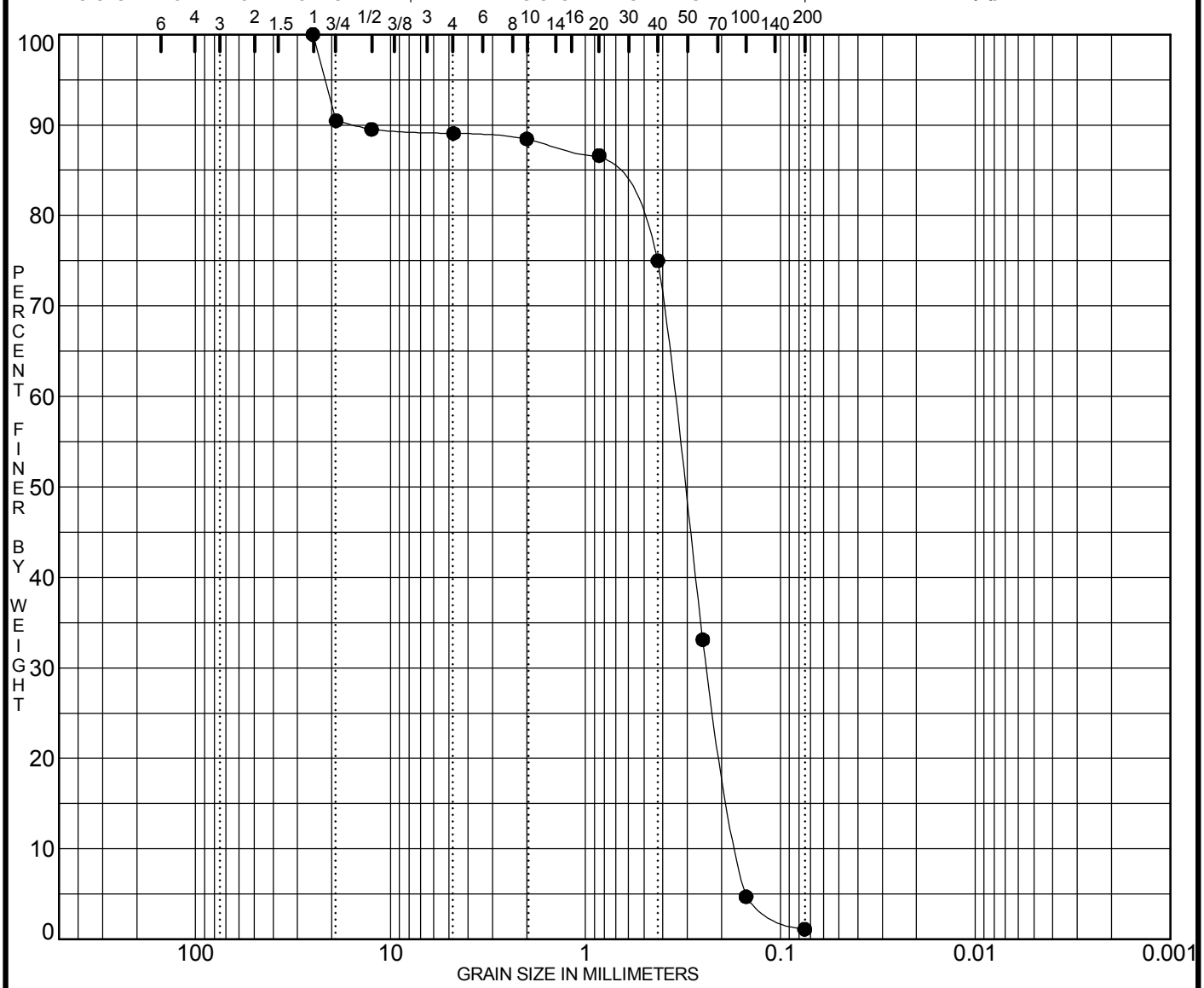

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**7-A**	**0.0 -**	**poorly graded SAND**	**28**				**0.96**	**2.1**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**7-A**	**0.0**	**0.35**	**0.31**	**0.236**	**0.1650**	**10.9**	**88.0**	**1.1**	

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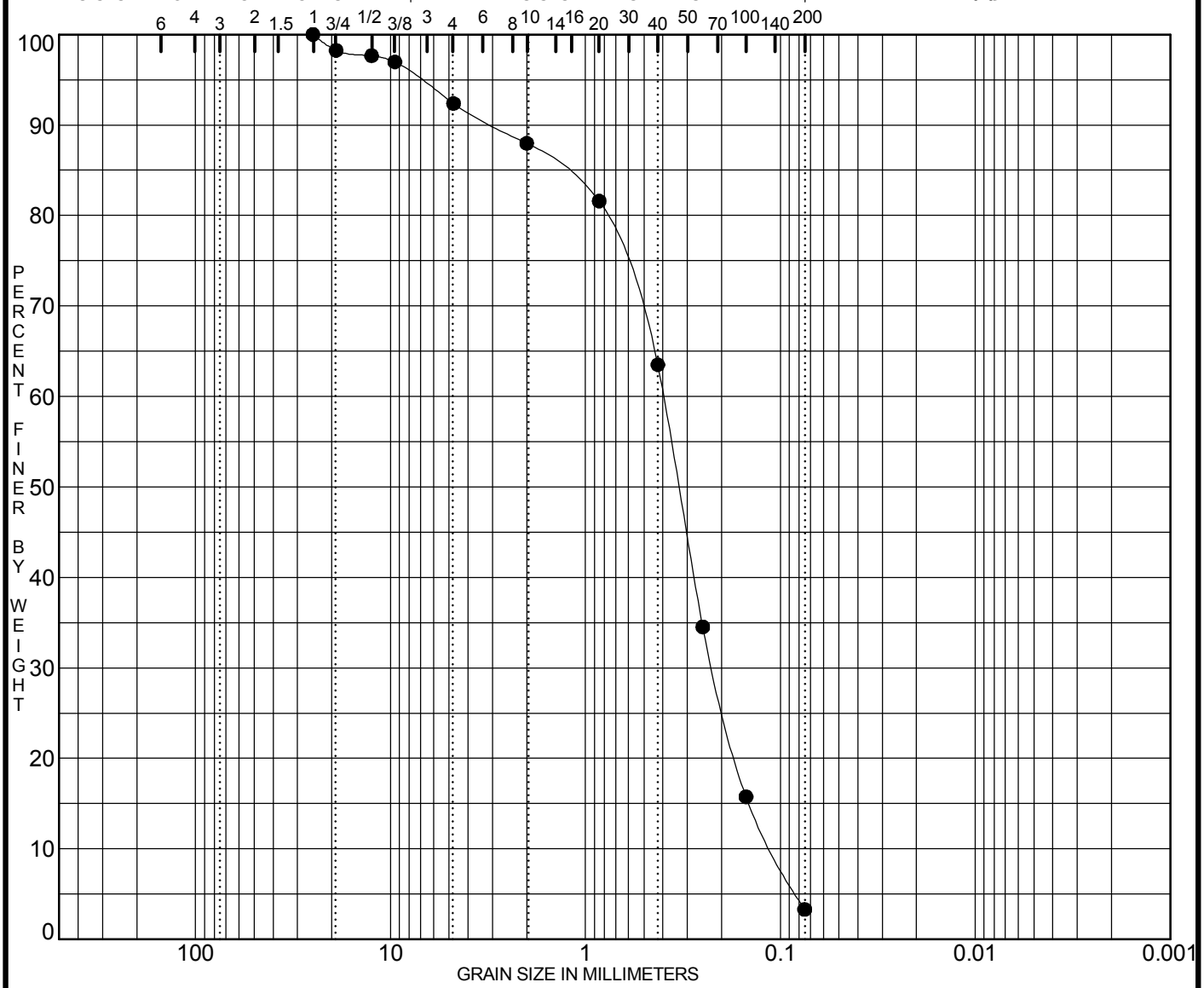

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**8-A**	**0.0 -**	**poorly graded SAND**	**27**				**1.13**	**3.7**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**8-A**	**0.0**	**0.40**	**0.33**	**0.221**	**0.1089**	**7.6**	**89.1**	**3.3**	

