Memorandum

To: Lower Duwamish Waterway Group (LDWG)

From: Matt Salmon, Anne Fitzpatrick, Chuck Vita, John Ryan - AECOM

Subject: Estimated Emission Reduction from Reduced Truck Transportation in the Lower Duwamish Waterway Corridor and Use of Lower Sulfur Fuels

Date: January 14, 2014

Introduction

As requested by LDWG to address a question from King County, this memorandum summarizes the analysis completed to estimate the changes in gas and particulate emissions in the Lower Duwamish Waterway (LDW) Corridor due to reduced truck transportation and the now required use of ultra-low sulfur diesel (ULSD) fuel.

Over the last decade, EPA has focused on reducing CO_2, NO_X, SO_X, and PM_{10} emissions under the Diesel Emissions Reduction Act (DERA). CO_2 emissions are known to contribute to the green house gas effect. Emissions from SO_X and PM_{10} are known to contribute to health problems, while NO_X also "contributes to the formation of ozone and PM through chemical reactions." New national emission requirements are intended to reduce CO_2 by up to 20%, NO_X by up to 90%, and PM by up to 95% by the year 2030. SO_X emissions are reduced by the switch from low sulfur diesel to ULSD. Two major steps taken by the EPA to reduce emissions involve updating engines in equipment fleets and mandatory use of ULSD fuel (EPA 2010).

For this analysis, the LDW Corridor is defined as the neighborhoods between the LDW and the Burlington Northern Santa Fe (BNSF) Railroad transfer stations in Georgetown and SODO. Neighborhoods in the LDW Corridor that could be affected by local truck transportation of contaminated sediment include Georgetown, Harbor Island, SODO, and South Park. [1]

Method Assumptions

The analysis uses the same AECOM Sustainability Tool developed for the LDW Feasibility Study (FS), to compare three remedial cleanup alternatives, each with three different truck transportation options (see assumptions) for a total of nine scenarios. The three LDW remedial

[1] Local truck transportation from the LDW to the BNSF transfer stations.

alternatives being compared are the LDWG Key Elements (LDWG 2011), EPA Preferred Alternative (Alternative 5CPlus) as presented in the Proposed Plan (EPA 2013a), and FS Alternative 5R (AECOM 2012). The first two alternatives use a combination of active technologies (dredging, capping, and ENR) to achieve remedial goals. LDW FS Alternative 5R is a removal-focused alternative that relies on dredging technology to achieve remedial goals. Table 1 shows the acreage addressed by each technology under each cleanup alternative.

Truck Transportation Options. Project-generated truck transportation through the LDW Corridor is varied by reducing the volume of contaminated sediment transported by trucks to the transfer station(s). The truck transportation options are:

- Truck option 1 – 100% of sediment is trucked to transfer station (assumes no direct-to-rail facilities are available);
- Truck option 2 – 60% of sediment is trucked to transfer station (assumes 1 direct-to-rail facility is available); and
- Truck option 3 – 22% of sediment is trucked to transfer station (assumes 2 direct-to-rail facilities are available).

This analysis assumes that the portion of contaminated dredge material not being trucked to a transfer station will be directly loaded onto rail cars at a local transloading facility (e.g., similar to operations currently used at the facility operated by LaFarge).

Truck options were selected based on the availability of direct-to-rail facilities. 100% truck transportation assumes no direct-to-rail facility will be available. 60% truck transportation assumes one direct-to-rail facility will be available, reducing trucked material by 40%. The 22% truck transportation assumes that two direct-to-rail facilities will be available and only the material within the intertidal area (~22%) would be loaded directly to trucks using land-based equipment.

Transportation of dredged contaminated sediment from the LDW to the Roosevelt Landfill[2] assumes three steps in the transport process:

1. Transport of contaminated sediment from the LDW barge to the rail cars:
    a. Trucking contaminated sediment over a 6-mile round-trip through the LDW Corridor from a transloading facility on the LDW to a BNSF transfer station located either in Georgetown or SODO. Contaminated sediment volumes transported through the LDW Corridor by truck will be either: 100% (Option 1), 60% (Option 2), or 22% (Option 3) of the total dredge volume.

