Appendix A

Carbon Footprint/ Greenhouse Gas Inventory Analysis for Sediment, Floodplain, and Treatment/Disposition Alternatives

Appendix A: Carbon Footprint/Greenhouse Gas Inventory Analysis for Sediment, Floodplain, and Treatment/Disposition Alternatives

1. Introduction

In response to the United States Environmental Protection Agency's (EPA's) General Comment #4 on the March 2008 Housatonic River – Rest of River Corrective Measures Study (CMS) Report, GE has conducted a greenhouse gas (GHG) inventory/carbon footprint calculation for the remedial alternatives described in the CMS Report. This inventory estimates the GHG emissions associated with each of the different sediment (SED), floodplain soil (FP), and treatment/disposition (TD) alternatives presented in the CMS Report. A GHG inventory is an accounting of the amount of greenhouse gases emitted to or removed from the atmosphere over a specific period of time associated with a process or project. The net carbon emission or sequestration associated with a defined activity is often referred to as the activity's carbon footprint.

This GHG inventory was based on carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions anticipated to result from activities supporting each remediation alternative outlined in the CMS Report (spanning several decades in some cases). This inventory also provides information on the activities that cause GHG emissions and removals, as well as background on the methods used to make the calculations, which were conducted in accordance with the Climate Leaders Greenhouse Gas Inventory Protocol, titled *Design Principles*, published by EPA (EPA 2005) (Design Principles).

The objective of this evaluation was to estimate and compare the carbon footprint associated with the work that would be conducted for each remedial alternative:

- For the sediment alternatives, the analysis includes sediment removal/capping and related ancillary activities for alternatives SED 3 through SED 8. Alternatives SED 1 and SED 2 were not included because those alternatives call for no action and monitored natural recovery, respectively, and hence no or minimal GHG emissions are anticipated for those alternatives.

- For the floodplain soil alternatives, the analysis includes soil removal/replacement and related ancillary activities for alternatives FP 2 through FP 7. As with the sediment alternatives, FP 1 (no action) was not included in this analysis due to its anticipated negligible GHG emissions.

- For the treatment/disposition alternatives, the analysis includes the activities associated with treatment and/or disposal of removed sediment and floodplain soil for alternatives TD 1 through TD 5. As discussed in Section 7 of the CMS Report, the TD alternatives have been evaluated for the range of potential removal volumes under the sediment and floodplain soil alternatives, except for TD 2.[1] Specifically, this range extends from 189,000 *in situ* cubic yards (cy), based on a combination of SED 3 and FP 2, to 2.9 million *in situ* cy, based on a combination of SED 8 and FP 7. These volumes are hereafter termed "lower-bound (LB) volume" and "upper-bound (UB) volume", respectively.[2] In addition, as discussed in Section 7.5 of the CMS Report, the potential for reusing approximately 50% of the treated floodplain soil on-site as backfill in the floodplain was evaluated for TD 5. Therefore, GHG emissions have been estimated both considering this potential 50% reuse and not considering it.

The assessments and calculations of GHG emissions used in this evaluation follow the Climate Leaders Design Principles guidance (EPA 2005),[3] which was based on a prior WRI/WBCSD (2004) protocol.[4] The Climate Leaders program also provides several guidance modules which were used to obtain relevant emissions factors for calculating GHG emissions (emissions from mobile combustion sources, stationary combustion sources, emissions from purchases of electricity, etc.).

In accordance with Design Principles guidance, emissions have been reported as metric tons (tonnes) of carbon dioxide equivalents (CO_2-eq). This approach allows for "comparing the radiative forcing ability of individual gases by using a relative

[1] It is important to note that the GHG emissions resulting from alternative TD 2 should not be compared directly to emissions of the other TD alternatives because this alternative would only treat a portion of the sediments under a few alternatives (SED 6, SED 7, and SED 8), and an additional TD option would be required to complete the sediment and floodplain remediation. Instead, the carbon footprint for TD 2 would be a fraction of the total carbon footprint and would be additive to the footprint of the selected TD option to treat the non-hydraulically dredged sediments in alternatives SED 6, SED 7, and SED 8, as well as the floodplain soil.

[2] The sediment and floodplain removal volumes used in this analysis differ from those presented in the CMS Report because they were updated in response to EPA's comments, as discussed in the main body of this Interim Response (i.e., Specific Comment 44 for sediment volumes and Specific Comments 95, 98, 112, 113, and 115 for floodplain volumes).

[3] EPA – http://www.epa.gov/climateleaders/resources/design-principles.html: "The Design Principles Guidance includes overall guidance on defining inventory boundaries, identifying greenhouse gas (GHG) emission sources, and defining and adjusting a base year."

[4] World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) report on Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard (revised March 2004).

measure for each GHG, termed its global warming potential (GWP). GWP is the ability of each greenhouse gas to trap heat in the atmosphere relative to carbon dioxide, which serves as the reference gas" (EPA 2005).

This GHG inventory reports estimated emissions expected to occur during the timeframe over which each project alternative is anticipated to be implemented, as they would be associated with activities such as sediment removal, floodplain soil removal, and ancillary activities such as construction of staging areas and access roads.[5]

[5] For certain activities, direct emissions are expected to extend beyond the project timeframe. These consist of the emissions relating to changes in forest carbon stocks – specifically those relating to the removal and chipping of trees (to facilitate access road/staging area construction and floodplain soil removal) and those relating to the replanting of trees as part of site restoration. CO_2 emissions resulting from the decay of chipped trees and from changes in carbon sequestration rates due to removal of mature trees and replanting with seedlings will last longer than the project duration, and an equilibrium in net emissions can eventually be expected over a longer timeframe (i.e., zero overall net emissions eventually resulting 100 years or more after project initiation). However, to provide comparability with the other CO_2 emissions estimated for the remedial alternatives and given the fluctuations in these forest-related emission rates over time, only the net direct emissions resulting from these components over the project timeframe have been included in the evaluations presented herein.

2. Methods for Setting Operational Boundaries and Identifying GHG Emissions

Development of a GHG inventory requires setting the operational boundaries, which involves identifying the various emissions associated with a particular company's operations that will be included in the carbon footprint analysis (EPA 2005), or in this case, with the anticipated components of the remedial activities. The operational boundaries for this analysis were determined based on a detailed examination of the component remedial activities that are anticipated to be implemented for each SED, FP, and TD alternative. In essence, the energy required for conducting the remedial activities was accounted for, as energy usage represents fossil fuel usage and hence results in GHG emissions (since no alternative fuels are anticipated to be used). Using the Design Principles guidance (EPA 2005), the emissions associated with each component of the remedial activities were identified and categorized as direct, indirect, or optional emissions:

- **Direct emissions** are defined by EPA (2005) as: *Emissions from sources that are owned or controlled by the company, e.g., emissions from combustion in owned or controlled boilers, furnaces, vehicles; emissions from chemical production in owned or controlled process equipment. Core direct emissions result from stationary, mobile, and process-related sources at a facility*. Operational boundaries associated with direct emissions in this analysis encompassed activities such as transportation of materials to the site, tree clearing/site preparation, access road/staging area construction, sediment and floodplain soil removal, placement of caps and backfill, sediment dewatering/stockpiling/stabilization, decay of chipped trees, and final treatment (if applicable) and disposition of materials in a regulated landfill.

- **Indirect emissions** are defined by EPA (2005) as: *Emissions that are a consequence of the activities of the company, but occur at sources owned or controlled by another company. Indirect emissions for the purchaser are characterized as direct emissions for the facility where the emissions are generated, e.g., emissions from the generation of purchased electricity consumed by a company. Core indirect emissions are emitted as a consequence of the import of electricity, heating/cooling, or steam*. For this analysis, operational boundaries associated with indirect emissions incorporated generation of purchased electricity used for water treatment, chemical extraction (TD 4), and thermal desorption (TD 5).

- **Optional emissions** are defined by EPA (2005) as: *Emissions that are a consequence of the activities of the reporting company, but occur from sources* *not owned or controlled by the reporting company, and are not part of the company's core emissions*. Operational boundaries associated with optional emissions in this analysis incorporate activities connected with the processing of materials that will be used as part of the remediation such as production of steel sheet piling, quarrying of rip rap (armor stone), refining of diesel fuel, excavation of gravel/backfill from borrow pits, and cement manufacture. Such emissions are termed optional in EPA's guidance because a reporting company may opt to include such contributions in their inventory or they can exclude them if such emissions are expected to be accounted for in the source company's own inventory. This category of emissions will subsequently be referred to herein as "Off-Site Emissions" so that its reporting is not misconstrued as being optional with respect to this GHG inventory for the CMS alternatives.

When discussing transportation of materials/wastes, EPA (2005) draws a distinction between Direct and Off-Site emissions as they relate to either company-owned/controlled or non-company-owned/controlled mobile combustion sources, respectively. This distinction is made for the benefit of GHG inventories; however, for the purpose of calculating a carbon footprint evaluation of the CMS remedial alternatives, the GHG emissions associated with the transportation of materials/wastes to and from the work site (e.g., construction equipment, gravel for access roads, steel sheet piling, dredged/excavated materials for disposal) were included as direct emissions. This approach is appropriate since these transportation activities, while they may be conducted in vehicles owned by private contractors, are significant components of the remedial activities and contribute to the carbon footprint.

The remedial activities to be conducted are summarized (in general terms) below with respect to the operational boundaries associated with the three emissions categories.

2.1 Direct Emissions

The direct emissions included in this analysis consisted of the following:

<u>SED Alternatives:</u> For the sediment alternatives, the direct emissions included vehicle/equipment emissions resulting from the following activities:

- Removal and chipping of trees as part of site clearing activities (to facilitate the construction of access roads and staging areas);

- Construction of access roads and staging areas (including transportation of materials to site);
- Sediment removal – both dredging in “wet” and removal in “dry”;
- Sediment transport to staging area/dewatering site;
- Sediment stockpiling/dewatering;
- Sheetpile transportation/installation/removal for excavations in the dry;
- Installation of thin-layer cap, engineered cap, and backfill materials (including transportation of materials to site); and
- Bank removal/stabilization (Reach 5A/5B erodible banks).

The direct emissions also included emissions from the decay of chipped trees (release of CO_2 via fungal and microbial decomposition) and from changes in carbon sequestration rates due to removal of mature trees and replanting with seedlings.

<u>FP Alternatives</u>: For the floodplain alternatives, the direct emissions included vehicle/equipment emissions resulting from the following activities:

- Removal and chipping of trees as part of site clearing activities (to facilitate both the construction of access roads and staging areas, as well as floodplain soil removal activities);
- Construction of access roads and staging areas (including transportation of materials to site);
- Soil removal/replacement (including transportation of backfill material to site); and
- Soil stockpiling.

The direct emissions also included emissions from the decay of chipped trees (release of CO_2 via fungal and microbial decomposition) and from changes in carbon sequestration rates due to removal of mature trees and replanting with seedlings.

TD Alternatives: For the treatment/disposition alternatives, the direct emissions included vehicle/equipment emissions resulting from the following activities:

- Transportation
  - Sediment and soil to landfill (TD 1 and TD 3);
  - Sediment and soil residuals to landfill (TD 4 & TD 5) after treatment;
  - Pumping of hydraulically dredged sediments to confined disposal facility (TD 2);
- Construction of confined disposal facility and landfill (TD 2 and TD 3, respectively);
- Construction of treatment buildings and systems (TD 4 and TD 5); and
- Transportation of sediment and soil to treatment facility (TD 4 and TD 5).

The direct emissions also included emissions due to conversion of the mass of carbon removed from the river and floodplain in the form of total organic carbon (TOC) to CO_2 (TD 5), and emissions from burning natural gas in the thermal desorption treatment system (TD 5).

2.2 Indirect Emissions

The indirect emissions included in this analysis are related to the generation of electricity that would be purchased during remedial activities, as described below. Annual output emission rates for CO_2, N_2O, and CH_4 were used to calculate the indirect GHG emission contributions from electricity use for each component anticipated to draw power from the Northeast Power Coordinating Council (NPCC) New England subregion (EPA 2008d).

SED Alternatives

- Power requirements for water treatment system that would be used to treat supernatant generated during sediment dewatering operations.

FP Alternatives – None

TD Alternatives

- Power requirements for chemical extraction system (TD 4).
- Power requirements for thermal desorption system (TD 5).

2.3 Off-Site Emissions

The off-site emissions included in this analysis consisted of vehicle/equipment or other emissions resulting from several types of activities, listed below:

SED Alternatives

- Excavation of gravel from borrow pit(s) to be used in construction of access roads;
- Excavation of sand (for isolation layer and for use in lining stockpile areas) from borrow pit(s);
- Manufacture of steel sheet piles;
- Manufacture of concrete for revetment matting;
- Manufacture of cement for stabilization (see discussion in Section 4 regarding alternative stabilization material options);
- Quarrying of rip-rap and armor stone materials; and
- Refining of diesel fuel for use in construction vehicles, equipment, machinery, etc.

FP Alternatives

- Excavation of gravel from borrow pit(s) to be used in construction of access roads;
- Excavation of backfill material from borrow pit(s);
- Excavation of sand (for use in lining stockpile areas) from borrow pit(s); and

- Refining of diesel fuel for use in construction vehicles, equipment, machinery, etc.

<u>TD Alternatives</u>

- Refining of diesel fuel for use in transportation to off-site landfill and for construction of and transportation to upland disposal facility (TD 1 and TD 3);

- Production (drilling) and distribution of natural gas for use in the thermal desorption treatment system (TD 5); and

- Manufacture of concrete used in construction of buildings to house chemical extraction and thermal desorption systems (TD 4 and TD 5).

2.4 Emissions Not Included in GHG Inventory/Carbon Footprint

The following sources of emissions were considered in the analysis, but were judged to likely result in no or minimal GHG emissions, or were not estimated due to the inability to readily obtain information to make such estimates, and were thus excluded from the calculations:

- Methane (CH_4) off-gas generation from landfilled sediment/floodplain material was considered, as the TOC component of the removed sediments and soil may decompose within the disposal landfills (thereby releasing CH_4 directly, or CO_2 if the CH_4 were to be collected and subsequently burned). However, discussions with personnel from Chemical Waste Management, Inc. (CWM), which is the operator of several commercial landfills that would be considered for off-site disposal of excavated materials, indicated that those types of landfills, in contrast to municipal solid waste landfills, do not maintain Title V (of the Clean Air Act Amendments) air permits nor do they operate any type of gas venting system (Banaszak, personal communication, 2009). It has been CWM's experience that after the addition of sediment stabilization agents such as cement or lime (as has been assumed for the CMS evaluations), the pH of the material is increased such that biological activity is no longer viable, thereby limiting the potential for the TOC contained in such material to be converted to CH_4. Therefore, it is expected that the TOC contained within the excavated sediment/floodplain material, as evaluated in the CMS, would remain sequestered within the disposal landfills.

- Direct vehicle emissions expected to result from activities associated with replanting of trees and other site restoration activities have not been estimated due to lack of information regarding the level of effort for such activities. However, it is reasonable to assume that these emissions will be no greater (and quite possibly much less) than those associated with tree removal activities (presented in Tables 1 and 2 in Section 4) due to the relative level of energy demands of such activities.

- Indirect emissions from purchased electricity to power field office trailers have also not been included, as these emissions are expected to be relatively minor. Estimates of the carbon footprint associated with field trailer electrical power use from a similar project resulted in values that were small relative to the other sources encompassed in this GHG inventory.[6]

- Heating/cooling energy requirements for the treatment system buildings have likewise not been estimated, as these emissions are unknown at this time. However, it is assumed that this usage would potentially be on the order of magnitude of the field office trailers (discussed above).

- Finally, energy expended due to operations at off-site disposal facilities (for TD 1, 4 and 5) once the material is delivered (i.e., additional vehicle usage in placing material in landfill cells, etc.) is difficult to estimate and has thus not been included. For example, CWM has indicated that CO_2 emissions due to vehicle usage at its facilities have not been quantified at this time (Banaszak, personal communication, 2009).

[6] Reviewing utility bills from another project of similar scope (in the same geographic region) revealed annual electric consumption to be approximately 12,000 kWh. It is assumed that approximately five field trailers would be in use at one time during the remedial activities (for whichever SED & FP combination is implemented), therefore consuming an estimated 60,000 kWh per year. Using a regional emissions factor of approximately 830 lbs CO_2/MWh (EPA 2008d) yields an emission rate of ~23 tonnes CO_2/yr. Considering only the emissions resulting from the SED alternatives, and factoring in the minimum/maximum timeframe for project completion (10-52 yrs [SED 3 - SED 8]), yields a range of 230 to 1,196 tonnes CO_2 emitted due to purchased electricity for field office trailers, which amounts to less than 1% of the total (see Table 1 in Section 4 below for Total Emissions).

3. Methods for Calculation and Reporting of GHG Emissions

3.1 Emissions from General Construction Activities

Based on procedures outlined in the Design Principles guidance (EPA 2005), tonnes of CO_2-eq were calculated for each of the identified direct, indirect, and off-site emissions associated with each remediation alternative. The data generated for the cost estimates prepared for the CMS Report (with revisions contained in this Interim Response) were used as the primary basis for calculating GHG emissions (except for tree removal activities and changes in forest carbon stocks discussed below in Sections 3.2 and 3.3, respectively). The cost estimates provide specific information related to soil/sediment volumes, construction vehicle types and quantities, hours of vehicle operation, fuel usage rates, number, and magnitude of required access roads and staging areas, treatment system requirements, etc. Much of this information was originally provided in Appendix A (the chemical extraction treatability report) and Appendix E (supporting cost information) of the CMS Report, as well as in the main body of the report itself.