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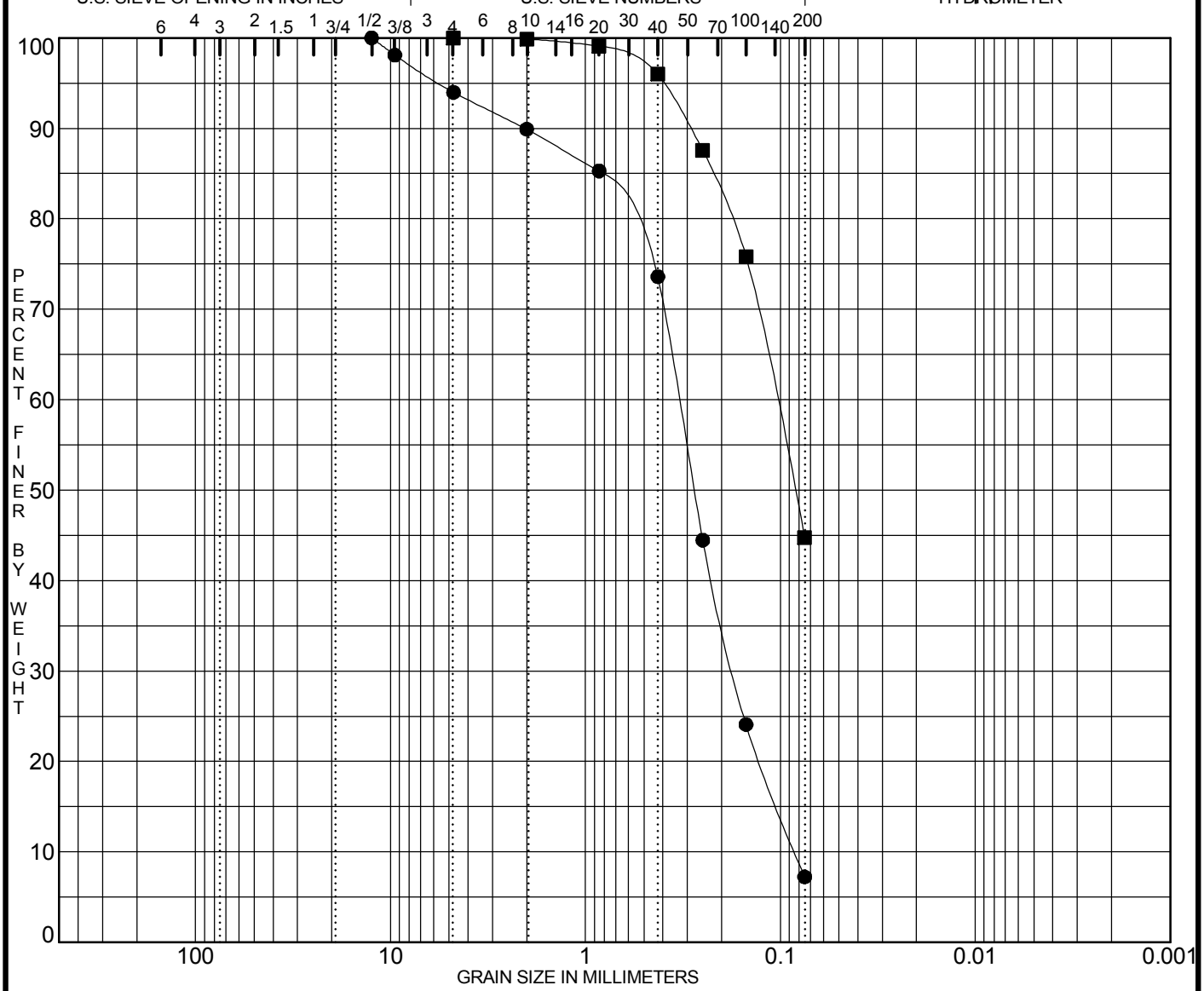

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**8-B**	**0.0 - 0.6**	**poorly graded SAND with silt**	**37**				**1.09**	**3.9**
■	**8-B**	**0.6 - 1.0**	**silty SAND**	**61**					

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**8-B**	**0.0**	**0.33**	**0.28**	**0.174**	**0.0840**	**6.0**	**86.7**	**7.2**	
■	**8-B**	**0.6**	**0.11**	**0.08**			**0.0**	**55.3**	**44.7**	

PROJECT **Lakeline Lakebed Analyses -**

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GRADATION CURVES

HWA GeoSciences Inc.

King County

Dow Constantine
King County Executive
401 Fifth Avenue, Suite 800
Seattle, WA 98104-1818
206-263-9600 Fax 206-296-0194
TTY Relay: 711
www.kingcounty.gov

March 26, 2020

The Honorable Claudia Balducci
Chair, King County Council
Room 1200
C O U R T H O U S E

Dear Councilmember Balducci:

This letter transmits a report regarding sedimentation effects of King County's Kenmore Interceptor and a proposed motion that would, if enacted, acknowledge receipt of the report. The report and motion are in response to Ordinance 18835, Section 108, Proviso P2.

To analyze sedimentation and impacts to fish populations in the vicinity of the pipeline, the Wastewater Treatment Division (WTD) of the Department of Natural Resources and Parks (DNRP) retained Environmental Science Associates (ESA) to conduct an analysis and write a report.

The report from ESA shows that the Kenmore Interceptor, which is buried throughout most of the Lyon Creek and McAleer Creek deltas, does not play a significant role in sedimentation patterns in the study area. The interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor exposed by no more than 10 inches above the lakebed. While the shoreline does not contain habitat suitable to most salmonids, the Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington.

The work described in the report furthers the King County Strategic Plan goal of Healthy Environment by ensuring that King County infrastructure is not impacting salmonid survival and migration in Lake Washington. This work also furthers the Strategic Climate Action Plan goal of Preparing for Climate Change by confirming King County's Kenmore Interceptor is not negatively impacting salmon recovery which could also be affected by climate change.

In developing the report, DNRP engaged staff from the City of Lake Forest Park and King County Council staff. WTD also briefed the Engineering and Planning subcommittee of the

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Metropolitan Water Pollution Abatement Advisory Committee regarding the results of the study on March 5.

It is estimated that the report required 40 hours by WTD staff to produce, costing approximately $4,500 in staff hours and $62,000 in consultant costs. The estimated printing cost for this report is nominal.

Thank you for your consideration of this report. The important work discussed in this report will help King County residents understand the impacts of the Kenmore Interceptor on Lake Washington, and on salmonid survival and migration.

If your staff have any questions, please contact Mark Isaacson, Division Director of the Wastewater Treatment Division of the Department of Natural Resources and Parks, at 206-477-4601.

Sincerely,

Dow Constantine
King County Executive

Enclosure

cc: King County Councilmembers
ATTN: Carolyn Busch, Chief of Staff
Melani Pedroza, Clerk of the Council
Shannon Braddock, Deputy Chief of Staff, Office of the Executive
Karan Gill, Director, Council Relations, Office of the Executive
Dwight Dively, Director, Office of Performance, Strategy and Budget
Christie True, Director, Department of Natural Resources and Parks (DNRP)
Mark Isaacson, Division Director, Wastewater Treatment Division, DNRP

Key Findings of the Kenmore Interceptor Report

Proviso

Ordinance 18835, Section 108, Proviso P2 identified four areas of concern relative to the placement and presence of the Kenmore Interceptor Section 2 along the bed of Lake Washington. The Kenmore Interceptor Section 2 is a 48-inch pipeline that conveys wastewater from the Kenmore area to the Matthews Beach Pump Station and the West Point Treatment Plant. The concerns identified in the proviso relate to the interceptor's impact on sediment accumulation and, subsequently, water fauna in Lake Washington, particularly on species of fish that migrate from the ocean to rivers or streams.

Background

Wastewater from the Bothell, North Creek, and Kenmore areas is conveyed by local sewer pipelines to the Kenmore Interceptor. The Kenmore Interceptor consists of five sections, for a total pipeline length of 16,031 linear feet. Construction of the Kenmore Interceptor began in the early 1960s. Designed to convey 26 million gallons of wastewater per day, this pipeline was a critical piece of King County's new regional wastewater treatment system designed to keep wastewater out of Lake Washington. Design of the interceptor was per uniform building codes in effect at that time, and called for placement of the 48-inch pipe within a precast concrete rectangular casement set on piles driven into the lake bed. The entire casement was placed within a trench excavated along the lakebed, between 75 and 200 feet offshore. Today, the Kenmore Interceptor continues to function as a critical piece of the wastewater system in north King County. Recent inspections confirm the pipe is in good condition and will be able to remain in service for many years to come.

Analysis

To address the areas of concern identified in the proviso, the Wastewater Treatment Division retained Environmental Science Associates (ESA) to analyze sedimentation and impacts to fish populations in the vicinity of the pipeline. The study area for the analysis encompassed the area between approximately Tracy Owen Station Park and Ballinger Way.

ESA's report included the following key findings:

- The Kenmore Interceptor, which is buried throughout most of the Lyon and McAleer creek deltas, does not play a significant role in sedimentation patterns in the study area.
- The Kenmore Interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor casement exposed by no more than 10 inches above the lakebed.
- No measurable differences in sediment accumulation were observed along near-shore and off-shore sides of the interceptor, with the exception of one area of approximately 500 square feet where localized effects of minor accumulation on the shore side have occurred in an area 10 to 20 feet wide.

Although Lake Washington continues to provide important habitat for many species of fish, the quality and quantity of fish habitat in the study area have been degraded over the years by several factors that are generally present on a lake-wide basis. The Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington.

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King County

Metropolitan King County Council
Regional Water Quality Committee

STAFF REPORT

Agenda Item:	9	**Name:**	Mike Reed
Proposed No.:	2020-B0070	**Date:**	September 2, 2020

SUBJECT

The determination by the Washington Department of Ecology to establish a General Permit restricting nutrient discharges into Puget Sound, and its related determination to provide for facility-specific caps on nutrient discharges.

SUMMARY:

The Washington Department of Ecology, after an extended process of outreach and analysis, announced a decision to develop a General Permit on nutrient discharges. That announcement was made pursuant to the agency's responsibilities under the federal Clean Water Act for managing discharge of nutrients into Puget Sound. King County's operation of two of the largest wastewater treatment plants discharging into Puget Sound, together with the information about the levels of nutrients in wastewater discharges, raise this as a topic of concern for the Regional Water Quality Committee, which has included the control of nutrients on its annual workplan for several years. Today's briefing will primarily focus on preliminary King County strategies in response to the anticipated regulatory action, and possible cost implications.

BACKGROUND:

Ecology Regulatory Determinations

In August of 2019, the Washington Department of Ecology arrived at a preliminary determination to develop a general permit regarding nutrient discharges, pursuant to requirements of the federal Clean Water Act, and associated regulations. Specifically, Ecology cites 40 CFR Sect. 122.44(d)(1)(i), which establishes the regulatory threshold, as follows:

"..(Permit) limitations must control all pollutants or pollutant parameters that are or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an excursion above any state water quality standard..."

Following the preliminary determination referenced above, Ecology provided a public comment period. In January of 2020, the agency formalized its earlier preliminary decision, determining that Ecology will develop a General Permit to implement nutrient control requirements at domestic wastewater treatment plants.