[2] The Roosevelt Landfill in Washington State was identified in the FS as the most likely site for receiving excavated sediments from the LDW.

   b. The remaining portion will be loaded directly from the barge, docked alongside the transloading facility, to rail (eliminates the 6-mile truck trip through the LDW Corridor).

2. Rail transport of contaminated sediment comprising a 569-mile round-trip from the transfer station or transloading facility (i.e., LaFarge) to Roosevelt Landfill.[3]

3. Trucking contaminated sediment over a 6-mile round-trip from the BNSF transfer station to Roosevelt Landfill for final disposal.

Table 2 presents the volumes used in the analyses by technology and remedial alternative. The inputs to the sustainability tool are provided in Attachment 1. Only Step 1 is varied in this analysis; Steps 2 and 3 are held constant.

AECOM Sustainability Tool Update - Use of ULSD Fuel. Since submittal of the final LDW FS in October 2012, EPA has mandated ULSD in all on-road (e.g., trucks) and non-road equipment (e.g., railroad locomotives, tug boats, and construction equipment)[4]. Since the timing of the compliance was uncertain, the FS did not assume these requirements in its emissions analysis, and instead assumed the use of low sulfur diesel (LSD) fuel. The most recent version of the Sustainability Tool has been updated to take this requirement into account (i.e., maximum sulfur content of 15 parts per million [ppm] sulfur). For this analysis, all engines are also assumed to meet all new EPA emission standards (i.e., use newer Tier 4 engines or retrofit older ones to accept clean diesel technology) regardless of age. Besides adjusting for ULSD and assuming that all equipment will meet new emission standards, no other structural changes have been made to the tool and its calculations since finalization of the LDW FS. For reference, emission factors for all of the technologies are provided in Attachment 2.

Equipment Emission Factors. For a limited time, EPA is providing financial benefits/compensation under DERA to owners who upgrade equipment with clean diesel

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[3] The 6-mile truck trip described in Step 1 does not vary. The distance is small compared to the entire 569-mile trip to the landfill, which is mostly by train. Because the BNSF transfer stations are located in close proximity to the LDW, it was assumed that any additional rail distance would be negligible. Therefore, rail transportation distance does not significantly increase as truck transport decreases. The transfer stations in Georgetown and SODO are approximately the same distance from the landfill as the potential LDW transloading facility sites.

[4] EPA instituted use of low sulfur diesel fuel in two phases. The first phase was instituted in 2007 and required low sulfur diesel (i.e., maximum sulfur content of 500 ppm) to be used in all on-road and non-road diesel equipment (except ocean going vessels). The second phase was instituted in 2010 and required use of ULSD with a maximum sulfur content of 15 ppm (EPA 2004).

emission reduction technology[5], including particulate filters, crankcase ventilators, etc. to reduce NOx and PM_{10} emissions (EPA 2010).

EPA has mandated engine manufacturers to reduce emissions over the past decade through a tiered system, tier 1 to 4, with each tier requiring lower emissions. Final requirements (i.e., tier 4) take effect at 2014 year end for heavy duty truck, non-road, locomotive, and marine diesel engines (ARB and EPA 2013).

EPA is requiring almost all refineries and importers to produce only diesel fuel with a sulfur content not to exceed 15 ppm by 2013 year end. This requirement does not yet apply to the small class of transmix fuel, which is fuel formed by mixing during pipeline transport. The transmix fuel can only be used in approved older model locomotives and marine engines (EPA 2013b). However, older engines using transmix fuel are not used in this analysis for transportation of LDW sediments.