For each anticipated GHG emissions source, input quantities (number of vehicles, hours of operation, fuel consumption rate, number of truckloads, kWh of electricity consumed, etc.) were tabulated. These values were then multiplied by relevant emissions factors published by EPA (EPA 2008a, EPA 2008b, EPA 2008c) and available from the Swiss Centre for Life Cycle Inventories (Swiss Centre for Life Cycle Inventories 2007). Direct and indirect emissions for CO_2, N_2O, and CH_4 were calculated separately and then converted to CO_2-eq using GWP factors specific for each GHG. Off-site emissions were calculated directly in CO_2-eq based on the emissions factors utilized (Swiss Centre for Life Cycle Inventories 2007).

As an example calculation, for direct emissions due to vehicle usage in transportation and construction activities, the total gallons of diesel fuel anticipated to be used was multiplied by an emissions factor of 10.15 kg CO_2/gallon (EPA 2008b). Similarly, emissions for N_2O and CH_4 were calculated by use of emission factors, 0.0048 g N_2O/mile and 0.0051 g CH_4/mile (EPA 2008b), with a fuel economy assumed to be 0.169 gallons/mile (EPA 2008b). Finally, the values resulting from these calculations were converted to tonnes CO_2-eq by use of the following formula (EPA 2005):

$$\textit{Total } CO_2\textit{-eq} = \textit{tonnes } CO_2(GWP[CO_2]) + \textit{tonnes } CH_4(GWP[CH_4]) + \textit{tonnes } N_2O(GWP[N_2O])$$

Where: GWP[X] denotes the global warming potential of greenhouse gas "X"

$GWP[CO_2] = 1$

$GWP[CH_4] = 21$

$GWP[N_2O]) = 310$

3.2 Emissions due to Tree Removal and Chipping Activities

Based on the assumption that trees will be removed and chipped on site, an estimate of expected emissions from equipment and vehicles used in tree clearing activities has been made. These estimates were based on an approximation for each alternative of the number of acres of forested land that would require clearing (discussed further in Section 3.3), together with published data regarding the approximate number of hours/tree required for operating a variety of tree removal equipment (e.g., chain saws, bucket truck/aerial lift, chipper, stump grinder, etc.), and associated carbon emissions factors for such equipment (Nowak et al. 2002).[7] An estimated value of 550 trees/acre was assumed based on an overall average number of live trees per acre in Massachusetts (USDA Forest Service 2006), along with an assumed number of standing dead trees.[8]

3.3 Emissions Resulting from Anticipated Disruptions in Forest Carbon Stocks due to Tree Removal/Replanting

As noted above, floodplain soil removal activities, as well as the construction of access roads and staging areas in support of both floodplain soil removal and sediment removal activities, will necessitate the clearing of trees and other vegetation within the Housatonic River floodplain. In addition to CO_2 emissions resulting from fossil-fuel burning activities associated with tree clearing, as discussed in Section 3.2, the active CO_2 sequestration taking place within these forests as well as the carbon stock held within the forest will be disrupted. The CO_2 sequestration capacity that the removed trees had maintained prior to removal will be lost, CO_2 will be released due to decomposition of the removed trees (as the trees are anticipated to be chipped/mulched on site), and CO_2 will again be sequestered as a result of the

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7 An average of the required equipment hours for removal of seven different size classes of trees was calculated in order to utilize this data, due to the fact that a mature forest is expected to contain trees spanning each of these size classes (Smith, personal communication, 2009).

8 Based on a ratio of "Dead Tree" to "Live Tree" from Table 2 of the COLE Carbon Report (Cole Development Group 2008), see footnote 10.

planting of new trees as part of site restoration activities. The magnitude of these emissions over the project timeframes has been estimated as part of this analysis.[9]

Several different forest types are anticipated to be encountered within the floodplain areas in which soil removal activities as well as the construction of access roads and staging areas are to occur. Data presenting the extent of various natural communities considered to be forests within the area of interest (Woodlot Alternatives, Inc. 2002) were compared with the horizontal extent of anticipated floodplain soil removal (for each FP alternative), as well as the anticipated footprints of access roads and staging areas (for each FP and SED alternative).[10] This resulted in an approximation of the number of acres of forested land that would require clearing. While all types of plants sequester CO_2 from the atmosphere, this evaluation focused only on CO_2 emissions/sequestration from trees, due to the availability of information for making such estimates, from the USDA Forest Service and others (as discussed below). Considering only tree removal should also provide a general order-of-magnitude estimate of the expected changes in carbon stocks due to vegetative clearing within the floodplain.

Methods Used

Due to the fact that "trees sequester and store carbon in their tissue at differing rates and amounts based on such factors as size at maturity, life span, and growth rate" (Nowak et al. 2002), and that current conditions within the floodplain forests regarding these factors are generally not well quantified, it is difficult to estimate the current level of CO_2 sequestration taking place within these trees. However, estimates for current tree sequestration and sequestration of future re-planted trees have been made by use of available USDA Forest Service resources (Cole Development Group 2008; Smith et al. 2006). In addition, estimates have been made regarding the emissions resulting from decomposition of mulched trees based on first-order decay and published decay rates from studies of decomposition of woody debris following clear-cutting (e.g., Abbott and Crossley 1982).

[9] As noted above, these emissions will actually extend beyond the project timeframe and will eventually, in 100 years or more, reach an equilibrium in net emissions. However, to provide comparability with the other estimated emissions, this analysis has focused on the net direct emissions resulting from these components over the project timeframe.

[10] Community types considered as forest in these evaluations are as follows: black ash-red maple-tamarack calcareous seepage swamp; high-terrace floodplain forest; Northern hardwoods-hemlock-white pine forest; red maple swamp; red oak-sugar maple transition forest; rich, mesic forest; successional northern hardwoods; and transitional floodplain forest.

To determine the CO_2 emissions from the removal of trees, the estimated number of acres of forested land that will require clearing was divided by the total anticipated time to implement for each FP and SED alternative, yielding an assumed number of acres of forest removal/replanting per year. This approach seemed reasonable as it is likely that as the remedial operations move down the river each construction season, that vegetative clearing will progress accordingly. This approach also assumes that the forested land anticipated to be impacted is equally distributed across the acres requiring site clearing.

An available online tool was utilized for estimating forest carbon based on inventory data of a user-specified area (Cole Development Group 2008).[11] In this case, a report for Berkshire County, MA was generated, and use was made of data presenting various components of forest carbon for this area. Specifically, an average value of existing non-soil carbon stock, from fourteen different reported forest types, was calculated to estimate the carbon stock that would likely be found to exist within a generic forest in the Housatonic River floodplain (considering that a variety of forest types will be encountered during site clearing activities). This value includes live tree, dead tree, under story, down dead wood, and forest floor carbon. This existing estimated total carbon stock per acre, together with an assumed first order decomposition rate for the chipped/mulched trees after clearing, was used to estimate the CO_2 released due to decomposition after site clearing and mulching activities.[12]

Additional data (Cole Development Group 2008) provided regional carbon stocks of forests by age class, at five year (0- to 40-years) and ten year (40- to 100-years) increments. These values were used to estimate the CO_2 that the removed trees would have sequestered in the future had they remained standing. It was assumed that the removed trees would be in the 40-50 year old range, as this is the age class

[11] The Carbon Online Estimator (COLE) [http://ncasi.uml.edu/COLE/] is an online package that was developed under a cooperative agreement between the National Council for Air and Stream Improvement (NCASI) and the USDA Forest Service, which "enables the user to examine forest carbon characteristics of any area of the continental United States. COLE data are based on USDA Forest Service Forest Inventory & Analysis and Resource Planning Assessment data, enhanced by other ecological data." (Cole Development Group 2008)

[12] Several decay rates for decomposition of tree material were reviewed in the literature. Although these varied according to the nature of material (e.g., ranging from 0.071/year for stumps [Shorohova 2008] to 0.638/year for red maple leaf tissue [Blair 1988]), the representative rate of 0.14/year (based on oak branches; Abbott and Crossley 1982) used in the evaluations presented herein was found to be generally consistent with the range reported in the literature.

corresponding to the average value of non-soil carbon stock discussed in the preceding paragraph.

Data from a USDA report that summarizes carbon stocks by age class for various tree stands with afforestation of land (i.e., conversion of previously unforested land into forest), specific to the Northeast, were also utilized (Smith et al. 2006).[13] This report presents the incremental increase in carbon stocks within six different forest types at 10 year intervals after afforestation. Using the average of the six forest types presented, a decade-by-decade overall assumed average carbon sequestration rate for afforestation was calculated.[14] These values were used to estimate sequestration over time by the new trees planted after completion of floodplain soil remediation activities each year.

A series of spreadsheets was prepared for each SED and FP alternative, incorporating the above information. These spreadsheets were used to simulate the carbon emissions/sequestration that would occur each year due to disruptions in forest carbon stocks, and include CO_2 released from decomposition of mulched material, the estimated loss of CO_2 sequestration capacity due to the removal of trees, and the estimated gain of CO_2 sequestration from the newly planted trees assumed to begin after planting at the end of each year. As noted above, for comparability with other GHG emission estimates, and given the temporal nature of CO_2 emissions from decaying organic matter (i.e., decay modeled as a first-order differential equation) as well as fluctuations in sequestration rates within trees over time, only the net direct emissions resulting from these components over the project timeframe have been reported and used in this analysis.

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[13] Afforestation data were used as opposed to reforestation data due to the fact that carbon stocks within the forest floor, down dead wood, and soil would also be removed due to site clearing and floodplain soil removal activities.

[14] The sequestration rate was obtained by subtracting the carbon stock at age class X from the carbon stock at age class X-1, and dividing by the period of growth (i.e., [X-(X-1)]).

4. Results of Carbon Footprint Calculations

Detailed calculations presenting the results from the GHG inventory are presented in a series of tables at the end of this Appendix. These tables contain detailed explanatory notes documenting the sources of emissions factors and methods of each calculation presented therein. Tables A-1 through A-13 present the GHG emission calculations for sediment alternatives SED 3 through SED 8. Similarly, the GHG emission calculations for floodplain alternatives FP 2 through FP 7 are contained in Tables A-14 through A-26. Tables A-13 and A-26 specifically present direct emissions expected to result from tree removal activities, as discussed above in Section 3.2, for the sediment and floodplain alternatives, respectively. Finally, Tables A-27 through A-31 present the detailed calculation results for treatment/disposition alternatives TD 1 through TD 5, respectively.

Three tables are presented below providing a summary of the estimated GHG emissions for the remedial alternatives (SED, FP, and TD alternatives) with respect to each of the emissions categories (i.e., direct, indirect, and off-site) and sub-categories if applicable (e.g., transportation, construction, etc.).

Table 1 below presents the carbon footprint results for the sediment alternatives. A graph of the GHG emissions for each SED alternative in relation to the volume of sediments proposed for removal is presented on Figure A-1. That figure shows direct, indirect, off-site, and total emissions.

Table 1. Calculated GHG Emissions Anticipated to Result from Sediment (SED) Alternatives

Emissions Category	Emissions Sub-Category (if applicable)	ESTIMATED TONNES OF CO_2-eq EMITTED SED 3	SED 4	SED 5	SED 6	SED 7	SED 8
Direct	tree removal[1]	1,500	1,800	1,800	1,700	1,700	1,700
	transportation[2]	750	1,300	1,700	2,100	2,600	6,200
	construction[2]	8,800	16,000	18,000	19,000	25,000	47,000
	mulch decay / sequestration changes[3]	3,300	4,500	4,800	5,300	4,800	5,000
	TOTAL Direct	14,400	23,600	26,300	28,100	34,100	59,900
Indirect[4]		1,200	1,700	2,300	3,400	4,500	9,700
Off-Site	access road gravel	217	251	293	299	317	456
	capping material	746	1,556	2,084	2,436	3,170	7,717
	rip rap	51	51	51	52	52	52
	steel sheeting	6,090	12,000	12,900	13,000	15,500	18,200
	cement for stabilization	9,470	21,800	31,700	48,200	70,500	234,000
	concrete revetment matting	530	530	530	530	530	530
	diesel refining	1,600	2,870	3,310	3,460	4,500	8,670
	TOTAL Off-Site	18,700	39,100	50,900	68,000	94,600	270,000
TOTAL[5]		34,000	64,000	80,000	100,000	133,000	340,000

Notes:

1. Refers to fossil-fuel combustion emissions anticipated to result from activities associated with tree removal and chipping of trees.
2. Emissions included under "transportation" generally consist of bringing equipment and materials to/from the site, etc. The emissions resulting from hauling excavated materials to the stockpile areas is included as "construction".
3. Refers to net emissions resulting from decomposition of mulched trees and differences in sequestration rates between removed mature trees and replanted seedlings up through the anticipated time to implement each alternative.
4. Indirect emissions are due to the purchase of electricity for operating the water treatment system.
5. Totals reflect rounding.

As shown in Table 1 and Figure A-1, the calculated GHG emissions increase progressively among the sediment alternatives, ranging from approximately 34,000 tonnes (SED 3) to 340,000 tonnes (SED 8). Comparison among the three emission categories indicates that the off-site emissions account for approximately 55-70% of the GHG emissions for each sediment alternative. The most significant off-site sources are associated with steel sheeting manufacture and production of cement to be used in sediment stabilization.[15] For the direct emissions sources, which account for approximately 25-40% of the total, the GHG emissions associated with construction activities (e.g., access roads/staging areas, installing steel sheeting, excavations, bank stabilization, installing rip-rap, placement of isolation layer/armor stone, etc.) are generally approximately ten times greater than those associated with transportation activities (i.e., delivery of equipment and materials to/from the work sites). Emissions due to the decay of mulched trees are estimated to account for approximately 10-25% of the total direct emissions.

Table 2 below presents the carbon footprint results for the floodplain alternatives. A graph of the GHG emissions for each FP alternative in relation to the volume of floodplain soils proposed for excavation is presented on Figure A-2. That figure shows direct, off-site, and total emissions.

[15] While the use of cement for sediment stabilization has been assumed for this evaluation, other materials could potentially be used, namely lime or fly ash. While cement production would produce CO_2-eq emissions of approximately 0.834 lbs CO_2-eq/lb (EPA 2008d), use of lime (calcium hydroxide) would produce similar emissions, approximately ranging from 0.757 – 0.833 lbs CO_2-eq/lb (depending on the level of post-production preparation. For example, the following three emissions factors: 0.757 for “Lime, hydrated, loose, at plant”, 0.763 “Lime, hydrated, packed, at plant”, and 0.833 for “Lime, hydraulic, at plant” (all units in lbs CO_2-eq/lb)), are listed in the Ecoinvent 2.0 database (Swiss Centre for Life Cycle Inventories 2007). On the other hand, the use of fly ash would produce close to zero emissions in its production due to the fact that this material is a by-product from the industrial combustion of coal, and therefore, there are no associated manufacturing emissions with its production (EPA 2003).

Table 2. Calculated GHG Emissions Anticipated to Result from Floodplain (FP) Alternatives

Emissions Category	Emissions Sub-Category (if applicable)	ESTIMATED TONNES OF CO_2-eq EMITTED					
		FP 2	FP 3	FP 4	FP 5	FP 6	FP 7
Direct	tree removal[1]	580	1,200	2,700	2,200	5,600	9,500
	transportation[2]	55	59	69	63	100	140
	construction[2]	870	2,300	3,600	3,500	10,900	18,200
	mulch decay / sequestration changes[3]	360	1,300	3,900	2,900	13,400	26,600
	TOTAL Direct	1,900	4,900	10,300	8,700	30,000	54,400
Indirect		--[4]	--	--	--	--	--
Off-Site	access road gravel	56	92	89	86	115	163
	backfill material	64	220	361	367	1,170	2,103
	diesel refining	153	393	597	579	1,816	3,035
	sand	2	2	2	2	3	4
	TOTAL Off-Site	275	707	1,050	1,030	3,100	5,300
TOTAL[5]		2,000	6,000	11,000	10,000	33,000	60,000

Notes:

1. Refers to fossil-fuel combustion emissions anticipated to result from activities associated with tree removal and chipping of trees.
2. Emissions included under "transportation" generally consist of bringing equipment and materials to/from the site, etc. The emissions resulting from hauling excavated materials to the stockpile areas is included as "construction".
3. Refers to net emissions resulting from decomposition of mulched trees and differences in sequestration rates between removed mature trees and replanted seedlings up through the anticipated time to implement each alternative.
4. -- = no emissions of this type were identified.
5. Totals reflect rounding.

As shown in Table 2 and Figure A-2, the calculated GHG emissions generally increase progressively among the floodplain alternatives, ranging from approximately 2,000 tonnes (FP 2) to 60,000 tonnes (FP 7), except for FP 4 and FP 5 which are approximately equal (due to their nearly equal volumes). Comparison among the three emission categories indicates that the direct emissions account for approximately 80-95% of the GHG emissions for each floodplain alternative. The most significant direct sources are associated with construction activities (access roads/staging areas, soil excavation, replacement of removed, etc.) and the decay of mulched trees (with only a slightly lesser contribution due to tree removal activities); emissions due to each of these components are over ten times greater than those associated with transportation activities (i.e., delivery of equipment and materials to/from the work sites). For the off-site emissions sources, which account for approximately 10-15% of the total, the most significant source is associated with diesel fuel refining.

Table 3 below presents the carbon footprint results for the treatment/disposition alternatives. A bar chart of the total GHG emissions for each TD alternative (lower-bound and upper-bound) is presented on Figure A-3.