Ecology has indicated that the general permit would apply to treatment plants discharging to Puget Sound; approximately 70 plants would be impacted.
Ecology indicated that it anticipates development of preliminary draft permit materials, to be followed by a formal draft permit in Quarter 4 of 2020; final permit issuance would occur in 2021.

Individual Permits
In December of 2019, the Department arrived at a related decision, that individual permits would have nutrient controls. Ecology would modify individual permits as necessary when the general permit is developed. The individual permits would establish facility-specific nutrient-related requirements; it is expected that provision would be made for:

- A Total Inorganic Nitrogen cap
- Monitoring requirements
- Assessment and optimization of the existing treatment process

Nutrient Management Plan
Ecology is developing a Nutrient Management Plan that will describe how the agency will reduce the different human sources of nutrients to Puget Sound. The goal is to restore water quality to meet dissolved oxygen standards. The agency anticipates release of a draft plan for public comment in 2022.

Context: Ecology's Puget Sound Nutrients Source Reduction Project

The Puget Sound Nutrients Source Reduction Project was undertaken to analyze and respond to the impacts of excessive nutrient discharges on marine biota in Puget Sound. Monitoring of marine waters by Ecology led the agency to conclude that the water quality of Puget Sound is changing as the result of excessive levels of nutrients from human sources. Ecology notes that monitoring data has identified many places throughout the Sound where levels of dissolved oxygen—critical for marine biota—are constrained.

The Regional Water Quality Committee was briefed on the Puget Sound Nutrients Source Reduction Project by the Director of the Washington Department of Ecology Water Quality Program, Heather Bartlett, at its May 2, 2018 and June 5, 2019 meetings.

What are Nutrients? How do they contribute to oxygen depletion?
Nutrients are chemicals such as nitrogen and phosphorous that stimulate the growth of plant life—either on land or in the water. The presence of nitrogen in lawn fertilizer, for example, is based on its status as a stimulant for growth in green plants. This is one of the numerous sources of nitrogen and phosphorous that are present in human environments; human and animal waste are other major sources of nitrogen, as are agricultural wastes, atmospheric deposition, urban runoff, and wastewater treatment plant effluent.

In the marine environment, nitrogen encourages the growth of algae. While nitrogen is a critical element in the cycle of marine life, excessive levels can lead to uncontrolled growth, such as large algae blooms covering extensive areas of water surfaces. When this algae dies, it sinks to the bottom of the water column; there, bacteria work to

decompose it, consuming available oxygen in the process, and depriving the water of oxygen needed by marine life.

The federal Clean Water Act requires that states develop a plan to address polluted waters. Washington's Ecology Department has been delegated authority by the federal Environmental Protection Agency to implement the federal Clean Water Act in Washington.

Chesapeake Bay Nutrients Management Example: Total Maximum Daily Load

Management of nutrient impacts has been the subject of federal and state action elsewhere in the nation. In 2010, the federal Environmental Protection Agency ("EPA") established the Chesapeake Bay Total Maximum Daily Load ("TMDL"), as tool for defining maximum pollution limits Bay-wide, and allocating pollution discharge amounts within those limits[1]. This followed extensive restoration efforts during the prior 25 years, which failed to achieve sufficient progress towards improvements in water quality, and triggered a federal Clean Water Act mandate for the TMDL. It also responded to a Presidential Executive Order to restore and protect Chesapeake Bay.

The TMDL set watershed limits of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorous, and 6.45 billion pounds of sediment per year, across jurisdictions with discharge into Chesapeake Bay, including Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia. Watershed Implementation Plans ("WIP") were established for the various jurisdictions defining how they would achieve the discharge reductions required for the TMDL allocations.

Wastewater facilities have been a particular point of focus in the Chesapeake Bay project. According to the EPA, upgrades and operational efficiencies at wastewater treatment plants throughout the Chesapeake Bay watershed have resulted in steep reductions in nitrogen and phosphorous pollution. From 1985 through 2015, the wastewater sector cumulatively prevented over 900 million pounds of nitrogen and phosphorous pollution from entering the Bay's tributaries, reducing nitrogen in the Bay by 57% and phosphorous by 75%. In 2015, annual progress in the wastewater sector effectively met its 2025 nutrient pollution limits set in the Chesapeake Bay TMDL.[2] The 472 municipal and industrial wastewater treatment plants in the Chesapeake Bay watershed were designated as significant sources by states and the EPA, and have annual nutrient pollutant limits in their NPDES permits, providing legally enforceable assurances that pollutant reductions will be achieved. Continuing investments in advanced wastewater treatment have exceeded $7 billion in the Bay watershed.[3]

Washington Department of Ecology Study 2014: Puget Sound and the Straits Dissolved Oxygen Assessment

Attention to the control of nutrients into Puget Sound has been growing in Washington State. The Washington Department of Ecology, participating with the Pacific Northwest National Laboratory, in 2014 published a report addressing the relationship of nitrogen

[1] https://www.epa.gov/chesapeake-bay-tmdl/wastewater-pollution-reduction-chesapeake-bay-watershed
[2] https://www.epa.gov/chesapeake-bay-tmdl/wastewater-pollution-reduction-chesapeake-bay-watershed
[3] https://www.epa.gov/sites/production/files/2016-06/documents/wastewater_progress_report_06142016.pdf

discharges to levels of oxygen. The "Puget Sound and the Straits Dissolved Oxygen Assessment: Impacts of Current and Future Nitrogen Sources and Climate Change through 2070"[4], summarizes current and future impacts of human nutrient loads, Pacific Ocean conditions, and climate change on dissolved oxygen levels in the Salish Sea. The geographic focus of the study was beyond Puget Sound specifically, and encompassed the larger Salish Sea—including Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia in British Columbia. The authors note that, while Puget Sound—defined as the waters south of Admiralty Inlet—is the area of primary interest, Puget Sound is connected to the Strait of Juan de Fuca and the Strait of Georgia, and cannot be considered in isolation—so the analysis includes all major U.S. and Canadian influences on circulation and water quality in the Salish Sea. Among the determinations of the Report:

- Human sources of nitrogen discharging into the Salish Sea—distinct from natural sources--have the greatest impacts on dissolved oxygen in South and Central Puget Sound. Between marine point sources—primarily wastewater treatment plants, with limited numbers of industrial outfalls—and watershed inflows, the marine point sources cause greater decreases of dissolved oxygen levels than watershed inflows—both of which will increase with increasing population growth.

- Strong influences on dissolved oxygen result from Pacific Ocean inflows. North Pacific dissolved oxygen concentrations have been declining for 50 years—and if those trends continue, Salish Sea dissolved oxygen would decline far more from ocean inflows than from human nutrient loads.

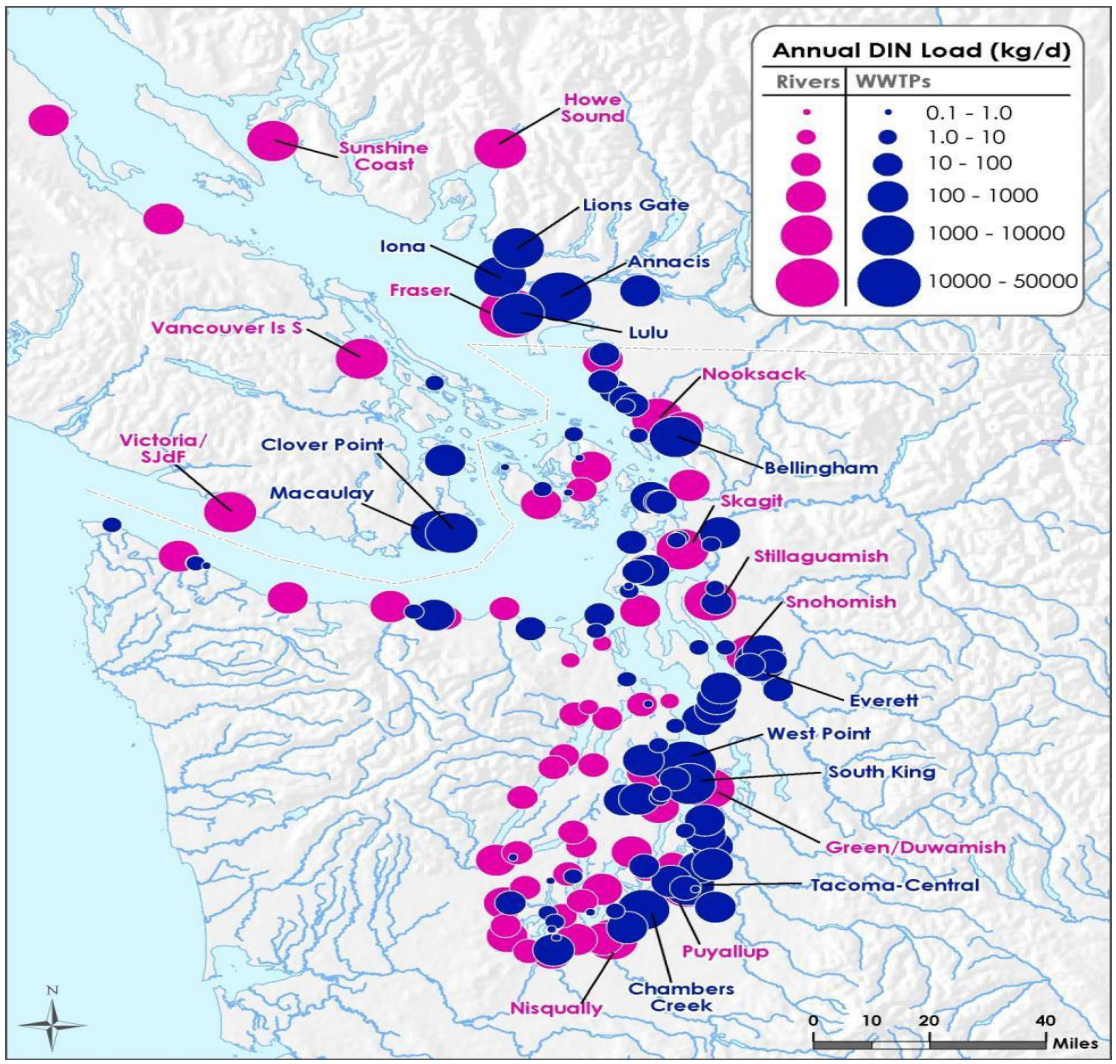
- Nitrogen naturally occurs in rivers and streams entering marine waters, but human activities have increased nitrogen loads above naturally occurring levels. Natural nitrogen concentrations in rivers are governed by nitrogen concentrations in rainfall and processes within forested watersheds. These baseline conditions are impacted if regional air emissions alter rainfall nitrogen concentration, or if forested areas are converted to other developed land uses. In a watershed, human contributions include point source discharges, including wastewater treatment plants. Nonpoint sources from developed lands also increase human contributions above natural levels.