Emission factors used in this analysis assume that all engines use ULSD and meet all EPA emission requirements by the year 2015 (e.g., low emission vehicles, Tier 4 engines, clean diesel technology upgrades, etc.). In reality, not all engines may be able to meet this new requirement when construction begins and some older engines may be used for sediment remediation in the LDW. Therefore, this analysis represents a best-case estimate of reduced emissions.

Results

The switch from LSD fuel (assumed in the FS) to ULSD fuel using the new EPA engine and clean diesel technology requirements to calculate emissions, results in a slight decrease in CO_2 emission estimates, and a larger decrease in NO_X, SO_X and PM_{10} emissions as shown in Table 3. For example, CO_2 emissions were reduced from 59,000 to 54,000 metric tons (an approximately 8% reduction from the FS) while NO_X, SO_X, and PM_{10} emissions were reduced by 46%, 78%, and 58%, respectively compared to the FS calculations.

The estimated total and annual gas and particulate emissions for all nine scenarios (three remedial alternatives, three transport options for each) are shown in Table 4. A detailed breakdown of emission calculations by technology is provided in Attachment 3.

All five emissions calculated (i.e., CO_2, CO, NO_X, SO_X, and PM_{10}) slightly decreased as the percentage of sediment traveling by truck through the LDW Corridor changed, as shown in Attachment 3 in the row labeled “transportation.” Reduced truck transportation (for the 6-mile local trip) results in only a small decrease in total emissions for CO_2 and SO_X, because of the contributions from the dredging equipment and rail transport. Thus, the reduction in emissions

5 According to newsletters, tug boat companies in Seattle, WA, including Harley Marine, Foss, and Crowley, have already begun to take advantage of upgrade incentives for converting their fleets to use ULSD.

from decreased truck use is insignificant (i.e., 1% or less) when compared to total emissions, and falls within the expected error of the emissions model.

The other emissions, CO, NO_X, and PM_{10}, did not see a noticeable reduction in their total emissions as the percentage of dredged sediment traveling by truck changed. This is because these emissions are driven by rail transportation and not by truck transportation. This is illustrated in Table 5 by the high emission factors for rail transport and the low emission factors for truck transport.

In conclusion, use of ULSD by cleanup project equipment and trucks operating in the LDW would reduce total project emissions as compared to project delivery with LSD. Reductions range from approximately 5% for CO_2 to almost 80% for SO_X. By comparison, reductions in local truck transport if more direct-to-rail transloading facilities were available would reduce emissions by less than 2% of the total emissions for CO_2 and SO_X.

References

AECOM 2012. *Lower Duwamish Waterway Final Feasibility Study.* Submitted to the U.S. Environmental Protection Agency and the Washington State Department of Ecology. Prepared for the Lower Duwamish Waterway Group. October 31, 2012.

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EPA 2004. *Regulatory Announcement – Clean Air Nonroad Diesel Rule*. EPA420-F-04-032. Office of Transportation and Air Quality. May 2004.

EPA 2010. *Second Report to Congress: Highlights of the Diesel Emissions Reduction Program.* Energy Policy Act of 2005 Title VII, Subtitle G, Sections 791-797. Prepared by U.S. EPA's Office of Transportation and Air Quality. 2010.

EPA 2013a. *Proposed Plan for the Lower Duwamish Waterway Superfund Site*. Environmental Protection Agency. February 28, 2013.

EPA 2013b. *Electronic Code of Federal Regulations, Subpart I – Motor Vehicle Diesel Fuel; Nonroad, Locomotive, and Marine Diesel Fuel; and ECA Marine Fuel.* Environmental Protection Agency. Accessed November 30, 2013.

GREET 2012. Center for Transportation Research, Energy Systems Division. Argonne National Laboratory. 2012

LDWG 2011. *Key Elements for Optimizing the Cleanup of the LDW – Technical Memorandum.* Prepared by AECOM for the Lower Duwamish Waterway Group. August 1, 2011.