Table 3. Calculated GHG Emissions Anticipated to Result from Treatment/Disposition (TD) Alternatives

		ESTIMATED TONNES OF CO_2-eq EMITTED											
Emissions Category	Emissions Sub-Category (if applicable)	TD 1		TD 2 (See Note 1)		TD 3		TD 4		TD 5			
										LB		UB	
		LB[1]	UB[1]	LB	UB	LB	UB	LB	UB	50% Reuse of FP soils	No Reuse	50% Reuse of FP soils	No Reuse
Direct	transportation	14,000	220,000	960	2,000	820	12,130	13,000	200,000	11,000	12,000	150,000	180,000
	construction/ operation	--[2]	--	1,200	5,000	4,800	13,000	1,700		43,000		670,000	
	TOTAL Direct	14,000	220,000	2,200	7,000	5,600	25,000	15,000	200,000	54,000	55,000	820,000	850,000
Indirect[3]		--	--	--	--	--	--	6,700	84,000	250		3,800	
Off-Site	concrete	--	--	--	--	--	--	300		300			
	steel sheeting	--	--	660	947	--	--	--	--	--	--	--	--
	diesel refining	2,331	35,806	300	1,200	920	4,200	2,200	33,000	1,800	2,000	25,000	30,000
	natural gas production / distribution	--	--	--	--	--	--	--	--	8,600		130,000	
	TOTAL Off-Site	2,300	36,000	1,000	2,100	900	4,200	2,500	33,000	10,700	10,900	155,000	160,000
TOTAL[4]		**16,000**	**256,000**	**3,200**	**9,100**	**6,500**	**29,000**	**24,000**	**317,000**	**65,000**	**66,000**	**979,000**	**1,014,000**

Notes

1. LB - Lower-Bound Volumes (SED 3, FP 2); UB - Upper-Bound Volumes (SED 8, FP 7), except for TD 2 where LB corresponds to SED 6 hydraulic dredging (300,000 cy) and UB corresponds to SED 8 hydraulic dredging (1,240,000 cy). Based on these differences, it should be noted that the values presented above for TD 2 cannot be directly compared to those for the other TDs.
2. -- = no emissions of this type were identified.
3. Indirect emissions are due to the purchase of electricity for operating the chemical extraction (TD 4) and thermal desorption (TD 5) treatment systems.
4. Totals reflect rounding.

As shown in Table 3, evaluations of the treatment/disposition alternatives were conducted for a range of removal scenarios, with the lower-bound (LB) based on a combination of SED 3 and FP 2 and the upper-bound (UB) based on a combination of SED 8 and FP 7, except for TD 2 where LB and UB denote hydraulically dredged sediments in SED 6 (300,000 cy) and SED 8 (1,240,000 cy), respectively. As shown in Figure A-3 and Table 3, emissions were in general lowest for TD 2 (disposition in a local in-water Confined Disposal Facility or CDF), followed by TD 3 (disposition in a local Upland Disposal Facility), TD 1 (off-site disposal), TD 4 (chemical extraction), and TD 5 (thermal desorption). However, as discussed in Section 1, it should be noted that TD 2 would only handle a portion of the sediments and thus a second TD option would be required to complete the sediment and floodplain remediation. Excluding TD 2, lower-bound emissions range from 6,500 tonnes to 66,000 tonnes and upper-bound emissions range from 29,000 tonnes to 1,014,000 tonnes. For both the lower and upper bounds, this range reflects a range from TD 3 to TD 5 (assuming no re-use of floodplain soils post-treatment for TD 5). Direct emissions from transportation of materials for off-site disposal account for the majority of emissions in TD 1 and TD 4, with a somewhat lesser contribution in TD 4 from the indirect emissions associated with operation of the chemical extraction facility. For TD 2 and TD 3, emissions from construction activities account for the majority of emissions, with a somewhat lesser contribution from transportation of materials. For TD 5, the majority of emissions consists of direct emissions from natural gas usage in the thermal desorption unit, conversion of TOC to CO_2, and transportation of the treated material for off-site disposal. Most of the remaining TD emissions are due to diesel fuel refining (off-site emissions) in all TD alternatives, natural gas production/distribution (off-site emissions) in TD 5, and purchased electricity (indirect emissions) for running the chemical extraction and thermal desorption apparatus (in TD 4 and TD 5, respectively).

5. Summary and Discussion

This evaluation has presented an estimate of the carbon footprint of each of the different sediment, floodplain soil, and treatment/disposition alternatives evaluated in the CMS Report. This analysis was conducted in accordance with the Design Principles guidance published by EPA (2005), and overall emissions for each alternative have been reported as tonnes of carbon dioxide equivalents (CO_2-eq).

In general, as expected, tonnes of CO_2-eq emissions were found to increase along with the quantities of removed sediments and floodplain soils, due to the associated increase in energy expenditures. Calculated emissions for the alternatives involving removal range from approximately 34,000 tonnes (SED 3) to 340,000 tonnes (SED 8) for the sediment alternatives, and 2,000 tonnes (FP 2) to 60,000 tonnes (FP 7) for the floodplain soil alternatives (with FP 4 and FP 5 being relatively equal due to their equal volumes). Emissions due to disruptions in forest carbon stocks – all or nearly all of which result from the decay of chipped trees (100% for the SED alternatives and 94% or greater for the FP alternatives) – account for approximately 20-45% of the total emissions for each floodplain alternative, while comprising a much smaller component (approximately 1-10%) of the total emissions for the sediment alternatives. For the treatment/disposition alternatives (excluding TD 2, which would need to be implemented in conjunction with another alternative since the CDF would not accommodate all of the removed material), calculated lower-bound emissions range from 6,500 tonnes to 66,000 tonnes and upper-bound emissions range from 29,000 tonnes to 1,014,000 tonnes – in both cases reflecting a range from TD 3 to TD 5 (assuming no re-use of floodplain soils post-treatment for TD 5).

In order to put the estimated emissions for the sediment, floodplain, and treatment/disposition alternatives into perspective, several comparison equivalencies have been summarized in Table 4 below. This table provides some context regarding the emissions reported herein by illustrating the size/quantity of other GHG-emitting activities that would be equivalent to the estimated SED, FP, and TD emissions. Specifically, the number of passenger vehicles that would emit an equivalent quantity of CO_2-eq in one year, the number of barrels of oil consumed that would emit an equivalent amount of CO_2, and the number of homes from which the energy used in one year would emit an equivalent amount of CO_2, are presented.

Table 4. Equivalencies of Total Emissions from Sediment, Floodplain, and Treatment/Disposition Alternatives

Remedial Alternative		Estimated Total CO_2-eq Emissions for SED, FP, and TD alternatives	Number of passenger vehicles with annual CO_2-eq emissions equivalent to emissions for remedial alternative[1]	Number of barrels of oil consumed resulting in CO_2 emissions equivalent to emissions for remedial alternative[1]	Number of homes with CO_2 emissions due to annual power usage equivalent to emissions for remedial alternative[1]
SED 3		**34,000**	6,200	79,100	3,100
SED 4		**64,000**	11,700	148,800	5,800
SED 5		**80,000**	14,700	186,000	7,300
SED 6		**100,000**	18,300	232,600	9,100
SED 7		**133,000**	24,400	309,300	12,100
SED 8		**340,000**	62,300	790,700	30,900
FP 2		**2,000**	400	4,700	200
FP 3		**6,000**	1,100	14,000	500
FP 4		**11,000**	2,000	25,600	1,000
FP 5		**10,000**	1,800	23,300	900
FP 6		**33,000**	6,000	76,700	3,000
FP 7		**60,000**	11,000	139,500	5,500
TD 1	**LB**	**16,000**	2,900	37,200	1,500
	UB	**256,000**	46,900	595,300	23,300
TD 2	**LB**	**3,200**	600	7,400	300
	UB	**9,100**	1,700	21,200	800
TD 3	**LB**	**6,500**	1,200	15,100	600
	UB	**29,000**	5,300	67,400	2,600
TD 4	**LB**	**24,000**	4,400	55,800	2,200
	UB	**317,000**	58,100	737,200	28,800
TD 5[2]	**LB**	**66,000**	12,100	153,500	6,000
	UB	**1,014,000**	185,700	2,358,100	92,300

Notes:

1. Values presented were generated from EPA's Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/solar/energy-resources/calculator.html), and have been rounded herein. EPA's website provides detailed explanations pertaining to how each calculation is derived.
2. Assuming no reuse of floodplain soils post-treatment.

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Appendix A - Carbon Footprint/Greenhouse Gas Inventory Analysis for Sediment, Floodplain, and Treatment/Disposition Alternatives

Response to EPA Interim Comments on CMS Report

TABLES

Sediment Alternatives

Table A-1. GHG Emissions from Sediment (SED) Alternative 3.
[167,000 cy of sediment removed (with 42 acres engineered cap after removal), 97 acres thin-layer capping, 10-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy) and Flatbed Truck	187	50	9,000	90	0.00026	0.00027	90	transportation
FROM: Dump Truck (20 cy)	187	50	9,000	90	0.00026	0.00027	90	transportation
Water Truck	2	50	100	1.0	0.0000028	0.0000030	1	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	1,716	50	86,000	870	0.022	0.050	880	construction
						TOTAL EMISSIONS	1,060	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	14	50	700	7.1	0.000020	0.000021	7	transportation
Flat Bed Truck - Equipment	3	50	150	1.5	0.0000043	0.0000045	2	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	130	50	7,000	71	0.002	0.004	70	construction
						TOTAL EMISSIONS	80	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
Cargo Truck	1	50	50	0.51	0.0000014	0.0000015	1	transportation
Portland Cement	29	50	1,500	15	0.000043	0.000045	15	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 167,000 cy)								
Dump Truck - 20 cy	2,618	50	130,000	1,300	0.034	0.075	1,300	construction
Excavator - Removal	1,298	50	65,000	660	0.017	0.038	670	construction
Long Reach - Removal	1,210	50	61,000	620	0.016	0.035	630	construction
Excavator - Blending	1,298	50	65,000	660	0.017	0.038	670	construction
Dewatering Pump	1,218	50	61,000	620	0.016	0.035	630	construction
						TOTAL EMISSIONS	3,900	

See Notes on Page 4

Table A-1. GHG Emissions from Sediment (SED) Alternative 3.
[167,000 cy of sediment removed (with 42 acres engineered cap after removal), 97 acres thin-layer capping, 10-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIA
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	52	50	2,600	30	0.00068	0.0015	30	construction
						TOTAL EMISSIONS	30	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	1,827	50	91,363	900	0.024	0.053	910	construction
						TOTAL EMISSIONS	920	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh used per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
29,236	110	3,215,960	1,210	0.0248	0.126	1,200
					TOTAL EMISSIONS	1,200

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	67	50	3,400	30	0.000097	0.00010	30	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	2,600	26	0.000074	0.000078	26	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	660	

See Notes on Page 4

Table A-1. GHG Emissions from Sediment (SED) Alternative 3.
[167,000 cy of sediment removed (with 42 acres engineered cap after removal), 97 acres thin-layer capping, 10-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	948	50	47,000	480	0.0013	0.0014	480	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	2	50	100	1.0	0.0000028	0.0000030	1	transportation
Flat Bed Truck	2	50	100	1.0	0.0000028	0.0000030	1	transportation
INSTALLATION								
Dump Truck - 20 cy	2,354	50	120,000	1,200	0.031	0.070	1,200	construction
Excavator - Fill	1,188	50	59,000	600	0.015	0.034	610	construction
Front-End Loader - Staging	1,188	50	59,000	600	0.015	0.034	610	construction
						TOTAL EMISSIONS	2,900	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)

► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
83,648	5.72	217	22,344	4.99	51

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
231,822	4.94	519	100,500	4.99	227	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
256,807	2.16	6,090	25,050,000	0.834	9,470	942,363	3.673	1,570

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	18,700

See Notes on Page 4

Table A-1. GHG Emissions from Sediment (SED) Alternative 3.
[167,000 cy of sediment removed (with 42 acres engineered cap after removal), 97 acres thin-layer capping, 10-yr duration]

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database
   (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.htm
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

General notes associated with even numbered tables A-2 through A-12.
(note numbers correspond to superscripts in table headings)

1. Initial value (at year zero) determined from average total non-soil carbon stock (tonnes/acre) from fourteen different forest types common in Berkshire County, MA (from Table 2 of COLE Carbon Report (Cole Development Group 2008): *Carbon Stocks by Forest Type for Massachusetts*) multiplied by estimated number of total acres assumed to be cleared (Woodlot Alternatives, Inc. 2002).
   Assumed number of forested acres requiring clearing for each alternative was determined by comparing the horizontal extent of anticipated floodplain soil removal (for each FP alternative), as well as the anticipated footprints of access roads and staging areas (for each FP and SED alternative) with data presenting the extent of various natural communities considered to be forests within the area of interest (Woodlot Alternatives, Inc. 2002).
   Decay of mulch based on a first-order differential equation of the form: $N_t = N_0e$^(-k*t), N_0 = carbon (as CO_2) remaining in mulch at time zero, N_t = carbon (as CO_2) remaining in mulch at time t, t = years, k = rate coefficient.
   A rate coefficient of 0.14/year was used (based on Chestnut Oak branches up to 5 cm diameter; Abbott and Crossley 1982).
   - Cole Development Group. 2008. Cole 1605(b) Report for Massachusetts. http://ncasi.uml.edu/COLE/ (December 19, 2008).
   - Woodlot Alternatives, Inc. 2002. Ecological Characterization of the Housatonic River. Prepared for U.S. Environmental Protection Agency, Region 1. Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, MA. September 2002.
   - Abbott, D.T. and D.A. Crossley, Jr. 1982. Wood litter decomposition following clear-cutting. *Ecology* . 63(1):35-42.
2. Table 1 of COLE Carbon Report (Cole Development Group 2008): *Carbon Stocks by Age Class for Massachusetts* provided regional carbon stocks of forests by age class, at five year (0- to 40-years) and ten year (40- to 100-years) increments. These values were used to estimate the CO_2 that the removed trees would have sequestered in the future had they remained standing.
3. Sequestration of newly planted trees calculated by using data from a USDA report that summarizes carbon stocks by age class for various tree stands with afforestation of land (i.e., conversion of previously unforested land into forest), specific to the Northeast (Smith et al. 2006). This data presents the incremental increase in carbon stocks within six different forest types at 10 year intervals after afforestation. Taking the average of the six forest types presented, yielded a decade-by-decade overall assumed average carbon sequestration rate for afforestation.
   - Smith, J.E., Heath, L.S., Skog, K.E. and R.A. Birdsey. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA Forest Service, Northeastern Research Station. General Technical Report NE-343. April 2006.

Table A-2. SED 3 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	6,946					
1	6,855	91	6	0	97	97
2	6,686	170	12	10	171	268
3	6,447	238	18	20	236	504
4	6,150	298	24	31	291	795
5	5,800	350	30	41	339	1134
6	5,405	395	36	51	380	1514
7	4,971	434	42	64	412	1926
8	4,503	468	48	78	438	2364
9	4,006	498	54	91	460	2824
10	3,482	523	60	105	478	3303
11	3,027	455	58	118	394	3697
12	2,632	396	55	122	329	4026
13	2,288	344	53	125	272	4298
14	1,989	299	51	128	221	4520
15	1,729	260	48	132	177	4696
16	1,503	226	46	135	137	4834
17	1,307	196	44	133	107	4941
18	1,136	171	41	131	81	5022
19	988	148	39	129	59	5081
20	859	129	37	127	39	5120
21	747	112	35	125	22	5142
22	649	98	34	123	8	5150
23	564	85	32	121	-4	5146
24	491	74	31	119	-15	5131
25	426	64	29	117	-24	5107
26	371	56	28	116	-32	5075
27	322	48	26	114	-39	5036
28	280	42	25	113	-46	4990
29	244	37	23	112	-52	4938
30	212	32	22	110	-57	4881
31	184	28	21	109	-60	4821
32	160	24	20	108	-64	4758
33	139	21	19	106	-66	4691
34	121	18	18	105	-69	4623
35	105	16	17	104	-71	4552
36	91	14	16	102	-72	4480
37	79	12	15	101	-73	4407
38	69	10	14	99	-75	4332
39	60	9	14	98	-75	4257
40	52	8	13	97	-76	4181
41	45	7	12	95	-76	4104
42	39	6	12	94	-76	4028
43	34	5	11	92	-76	3952
44	30	4	10	91	-76	3876
45	26	4	10	90	-76	3800
46	23	3	9	88	-75	3725
47	20	3	9	87	-75	3650
48	17	3	8	86	-75	3574
49	15	2	8	85	-75	3499
50	13	2	7	84	-75	3425
51	11	2	7	83	-74	3350
52	10	1	7	82	-74	3277
53	8	1	6	81	-73	3203
54	7	1	6	80	-73	3131
55	6	1	6	79	-72	3059
56	6	1	5	78	-71	2987
57	5	1	5	77	-71	2916
58	4	1	5	76	-71	2846
59	4	1	4	75	-70	2775
60	3	0	4	75	-70	2705
61	3	0	4	74	-69	2636
62	2	0	4	73	-69	2567
63	2	0	4	72	-68	2499
64	2	0	4	72	-67	2432
65	2	0	4	71	-67	2366
66	1	0	4	70	-66	2300
67	1	0	4	69	-65	2235