- In the U.S. (excluding plants serving Vancouver, Victoria and other Canadian communities) 78 municipal wastewater treatment plants and 10 industrial facilities discharge treated effluent through outfalls to Puget Sound and the Straits. Water volumes from wastewater plants are small compared to inflows from watersheds; however, municipal wastewater treatment plant effluent contains higher concentrations of nitrogen compared to inputs from rivers and streams. Industrial plant discharges generally have lower nitrogen concentrations than municipal wastewater plants.

[4] https://fortress.wa.gov/ecy/publications/SummaryPages/1403007.html

- The population served by the 78 municipal WWTPs serving the U.S. portion of the Salish Sea will double by 2070, from 4.2 million served currently to 7.8 – 8.8 million served by the year 2070. Compared to current flows from these 78 municipal WWTPs (320 mgd), future flows are projected to grow to 390 to 400 mgd by 2020 and 570 to 660 mgd by 2070. With this doubling of population, marine point source loads of nitrogen would increase by an additional 47,200 kg/d discharging to Puget Sound and the Straits. Land use changes would increase nitrogen loads by 31,300 kg/d by 2070 compared with current conditions due to the conversion of forested land to developed land such as residential and agricultural uses.

Chart 1: Distribution of Sources of Dissolved Inorganic Nitrogen into Salish Sea

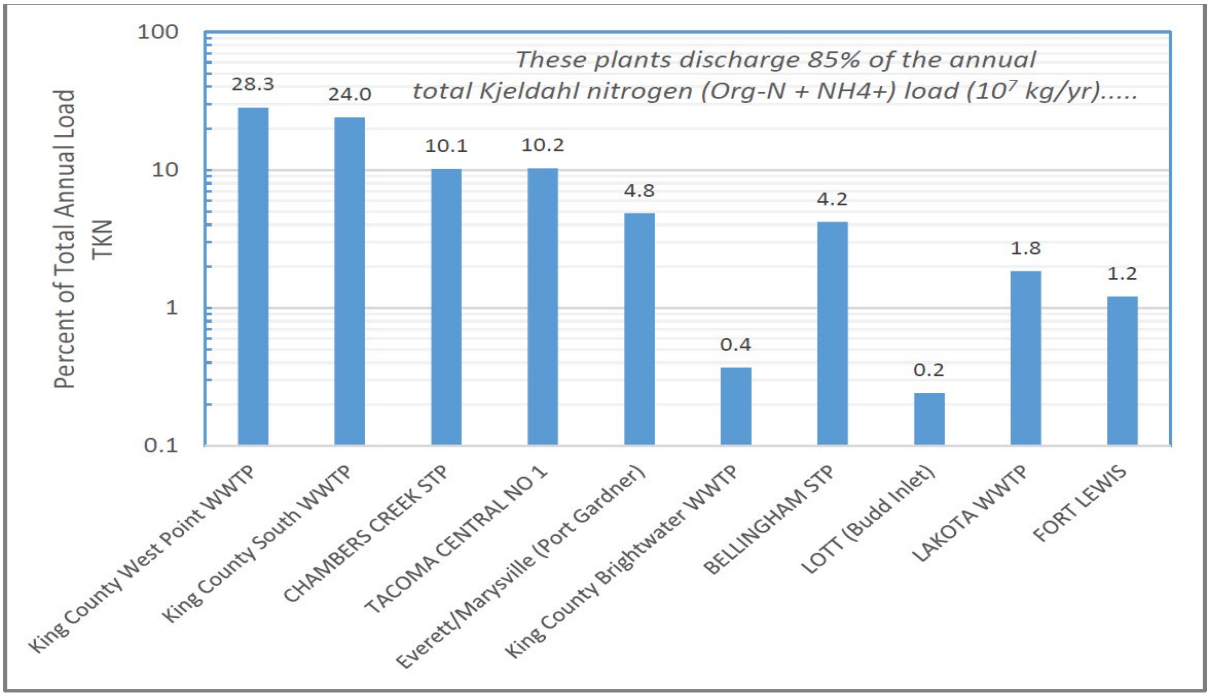


Nitrogen Load Allocation among Puget Sound Wastewater Plants

King County operates three regional wastewater treatment facilities—the West Point Treatment Plant, the South Treatment Plant, and the Brightwater Treatment Plant. West Point and South are among the largest facilities serving the Puget Sound population. Among 69 plants reviewed by Ecology with marine discharge in the greater Puget Sound area, 10 plants serve around 80% of the total population connected to a central sewer collection system. Most of these are connected to West Point (26% of the population

total) and South Plant (21% of the population total). According to Chart 2 below, West Point and South Plant generate over half (52%) of the total nitrogen load.

Chart 2: Allocation of Nitrogen Load among Puget Sound Wastewater Plants



Washington Water Quality Standards—Nutrients

The water quality standards established by WDOE[5] include provisions for the minimum concentrations of dissolved oxygen needed to protect aquatic life. The standards vary by basin. Most U.S. waters of the Salish Sea have the most protective "Extraordinary" water quality requirements to protect aquatic life with a minimum dissolved oxygen concentration of 7.0 mg/L. Several bays and inlets have a lower "Excellent" standard to protect aquatic life where dissolved oxygen must be >6.0 mg/L. Urban bays must maintain minimum concentrations above 5.0 mg/L to protect "Good" aquatic life uses. If a water body is naturally lower in oxygen than these thresholds, then the combined effects of all human activities must not cause the naturally lower oxygen to decrease by more than 0.2 mg/L.

Regulatory Agency Pressure to Act

Both the federal Environmental Protection Agency and the Washington Department of Ecology have encountered pressure to move forward with measures to control discharge of nutrients into national and state waters. In August, 2009, the U.S. Environmental

[5] https://fortress.wa.gov/ecy/publications/documents/0610091.pdf P 19 (i) When a water body's D.O. is lower than the criteria in Table 210 (1)(d) (or within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the D.O. of that water body to decrease more than 0.2 mg/L.

Protection Agency Office of the Inspector General issued an Evaluation Report entitled "EPA Needs to Accelerate Adoption of Numeric Nutrient Water Quality Standards"[6] The Inspector General's Office found that

EPA's 1998 National Strategy and Plan to promote State adoption of nutrient water quality standards (which better protect aquatic life and human health) has been ineffective. In 1998, EPA stated that a critical need existed for improved water quality standards, given the number of waters that were impaired from nutrients. In the 11 years since EPA issued its strategy, half the States still had nonnumeric nutrient standards. States have not been motivated to create these standards because implementing them is costly and often unpopular with various constituencies. EPA has not held the States accountable to committed milestones. The current approach does not assure that States will develop standards that provide adequate protection for downstream waters. Until recently, EPA has not used its Clean Water Act authority to promulgate water quality standards for States. EPA cannot rely on the States alone to ensure that numeric nutrient standards are established. EPA should prioritize States/waters significantly impacted by excess nutrients and determine if it should set the standards. EPA also needs to establish effective monitoring and measures so that accurate program progress is reported. This will assist EPA management in program decision-making.

We recommend that the Assistant Administrator for Water:

- *Select significant waters of national value which need numeric nutrient water quality standards to meet the requirements of the Clean Water Act.*
- *Set numeric nutrient water quality standards for the waters identified in the first recommendation to meet the requirements of the Clean Water Act.*
- *Establish EPA and State accountability for adopting numeric nutrient standards for the rest of the Nation's waters.*
- *Establish metrics to gauge the actual progress made by the States.*

The Washington Department of Ecology has also been the subject of pressure to act. In 2017, Northwest Environmental Advocates petitioned Ecology to launch a "Total Maximum Daily Load" study immediately, and asserted that the agency should limit releases of nitrogen from sewage treatment plants that discharge into Puget Sound[7]. Ecology denied the petition for a TMDL, indicating that it does not have sufficient information to begin the process. In the letter denying the petition, Ecology indicated,

"Although Ecology has decided to deny your petition, we share many of your concerns regarding nutrient impacts in Puget Sound. Further, Ecology agrees that Puget Sound is impaired by nutrient pollution and that a TMDL may be necessary to address this impairment."

ANALYSIS:

The Washington Department of Ecology has, following extensive analysis of the sources of, and impacts of, nutrient discharge into Puget Sound, arrived at a determination to limit nutrient discharges from wastewater plants through the issuance of a General Permit and individual plant discharge limits. Details on exactly how these determinations will be implemented are currently being developed. The King County Wastewater Treatment

[6] "EPA Needs to Accelerate Adoption of Numeric Nutrient Water Quality Standards" Report No. 09-P-0223, August 26, 2009 EPA Office of Inspector General

[7] https://www.eopugetsound.org/magazine/is/nutrients

Division has been active in participating with Ecology in the process leading to the determinations, and is expected to continue to play a role in the process moving forward.

While there are a number of major sources, wastewater treatment plants appear to be among the major human-driven generators, and King County's plants appear to be among the larger generators within the community of Puget Sound wastewater plants.