Table 1 Active Technology Assignment Areas - for Each Alternative

Technology	Remedial Alternative		
	LDWG Key Elements (Acres)	EPA Preferred Alternative (Acres)	LDW FS Alternative 5R (Acres)
Dredge	38	64	143
Partial Dredge and Cap	17	20	14
Capping	17	24	—
Enhanced Natural Recovery (ENR)	65	48	—
Total Active Area	137	156	157

Table 2 Volumes by Technology Used in the Sustainability Analysis

Technology		Remedial Alternative		
		LDWG Key Elements (CY)	EPA Preferred Alternative (CY)	LDW FS Alternative 5R (CY)
Dredge Volume[a]		620,000	790,000	1,600,000
Total Material Placement Volume[b]		480,000	360,000	590,000
Volume of sediment transported by truck through LDW corridor to BNSF transfer station(s)[c]	Option 1 – 100%	620,000	790,000	1,600,000
	Options 2 – 60%	372,000	474,000	960,000
	Option 3 – 22%	136,400	173,800	352, 000
Volume of sediment transported by train to landfill[c]		620,000	790,000	1,600,000
Final Truck Transportation Volume at Roosevelt Landfill from Rail[c]		620,000	790,000	1,600,000
Construction Period (Years)		5	7	17

Notes:

[a] Includes sediment removed by dredging, including areas of partial dredging and capping. Assumes dredge cut prism volume, with performance contingency volumes.

[b] Material placement includes sand and amendments placed as capping, ENR, stone armor material, dredge residuals management, and/or dredge footprint habitat restoration. Placement material is assumed to be transported to the LDW via barge.

[c] Transportation to Roosevelt Landfill for disposal assumes a round trip of 581 miles. The trip includes 6 miles of truck transport to a BNSF transfer station from the LDW, 569 miles of rail transport between Seattle and Roosevelt BNSF transfer stations, and 6 miles of truck transport from a BNSF transfer station to Roosevelt Landfill.

Table 3 Comparison of Emissions between Low Sulfur and Ultra Low Sulfur Diesel Fuels

Emission	LDW FS Alternative 5R		Percent Reduction in Emissions
	Low Sulfur Diesel (metric tons)	Ultra Low Sulfur Diesel (metric tons)	
CO_2	59,000	54,000	8%
CO	160	142	11%
NO_X	1,200	646	46%
SO_X	28	6	78%
PM_{10}	50	21	58%

Table 4 Emission Results in Metric Tons

		Alternative:	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
		Truck Transportation Option:	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Total Emissions	CO_2	metric tons	23,200	23,000	22,800	27,300	27,100	26,900	54,000	53,600	53,200
	CO	metric tons	61	61	61	72	72	72	142	142	142
	NO_x	metric tons	279	279	279	327	327	327	646	646	645
	SO_x	metric tons	2	2	2	3	3	3	6	6	5
	PM_{10}	metric tons	9	9	9	11	11	11	21	21	21
Annual Emissions	CO_2	metric tons	4,630	4,600	4,570	3,890	3,870	3,840	3,180	3,150	3,130
	CO	metric tons	12.3	12.3	12.3	10.3	10.3	10.3	8.4	8.4	8.3
	NO_x	metric tons	55.8	55.8	55.8	46.7	46.7	46.6	38.0	38.0	38.0
	SO_x	metric tons	0.48	0.47	0.47	0.40	0.40	0.39	0.33	0.32	0.32
	PM_{10}	metric tons	1.89	1.89	1.88	1.55	1.55	1.55	1.26	1.26	1.26

Notes:

1. Option 1 assumes 100% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes no direct-to-rail facilities are available)
2. Option 2 assumes 60% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes 1 direct-to-rail facilities are available)
3. Option 3 assumes 22% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes 2 direct-to-rail facilities are available)
4. Annual emission calculations are based on construction periods of 5, 7, and 17 years for the LDWG Key Elements, EPA Preferred Alternative, and LDW FS Alternative 5R, respectively.