Table A-2. SED 3 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	1	0	4	69	-64	2170
69	1	0	4	68	-64	2107
70	1	0	4	67	-63	2044
71	1	0	4	66	-62	1982
72	1	0	4	66	-61	1920
73	1	0	4	65	-61	1859
74	0	0	4	64	-60	1799
75	0	0	4	64	-59	1740
76	0	0	4	63	-59	1681
77	0	0	4	62	-58	1623
78	0	0	4	62	-58	1566
79	0	0	4	61	-57	1509
80	0	0	4	61	-57	1452
81	0	0	4	60	-56	1396
82	0	0	4	60	-56	1340
83	0	0	4	59	-55	1285
84	0	0	4	59	-55	1230
85	0	0	4	58	-54	1176
86	0	0	4	58	-54	1122
87	0	0	4	57	-53	1069
88	0	0	4	57	-53	1016
89	0	0	4	56	-52	964
90	0	0	4	56	-52	912
91	0	0	4	56	-51	861
92	0	0	4	55	-51	810
93	0	0	4	55	-50	759
94	0	0	4	54	-50	709
95	0	0	4	54	-50	660
96	0	0	4	53	-49	610
97	0	0	4	53	-49	562
98	0	0	4	52	-48	514
99	0	0	4	52	-48	466
100	0	0	4	52	-47	418
101	0	0	4	51	-47	371
102	0	0	4	51	-47	324
103	0	0	4	50	-46	278
104	0	0	4	50	-46	232
105	0	0	4	50	-46	187
106	0	0	4	49	-45	141
107	0	0	4	49	-45	97
108	0	0	4	49	-44	52
109	0	0	4	48	-44	8
110	0	0	4	48	-44	-35
111	0	0	4	47	-43	-79
112	0	0	4	47	-43	-122
113	0	0	4	47	-43	-164
114	0	0	4	46	-42	-206
115	0	0	4	46	-42	-248
116	0	0	4	46	-41	-290
117	0	0	4	45	-41	-331
118	0	0	4	45	-41	-371
119	0	0	4	45	-41	-412
120	0	0	4	44	-40	-452
121	0	0	4	44	-40	-492
122	0	0	4	44	-40	-532
123	0	0	4	43	-39	-571
124	0	0	4	43	-39	-610
125	0	0	4	43	-39	-649

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-3. GHG Emissions from Sediment (SED) Alternative 4.
[295,000 cy of sediment removed (with 91 acres engineered cap after removal), 119 acres thin-layer capping, 37 acres engineered capping, 15-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	225	50	11,000	110	0.00031	0.00033	110	transportation
FROM: Dump Truck (20 cy)	225	50	11,000	110	0.00031	0.00033	110	transportation
Water Truck	2	50	100	1.0	0.0000028	0.0000030	1	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	2,442	50	120,000	1,200	0.031	0.070	1,200	construction
						TOTAL EMISSIONS	1,400	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	27	50	1,400	14	0.000040	0.000042	14	transportation
Flat Bed Truck - Equipment	4	50	200	2.0	0.0000057	0.0000060	2	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	191	50	10,000	100	0.003	0.006	100	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	4	50	200	2.0	0.0000057	0.0000060	2	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Cargo Truck	1	50	50	0.5	0.0000014	0.0000015	1	transportation
Portland Cement	66	50	3,300	33	0.000094	0.000100	34	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 206,000 cy)								
Dump Truck - 20 cy	3,344	50	170,000	1,700	0.044	0.099	1,700	construction
Excavator - Removal	1,650	50	83,000	840	0.022	0.048	850	construction
Long Reach - Removal	1,650	50	83,000	840	0.022	0.048	850	construction
Excavator - Blending	1,650	50	83,000	840	0.022	0.048	850	construction
Dewatering Pump	1,575	50	79,000	800	0.021	0.046	810	construction
► EXCAVATION IN WET (approximately 89,000 cy)								
Dump Truck - 20 cy	638	50	32,000	320	0.0083	0.019	320	construction
Excavator - Removal	330	50	17,000	170	0.0044	0.010	170	construction
Long Reach - Removal	330	50	17,000	170	0.0044	0.010	170	construction
Excavator - Blending	330	50	17,000	170	0.0044	0.010	170	construction
						TOTAL EMISSIONS	5,900	

See Notes on Page 4

Table A-3. GHG Emissions from Sediment (SED) Alternative 4.
[295,000 cy of sediment removed (with 91 acres engineered cap after removal), 119 acres thin-layer capping, 37 acres engineered capping, 15-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIAL
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	92	50	4,600	50	0.0012	0.0027	50	construction
						TOTAL EMISSIONS	50	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	2,605	50	130,000	1,300	0.034	0.075	1,300	construction
						TOTAL EMISSIONS	1,300	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh used per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
41,685	110	4,585,397	1,700	0.0354	0.180	1,700
					TOTAL EMISSIONS	1,700

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	67	50	3,400	30	0.000097	0.00010	30	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	2,600	26	0.000074	0.000078	26	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	660	

See Notes on Page 4

Table A-3. GHG Emissions from Sediment (SED) Alternative 4.
[295,000 cy of sediment removed (with 91 acres engineered cap after removal), 119 acres thin-layer capping, 37 acres engineered capping, 15-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	2,001	50	100,000	1,000	0.0028	0.0030	1,000	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	4	50	200	2.0	0.0000057	0.0000060	2	transportation
Flat Bed Truck	5	50	250	2.5	0.0000071	0.0000075	3	transportation
INSTALLATION								
Dump Truck - 20 cy	6,094	50	300,000	3,000	0.078	0.17	3,000	construction
Excavator - Fill	4,642	50	230,000	2,300	0.060	0.13	2,300	construction
Front-End Loader - Staging	3,036	50	150,000	1,500	0.039	0.087	1,500	construction
						TOTAL EMISSIONS	7,800	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
96,735	5.72	251	22,344	4.99	51

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
472,261	4.94	1,060	219,182	4.99	496	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
505,477	2.16	12,000	57,558,000	0.834	21,800	1,720,950	3.673	2,870

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	39,100

See Notes on Page 4

Table A-3. GHG Emissions from Sediment (SED) Alternative 4.
[295,000 cy of sediment removed (with 91 acres engineered cap after removal), 119 acres thin-layer capping, 37 acres engineered capping, 15-yr duration]

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database
   (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.htm
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-4. SED 4 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	8,004					
1	7,934	70	5	0	74	74
2	7,804	130	9	8	132	206
3	7,621	183	14	16	181	387
4	7,392	229	18	23	224	611
5	7,124	269	23	31	260	871
6	6,820	303	28	39	292	1163
7	6,487	333	32	49	316	1479
8	6,127	359	37	60	337	1816
9	5,745	382	41	70	354	2170
10	5,343	402	46	81	368	2537
11	4,924	419	49	91	377	2914
12	4,490	434	52	101	385	3299
13	4,043	447	55	112	390	3689
14	3,584	458	57	122	394	4083
15	3,116	468	60	132	396	4479
16	2,709	407	58	143	323	4802
17	2,355	354	57	144	267	5069
18	2,047	308	55	145	218	5287
19	1,780	267	53	146	175	5462
20	1,547	233	51	147	137	5599
21	1,345	202	48	148	103	5701
22	1,169	176	45	146	75	5776
23	1,017	153	43	145	50	5826
24	884	133	40	143	29	5855
25	768	115	37	142	10	5865
26	668	100	36	141	-5	5861
27	581	87	34	138	-16	5844
28	505	76	33	136	-26	5818
29	439	66	32	133	-35	5783
30	382	57	31	131	-42	5741
31	332	50	29	128	-49	5692
32	288	43	27	127	-56	5635
33	251	38	25	126	-63	5572
34	218	33	23	125	-69	5503
35	189	28	22	124	-74	5430
36	165	25	21	123	-77	5352
37	143	22	20	121	-79	5273
38	125	19	19	119	-80	5193
39	108	16	19	117	-82	5111
40	94	14	18	114	-82	5029
41	82	12	17	112	-83	4946
42	71	11	16	111	-85	4861
43	62	9	15	110	-86	4775
44	54	8	14	109	-87	4688
45	47	7	13	108	-89	4599
46	41	6	12	107	-89	4510
47	35	5	12	105	-88	4422
48	31	5	11	103	-87	4335
49	27	4	11	101	-86	4248
50	23	3	10	99	-86	4163
51	20	3	10	98	-85	4078
52	18	3	9	97	-85	3993
53	15	2	8	96	-85	3908
54	13	2	8	95	-85	3823
55	12	2	7	94	-85	3737
56	10	2	7	93	-85	3652
57	9	1	7	92	-84	3568
58	8	1	6	91	-83	3485
59	7	1	6	89	-82	3403
60	6	1	6	88	-81	3322
61	5	1	6	87	-80	3242
62	4	1	5	86	-80	3162
63	4	1	5	85	-80	3082
64	3	0	5	85	-79	3003
65	3	0	5	84	-79	2924
66	2	0	5	84	-79	2845
67	2	0	5	83	-77	2768

Table A-4. SED 4 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	2	0	5	81	-76	2691
69	2	0	5	80	-75	2616
70	1	0	5	79	-74	2542
71	1	0	5	78	-73	2469
72	1	0	5	77	-72	2396
73	1	0	5	77	-72	2324
74	1	0	5	76	-71	2253
75	1	0	5	76	-71	2182
76	1	0	5	75	-70	2112
77	1	0	5	74	-69	2043
78	0	0	5	73	-68	1974
79	0	0	5	72	-68	1907
80	0	0	5	71	-67	1840
81	0	0	5	70	-66	1774
82	0	0	5	70	-65	1709
83	0	0	5	70	-65	1644
84	0	0	5	69	-65	1580
85	0	0	5	69	-64	1515
86	0	0	5	69	-64	1452
87	0	0	5	68	-63	1389
88	0	0	5	67	-62	1326
89	0	0	5	66	-62	1265
90	0	0	5	66	-61	1204
91	0	0	5	65	-60	1144
92	0	0	5	65	-60	1084
93	0	0	5	64	-59	1025
94	0	0	5	64	-59	965
95	0	0	5	63	-59	907
96	0	0	5	63	-58	848
97	0	0	5	62	-58	791
98	0	0	5	62	-57	734
99	0	0	5	61	-56	677
100	0	0	5	60	-56	622
101	0	0	5	60	-55	567
102	0	0	5	59	-55	512
103	0	0	5	59	-54	457
104	0	0	5	59	-54	403
105	0	0	5	59	-54	350
106	0	0	5	58	-54	296
107	0	0	5	58	-53	243
108	0	0	5	57	-52	191
109	0	0	5	57	-52	139
110	0	0	5	56	-51	88
111	0	0	5	55	-51	37
112	0	0	5	55	-50	-13
113	0	0	5	55	-50	-63
114	0	0	5	54	-50	-113
115	0	0	5	54	-49	-162
116	0	0	5	54	-49	-211
117	0	0	5	53	-49	-260
118	0	0	5	53	-48	-308
119	0	0	5	52	-48	-356
120	0	0	5	52	-47	-403
121	0	0	5	51	-47	-450
122	0	0	5	51	-46	-496
123	0	0	5	51	-46	-542
124	0	0	5	51	-46	-588
125	0	0	5	50	-46	-634

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-5. GHG Emissions from Sediment (SED) Alternative 5.
[410,000 cy of sediment removed (with 126 acres engineered cap after removal), 102 acres thin-layer capping, 60 acres engineeered capping, 19-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	265	50	13,000	130	0.00037	0.00039	130	transportation
FROM: Dump Truck (20 cy)	265	50	13,000	130	0.00037	0.00039	130	transportation
Water Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	3,234	50	160,000	1,600	0.042	0.093	1,600	construction
						TOTAL EMISSIONS	1,900	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	29	50	1,500	15	0.000043	0.000045	15	transportation
Flat Bed Truck - Equipment	6	50	300	3.0	0.0000085	0.0000091	3	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	192	50	10,000	100	0.0026	0.0058	100	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	9	50	450	4.6	0.000013	0.000014	5	transportation
Cargo Truck	1	50	50	0.51	0.0000014	0.0000015	1	transportation
Portland Cement	96	50	4,800	49	0.00014	0.00014	49	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 255,000 cy)								
Dump Truck - 20 cy	4,048	50	200,000	2,000	0.052	0.12	2,000	construction
Excavator - Removal	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Long Reach - Removal	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Excavator - Blending	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Dewatering Pump	2,018	50	100,000	1,000	0.026	0.058	1,000	construction
► EXCAVATION IN WET (approximately 155,000 cy)								
Dump Truck - 20 cy	1,122	50	56,000	570	0.015	0.032	580	construction
Excavator - Removal	572	50	29,000	290	0.0075	0.017	290	construction
Long Reach - Removal	572	50	29,000	290	0.0075	0.017	290	construction
Excavator - Blending	572	50	29,000	290	0.0075	0.017	290	construction
						TOTAL EMISSIONS	7,500	construction

See Notes on Page 4

Table A-5. GHG Emissions from Sediment (SED) Alternative 5.
[410,000 cy of sediment removed (with 126 acres engineered cap after removal), 102 acres thin-layer capping, 60 acres engineeered capping, 19-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIALS
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	126	50	6,300	60	0.0016	0.0037	61	construction
						TOTAL EMISSIONS	61	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	3,510	50	175,481	1,800	0.046	0.102	1,800	construction
						TOTAL EMISSIONS	1,800	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh used per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
56,154	110	6,176,940	2,300	0.048	0.24	2,300
					TOTAL EMISSIONS	2,300

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	67	50	3,400	30	0.000097	0.00010	30	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	2,600	26	0.000074	0.000078	26	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	660	

See Notes on Page 4

Table A-5. GHG Emissions from Sediment (SED) Alternative 5.
[410,000 cy of sediment removed (with 126 acres engineered cap after removal), 102 acres thin-layer capping, 60 acres engineeered capping, 19-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	2,698	50	130,000	1,300	0.0037	0.0039	1,300	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	5	50	250	2.5	0.0000071	0.0000075	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
INSTALLATION								
Dump Truck - 20 cy	6,226	50	310,000	3,100	0.081	0.18	3,100	construction
Excavator - Fill	3,872	50	190,000	1,900	0.049	0.11	1,900	construction
Front-End Loader - Staging	3,124	50	160,000	1,600	0.042	0.093	1,600	construction
						TOTAL EMISSIONS	7,900	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
112,821	5.72	293	22,626	4.99	51

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
572,052	4.94	1,280	355,416	4.99	804	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
545,776	2.16	12,900	83,886,000	0.834	31,700	1,986,231	3.673	3,310

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	50,900

See Notes on Page 4

Table A-5. GHG Emissions from Sediment (SED) Alternative 5.
[410,000 cy of sediment removed (with 126 acres engineered cap after removal), 102 acres thin-layer capping, 60 acres engineeered capping, 19-yr duration]

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database
   (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website:http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-6. SED 5 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	8,050					
1	7,995	55	4	0	59	59
2	7,891	103	7	6	105	164
3	7,746	145	11	12	144	307
4	7,564	182	15	19	178	485
5	7,351	213	18	25	207	692
6	7,110	241	22	31	232	924
7	6,845	265	26	39	251	1175
8	6,560	285	29	47	267	1442
9	6,257	304	33	56	281	1723
10	5,937	319	37	64	292	2014
11	5,604	333	39	72	300	2314
12	5,260	345	41	80	305	2619
13	4,905	355	43	89	310	2929
14	4,541	364	46	97	313	3242
15	4,169	372	48	105	315	3557
16	3,790	379	50	113	315	3872
17	3,406	384	52	120	316	4188
18	3,016	390	55	127	317	4505
19	2,622	394	57	134	316	4822
20	2,280	343	55	141	257	5078
21	1,982	298	53	142	209	5287
22	1,723	259	51	143	167	5453
23	1,498	225	48	144	130	5583
24	1,302	196	46	145	97	5680
25	1,132	170	44	146	68	5748
26	984	148	41	144	45	5793
27	856	129	39	142	25	5818
28	744	112	37	140	8	5826
29	647	97	34	139	-7	5819
30	562	84	34	137	-19	5801
31	489	73	32	135	-29	5772
32	425	64	31	133	-38	5734
33	369	56	29	131	-46	5688
34	321	48	28	129	-53	5635
35	279	42	26	127	-58	5576
36	243	36	25	126	-65	5512
37	211	32	23	124	-69	5443
38	183	28	22	122	-73	5369
39	159	24	20	121	-77	5293
40	139	21	20	119	-79	5214
41	121	18	19	117	-81	5134
42	105	16	18	116	-82	5052
43	91	14	17	114	-83	4968
44	79	12	16	112	-84	4884
45	69	10	15	111	-85	4799
46	60	9	14	110	-87	4712
47	52	8	13	108	-87	4625
48	45	7	13	107	-88	4538
49	39	6	12	105	-88	4450
50	34	5	11	104	-87	4363
51	30	4	11	102	-87	4276
52	26	4	10	101	-87	4189
53	22	3	10	99	-86	4103
54	20	3	9	98	-86	4017
55	17	3	9	96	-85	3932
56	15	2	8	96	-85	3847
57	13	2	8	95	-85	3762
58	11	2	7	94	-85	3677
59	10	1	7	92	-84	3593
60	8	1	7	91	-84	3509
61	7	1	6	90	-83	3426
62	6	1	6	89	-82	3344
63	6	1	6	88	-81	3263
64	5	1	6	87	-80	3183
65	4	1	6	86	-80	3103
66	4	1	5	85	-79	3023
67	3	0	5	84	-79	2945

Table A-6. SED 5 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	3	0	5	84	-78	2866
69	2	0	5	83	-78	2789
70	2	0	5	82	-77	2712
71	2	0	5	81	-76	2636
72	2	0	5	80	-75	2561
73	1	0	5	79	-74	2487
74	1	0	5	78	-73	2414
75	1	0	5	77	-72	2342
76	1	0	5	77	-72	2270
77	1	0	5	76	-71	2199
78	1	0	5	75	-70	2129
79	1	0	5	75	-70	2059
80	1	0	5	74	-69	1990
81	0	0	5	73	-68	1922
82	0	0	5	72	-67	1854
83	0	0	5	72	-67	1788
84	0	0	5	71	-66	1722
85	0	0	5	70	-65	1656
86	0	0	5	70	-65	1591
87	0	0	5	69	-64	1527
88	0	0	5	69	-64	1463
89	0	0	5	68	-63	1400
90	0	0	5	67	-63	1338
91	0	0	5	67	-62	1275
92	0	0	5	66	-61	1214
93	0	0	5	66	-61	1153
94	0	0	5	65	-60	1093
95	0	0	5	65	-60	1033
96	0	0	5	64	-59	974
97	0	0	5	64	-59	915
98	0	0	5	63	-58	856
99	0	0	5	63	-58	799
100	0	0	5	62	-57	741
101	0	0	5	62	-57	684
102	0	0	5	61	-56	628
103	0	0	5	61	-56	572
104	0	0	5	60	-55	517
105	0	0	5	59	-55	462
106	0	0	5	59	-54	408
107	0	0	5	59	-54	354
108	0	0	5	58	-54	300
109	0	0	5	58	-53	247
110	0	0	5	57	-53	195
111	0	0	5	57	-52	143
112	0	0	5	56	-52	91
113	0	0	5	56	-51	40
114	0	0	5	56	-51	-11
115	0	0	5	55	-50	-61
116	0	0	5	55	-50	-111
117	0	0	5	54	-50	-161
118	0	0	5	54	-49	-210
119	0	0	5	54	-49	-259
120	0	0	5	53	-48	-307
121	0	0	5	53	-48	-355
122	0	0	5	52	-48	-403
123	0	0	5	52	-47	-450
124	0	0	5	52	-47	-497
125	0	0	5	51	-46	-543