Upland sources also generate significant nutrient volumes, and the Pacific Ocean contributes large volumes to the overall load of nitrogen in particular.

Other parts of the country have moved forward with efforts to control nutrient discharges into waters of national significance; jurisdictions surrounding Chesapeake Bay, for example, have made notable progress in reducing discharge of nutrients, with federal financial assistance.

Given the limited footprint of the West Point Treatment Plant, development and operation of nitrogen discharge reduction mechanisms is expected to be particularly challenging.

Today's briefing will primarily focus on preliminary King County strategies to the anticipated regulatory action, and possible cost implications.

INVITED

- Rebecca Singer, Resource Recovery Manager and Nutrients Lead

ATTACHMENTS

1. Wastewater Treatment Division's Nutrient Management Strategy Presentation

ATTACHMENT 1

WTD Nutrient Management Strategy

Near term approach for long term results

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

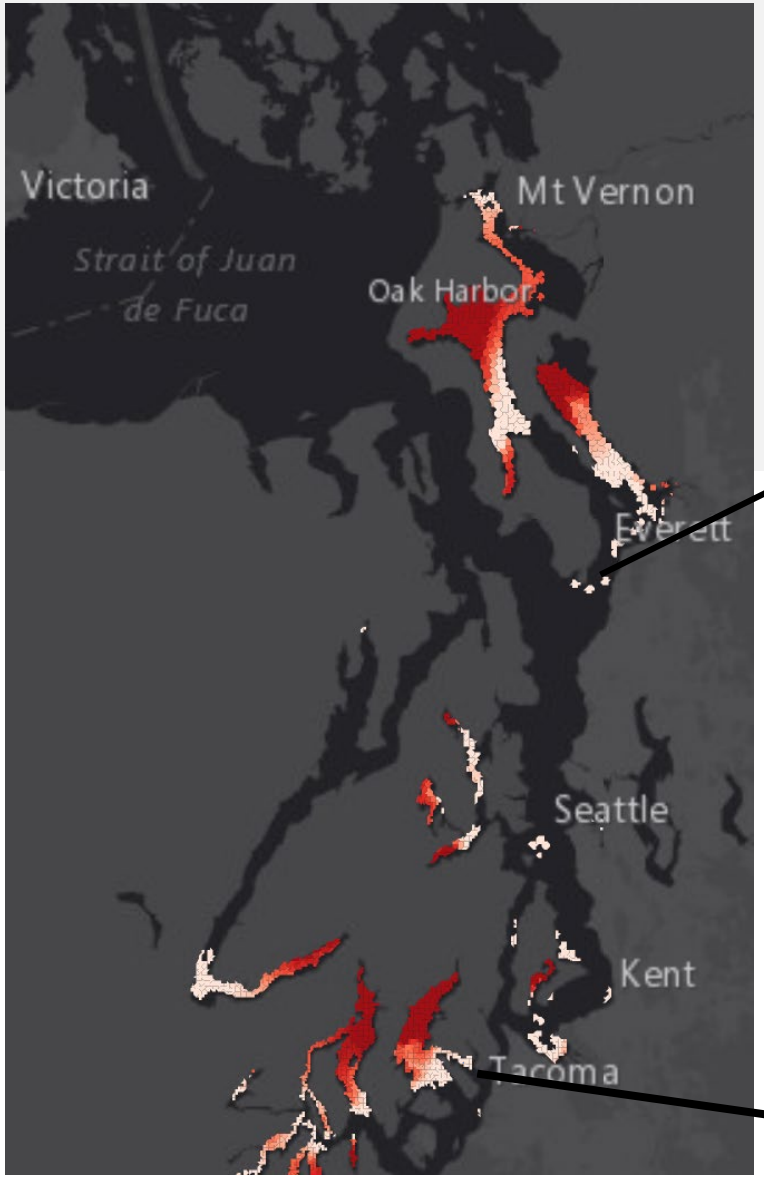
Background- What are the drivers?

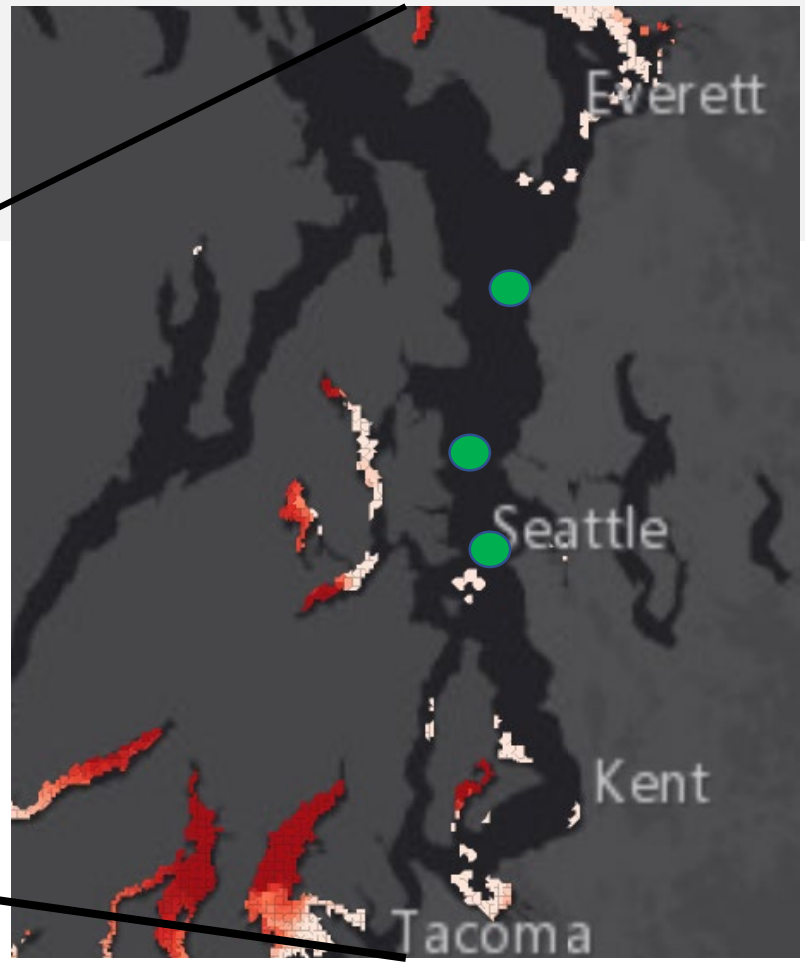
- Low dissolved oxygen (DO) levels have been found in Puget Sound
- Low DO is attributed to nitrogen loading – wastewater treatment plants are the largest dischargers of anthropogenic nitrogen
- Although Ecology has been working to better understand how, where and by what, low DO is being detected, they have faced lawsuits by environmental groups
- Northwest Environmental Advocates filed a petition for rulemaking that would require nutrient limits and tertiary treatment by wastewater treatment plants

- Ecology denied petition but committed to the following:
  - Set nutrient loading limits at current levels for all permitted dischargers
  - Require facilities to begin planning efforts to evaluate treatment implications of different nitrogen targets
  - For facilities capable of nitrogen removal, amend NPDES permit to include limits commensurate with their treatment capability

Timeline

2006-2014	• King County (KC) participated on a Technical Advisory Committee for Ecology's South Sound and Salish Sea Model development
2017	• July – KC staff presented nutrient and phytoplankton trends in central Puget Sound at Ecology's Puget Sound Nutrient workshop • Sept – KC met with Ecology to discuss Ecology's Puget Sound Nutrient Source Reduction Project and identify opportunities for King County to participate. • Nov – KC sent Ecology technical questions on the Salish Sea Model
2018	• Jan – Ecology presented KC with answers to technical questions on Salish Sea Model • April – Staff attend the Nutrient Form meetings (ongoing – monthly) • Sept – KC participated in Puget Sound Partnership's Implementation Strategy for Marine Water Quality
2019	• Jan – WTD begins Nitrogen Removal Study • Aug – Ecology announces Puget Sound Nutrient General Permit concept • Oct - KC comments in Ecology's General Permit solicitation process • Dec – Ecology announced Total Inorganic Nitrogen (TIN) caps in individual permits
2020	• Jan – Ecology announces moving forward with a general permit • Feb - General Permit Advisory Committee process begins – KC sits on the Advisory Committee • April – WTD contracts with The Freshwater Trust





Preliminary Modeling Results

- 88% of total nitrogen in the Puget Sound comes from Oceanic influx

King County discharge (green dots)