Table 5 Ultra Low Sulfur Diesel Emission Factors Used for Transportation

Source	Emission	ULSD Factor (lb/gal)
Truck Transportation (GREET 2012)	CO_2	23.701
	CO	0.004
	NO_x	0.013
	SO_x	0.003
	PM_{10}	0.001
Train Transportation (GREET 2012)	CO_2	23.567
	CO	0.062
	NO_x	0.318
	SO_x	0.002
	PM_{10}	0.008

1. These emission factors account for 100% use of ULSD in equipment that meets meet all EPA emission requirements by the year 2015 (e.g., Tier 4 engines, clean diesel technology upgrades, etc.).

Last revised by MLS an AGF 1/13/14 and checked by KAP 1/13/14
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Attachments

Attachment 1 – AECOM Sustainability Tool Inputs

Attachment 2 – Technology Emission Factors Applicable for Year 2015

Attachment 3 – Emissions by Technology, Remedial Alternative, and Truck Miles

Attachment 1 – AECOM Sustainability Tool Inputs

1 DREDGING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume removed below -10 ft	Barge-mounted derrick crane	cy	465,000	465,000	465,000	592,500	592,500	592,500	1,200,000	1,200,000	1,200,000
Volume removed above -10 ft	Barge-mounted backhoe	cy	155,000	155,000	155,000	197,500	197,500	197,500	400,000	400,000	400,000
Fuel consumption	Barge-mounted derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
	Barge-mounted backhoe	gal/hr	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
	Survey boat	gal/hr	8	8	8	8	8	8	8	8	8
Dredging rate	Barge-mounted derrick crane	cy/hr	55	55	55	55	55	55	55	55	55
	Barge-mounted backhoe	cy/hr	39	39	39	39	39	39	39	39	39
Total time required for survey operation	Survey boat	hr	596	596	596	760	760	760	1,588	1,588	1,588

2 TRANSLOADING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume transloaded	Tug	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
Offloading volume material to lined containers	Derrick crane	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
Fuel consumption	Tug full engine	gal/hr	85	85	85	85	85	85	85	85	85
	Derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
Distance from the site to the offloading area	Tugs	miles	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Speed	Tugs	miles/hr	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Barge capacity	Barge	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Offloading rate by derrick crane	Derrick crane	cy/hr	110	110	110	110	110	110	110	110	110
Number of water equipment operators	—	worker	3	3	3	3	3	3	3	3	3
Number of construction equipment operators	—	worker	3	3	3	3	3	3	3	3	3

3 TRANSPORTATION											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume transported	Truck in LDW	cy	620,000	372,000	136,400	790,000	474,000	173,800	1,600,000	960,000	352,000
	Truck at landfill	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Railcar to landfill	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Tug clean capping material to the site	cy	480,000	480,000	480,000	360,000	360,000	360,000	590,000	590,000	590,000
	Truck in LDW (one way)	miles	3	3	3	3	3	3	3	3	3
Distance	Truck at landfill (one way)	miles	3	3	3	3	3	3	3	3	3
	Train (total distance)	miles	568.6	568.6	568.6	568.6	568.6	568.6	568.6	568.6	568.6
Fuel consumption	Truck	gal/miles	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Train	gal/miles	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
	Tug	gal/hr	85	85	85	85	85	85	85	85	85
Load capacity	Truck	cy	20	20	20	20	20	20	20	20	20
	Railcar	cy	67	67	67	67	67	67	67	67	67
Transportation rate	Tug	cy/hr	122.7	122.7	122.7	122.7	122.7	122.7	122.7	122.7	122.7
Speed	Truck	miles/hr	40	40	40	40	40	40	40	40	40
	Train	miles/hr	50	50	50	50	50	50	50	50	50