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-7. GHG Emissions from Sediment (SED) Alternative 6.
[554,000 cy of sediment removed, (with 178 acres engineered cap after removal), 112 acres thin-layer capping, 45 acres engineered capping, 21-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	297	50	15,000	150	0.00043	0.00045	150	transportation
FROM: Dump Truck (20 cy)	297	50	15,000	150	0.00043	0.00045	150	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	3,630	50	180,000	1,800	0.047	0.10	1,800	construction
						TOTAL EMISSIONS	2,100	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	30	50	1,500	15	0.000043	0.000045	15	transportation
Flat Bed Truck - Equipment	7	50	350	3.6	0.0000099	0.000011	4	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	191	50	10,000	100	0.003	0.006	100	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	9	50	450	4.6	0.000013	0.000014	5	transportation
Cargo Truck	1	50	50	0.51	0.0000014	0.0000015	1	transportation
Portland Cement	145	50	7,300	74	0.00021	0.00022	74	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 255,000 cy)								
Dump Truck - 20 cy	4,048	50	200,000	2,000	0.052	0.116	2,000	construction
Excavator - Removal	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Long Reach - Removal	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Excavator - Blending	2,002	50	100,000	1,000	0.026	0.058	1,000	construction
Dewatering Pump	2,018	50	100,000	1,000	0.026	0.058	1,000	construction
► EXCAVATION IN WET (approximately 299,000 cy)								
8" Cutter Head Dredge	770	50	40,000	400	0.010	0.023	400	construction
Tender Tug	1,100	50	55,000	600	0.014	0.032	600	construction
Booster Pump	1,100	50	60,000	600	0.016	0.035	600	construction
						TOTAL EMISSIONS	7,700	

See Notes on Page 4

Table A-7. GHG Emissions from Sediment (SED) Alternative 6.
[554,000 cy of sediment removed, (with 178 acres engineered cap after removal), 112 acres thin-layer capping, 45 acres engineered capping, 21-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIALS
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	172	50	8,600	90	0.0022	0.0050	91	construction
						TOTAL EMISSIONS	91	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	3,360	50	167,975	1,700	0.044	0.097	1,700	construction
						TOTAL EMISSIONS	1,700	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
48,436	110	5,327,960	2,000	0.041	0.21	2,000
14,865	250	3,716,250	1,400	0.029	0.15	1,400
					TOTAL EMISSIONS	3,400

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	68	50	3,400	30	0.000097	0.00010	30	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	2,600	26	0.000074	0.000078	26	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	660	

See Notes on Page 4

Table A-7. GHG Emissions from Sediment (SED) Alternative 6.
[554,000 cy of sediment removed, (with 178 acres engineered cap after removal), 112 acres thin-layer capping, 45 acres engineered capping, 21-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in Off-Site GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	3,139	50	160,000	1,620	0.0045	0.0048	1,600	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
INSTALLATION								
Dump Truck - 20 cy	6,600	50	330,000	3,300	0.086	0.19	3,300	construction
Excavator - Fill	3,740	50	190,000	1,900	0.049	0.11	1,900	construction
Front-End Loader - Staging	3,344	50	170,000	1,700	0.044	0.099	1,700	construction
						TOTAL EMISSIONS	8,500	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)

► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
115,152	5.72	299	22,778	4.99	52

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
677,938	4.94	1,520	404,951	4.99	916	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
547,318	2.16	13,000	127,312,000	0.834	48,200	2,079,525	3.673	3,460

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	68,000

See Notes on Page 4

Table A-7. GHG Emissions from Sediment (SED) Alternative 6.
[554,000 cy of sediment removed, (with 178 acres engineered cap after removal), 112 acres thin-layer capping, 45 acres engineered capping, 21-yr duration]

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website:http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-8. SED 6 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	7,636					
1	6,861	775	3	0	778	778
2	6,772	89	6	5	90	868
3	6,648	125	9	11	123	991
4	6,492	156	13	16	152	1144
5	6,309	183	16	21	177	1321
6	6,102	207	19	27	199	1520
7	5,875	227	22	34	215	1735
8	5,630	245	25	41	229	1965
9	5,370	260	28	48	241	2206
10	5,096	274	31	55	250	2456
11	4,810	286	33	62	257	2713
12	4,514	296	35	69	262	2975
13	4,209	305	37	76	266	3241
14	3,897	312	39	83	268	3510
15	3,578	319	41	90	270	3780
16	3,253	325	43	97	271	4050
17	2,923	330	45	103	272	4322
18	2,589	334	47	109	272	4594
19	2,250	338	49	115	272	4865
20	1,956	294	51	121	223	5089
21	1,701	256	52	127	180	5269
22	1,479	222	50	133	139	5407
23	1,285	193	48	134	107	5514
24	1,118	168	46	135	79	5593
25	972	146	44	136	54	5647
26	845	127	42	136	32	5679
27	734	110	40	136	14	5693
28	638	96	38	135	-1	5692
29	555	83	36	133	-14	5678
30	482	73	34	131	-25	5654
31	419	63	31	130	-35	5618
32	365	55	30	128	-43	5575
33	317	48	29	126	-50	5526
34	276	41	28	124	-55	5470
35	240	36	26	123	-60	5410
36	208	31	25	121	-65	5345
37	181	27	24	119	-68	5277
38	157	24	22	117	-71	5206
39	137	21	21	116	-74	5133
40	119	18	20	114	-76	5056
41	103	16	18	113	-79	4977
42	90	14	18	111	-80	4897
43	78	12	17	110	-81	4816
44	68	10	16	109	-82	4733
45	59	9	15	107	-83	4650
46	51	8	15	106	-83	4567
47	45	7	14	104	-83	4484
48	39	6	13	102	-84	4400
49	34	5	12	101	-84	4317
50	29	4	12	100	-84	4233
51	26	4	11	99	-84	4149
52	22	3	10	97	-84	4065
53	19	3	10	96	-83	3981
54	17	3	9	95	-83	3899
55	15	2	9	93	-82	3816
56	13	2	8	92	-82	3734
57	11	2	8	90	-81	3654
58	10	1	8	90	-81	3573
59	8	1	7	89	-80	3493
60	7	1	7	88	-80	3413
61	6	1	6	87	-80	3333
62	5	1	6	86	-79	3254
63	5	1	6	85	-78	3176
64	4	1	6	84	-78	3099
65	4	1	6	83	-77	3022
66	3	0	5	82	-76	2946
67	3	0	5	81	-75	2871

Table A-8. SED 6 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	2	0	5	80	-74	2796
69	2	0	5	79	-74	2722
70	2	0	5	78	-73	2649
71	2	0	5	78	-73	2576
72	1	0	5	77	-72	2504
73	1	0	5	76	-71	2433
74	1	0	5	75	-70	2362
75	1	0	5	74	-70	2293
76	1	0	5	74	-69	2224
77	1	0	5	73	-68	2156
78	1	0	5	72	-67	2088
79	1	0	5	71	-67	2022
80	0	0	5	71	-66	1956
81	0	0	5	70	-65	1890
82	0	0	5	69	-65	1825
83	0	0	5	69	-64	1761
84	0	0	5	68	-64	1698
85	0	0	5	67	-63	1635
86	0	0	5	67	-62	1573
87	0	0	5	66	-61	1511
88	0	0	5	65	-61	1450
89	0	0	5	65	-60	1390
90	0	0	5	64	-60	1330
91	0	0	5	64	-59	1271
92	0	0	5	63	-59	1212
93	0	0	5	63	-58	1153
94	0	0	5	62	-58	1096
95	0	0	5	62	-57	1038
96	0	0	5	61	-57	981
97	0	0	5	61	-56	925
98	0	0	5	60	-56	869
99	0	0	5	60	-55	814
100	0	0	5	59	-55	759
101	0	0	5	59	-54	705
102	0	0	5	58	-54	651
103	0	0	5	58	-53	597
104	0	0	5	58	-53	544
105	0	0	5	57	-53	492
106	0	0	5	57	-52	440
107	0	0	5	56	-51	388
108	0	0	5	56	-51	337
109	0	0	5	55	-51	286
110	0	0	5	55	-50	236
111	0	0	5	54	-50	186
112	0	0	5	54	-49	137
113	0	0	5	54	-49	88
114	0	0	5	53	-49	39
115	0	0	5	53	-48	-9
116	0	0	5	52	-48	-57
117	0	0	5	52	-47	-104
118	0	0	5	52	-47	-151
119	0	0	5	51	-47	-198
120	0	0	5	51	-46	-244
121	0	0	5	50	-46	-290
122	0	0	5	50	-46	-336
123	0	0	5	50	-45	-381
124	0	0	5	49	-45	-426
125	0	0	5	49	-45	-470

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-9. GHG Emissions from Sediment (SED) Alternative 7.
[803,000 cy of sediment removed (with 219 acres backfill after removal), 72 acres thin-layer capping, 45 acres engineered capping, 26-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	323	50	16,000	160	0.00045	0.00048	160	transportation
FROM: Dump Truck (20 cy)	323	50	16,000	160	0.00045	0.00048	160	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	4510	50	230,000	2,300	0.060	0.133	2,300	construction
						TOTAL EMISSIONS	2,600	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	35	50	1,800	18	0.000051	0.000054	18	transportation
Flat Bed Truck - Equipment	7	50	350	3.6	0.0000099	0.0000106	4	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	192	50	10,000	100	0.003	0.006	100	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	14	50	700	7.1	0.000020	0.000021	7	transportation
Cargo Truck	1	50	50	0.5	0.0000014	0.0000015	1	transportation
Portland Cement	212	50	11,000	112	0.00031	0.00033	110	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 360,000 cy)								
Dump Truck - 20 cy	5,104	50	260,000	2,600	0.068	0.151	2,600	construction
Excavator - Removal	2,552	50	130,000	1,300	0.034	0.075	1,300	construction
Long Reach - Removal	2,552	50	130,000	1,300	0.034	0.075	1,300	construction
Excavator - Blending	2,552	50	130,000	1,300	0.034	0.075	1,300	construction
Dewatering Pump	2,548	50	130,000	1,300	0.034	0.075	1,300	construction
► EXCAVATION IN WET (approximately 443,000 cy)								
Dump Truck - 20 cy	744	50	37,000	380	0.0096	0.021	380	construction
Excavator - Removal	180	50	9,000	90	0.0023	0.005	90	construction
Long Reach - Removal	180	50	9,000	90	0.0023	0.005	90	construction
Excavator - Blending	22	50	1,100	10	0.0003	0.001	10	construction
8" Cutter Head Dredge	858	50	40,000	400	0.010	0.023	400	construction
Tender Tug	1,298	50	65,000	660	0.017	0.038	670	construction
Booster Pump	1,298	50	100,000	1,000	0.0260	0.058	1,000	construction
						TOTAL EMISSIONS	10,600	

See Notes on Page 4

Table A-9. GHG Emissions from Sediment (SED) Alternative 7.
[803,000 cy of sediment removed (with 219 acres backfill after removal), 72 acres thin-layer capping, 45 acres engineered capping, 26-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIA
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	249	50	12,000	120	0.0031	0.0070	120	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	5,228	50	261,388	2,700	0.068	0.15	2,700	construction
						TOTAL EMISSIONS	2,700	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh used per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
65,588	110	7,214,680	2,700	0.056	0.28	2,700
18,900	250	4,725,000	1,800	0.036	0.19	1,800
					TOTAL EMISSIONS	4,500

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	68	50	3,400	30	0.000097	0.00010	30	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	3,000	30	0.000085	0.000091	30	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	660	

See Notes on Page 4

Table A-9. GHG Emissions from Sediment (SED) Alternative 7.
[803,000 cy of sediment removed (with 219 acres backfill after removal), 72 acres thin-layer capping, 45 acres engineered capping, 26-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	4,107	50	210,000	2,130	0.0060	0.0063	2,100	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
INSTALLATION								
Dump Truck - 20 cy	8,008	50	400,000	4,100	0.10	0.23	4,100	construction
Excavator - Fill	4,686	50	230,000	2,300	0.060	0.13	2,300	construction
Front-End Loader - Staging	4,048	50	200,000	2,000	0.052	0.12	2,000	construction
						TOTAL EMISSIONS	10,500	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)

► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
122,303	5.72	317	22,806	4.99	52

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
892,653	4.94	2,000	518,099	4.99	1,170	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
652,809	2.16	15,500	186,290,000	0.834	70,500	2,709,238	3.673	4,500

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	94,600

See Notes on Page 4

Table A-9. GHG Emissions from Sediment (SED) Alternative 7.
[803,000 cy of sediment removed (with 219 acres backfill after removal), 72 acres thin-layer capping, 45 acres engineered capping, 26-yr duration]

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database
   (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-10. SED 7 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	7,636					
1	7,598	38	3	0	41	41
2	7,526	72	5	4	72	113
3	7,425	101	8	9	100	213
4	7,299	126	10	13	123	336
5	7,151	148	13	17	143	480
6	6,985	167	15	22	161	640
7	6,801	183	18	27	174	814
8	6,603	198	20	33	185	999
9	6,393	210	23	39	195	1194
10	6,172	221	25	44	202	1396
11	5,941	231	27	50	208	1604
12	5,702	239	28	56	212	1816
13	5,456	246	30	61	215	2030
14	5,203	252	32	67	217	2247
15	4,946	258	33	73	218	2465
16	4,683	262	35	79	219	2684
17	4,417	267	36	83	219	2903
18	4,147	270	38	88	220	3123
19	3,874	273	39	93	219	3342
20	3,598	276	41	98	219	3561
21	3,320	278	42	103	217	3778
22	3,039	280	43	108	215	3993
23	2,757	282	44	113	213	4206
24	2,474	283	45	118	211	4417
25	2,189	285	46	122	208	4625
26	1,903	286	46	127	205	4830
27	1,654	249	45	132	162	4992
28	1,438	216	43	132	128	5119
29	1,250	188	42	132	98	5217
30	1,087	163	40	132	72	5289
31	945	142	38	132	48	5337
32	822	123	36	132	28	5365
33	714	107	34	130	11	5376
34	621	93	32	129	-4	5372
35	540	81	30	128	-17	5355
36	469	71	28	126	-28	5328
37	408	61	27	124	-36	5292
38	355	53	26	122	-43	5249
39	308	46	25	120	-49	5200
40	268	40	24	118	-54	5145
41	233	35	23	116	-59	5087
42	203	30	21	114	-63	5024
43	176	26	20	113	-67	4957
44	153	23	19	112	-70	4887
45	133	20	18	111	-73	4814
46	116	17	16	110	-76	4738
47	101	15	16	108	-77	4661
48	87	13	15	107	-78	4582
49	76	11	15	105	-79	4503
50	66	10	14	103	-80	4424
51	57	9	13	102	-80	4344
52	50	8	12	100	-80	4264
53	43	7	12	99	-81	4183
54	38	6	11	98	-81	4101
55	33	5	10	97	-82	4019
56	29	4	9	96	-82	3937
57	25	4	9	95	-82	3855
58	22	3	9	93	-81	3774
59	19	3	8	92	-81	3693
60	16	2	8	91	-80	3613
61	14	2	8	89	-79	3534
62	12	2	7	88	-79	3455
63	11	2	7	87	-79	3376
64	9	1	7	86	-78	3298
65	8	1	6	86	-78	3220
66	7	1	6	85	-78	3142
67	6	1	6	84	-77	3065

Table A-10. SED 7 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	5	1	6	83	-76	2989
69	5	1	5	82	-75	2913
70	4	1	5	81	-75	2838
71	3	1	5	79	-74	2765
72	3	0	5	78	-73	2692
73	3	0	5	78	-72	2619
74	2	0	5	77	-72	2547
75	2	0	5	77	-72	2476
76	2	0	5	76	-71	2405
77	2	0	5	75	-70	2335
78	1	0	5	74	-69	2265
79	1	0	5	73	-69	2196
80	1	0	5	73	-68	2129
81	1	0	5	72	-67	2062
82	1	0	5	71	-66	1995
83	1	0	5	70	-66	1930
84	1	0	5	70	-65	1864
85	0	0	5	69	-65	1800
86	0	0	5	69	-64	1736
87	0	0	5	68	-63	1672
88	0	0	5	67	-63	1609
89	0	0	5	67	-62	1547
90	0	0	5	66	-61	1486
91	0	0	5	65	-61	1425
92	0	0	5	65	-60	1365
93	0	0	5	64	-60	1306
94	0	0	5	64	-59	1247
95	0	0	5	63	-59	1188
96	0	0	5	63	-58	1129
97	0	0	5	62	-58	1072
98	0	0	5	62	-57	1014
99	0	0	5	61	-57	958
100	0	0	5	61	-56	902
101	0	0	5	60	-55	846
102	0	0	5	59	-55	791
103	0	0	5	59	-55	737
104	0	0	5	59	-54	683
105	0	0	5	58	-54	629
106	0	0	5	58	-53	575
107	0	0	5	57	-53	522
108	0	0	5	57	-52	470
109	0	0	5	56	-52	418
110	0	0	5	56	-51	367
111	0	0	5	55	-51	316
112	0	0	5	55	-50	265
113	0	0	5	55	-50	215
114	0	0	5	54	-50	166
115	0	0	5	54	-49	116
116	0	0	5	54	-49	67
117	0	0	5	53	-49	19
118	0	0	5	53	-48	-29
119	0	0	5	52	-48	-77
120	0	0	5	52	-47	-124
121	0	0	5	51	-47	-171
122	0	0	5	51	-46	-217
123	0	0	5	51	-46	-264
124	0	0	5	50	-46	-309
125	0	0	5	50	-45	-355