- We discharge an equivalent of 4% of the oceanic total

Issues

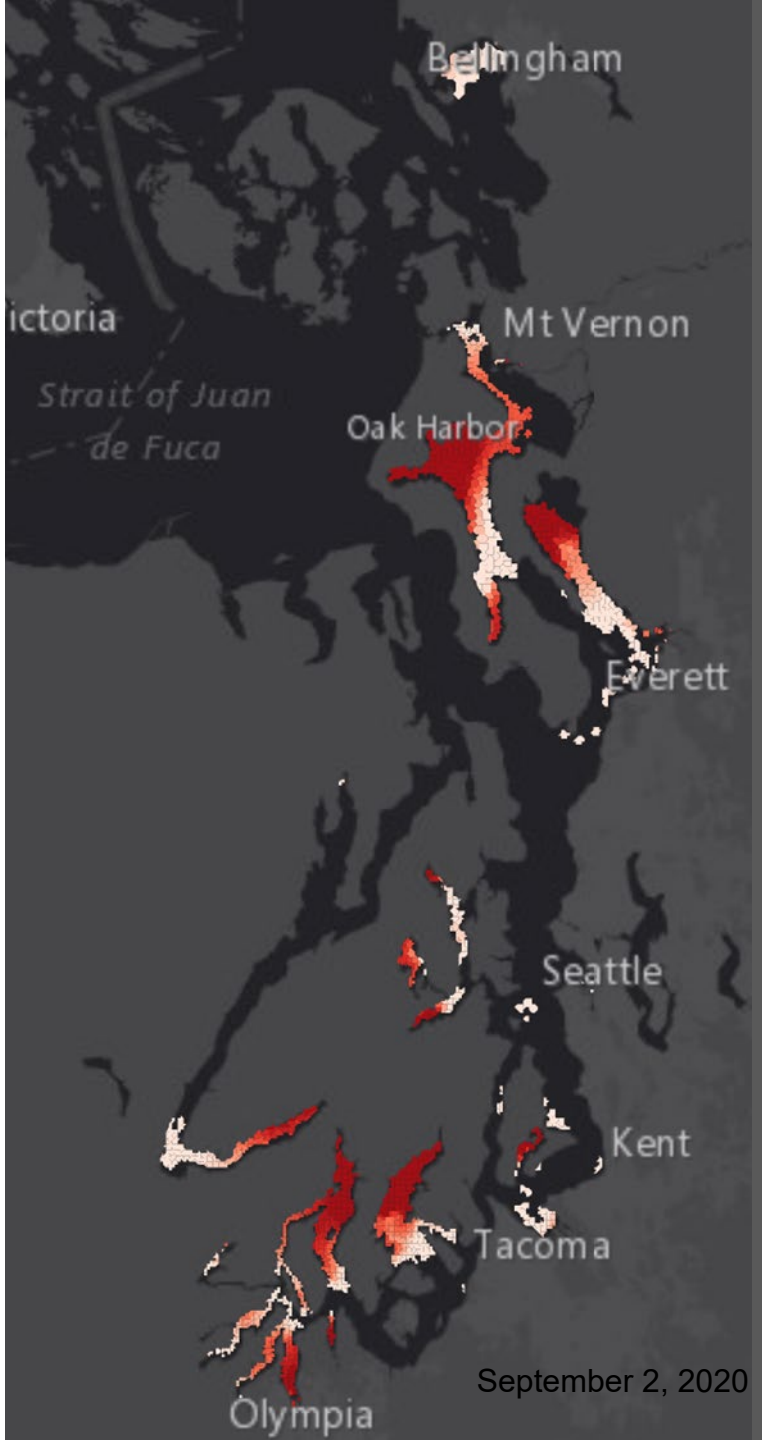
Modeling/Data: Not complete and there is disagreement between scientists and regulated entities and Ecology regarding accuracy. Will improvements be seen?

Timing: Ecology caps on nutrients by 2021. Total TIN limits established by 2022. South Plant and West Point NPDES permit with caps fall of 2020.

Stakeholder/Public Involvement: There has been limited interaction with key stakeholders during this process. Ecology is moving quickly. Public does not yet understand cost estimates

Cost: Removing nitrogen is costly. How are the environmental, equity and economic costs balanced? Anticipate billions over the next two decades

Implementation: Most facilities were not built to remove nitrogen and interim caps could limit growth.



Nitrogen Removal Study

Approach

1. Technology Screening
2. Nitrogen Removal Scenario Development
3. Technology Combination Screening
4. Site-Specific Analysis

Scenario Development

- Wanted a spectrum of all probable nitrogen (N) removal outcomes
- Used Ecology Bounding Scenario Report (January 2019) for concentrations

Less N removal → More N removal

"Base Case"	"Low Hanging Fruit" (sidestream)	Seasonal removal 8 mg/L TIN limit	Year-round removal 8 mg/L TIN limit	Year-round removal 3 mg/L TIN limit
10%-55% removal	20%-66% removal	39%-60% removal*	75%-79% removal	85%-90% removal

Less $ → More $

*No seasonal removal for Brightwater

West Point - Summary

	Scenarios	Total N removal	Constructability	Other impacts
1	Sidestream treatment, no effluent limit	20%	Feasible	Minimal
2	Year-round, lowest effluent possible, maintain capacity	75-85%	Most difficult (near impossible)	Extreme - conversion to all MBRs
3	Seasonal, lowest effluent possible, maintain capacity	55-60%	Extremely difficult	Very high – create parallel MBR plant within WP
4	Year-round, 8 mg/L effluent, reduced WP secondary capacity	**	New treatment plant required	High

South Plant - Summary

Scenarios		Total N removal	Constructability	Other impacts
1	Sidestream treatment	35%	Very feasible	Minimal
2	Seasonal, 8 mg/L effluent	40-45%	Feasible	Moderate
3	Year-round, 8 mg/L effluent equivalent	80%	Difficult	High
4	Year-round, 3 mg/L effluent	90%	Difficult	Very high

Brightwater - Summary

Scenarios [a]		Total N removal	Constructability	Other impacts
1	Sidestream treatment [b]	66%	Very Feasible	Moderate
2	Year-round, 8 mg/L effluent TIN equivalent	77%	Feasible	Moderate
3	Year-round, 3 mg/L effluent TIN	89%	Moderate	High

a. Base case assumes new aeration basin, two new membrane basins, and new membranes installed to meet NPDES rated capacity.

b. BWABO project trialing Simultaneous Nitrification-Denitrification (SND), and this study assumes it is successful.

What we know

As nitrogen removal increases so do:

- Capital and operating costs
- Operational complexity
- Truck traffic (chemicals)
- Green house gas emissions
- Footprint requirement

Alternatives

- Permit flexibility
- Regional Partnerships
- Water Quality Trading

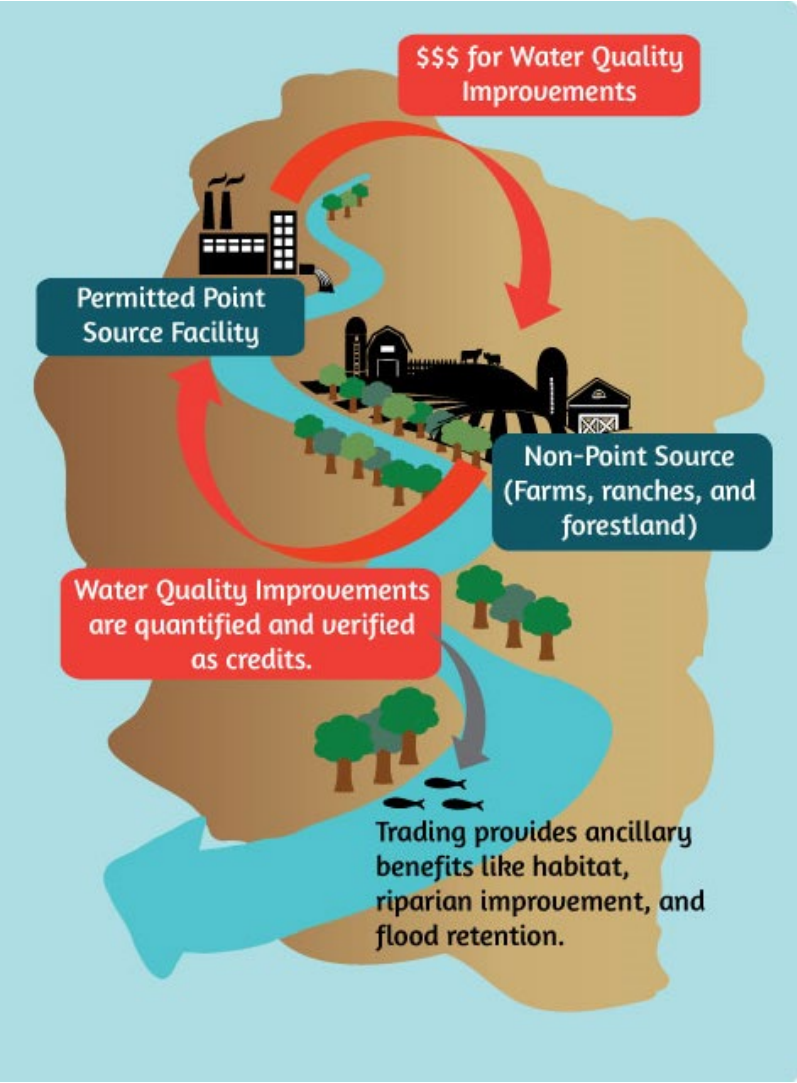
Water Quality Approach

Water quality trading/offsets provide:

- flexibility
- benefits that affect an entire watershed such as riparian improvements and fish and wildlife habitats

Water quality trading encompasses:

- non-point water pollution sources as well as point source
- provides economic incentives for non-point source dischargers to reduce nitrogen loading



Willamettepartnership.org

The Freshwater Trust

1. Policy, regulatory and legal

2. Engage stakeholders, regulators, partner agencies

3. Bridge KC efforts: Clean Water Healthy Habitat and Clean Water Plan

4. Outline a playbook for implementation

Next steps..

Further exploration:

- Best technology for site and process with expanded capacity
- System wide ‘bubble’ permit alternative using study results
- Optimization planning
- Water Quality Trading - develop a regional approach to water quality improvement

Continue:

- Participating in the Puget Sound Nutrients General Permit Advisory Committee and Nutrient Management Forum
- Working with the universities and regional partners to enhance our scientific understanding
- Coordination with Clean Water Healthy Habitat and Clean Water Plan to build framework for Water Quality Trading in partnership with The Freshwater Trust

Additional Reference Slides

Puget Sound Nutrients General Permit – Advisory Committee

Membership

5 Caucuses

- Federal (1)
- State (2)
- Tribal (1)
- Environmental (2)
- Utility (7)

Timeline

April 15 – General Permit-Advisory Committee kick-off

- Monthly meetings there after
- Each meeting focused on a topic
  - Cap calculation - May
  - Optimization – June
  - Planning - July
  - Monitoring - Aug

September 30 – finalize draft recommendation

October 21 – review and adopt final recommendations

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King County

Metropolitan King County Council
Regional Water Quality Committee

STAFF REPORT

Agenda Item:	10	**Name:**	Mike Reed
Proposed No.:	2020-B0071	**Date:**	September 2, 2020

SUBJECT

RWQC Engagement process preliminary to the 2022 wastewater rate setting effort.