4 SEDIMENT CAPPING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume placed below - 10 ft	Barge-mounted derrick crane	cy	336,000	336,000	336,000	252,000	252,000	252,000	413,000	413,000	413,000
	Precision excavator	cy	72,000	72,000	72,000	54,000	54,000	54,000	88,500	88,500	88,500
Volume placed above - 10 ft	Precision excavator	cy	72,000	72,000	72,000	54,000	54,000	54,000	88,500	88,500	88,500
Fuel consumption	Barge-mounted derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
	Precision excavator	gal/hr	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
	Survey boat	gal/hr	8	8	8	8	8	8	8	8	8
C = Capping placement rate (>0)	Barge-mounted derrick crane	cy/hr	163	163	163	163	163	163	163	163	163
	Precision excavator	cy/hr	128	128	128	128	128	128	128	128	128
Total time required for survey operation	Survey boat	hr	350	350	350	262	262	262	429	429	429

5 MISCELLANEOUS											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume	Loader	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Dozer	cy	0	0	0	0	0	0	0	0	0
Fuel consumption	Loader	gal/hr	7	7	7	7	7	7	7	7	7
	Dozer	gal/hr	0	0	0	0	0	0	0	0	0
Excavation rate	Loader	cy/hr	200	200	200	200	200	200	200	200	200
	Dozer	cy/hr	70	70	70	70	7	70	70	70	70

NOTES

Distance: Average distance is the total distance travelled; one way is the distance of the landfill from the site (will be doubled for calculations).

Attachment 2 – Technology Emission Factors[6] Applicable for Year 2015

1 DREDGING			
References	Description	Units	Value
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NOx	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

2 TRANSLOADING			
References	Description	Units	Value
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NO_x	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

6 Emission factors assume that all engines use ULSD and meet all EPA emission requirements by the year 2015 (e.g., Tier 4 engines, clean diesel technology upgrades, etc.)

3 TRANSPORTATION			
References	Description	Units	Value
GREET – Truck Transportation, Diesel - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012	Emission factor for CO_2	lb/gal	23.701
	Emission factor for CO	lb/gal	0.004
	Emission factor for NO_x	lb/gal	0.013
	Emission factor for SOx	lb/gal	0.003
	Emission factor for PM_{10}	lb/gal	0.001
GREET – Train Transportation, Diesel - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012	Emission factor for CO_2	lb/gal	23.567
	Emission factor for CO	lb/gal	0.062
	Emission factor for NO_x	lb/gal	0.318
	Emission factor for SOx	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.008
GREET – Barge Transportation, Diesel - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NOx	lb/gal	0.334
	Emission factor for SOx	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

4 SEDIMENT CAPPING			
References	Description	Units	Value
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NO_x	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

5 MISCELLANEOUS			
References	Description	Units	Value
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

Attachment 3 – Emissions by Technology, Remedial Alternative, and Truck Miles

Technology	Technology Description	Emissions (in metric tons)	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
			Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Dredging	Dredging Equipment	CO_2	2,708	2,708	2,708	3,452	3,452	3,452	6,985	6,985	6,985
		CO	8	8	8	10	10	10	21	21	21
		NO_x	16	16	16	21	21	21	42	42	42
		SO_x	0.28	0.28	0.28	0.36	0.36	0.36	0.72	0.72	0.72
		PM_{10}	1	1	1	2	2	2	4	4	4
	Bathymetric Survey of Dredging Footprint	CO_2	51	51	51	65	65	65	136	136	136
		CO	0.14	0.14	0.14	0.18	0.18	0.18	0.38	0.38	0.38
		NOx	0.72	0.72	0.72	0.92	0.92	0.92	1.92	1.92	1.92
		SO_x	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		PM_{10}	0.03	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07
Transloading	Transloading Tug transport of Dredge Sediment	CO_2	1,411	1,411	1,411	1,796	1,796	1,796	3,638	3,638	3,638
		CO	4	4	4	5	5	5	10	10	10
		NO_x	20	20	20	25	25	25	52	52	52
		SO_x	0	0	0	0	0	0	0	0	0
		PM_{10}	1	1	1	1	1	1	2	2	2
	Offloading barge with derrick crane	CO_2	1,506	1,506	1,506	1,919	1,919	1,919	3,892	3,892	3,892
		CO	4.26	4.26	4.26	5.44	5.44	5.44	11.02	11.02	11.02
		NO_x	21	21	21	27	27	27	55	55	55
		SO_x	0.15	0.15	0.15	0.20	0.20	0.20	0.40	0.40	0.40
		PM_{10}	0.77	0.77	0.77	0.98	0.98	0.98	1.98	1.98	1.98
Transportation	Truck Transport in LDW Corridor to transfer facility	CO_2	400	240	88	508	306	112	1,034	621	227
		CO	0.08	0.05	0.02	0.10	0.06	0.02	0.20	0.12	0.04
		NO_x	0.22	0.13	0.05	0.29	0.17	0.06	0.58	0.35	0.13
		SO_x	0.05	0.03	0.01	0.06	0.04	0.01	0.13	0.08	0.03
		PM_{10}	0.02	0.01	0.00	0.02	0.01	0.00	0.04	0.03	0.01