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-11. GHG Emissions from Sediment (SED) Alternative 8.
[2,285,000 cy of sediment removed (with 351 acres backfill after removal), 52-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	533	50	27,000	270	0.00077	0.00081	270	transportation
FROM: Dump Truck (20 cy)	533	50	27,000	270	0.00077	0.00081	270	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	7,700	50	390,000	4,000	0.10	0.23	4,000	construction
						TOTAL EMISSIONS	4,500	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO STEEL SHEET PILE ACTIVITIES (TRANSPORTATION/INSTALLATION/REMOVAL)
[NOTE: Emissions from production of steel sheet piling are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Flat Bed Truck - Materials	41	50	2,100	21	0.000060	0.000063	21	transportation
Flat Bed Truck - Equipment	7	50	350	3.6	0.000010	0.000011	4	transportation
INSTALLATION/REMOVAL OF SHEETING								
Hydraulic Excavator - Vibratory Hammer	192	50	10,000	100	0.0026	0.006	100	construction
						TOTAL EMISSIONS	120	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION/DREDGING OF SEDIMENT (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	11	50	550	5.6	0.000016	0.000017	6	transportation
Cargo Truck	1	50	50	0.51	0.0000014	0.0000015	1	transportation
Portland Cement	705	50	40,000	410	0.0011	0.0012	410	transportation
ON-SITE EXCAVATION ACTIVITIES								
► EXCAVATION IN DRY (approximately 454,000 cy)								
Dump Truck - 20 cy	6,006	50	300,000	3,000	0.078	0.17	3,000	construction
Excavator - Removal	3,014	50	150,000	1,500	0.039	0.087	1,500	construction
Long Reach - Removal	3,014	50	150,000	1,500	0.039	0.087	1,500	construction
Excavator - Blending	3,014	50	150,000	1,500	0.039	0.087	1,500	construction
Dewatering Pump	3,007	50	150,000	1,500	0.039	0.087	1,500	construction
► EXCAVATION IN WET (approximately 1,831,000 cy)								
8" Cutter Head Dredge	1,738	50	90,000	900	0.023	0.052	900	construction
Tender Tug	5,610	50	280,000	2,800	0.073	0.16	2,800	construction
Booster Pump	5,170	50	260,000	2,600	0.068	0.15	2,600	construction
						TOTAL EMISSIONS	15,700	

See Notes on Page 4

Table A-11. GHG Emissions from Sediment (SED) Alternative 8.
[2,285,000 cy of sediment removed (with 351 acres backfill after removal), 52-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO ON-SITE TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS AND DEWATERING OF MATERIA
[NOTE: Emissions from concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	636	50	32,000	320	0.0083	0.0186	320	construction
						TOTAL EMISSIONS	320	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO WATER TREATMENT SYSTEM (TRANSPORTATION/SET-UP & TAKE-DOWN/OPERATION)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF WATER TREATMENT EQUIPMENT/MATERIALS TO/FROM SITE								
Vacuum Truck	1	50	50	1	0.000013	0.000029	1	transportation
SET-UP/TAKE-DOWN OF WATER TREATMENT SYSTEM								
Flat Bed Truck	8	50	400	4	0.00010	0.00023	4	construction
Cargo Truck	8	50	400	4	0.00010	0.00023	4	construction
Front-End Loader	4	50	200	2	0.000052	0.00012	2	construction
OPERATION OF WATER TREATMENT SYSTEM - DIRECT FUEL USAGE								
Vacuum Truck	9,124	50	456,194	4,600	0.12	0.26	4,600	construction
						TOTAL EMISSIONS	4,600	

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO2-eq) DUE TO OPERATION OF WATER TREATMENT SYSTEM - PURCHASED ELECTRICITY

Estimated Hours of Operation	Total number of kWh used per hour of operation[3]	Estimated total number of kWh used	Tonnes of CO_2 associated with purchased electricity[4]	Tonnes of N_2O associated with purchased electricity[4]	Tonnes of CH_4 associated with purchased electricity[4]	Tonnes CO_2-eq associated with purchased electricity[2]
82,731	110	9,100,410	3,400	0.070	0.36	3,400
66,305	250	16,576,250	6,200	0.13	0.65	6,300
					TOTAL EMISSIONS	9,700

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO BANK REMOVAL/STABILIZATION AND PLACEMENT OF RIP-RAP AND CONCRETE REVETMENT MATTING (DELIVERY TO SITE/INSTALLATION) [NOTE: Emissions from quarrying rip-rap & concrete production are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY OF RIP-RAP (ARMOR STONE) TO SITE								
Dump Truck - 20 cy	69	50	3,500	36	0.000099	0.00011	36	transportation
DELIVERY OF CONCRETE REVETMENT MATTING TO SITE								
Dump Truck - 20 cy	52	50	2,600	30	0.000074	0.000078	30	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	3	50	150	1.5	0.0000043	0.0000045	2	transportation
Flat Bed Truck	3	50	150	1.5	0.0000043	0.0000045	2	transportation
BANK STABILIZATION ACTIVITIES (INSTALLATION OF RIP-RAP AND REVETMENT MATTING)								
Dump Truck - 20 cy	594	50	30,000	300	0.0078	0.017	300	construction
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader - Staging	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	670	

See Notes on Page 4

Table A-11. GHG Emissions from Sediment (SED) Alternative 8.
[2,285,000 cy of sediment removed (with 351 acres backfill after removal), 52-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CAPPING/BACKFILL ACTIVITIES (DELIVERY TO SITE/INSTALLATION)
[NOTE: Emissions from excavating armor/isolation layer materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
DELIVERY TO SITE								
Dump Truck - 20 cy	10,062	50	500,000	5,100	0.014	0.015	5,100	transportation
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	5	50	250	2.5	0.0000071	0.0000075	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
INSTALLATION								
Dump Truck - 20 cy	19,954	50	1,000,000	10,200	0.26	0.58	10,300	construction
Excavator - Fill	12,364	50	620,000	6,300	0.16	0.36	6,400	construction
Front-End Loader - Staging	9,988	50	500,000	5,100	0.13	0.29	5,100	construction
						TOTAL EMISSIONS	26,900	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)

► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL) AND QUARRYING OF LIMESTONE RIP-RAP

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[5]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of rip-rap required (tons)	Pounds of CO_2-eq emitted per ton of rip-rap quarried[6]	Tonnes of CO_2-eq emitted from rip-rap quarrying activities
175,794	5.72	456	23,078	4.99	52

► DUE TO EXCAVATION/QUARRYING OF CAPPING MATERIAL (SAND ISOLATION LAYER AND LIMESTONE ARMOR) AND PRODUCTION OF CONCRETE FOR REVETMENT MATTING

Quantity of sand required (for isolation layer and lining stockpile areas) (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[7]	Tonnes of CO_2-eq emitted from sand excavation activities	Quantity of armor stone required (tons)	Pounds of CO_2-eq emitted per ton of armor stone quarried[8]	Tonnes of CO_2-eq emitted from armor stone quarrying activities	Quantity of concrete revetment matting required (cy)	Pounds of CO_2-eq emitted per cy of revetment matting produced[9]	Tonnes of CO_2-eq emitted from concrete revetment matting production activities
3,042,428	4.94	6,820	396,321	4.99	897	2,700	433	530

► DUE TO MANUFACTURE OF STEEL SHEET PILING, PRODUCTION OF CEMENT (STABILIZING AGENT), AND DIESEL FUEL REFINING

Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[10] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture	Quantity of cement required for sediment stabilization (lbs)	Pounds of CO_2-eq emitted per pound of cement produced[11]	Tonnes of CO_2-eq emitted from cement manufacture	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[12]	Tonnes of CO_2-eq emitted from diesel refining
766,930	2.16	18,200	617,952,000	0.834	234,000	5,203,594	3.673	8,670

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	270,000

See Notes on Page 4

Table A-11. GHG Emissions from Sediment (SED) Alternative 8.
[2,285,000 cy of sediment removed (with 351 acres backfill after removal), 52-yr duration]

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Based on an estimated operation rate of 110 kWh/hour for non-hydraulically dredged sediments and an estimated operation rate of 250 kWh/hr for hydraulically dredged sediments.
4. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database
   (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.htm
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Emissions factors referenced in notes 5 through 12 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

5. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
6. The presented emissions factor for limestone quarrying combines the Ecoinvent 2.0 database entries for “Limestone, at mine” (3.86 lb CO2-eq /ton) and “Crushing, rock” (0.025 lb CO2-eq / ton), along with an electricity consumption rate of 3.25 e-4 kWh / lb for the crushing equipment (corresponding to a carbon emissions factor of 1.105 lb CO2-eq / ton) to yield 4.99 lb CO2-eq /ton.
7. Sand, at mine (or borrow pit).
8. See Note 4.
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.
10. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).
11. Portland cement, strength class Z 52.5, at plant.
12. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-12. SED 8 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	7,636					
1	7,617	19	1	0	20	20
2	7,581	36	3	2	36	57
3	7,531	50	4	4	50	107
4	7,468	63	5	6	62	168
5	7,394	74	6	9	72	240
6	7,310	83	8	11	80	320
7	7,219	92	9	14	87	407
8	7,120	99	10	16	93	500
9	7,014	105	11	19	97	597
10	6,904	111	13	22	101	698
11	6,788	115	13	25	104	802
12	6,669	119	14	28	106	908
13	6,546	123	15	31	107	1015
14	6,420	126	16	34	108	1124
15	6,291	129	17	36	109	1233
16	6,160	131	17	39	109	1342
17	6,026	133	18	42	110	1452
18	5,891	135	19	44	110	1561
19	5,755	137	20	47	110	1671
20	5,617	138	20	49	109	1781
21	5,478	139	21	51	109	1889
22	5,338	140	21	54	108	1997
23	5,197	141	22	56	106	2103
24	5,055	142	22	59	105	2208
25	4,913	142	23	61	104	2312
26	4,770	143	23	64	103	2415
27	4,626	143	22	66	100	2515
28	4,482	144	22	66	100	2615
29	4,338	144	21	66	99	2714
30	4,193	145	20	66	99	2813
31	4,048	145	19	66	98	2911
32	3,903	145	18	66	97	3008
33	3,758	145	17	65	97	3105
34	3,612	146	16	65	97	3202
35	3,466	146	15	64	97	3299
36	3,320	146	14	63	97	3396
37	3,174	146	13	62	97	3493
38	3,028	146	13	61	98	3591
39	2,882	146	12	60	99	3690
40	2,736	146	12	59	99	3789
41	2,589	146	11	58	100	3888
42	2,443	146	11	57	100	3988
43	2,296	146	10	57	100	4088
44	2,150	147	9	56	100	4188
45	2,003	147	9	55	100	4288
46	1,857	147	8	55	100	4388
47	1,710	147	8	54	100	4489
48	1,563	147	8	53	101	4590
49	1,417	147	7	52	101	4691
50	1,270	147	7	52	102	4793
51	1,123	147	7	51	102	4895
52	977	147	6	50	103	4998
53	849	128	6	50	84	5082
54	738	111	5	49	67	5150
55	642	96	5	49	53	5203
56	558	84	5	48	41	5243
57	485	73	5	47	30	5273
58	422	63	4	47	21	5294
59	366	55	4	46	13	5307
60	319	48	4	45	7	5314
61	277	42	4	45	1	5315
62	241	36	4	44	-4	5311
63	209	31	3	44	-9	5302
64	182	27	3	43	-13	5290
65	158	24	3	43	-16	5274
66	138	21	3	42	-19	5255
67	120	18	3	42	-21	5234
68	104	16	3	41	-23	5211

Table A-12. SED 8 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-2)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
69	90	14	3	41	-24	5186
70	79	12	3	40	-26	5161
71	68	10	3	40	-27	5134
72	59	9	3	39	-28	5106
73	52	8	2	39	-29	5077
74	45	7	2	39	-29	5048
75	39	6	2	38	-30	5018
76	34	5	2	38	-31	4987
77	29	4	2	38	-31	4957
78	26	4	2	37	-31	4926
79	22	3	2	37	-31	4894
80	19	3	2	36	-31	4863
81	17	3	2	36	-31	4832
82	15	2	2	35	-31	4801
83	13	2	2	35	-31	4770
84	11	2	2	35	-31	4739
85	10	1	2	35	-31	4708
86	8	1	2	34	-31	4678
87	7	1	2	34	-31	4647
88	6	1	2	34	-30	4616
89	5	1	2	33	-30	4586
90	5	1	2	33	-30	4556
91	4	1	2	33	-30	4527
92	4	1	2	32	-29	4497
93	3	0	2	32	-29	4468
94	3	0	2	32	-29	4439
95	2	0	2	32	-29	4410
96	2	0	2	31	-29	4381
97	2	0	2	31	-29	4352
98	2	0	2	31	-28	4324
99	1	0	2	31	-28	4296
100	1	0	2	30	-28	4268
101	1	0	2	30	-28	4240
102	1	0	2	30	-27	4213
103	1	0	2	30	-27	4186
104	1	0	2	29	-27	4159
105	1	0	2	29	-27	4132
106	1	0	2	29	-27	4105
107	0	0	2	29	-26	4079
108	0	0	2	28	-26	4053
109	0	0	2	28	-26	4027
110	0	0	2	28	-26	4001
111	0	0	2	28	-25	3976
112	0	0	2	27	-25	3951
113	0	0	2	27	-25	3926
114	0	0	2	27	-25	3901
115	0	0	2	27	-25	3876
116	0	0	2	27	-25	3852
117	0	0	2	27	-24	3827
118	0	0	2	26	-24	3803
119	0	0	2	26	-24	3779
120	0	0	2	26	-24	3756
121	0	0	2	26	-23	3732
122	0	0	2	25	-23	3709
123	0	0	2	25	-23	3686
124	0	0	2	25	-23	3663
125	0	0	2	25	-23	3641

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-13. Direct GHG Emissions from tree removal and chipping activities.

TOTAL HOURS OF EQUIPMENT RUN-TIME BY DBH[1] CLASS FOR TREE REMOVAL (See Note 2).

Dbh[1] class (inches)	2.3-hp saw	3.7-hp saw	7.5-hp saw	Bucket truck	Chipper	Stump grinder
1-6	0.3	NA	NA	0.2	0.1	0.25
7-12	0.3	0.2	NA	0.4	0.25	0.33
13-18	0.5	0.5	0.1	0.75	0.4	0.5
19-24	1.5	1	0.5	2.2	0.75	0.7
25-30	1.8	1.5	0.8	3	1	1
31-36	2.2	1.8	1	5.5	2	1.5
36+	2.2	2.3	1.5	7.5	2.5	2
average:	1.26	1.22	0.78	2.79	1.00	0.90

TOTAL CARBON EMISSIONS FOR VARIOUS TREE REMOVAL EQUIPMENT (See Note 2).

Equipment	Total C emission (kg/hr)
Aerial lift / bucket truck	3.2
Chain saw < 4 hp	1.5
Chain saw > 4 hp	3.2
Chipper / stump grinder	5.4

ESTIMATED DIRECT EMISSIONS (CO_2) DUE TO TREE REMOVAL ACTIVITIES.

			Estimated Number of Hours of Operation				Estimated CO_2 emissions (tonnes)				
	Assumed number of forested acres[3]	Assumed number of trees[4]	chain saw < 4 hp	chain saw > 4 hp	bucket truck/ aerial lift	chipper / stump grinder	chain saw < 4 hp	chain saw > 4 hp	bucket truck/ aerial lift	chipper / stump grinder	Total
SED 3	30	16,610	41,090	12,956	46,389	31,512	226	152	544	624	1,500
SED 4	35	19,140	47,349	14,929	53,455	36,311	260	175	627	719	1,800
SED 5	35	19,250	47,621	15,015	53,763	36,520	262	176	631	723	1,800
SED 6	33	18,260	45,172	14,243	50,998	34,642	248	167	598	686	1,700
SED 7	33	18,260	45,172	14,243	50,998	34,642	248	167	598	686	1,700
SED 8	33	18,260	45,172	14,243	50,998	34,642	248	167	598	686	1,700

Notes:
1. dbh - diameter at breast height.
2. From tables 1 and 2 of Nowak et al. 2002.
   - Nowak, D.J., Stevens, J.C., Sisinni, S.M. and J. Luley. 2002. Effects of urban tree management and species selection on atmospheric carbon dioxide. *Journal of Arboriculture*. 28(3):113-122. May 2002.
3. Assumed number of forested acres requiring clearing for each alternative was determined by comparing the horizontal extent of anticipated floodplain soil removal (for each FP alternative), as well as the anticipated footprints of access roads and staging areas (for each FP and SED alternative) with data presenting the extent of various natural communities considered to be forests within the area of interest (Woodlot Alternatives, Inc. 2002).
   - Woodlot Alternatives, Inc. 2002. Ecological Characterization of the Housatonic River. Prepared for U.S. Environmental Protection Agency, Region 1. Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, MA. September 2002.
4. Uses value of 550 trees/acre based on 2005 USDA Forest Service Inventory of Massachusetts (Forest area: 3,166,400 acres; Number of live trees: 1,583,395,000) adjusted to include standing dead trees (from Table 2 of COLE Carbon Report) [dead trees comprise ~11% of live trees].
   - Cole Development Group. 2008. Cole 1605(b) Report for Massachusetts. http://ncasi.uml.edu/COLE/ (December 19, 2008).