SUMMARY

The Regional Water Quality Committee is briefed annually on recommended sewer rates and capacity charges, prior to adoption by Council. In the 2021 rate setting process, significant projected rate increases in coming years became a point of discussion, and Asset Management emerged as a key element in those discussions. For the 2022 rate setting process, the Wastewater Treatment Division has committed to engaging key participants, including the Regional Water Quality Committee, in framework discussions to inform that rate setting effort. The Division has conducted several briefings for the Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC); today's briefing will initiate that engagement process for RWQC.

BACKGROUND

The regional wastewater rate-setting process for 2021 rates, which occurred at the MWPAAC and Council level in the spring of 2020, resulted in a heightened regional recognition of significant upward pressure on sewer rates, that are projected to result in recommendations for substantial rate increases in coming years. Table 1 below depicts the rate history of recent years, and projected rates for coming years.

Table 1. Sewer Rates (2009-2020 Actual; 2021 Proposed; 2022-2025 Projected)

Year(s)	Rate ($/RCE/ Month)	% Increase
2009 – 2010	31.90	14.1%
2011 – 2012	36.10	13.2%
2013 – 2014	39.79	10.4%
2015 – 2016	42.03	5.6%
2017	44.22	5.2%
2018	44.22	0.0%
2019	45.33	2.5%
2020	45.33	0.0%

Year(s)	Rate ($/RCE/ Month)	% Increase
2021	**47.37**	**4.5%**
2022	47.37	0.0%
2023	52.23	10.25%
2024	52.23	0.0%
2025	57.58	10.25%

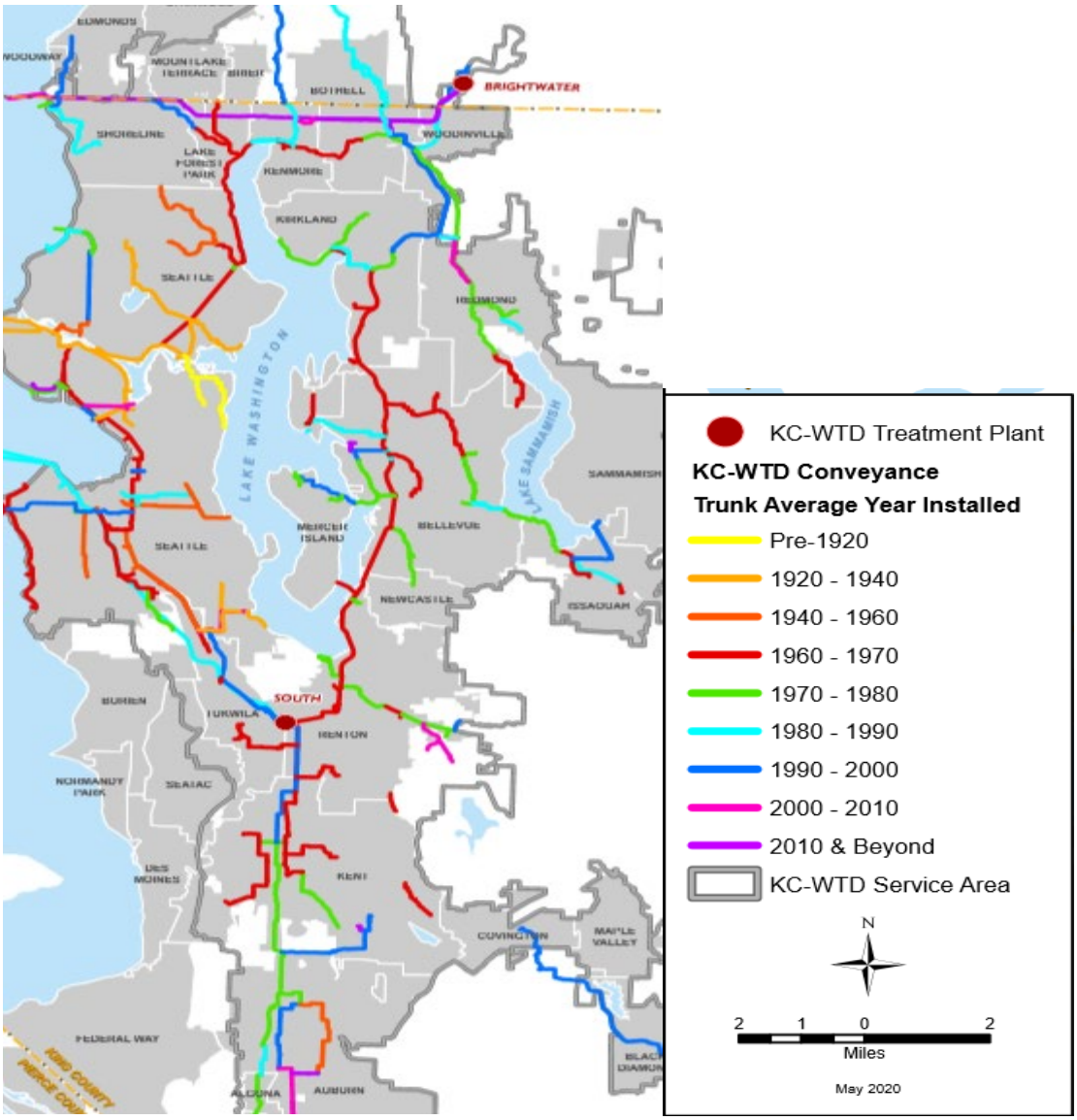
It is important to note that, while the 2022 rate is projected to hold constant in the table above, that projection was included as a "placeholder" after initial indications of significantly greater rate recommendations for the 2021-2022 period; it was inserted pending a robust engagement process leading to the development of a 2022 rate recommendation.

There are a number of rate "drivers" that are often discussed as shaping the emerging rate picture. These include:

- The requirement for establishment of Combined Sewer Overflow facilities to control discharge of untreated wastes during periods of high stormflow, resulting from the CSO Consent Decree between King County, the Washington Department of Ecology, the federal Environmental Protection Agency and the federal Department of Justice.
- The Washington Department of Ecology is moving forward with development of a regulatory project that is expected to result in a limitation on the level of nutrients that can be discharged in the effluent of wastewater plants discharging into Puget Sound. Response to those regulations may have significant capital cost implications for King County wastewater processing facilities.
- Regional population growth, requiring assessment of the capacity of the existing system to effectively capture and process anticipated wastewater volumes; the Division has completed a wastewater Flows and Loads study which should help inform the discussion regarding growth-driven capacity needs.
- The need for system resilience, which was dramatically illustrated by the West Point system failure in 2017, and which resulted in a third-party analysis that emphasized system resilience as a key means of preventing recurrence of similar events
- Aging of the physical plant. The primary elements of the wastewater conveyance and processing system, including the interceptor pipelines and West Point and South treatment plants, were constructed in the 1960s and 1970s. Those facilities are now approaching or exceeding 50 years old, and to a greater or lesser extent, experiencing the challenges of an aging system. The Wastewater Treatment Division is addressing the need to evaluate, rehabilitate and replace aging segments of the conveyance system through the Conveyance System Improvement project, which identifies segments in need of upgrade to assure conveyance capacity capable of handling a 20-year peak flood through the year 2060. The urgency of the need to address conveyance system needs was highlighted

in the 2021 rate discussion. Figure 1 below illustrates the age of various interceptor system segments:

Chart 1 Interceptors By Age[1]



These aging wastewater facilities, or system "assets", are the subject of the agency Asset Management project. Asset Management is the systematic evaluation, project development, costing, and scheduling of projects intended to address the functioning and reliability of the wastewater physical plant.

Asset Management is emerging as a key element in discussions regarding rate drivers. The Wastewater Treatment Division is presenting a series of briefings to city and sewer

[1] Map produced by Shari Cross of the GIS program of the Wastewater Treatment Division

district participants in the wastewater system, through the Metropolitan Water Pollution Abatement Advisory Committee.

Today's briefing will introduce the Regional Water Quality Committee to this topic, as a means of engaging the Committee with the specifics of the framework that will define the development of the projected sewer rate proposal for 2022 and beyond.

INVITED

- Bruce Kessler, Deputy Division Director, Wastewater Treatment Division

ATTACHMENTS

1. Wastewater Treatment Division's Asset Management Overview Presentation

ATTACHMENT 1

Asset Management Overview

Presented to the Regional Water Quality Committee

September 2, 2020

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

Presentation Overview

- Asset Management Overview
- Asset Management Capital Project Prioritization
- Asset Management Presentations to MWPAAC
- Additional Briefings and Resources

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What Defines an Asset?