Technology	Technology Description	Emissions (in metric tons)	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
			Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Transportation *(continued)*	Rail Transport to Roosevelt	CO_2	12,156	12,156	12,156	15,513	15,513	15,513	31,434	31,434	31,434
		CO	32	32	32	41	41	41	83	83	83
		NO_x	164	164	164	209	209	209	424	424	424
		SO_x	1.24	1.24	1.24	1.58	1.58	1.58	3.20	3.20	3.20
		PM_{10}	4.24	4.24	4.24	5.40	5.40	5.40	10.93	10.93	10.93
	Truck Transport at Roosevelt Landfill	CO_2	400	400	400	508	508	508	1,034	1,034	1,034
		CO	0.08	0.08	0.08	0.10	0.10	0.10	0.20	0.20	0.20
		NO_x	0.22	0.22	0.22	0.29	0.29	0.29	0.58	0.58	0.58
		SO_x	0.05	0.05	0.05	0.06	0.06	0.06	0.13	0.13	0.13
		PM_{10}	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04
	Tug Transport of Clean Aggregate to the Site	CO_2	3,556	3,556	3,556	2,667	2,667	2,667	4,373	4,373	4,373
		CO	10	10	10	8	8	8	12	12	12
		NO_x	50	50	50	38	38	38	62	62	62
		SO_x	0.36	0.36	0.36	0.27	0.27	0.27	0.44	0.44	0.44
		PM_{10}	2	2	2	1	1	1	2	2	2
Capping	Placing Capping Material	CO_2	676	676	676	508	508	508	835	835	835
		CO	2.00	2.00	2.00	1.50	1.50	1.50	2.46	2.46	2.46
		NO_x	4.04	4.04	4.04	3.03	3.03	3.03	4.94	4.94	4.94
		SO_x	0.07	0.07	0.07	0.05	0.05	0.05	0.09	0.09	0.09
		PM_{10}	0.34	0.34	0.34	0.26	0.26	0.26	0.42	0.42	0.42
	Bathymetric Survey of Material Placement Footprint	CO_2	30	30	30	22	22	22	37	37	37
		CO	0.08	0.08	0.08	0.06	0.06	0.06	0.10	0.10	0.10
		NO_x	0.42	0.42	0.42	0.32	0.32	0.32	0.52	0.52	0.52
		SO_x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		PM_{10}	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02
Miscellaneous	Front-End Loader Used at Transloading Facility to Load Containers.	CO_2	232	232	232	295	295	295	599	599	599
		CO	0.68	0.68	0.68	0.87	0.87	0.87	1.77	1.77	1.77
		NO_x	1.38	1.38	1.38	1.76	1.76	1.76	3.57	3.57	3.57
		SO_x	0.02	0.02	0.02	0.03	0.03	0.03	0.06	0.06	0.06
		PM_{10}	0.12	0.12	0.12	0.15	0.15	0.15	0.30	0.30	0.30