Appendix A - Carbon Footprint/Greenhouse Gas Inventory Analysis for Sediment, Floodplain, and Treatment/Disposition Alternatives

Response to EPA Interim Comments on CMS Report

Floodplain Alternatives

Table A-14. GHG Emissions from Floodplain (FP) Alternative 2.
[22,000 cy of soil removed over 13 acre area, 1-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in Off-Site GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	35	50	1,800	18	0.00005	0.00005	18	transportation
FROM: Dump Truck (20 cy)	35	50	1,800	18	0.00005	0.00005	18	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	198	50	9,900	100	0.0026	0.0057	100	construction
						TOTAL EMISSIONS	140	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.000010	0.000011	4	transportation
Flat Bed Truck	7	50	350	4.0	0.000010	0.000011	4	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Excavator - Removal	198	50	9,900	100	0.0026	0.0057	100	construction
Dump Truck	396	50	20,000	200	0.0052	0.012	200	construction
Excavator - Loading	198	50	9,900	100	0.0026	0.0057	100	construction
Water Pump	127	50	6,400	60	0.0017	0.0037	61	construction
						TOTAL EMISSIONS	470	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	5	50	250	3.0	0.000065	0.00015	3	construction
						TOTAL EMISSIONS	3	

See Notes on Pages 2 & 3

Table A-14. GHG Emissions from Floodplain (FP) Alternative 2.
[22,000 cy of soil removed over 13 acre area, 1-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in Off-Site GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.000010	0.000011	4	transportation
Flat Bed Truck	7	50	350	4.0	0.000010	0.000011	4	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	154	50	7,700	80	0.0020	0.0045	80	construction
Front-End Loader	154	50	7,700	80	0.0020	0.0045	80	construction
Dump Truck	308	50	15,000	150	0.0039	0.0087	150	construction
						TOTAL EMISSIONS	320	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill)[4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
21,735	5.72	56	18,920	4.94	64	92,000	3.673	153

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
834	4.94	1.9

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	275

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
- CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
- N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
- CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
- N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
- CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-14. GHG Emissions from Floodplain (FP) Alternative 2.
[22,000 cy of soil removed over 13 acre area, 1-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

General notes associated with odd numbered tables A-15 through A-25.
(note numbers correspond to superscripts in table headings)

Notes:

1. Initial value (at year zero) determined from average total non-soil carbon stock (tonnes/acre) from fourteen different forest types common in Berkshire County, MA (from Table 2 of COLE Carbon Report (Cole Development Group 2008): *Carbon Stocks by Forest Type for Massachusetts*) multiplied by estimated number of total acres assumed to be cleared (Woodlot Alternatives, Inc. 2002).
   Assumed number of forested acres requiring clearing for each alternative was determined by comparing the horizontal extent of anticipated floodplain soil removal (for each FP alternative), as well as the anticipated footprints of access roads and staging areas (for each FP and SED alternative) with data presenting the extent of various natural communities considered to be forests within the area of interest (Woodlot Alternatives, Inc. 2002).
   Decay of mulch based on a first-order differential equation of the form: $N_t = N_0e$^(-k*t), N_0 = carbon (as CO_2) remaining in mulch at time zero, N_t = carbon (as CO_2) remaining in mulch at time t, t = years, k = rate coefficient.
   A rate coefficient of 0.14/year was used (based on Chestnut Oak branches up to 5 cm diameter; Abbott and Crossley 1982).
   - Cole Development Group. 2008. Cole 1605(b) Report for Massachusetts. http://ncasi.uml.edu/COLE/ (December 19, 2008).
   - Woodlot Alternatives, Inc. 2002. Ecological Characterization of the Housatonic River. Prepared for U.S. Environmental Protection Agency, Region 1. Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, MA. September 2002.
   - Abbott, D.T. and D.A. Crossley, Jr. 1982. Wood litter decomposition following clear-cutting. *Ecology* . 63(1):35-42.
2. Table 1 of COLE Carbon Report (Cole Development Group 2008): *Carbon Stocks by Age Class for Massachusetts* provided regional carbon stocks of forests by age class, at five year (0- to 40-years) and ten year (40- to 100-years) increments. These values were used to estimate the CO_2 that the removed trees would have sequestered in the future had they remained standing.
3. Sequestration of newly planted trees calculated by using data from a USDA report that summarizes carbon stocks by age class for various tree stands with afforestation of land (i.e., conversion of previously unforested land into forest), specific to the Northeast (Smith et al. 2006). This data presents the incremental increase in carbon stocks within six different forest types at 10 year intervals after afforestation. Taking the average of the six forest types presented, yielded a decade-by-decade overall assumed average carbon sequestration rate for afforestation.
   - Smith, J.E., Heath, L.S., Skog, K.E. and R.A. Birdsey. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA Forest Service, Northeastern Research Station. General Technical Report NE-343. April 2006.

Table A-15. FP 2 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	2,599					
1	2,259	340	22	0	362	362
2	1,964	295	22	38	280	642
3	1,708	257	22	38	241	883
4	1,485	223	22	38	207	1,090
5	1,291	194	22	38	178	1,268
6	1,122	169	22	38	153	1,421
7	975	147	22	50	119	1,540
8	848	127	22	50	99	1,639
9	737	111	22	50	83	1,722
10	641	96	22	50	68	1,790
11	557	84	14	50	47	1,837
12	484	73	14	50	36	1,874
13	421	63	14	50	27	1,900
14	366	55	14	50	18	1,919
15	318	48	14	50	11	1,930
16	277	42	14	50	5	1,935
17	241	36	14	43	7	1,941
18	209	31	14	43	2	1,943
19	182	27	14	43	-2	1,941
20	158	24	14	43	-6	1,936
21	137	21	8	43	-14	1,921
22	119	18	8	43	-17	1,904
23	104	16	8	43	-19	1,885
24	90	14	8	43	-22	1,863
25	78	12	8	43	-23	1,840
26	68	10	8	43	-25	1,815
27	59	9	8	38	-21	1,794
28	52	8	8	38	-22	1,771
29	45	7	8	38	-23	1,748
30	39	6	8	38	-24	1,724
31	34	5	5	38	-28	1,695
32	29	4	5	38	-29	1,666
33	26	4	5	38	-30	1,637
34	22	3	5	38	-30	1,607
35	19	3	5	38	-31	1,576
36	17	3	5	38	-31	1,545
37	15	2	5	33	-26	1,519
38	13	2	5	33	-26	1,493
39	11	2	5	33	-27	1,466
40	10	1	5	33	-27	1,439
41	8	1	3	33	-29	1,410
42	7	1	3	33	-29	1,381
43	6	1	3	33	-29	1,352
44	5	1	3	33	-29	1,322
45	5	1	3	33	-30	1,293
46	4	1	3	33	-30	1,263
47	4	1	3	29	-26	1,237
48	3	0	3	29	-26	1,211
49	3	0	3	29	-26	1,185
50	2	0	3	29	-26	1,159
51	2	0	2	29	-27	1,132
52	2	0	2	29	-27	1,105
53	2	0	2	29	-27	1,078
54	1	0	2	29	-27	1,051
55	1	0	2	29	-27	1,023
56	1	0	2	29	-27	996
57	1	0	2	26	-25	971
58	1	0	2	26	-25	947
59	1	0	2	26	-25	922
60	1	0	2	26	-25	898
61	1	0	2	26	-25	873
62	0	0	2	26	-25	848
63	0	0	2	26	-25	824
64	0	0	2	26	-25	799
65	0	0	2	26	-25	774
66	0	0	2	26	-25	750
67	0	0	2	23	-22	728
68	0	0	2	23	-22	706

Table A-15. FP 2 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
69	0	0	2	23	-22	684
70	0	0	2	23	-22	662
71	0	0	2	23	-22	640
72	0	0	2	23	-22	618
73	0	0	2	23	-22	596
74	0	0	2	23	-22	574
75	0	0	2	23	-22	552
76	0	0	2	23	-22	530
77	0	0	2	22	-20	510
78	0	0	2	22	-20	490
79	0	0	2	22	-20	470
80	0	0	2	22	-20	450
81	0	0	2	22	-20	430
82	0	0	2	22	-20	410
83	0	0	2	22	-20	390
84	0	0	2	22	-20	370
85	0	0	2	22	-20	350
86	0	0	2	22	-20	329
87	0	0	2	20	-18	311
88	0	0	2	20	-18	293
89	0	0	2	20	-18	274
90	0	0	2	20	-18	256
91	0	0	2	20	-18	238
92	0	0	2	20	-18	219
93	0	0	2	20	-18	201
94	0	0	2	20	-18	183
95	0	0	2	20	-18	164
96	0	0	2	20	-18	146
97	0	0	2	18	-17	129
98	0	0	2	18	-17	112
99	0	0	2	18	-17	95
100	0	0	2	18	-17	78
101	0	0	2	18	-17	61
102	0	0	2	18	-17	44
103	0	0	2	18	-17	28
104	0	0	2	18	-17	11
105	0	0	2	18	-17	-6
106	0	0	2	18	-17	-23
107	0	0	2	17	-16	-39
108	0	0	2	17	-16	-54
109	0	0	2	17	-16	-70
110	0	0	2	17	-16	-85
111	0	0	2	17	-16	-101
112	0	0	2	17	-16	-116
113	0	0	2	17	-16	-132
114	0	0	2	17	-16	-147
115	0	0	2	17	-16	-163
116	0	0	2	17	-16	-178
117	0	0	2	16	-14	-192
118	0	0	2	16	-14	-207
119	0	0	2	16	-14	-221
120	0	0	2	16	-14	-236
121	0	0	2	16	-14	-250
122	0	0	2	16	-14	-264
123	0	0	2	16	-14	-279
124	0	0	2	16	-14	-293
125	0	0	2	16	-14	-307

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-16. GHG Emissions from Floodplain (FP) Alternative 3.
[74,000 cy of soil removed over 44 acre area, 3-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	43	50	2,000	20	0.00006	0.00006	20	transportation
FROM: Dump Truck (20 cy)	43	50	2,000	20	0.00006	0.00006	20	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	572	50	28,600	290	0.0074	0.0166	300	construction
						TOTAL EMISSIONS	340	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.000010	0.000011	4	transportation
Flat Bed Truck	7	50	350	4.0	0.000010	0.000011	4	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Excavator - Removal	572	50	29,000	290	0.0075	0.017	290	construction
Dump Truck	1,144	50	57,000	580	0.015	0.033	590	construction
Excavator - Loading	572	50	29,000	290	0.0075	0.017	290	construction
Water Pump	497	50	25,000	250	0.0065	0.015	250	construction
						TOTAL EMISSIONS	1,430	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	19	50	950	10	0.0002	0.001	10	construction
						TOTAL EMISSIONS	10	

See Notes on Pages 2 & 3

Table A-16. GHG Emissions from Floodplain (FP) Alternative 3.
[74,000 cy of soil removed over 44 acre area, 3-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.00001	0.00001	4	transportation
Flat Bed Truck	7	50	350	4.0	0.00001	0.00001	4	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	308	50	15,000	150	0.0039	0.0087	150	construction
Front-End Loader	308	50	15,000	150	0.0039	0.0087	150	construction
Dump Truck	616	50	31,000	310	0.0081	0.0180	310	construction
						TOTAL EMISSIONS	620	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill) [4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
35,289	5.72	92	66,000	4.94	220	236,200	3.673	393

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
1,011	4.94	2.3

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	707

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-16. GHG Emissions from Floodplain (FP) Alternative 3.
[74,000 cy of soil removed over 44 acre area, 3-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

Table A-17. FP 3 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	5,382					
1	5,148	234	15	0	250	250
2	4,710	438	31	26	443	693
3	4,094	615	46	53	609	1,302
4	3,559	535	46	79	503	1,804
5	3,094	465	46	79	433	2,237
6	2,690	404	46	79	372	2,609
7	2,339	351	46	87	311	2,919
8	2,033	306	46	96	256	3,176
9	1,768	266	46	104	208	3,383
10	1,537	231	46	104	173	3,556
11	1,336	201	41	104	137	3,693
12	1,161	175	35	104	105	3,797
13	1,010	152	29	104	76	3,873
14	878	132	29	104	56	3,929
15	763	115	29	104	39	3,968
16	663	100	29	104	24	3,992
17	577	87	29	99	16	4,008
18	501	75	29	94	9	4,017
19	436	65	29	90	5	4,021
20	379	57	29	90	-4	4,017
21	329	50	25	90	-15	4,002
22	286	43	21	90	-26	3,976
23	249	37	17	90	-35	3,941
24	216	33	17	90	-40	3,901
25	188	28	17	90	-44	3,857
26	164	25	17	90	-48	3,809
27	142	21	17	86	-48	3,761
28	124	19	17	83	-47	3,714
29	107	16	17	79	-46	3,668
30	93	14	17	79	-48	3,619
31	81	12	15	79	-52	3,567
32	71	11	12	79	-56	3,511
33	61	9	10	79	-60	3,450
34	53	8	10	79	-61	3,389
35	46	7	10	79	-62	3,327
36	40	6	10	79	-63	3,263
37	35	5	10	76	-60	3,203
38	30	5	10	72	-58	3,145
39	27	4	10	68	-55	3,091
40	23	3	10	68	-55	3,036
41	20	3	8	68	-57	2,979
42	17	3	7	68	-59	2,920
43	15	2	6	68	-60	2,860
44	13	2	6	68	-61	2,799
45	11	2	6	68	-61	2,738
46	10	1	6	68	-61	2,677
47	9	1	6	66	-59	2,618
48	8	1	6	63	-56	2,562
49	7	1	6	60	-54	2,508
50	6	1	6	60	-54	2,455
51	5	1	5	60	-55	2,400
52	4	1	4	60	-55	2,345
53	4	1	3	60	-56	2,288
54	3	0	3	60	-56	2,232
55	3	0	3	60	-57	2,175
56	2	0	3	60	-57	2,119
57	2	0	3	58	-55	2,064
58	2	0	3	56	-53	2,011
59	2	0	3	54	-51	1,960
60	1	0	3	54	-51	1,909
61	1	0	3	54	-51	1,859
62	1	0	3	54	-51	1,808
63	1	0	3	54	-51	1,757
64	1	0	3	54	-51	1,706
65	1	0	3	54	-51	1,655
66	1	0	3	54	-51	1,604
67	1	0	3	52	-49	1,554

Table A-17. FP 3 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	0	0	3	51	-47	1,507
69	0	0	3	49	-45	1,462
70	0	0	3	49	-45	1,416
71	0	0	3	49	-45	1,371
72	0	0	3	49	-45	1,326
73	0	0	3	49	-45	1,280
74	0	0	3	49	-45	1,235
75	0	0	3	49	-45	1,189
76	0	0	3	49	-45	1,144
77	0	0	3	47	-44	1,100
78	0	0	3	46	-43	1,057
79	0	0	3	45	-42	1,015
80	0	0	3	45	-42	974
81	0	0	3	45	-42	932
82	0	0	3	45	-42	890
83	0	0	3	45	-42	849
84	0	0	3	45	-42	807
85	0	0	3	45	-42	765
86	0	0	3	45	-42	724
87	0	0	3	44	-40	683
88	0	0	3	42	-39	644
89	0	0	3	41	-38	606
90	0	0	3	41	-38	568
91	0	0	3	41	-38	530
92	0	0	3	41	-38	492
93	0	0	3	41	-38	454
94	0	0	3	41	-38	416
95	0	0	3	41	-38	378
96	0	0	3	41	-38	340
97	0	0	3	40	-37	303
98	0	0	3	39	-36	267
99	0	0	3	38	-35	232
100	0	0	3	38	-35	197
101	0	0	3	38	-35	162
102	0	0	3	38	-35	127
103	0	0	3	38	-35	92
104	0	0	3	38	-35	57
105	0	0	3	38	-35	22
106	0	0	3	38	-35	-13
107	0	0	3	37	-34	-47
108	0	0	3	36	-33	-80
109	0	0	3	35	-32	-112
110	0	0	3	35	-32	-144
111	0	0	3	35	-32	-176
112	0	0	3	35	-32	-208
113	0	0	3	35	-32	-240
114	0	0	3	35	-32	-272
115	0	0	3	35	-32	-305
116	0	0	3	35	-32	-337
117	0	0	3	35	-31	-368
118	0	0	3	34	-31	-399
119	0	0	3	33	-30	-428
120	0	0	3	33	-30	-458
121	0	0	3	33	-30	-488
122	0	0	3	33	-30	-518
123	0	0	3	33	-30	-547
124	0	0	3	33	-30	-577
125	0	0	3	33	-30	-607

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-18. GHG Emissions from Floodplain (FP) Alternative 4.
[121,000 cy of soil removed over 72 acre area, 5-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	49	50	2,500	25	0.00007	0.00008	25	transportation
FROM: Dump Truck (20 cy)	49	50	2,500	25	0.00007	0.00008	25	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	836	50	42,000	430	0.011	0.024	430	construction
						TOTAL EMISSIONS	480	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.000010	0.000011	4	transportation
Flat Bed Truck	7	50	350	4.0	0.000010	0.000011	4	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Excavator - Removal	836	50	42,000	430	0.011	0.024	430	construction
Dump Truck	1672	50	84,000	850	0.022	0.049	860	construction
Excavator - Loading	836	50	42,000	430	0.011	0.024	430	construction
Water Pump	780	50	39,000	400	0.010	0.023	400	construction
						TOTAL EMISSIONS	2,130	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	31	50	1,600	20	0.000	0.001	20	construction
						TOTAL EMISSIONS	20	