- WTD defines a “capital asset” as a:
  - Tangible or intangible possession
  - Acquired for the use of operations
  - Estimated useful life exceeding one year

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WTD's Assets

- WTD manages over 66,000 Assets valued at almost $5 Billion total
- Common WTD Assets:
  - Fixed Equipment (pumps, motors, transformers, switchgear, instrumentation)
  - Infrastructure (pipelines, tanks)
  - Buildings and grounds (roofing)
  - Vehicles (Loop trucks)
  - Technology and Software (controls systems, databases)

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History of Significant System Upgrades

1960s – Metro establishment- construction of treatment plants, pump stations, 100+ miles of interceptor sewers

1980s – South plant expansion and new effluent discharge to Puget Sound

1990s – West Point secondary treatment

2000s – South plant expansion, multiple CSO facilities

2010s – Brightwater, multiple CSO facilities

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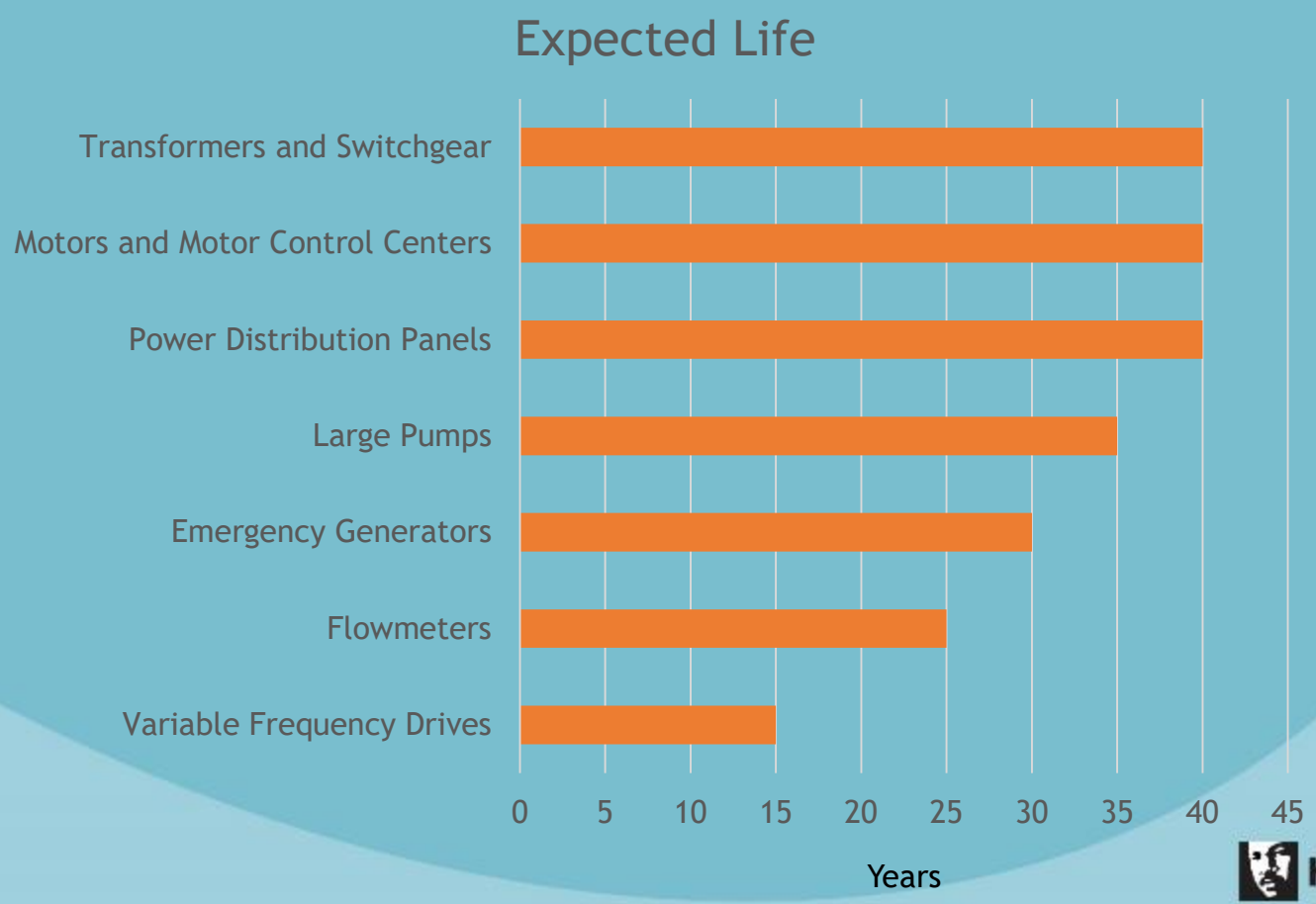
Expected Life of Common Wastewater Assets



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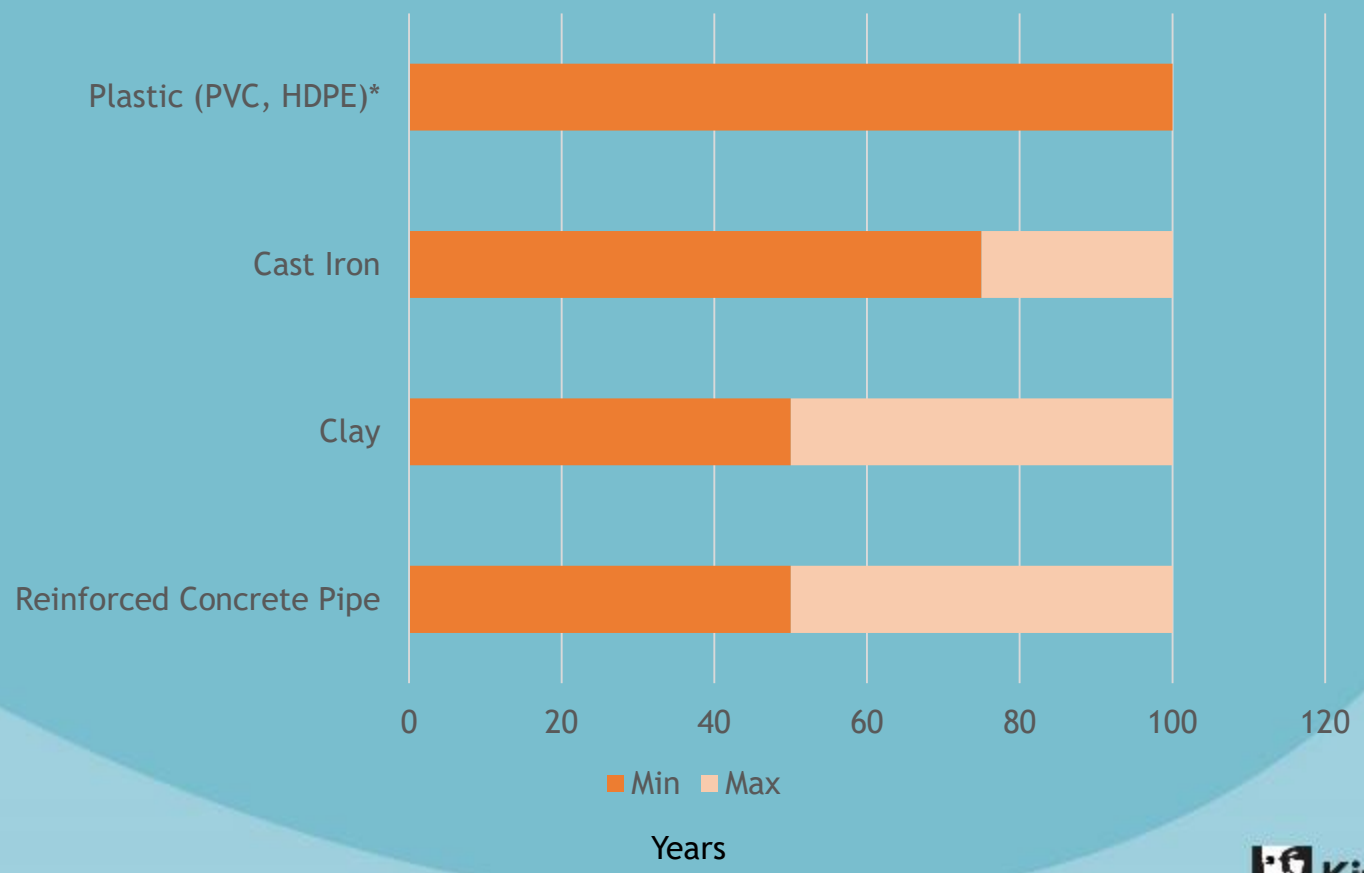
Expected Life of Wastewater Conveyance Pipe Materials



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Example: Projected End of Life of Major West Point Secondary Expansion Assets

	1995	2000	2005	2010	2015	2020	2025	2030	2035
Influent Pump Station (IPS)/Effluent Pump Station (EPS) Variable Frequency Drives	In progress, completion 2020								
Liquids Stream Flowmeters	Partially in progress								
IPS/EPS Pumps	Not started								
IPS/EPS Motors	Not started								
Power Distribution Panels	Not started								
Motor Control Centers	Not started								
Transformers and Switchgear	Not started								

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Project Prioritization

- When O&M determines that a capital project is warranted, a project request process is formally submitted for evaluation
- Projects are scored using objective criteria applied using a numerical scale
- Scores are applied by a ranking team comprised of subject matter experts (SMEs)
- Team members discuss each project request together and seek out any additional information that may be needed to help develop a common understanding of the project request
- Team member scores are aggregated to determine a calculated consensus score
- Scores for each project are used to determine their relative priority
- Prioritized project lists are elevated to management for budget consideration

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2020 MWPAAC Past Presentations

- March 25 – Overview of Priority Asset Management Needs
- May 27 – Asset Management: Overview and Portfolio Management
- June 4 – History of WTD's Asset Management Program
- July 22 – Asset Management Informational Session

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2020-21 Upcoming MWPAAC Presentations

- September 3 – Asset Management: Brightwater
- October 1 – Asset Management: South Plant
- November 5 – Asset Management: West Point
- December 3 – Six-Year CIP
- February 4 – Asset Management: Conveyance and Other Facilities

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Additional Briefings and Resources

- December 2 - RWQC Broader Asset Management Presentation
- Upcoming Asset Management Webpage

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Summary

- Over time, significant investments have been made into the conveyance and treatment system. Many assets are reaching end of life.
- WTD uses objective and measurable criteria to prioritize asset management projects.
- WTD will continue to engage with MWPAAC and RWQC on how to best address asset management in the regional wastewater system.

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Questions?

Bruce Kessler

Deputy Division Director

King County Wastewater Treatment Division

Bruce.Kessler@kingcounty.gov

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