See Notes on Pages 2 & 3

Table A-18. GHG Emissions from Floodplain (FP) Alternative 4.
[121,000 cy of soil removed over 72 acre area, 5-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.00001	0.00001	4	transportation
Flat Bed Truck	7	50	350	4.0	0.00001	0.00001	4	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	506	50	25,000	250	0.0065	0.0145	250	construction
Front-End Loader	506	50	25,000	250	0.0065	0.0145	250	construction
Dump Truck	1,012	50	51,000	520	0.0133	0.0296	520	construction
						TOTAL EMISSIONS	1,030	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill)[4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
34,274	5.72	89	107,367	4.94	361	358,250	3.673	597

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
1,035	4.94	2.3

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	1,050

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
- CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
- N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
- CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
- N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
- CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-18. GHG Emissions from Floodplain (FP) Alternative 4.
[121,000 cy of soil removed over 72 acre area, 5-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

Table A-19. FP 4 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	12,075					
1	11,760	315	21	0	336	336
2	11,170	590	42	35	596	932
3	10,341	828	63	71	820	1,753
4	9,306	1,036	83	106	1,013	2,765
5	8,090	1,216	104	141	1,179	3,944
6	7,033	1,057	104	177	984	4,928
7	6,114	919	104	188	835	5,763
8	5,316	799	104	200	703	6,466
9	4,621	694	104	211	587	7,054
10	4,017	604	104	223	485	7,539
11	3,493	525	96	234	387	7,925
12	3,036	456	88	234	310	8,235
13	2,640	397	80	234	242	8,478
14	2,295	345	72	234	183	8,660
15	1,995	300	64	234	129	8,790
16	1,734	261	64	234	90	8,880
17	1,508	227	64	228	63	8,943
18	1,311	197	64	221	40	8,983
19	1,140	171	64	214	21	9,004
20	991	149	64	208	5	9,010
21	861	129	59	201	-13	8,997
22	749	113	54	201	-35	8,963
23	651	98	48	201	-55	8,908
24	566	85	43	201	-73	8,835
25	492	74	38	201	-89	8,746
26	428	64	38	201	-99	8,648
27	372	56	38	196	-102	8,545
28	323	49	38	192	-105	8,440
29	281	42	38	187	-107	8,333
30	244	37	38	182	-108	8,226
31	212	32	35	178	-111	8,114
32	185	28	32	178	-118	7,996
33	161	24	28	178	-125	7,871
34	140	21	25	178	-132	7,739
35	121	18	22	178	-137	7,602
36	105	16	22	178	-140	7,462
37	92	14	22	173	-137	7,325
38	80	12	22	168	-134	7,191
39	69	10	22	163	-131	7,060
40	60	9	22	158	-127	6,933
41	52	8	20	153	-125	6,808
42	46	7	18	153	-128	6,680
43	40	6	16	153	-131	6,549
44	34	5	14	153	-134	6,415
45	30	4	13	153	-136	6,279
46	26	4	13	153	-137	6,142
47	23	3	13	150	-134	6,009
48	20	3	13	146	-130	5,879
49	17	3	13	142	-127	5,751
50	15	2	13	139	-124	5,628
51	13	2	12	135	-121	5,506
52	11	2	10	135	-123	5,383
53	10	1	9	135	-124	5,259
54	8	1	8	135	-125	5,134
55	7	1	7	135	-127	5,007
56	6	1	7	135	-127	4,881
57	6	1	7	132	-124	4,756
58	5	1	7	130	-122	4,634
59	4	1	7	127	-119	4,515
60	4	1	7	124	-117	4,398
61	3	0	7	122	-114	4,284
62	3	0	7	122	-114	4,170
63	2	0	7	122	-114	4,055
64	2	0	7	122	-114	3,941
65	2	0	7	122	-114	3,827
66	2	0	7	122	-114	3,712
67	1	0	7	119	-112	3,600

Table A-19. FP 4 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	1	0	7	117	-109	3,491
69	1	0	7	114	-107	3,384
70	1	0	7	112	-104	3,279
71	1	0	7	109	-102	3,178
72	1	0	7	109	-102	3,076
73	1	0	7	109	-102	2,974
74	1	0	7	109	-102	2,872
75	0	0	7	109	-102	2,770
76	0	0	7	109	-102	2,668
77	0	0	7	107	-100	2,568
78	0	0	7	106	-98	2,470
79	0	0	7	104	-97	2,373
80	0	0	7	102	-95	2,278
81	0	0	7	101	-93	2,184
82	0	0	7	101	-93	2,091
83	0	0	7	101	-93	1,998
84	0	0	7	101	-93	1,904
85	0	0	7	101	-93	1,811
86	0	0	7	101	-93	1,717
87	0	0	7	99	-92	1,626
88	0	0	7	97	-90	1,535
89	0	0	7	96	-89	1,447
90	0	0	7	94	-87	1,360
91	0	0	7	92	-85	1,275
92	0	0	7	92	-85	1,189
93	0	0	7	92	-85	1,104
94	0	0	7	92	-85	1,019
95	0	0	7	92	-85	933
96	0	0	7	92	-85	848
97	0	0	7	91	-84	764
98	0	0	7	90	-83	681
99	0	0	7	88	-81	600
100	0	0	7	87	-80	520
101	0	0	7	86	-78	442
102	0	0	7	86	-78	364
103	0	0	7	86	-78	285
104	0	0	7	86	-78	207
105	0	0	7	86	-78	128
106	0	0	7	86	-78	50
107	0	0	7	84	-77	-27
108	0	0	7	83	-76	-103
109	0	0	7	82	-75	-178
110	0	0	7	80	-73	-251
111	0	0	7	79	-72	-323
112	0	0	7	79	-72	-395
113	0	0	7	79	-72	-467
114	0	0	7	79	-72	-539
115	0	0	7	79	-72	-611
116	0	0	7	79	-72	-683
117	0	0	7	78	-71	-754
118	0	0	7	77	-70	-824
119	0	0	7	76	-69	-893
120	0	0	7	75	-68	-961
121	0	0	7	74	-67	-1,028
122	0	0	7	74	-67	-1,095
123	0	0	7	74	-67	-1,161
124	0	0	7	74	-67	-1,228
125	0	0	7	74	-67	-1,295

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-20. GHG Emissions from Floodplain (FP) Alternative 5.
[104,000 cy of soil removed over 63 acre area, 4-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	48	50	2,400	24	0.00007	0.00007	24	transportation
FROM: Dump Truck (20 cy)	48	50	2,400	24	0.00007	0.00007	24	transportation
Water Truck	3	50	150	2.0	0.0000043	0.0000045	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	814	50	41,000	420	0.011	0.024	420	construction
						TOTAL EMISSIONS	470	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Dump Truck	1,628	50	81,000	820	0.021	0.047	830	construction
Excavator - Removal	814	50	41,000	420	0.011	0.024	420	construction
Excavator - Loading	814	50	41,000	420	0.011	0.024	420	construction
Water Pump	793	50	40,000	410	0.010	0.023	410	construction
						TOTAL EMISSIONS	2,090	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	31	50	1,600	20	0.000	0.001	20	construction
						TOTAL EMISSIONS	20	

See Notes on Pages 2 & 3

Table A-20. GHG Emissions from Floodplain (FP) Alternative 5.
[104,000 cy of soil removed over 63 acre area, 4-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.00001	0.00001	3	transportation
Flat Bed Truck	6	50	300	3.0	0.00001	0.00001	3	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	484	50	24,000	240	0.0062	0.0139	240	construction
Front-End Loader - Staging	484	50	24,000	240	0.0062	0.0139	240	construction
Dump Truck	968	50	48,000	490	0.0125	0.0278	490	construction
						TOTAL EMISSIONS	980	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill)[4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
33,119	5.72	86	109,121	4.94	367	347,800	3.673	579

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
922	4.94	2.1

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	1,030

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
- CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
- N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
- CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
- N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
- CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-20. GHG Emissions from Floodplain (FP) Alternative 5.
[104,000 cy of soil removed over 63 acre area, 4-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

Table A-21. FP 5 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	10,028					
1	9,700	328	22	0	349	349
2	9,088	612	43	37	619	968
3	8,228	860	65	73	851	1,819
4	7,153	1,075	87	110	1,051	2,871
5	6,219	935	87	147	874	3,745
6	5,406	812	87	147	752	4,497
7	4,700	706	87	159	634	5,131
8	4,086	614	87	171	530	5,661
9	3,552	534	87	183	438	6,099
10	3,088	464	87	195	356	6,455
11	2,685	403	78	195	287	6,742
12	2,334	351	70	195	226	6,968
13	2,029	305	62	195	172	7,140
14	1,764	265	53	195	124	7,263
15	1,534	230	53	195	89	7,352
16	1,333	200	53	195	59	7,411
17	1,159	174	53	188	40	7,451
18	1,008	151	53	181	24	7,475
19	876	132	53	174	11	7,486
20	762	114	53	167	1	7,487
21	662	99	48	167	-20	7,467
22	576	86	42	167	-38	7,429
23	500	75	37	167	-55	7,375
24	435	65	31	167	-70	7,305
25	378	57	31	167	-78	7,226
26	329	49	31	167	-86	7,140
27	286	43	31	162	-88	7,053
28	248	37	31	157	-88	6,964
29	216	32	31	152	-88	6,876
30	188	28	31	148	-88	6,788
31	163	25	28	148	-95	6,693
32	142	21	25	148	-101	6,592
33	123	19	22	148	-107	6,484
34	107	16	18	148	-113	6,371
35	93	14	18	148	-115	6,256
36	81	12	18	148	-117	6,139
37	70	11	18	142	-114	6,025
38	61	9	18	137	-110	5,915
39	53	8	18	132	-106	5,809
40	46	7	18	127	-102	5,707
41	40	6	16	127	-105	5,602
42	35	5	14	127	-108	5,495
43	30	5	12	127	-110	5,384
44	26	4	10	127	-113	5,271
45	23	3	10	127	-113	5,158
46	20	3	10	127	-114	5,044
47	17	3	10	123	-110	4,934
48	15	2	10	120	-107	4,827
49	13	2	10	116	-103	4,724
50	11	2	10	112	-100	4,624
51	10	1	9	112	-101	4,523
52	9	1	8	112	-103	4,420
53	8	1	7	112	-104	4,316
54	7	1	6	112	-105	4,211
55	6	1	6	112	-105	4,106
56	5	1	6	112	-105	4,001
57	4	1	6	109	-103	3,898
58	4	1	6	107	-100	3,798
59	3	0	6	104	-97	3,700
60	3	0	6	101	-95	3,605
61	2	0	6	101	-95	3,510
62	2	0	6	101	-95	3,415
63	2	0	6	101	-95	3,320
64	2	0	6	101	-95	3,225
65	1	0	6	101	-95	3,130
66	1	0	6	101	-95	3,035
67	1	0	6	99	-92	2,943
68	1	0	6	96	-90	2,853

Table A-21. FP 5 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
69	1	0	6	93	-87	2,766
70	1	0	6	91	-85	2,681
71	1	0	6	91	-85	2,597
72	1	0	6	91	-85	2,512
73	0	0	6	91	-85	2,427
74	0	0	6	91	-85	2,343
75	0	0	6	91	-85	2,258
76	0	0	6	91	-85	2,174
77	0	0	6	89	-83	2,091
78	0	0	6	87	-81	2,010
79	0	0	6	85	-79	1,930
80	0	0	6	84	-78	1,853
81	0	0	6	84	-78	1,775
82	0	0	6	84	-78	1,698
83	0	0	6	84	-78	1,620
84	0	0	6	84	-78	1,543
85	0	0	6	84	-78	1,465
86	0	0	6	84	-78	1,387
87	0	0	6	82	-76	1,312
88	0	0	6	80	-74	1,237
89	0	0	6	78	-73	1,165
90	0	0	6	77	-71	1,094
91	0	0	6	77	-71	1,023
92	0	0	6	77	-71	952
93	0	0	6	77	-71	881
94	0	0	6	77	-71	811
95	0	0	6	77	-71	740
96	0	0	6	77	-71	669
97	0	0	6	75	-69	599
98	0	0	6	74	-68	531
99	0	0	6	73	-67	465
100	0	0	6	71	-65	400
101	0	0	6	71	-65	334
102	0	0	6	71	-65	269
103	0	0	6	71	-65	204
104	0	0	6	71	-65	139
105	0	0	6	71	-65	74
106	0	0	6	71	-65	9
107	0	0	6	70	-64	-55
108	0	0	6	68	-62	-118
109	0	0	6	67	-61	-179
110	0	0	6	66	-60	-239
111	0	0	6	66	-60	-298
112	0	0	6	66	-60	-358
113	0	0	6	66	-60	-418
114	0	0	6	66	-60	-478
115	0	0	6	66	-60	-538
116	0	0	6	66	-60	-597
117	0	0	6	65	-59	-656
118	0	0	6	64	-58	-714
119	0	0	6	63	-57	-770
120	0	0	6	61	-55	-826
121	0	0	6	61	-55	-881
122	0	0	6	61	-55	-937
123	0	0	6	61	-55	-992
124	0	0	6	61	-55	-1,048
125	0	0	6	61	-55	-1,103

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-22. GHG Emissions from Floodplain (FP) Alternative 6.
[320,000 cy of soil removed over 197 acre area, 13-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	80	50	4,000	41	0.00011	0.00012	41	transportation
FROM: Dump Truck (20 cy)	80	50	4,000	41	0.00011	0.00012	41	transportation
Water Truck	3	50	150	2.0	0.0000043	0.0000045	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	2,574	50	130,000	1,300	0.034	0.075	1,300	construction
						TOTAL EMISSIONS	1,400	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Flat Bed Truck	6	50	300	3.0	0.0000085	0.0000091	3	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Excavator - Removal	2,574	50	130,000	1,300	0.034	0.075	1,300	construction
Dump Truck	5,148	50	260,000	2,600	0.068	0.15	2,600	construction
Excavator - Loading	2,574	50	130,000	1,300	0.034	0.075	1,300	construction
Water Pump	2,545	50	130,000	1,300	0.034	0.075	1,300	construction
						TOTAL EMISSIONS	6,500	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	99	50	5,000	50	0.001	0.003	50	construction
						TOTAL EMISSIONS	50	

See Notes on Pages 2 & 3

Table A-22. GHG Emissions from Floodplain (FP) Alternative 6.
[320,000 cy of soil removed over 197 acre area, 13-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	6	50	300	3.0	0.00001	0.00001	3	transportation
Flat Bed Truck	6	50	300	3.0	0.00001	0.00001	3	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	1,452	50	73,000	740	0.0190	0.0423	750	construction
Front-End Loader	1,452	50	73,000	740	0.0190	0.0423	750	construction
Dump Trucks	2,904	50	150,000	1,500	0.0390	0.0870	1,500	construction
						TOTAL EMISSIONS	3,000	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill)[4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
44,349	5.72	115	348,479	4.94	1,170	1,090,400	3.673	1,816

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
1,317	4.94	3.0

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	3,100

Notes:
1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
- CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
- N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
- CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
- N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
- CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-22. GHG Emissions from Floodplain (FP) Alternative 6.
[320,000 cy of soil removed over 197 acre area, 13-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

Table A-23. FP 6 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	25,185					
1	24,932	253	17	0	270	270
2	24,459	473	33	28	478	748
3	23,794	664	50	57	658	1,406
4	22,964	831	67	85	812	2,218
5	21,988	975	84	114	945	3,164
6	20,887	1,101	100	142	1,059	4,223
7	19,677	1,210	117	179	1,148	5,371
8	18,372	1,305	134	217	1,222	6,593
9	16,984	1,388	151	255	1,284	7,877
10	15,525	1,460	167	292	1,335	9,211
11	14,003	1,522	178	330	1,370	10,581
12	12,426	1,576	188	368	1,397	11,978
13	10,803	1,623	198	405	1,416	13,394
14	9,392	1,411	192	443	1,160	14,554
15	8,165	1,227	185	452	960	15,514
16	7,098	1,067	179	461	784	16,299
17	6,171	927	172	465	635	16,933
18	5,365	806	166	469	503	17,437
19	4,664	701	159	473	388	17,824
20	4,055	609	153	467	295	18,119
21	3,525	530	142	462	210	18,329
22	3,064	460	132	457	136	18,465
23	2,664	400	121	451	70	18,535
24	2,316	348	117	446	19	18,554
25	2,013	303	113	440	-25	18,529
26	1,750	263	108	435	-64	18,465
27	1,522	229	104	426	-93	18,372
28	1,323	199	100	417	-118	18,254
29	1,150	173	96	408	-139	18,115
30	1,000	150	92	404	-162	17,953
31	869	131	85	400	-185	17,768
32	756	114	78	397	-205	17,563
33	657	99	71	393	-223	17,341
34	571	86	69	389	-234	17,106
35	496	75	66	385	-245	16,862
36	432	65	64	382	-253	16,608
37	375	56	61	374	-257	16,352
38	326	49	59	366	-259	16,093
39	284	43	56	359	-260	15,833
40	247	37	53	355	-264	15,569
41	214	32	49	351	-269	15,299
42	186	28	45	347	-274	15,026
43	162	24	41	343	-277	14,748
44	141	21	40	339	-278	14,470
45	122	18	38	335	-279	14,191
46	106	16	37	331	-279	13,913
47	93	14	35	325	-275	13,637
48	80	12	34	318	-272	13,366
49	70	11	32	311	-268	13,098
50	61	9	31	308	-268	12,830
51	53	8	28	305	-269	12,561
52	46	7	26	302	-269	12,292
53	40	6	24	299	-269	12,023
54	35	5	23	296	-268	11,755
55	30	5	22	293	-267	11,488
56	26	4	21	290	-265	11,223
57	23	3	20	285	-262	10,961
58	20	3	19	280	-258	10,703
59	17	3	18	275	-254	10,449
60	15	2	18	273	-253	10,196
61	13	2	17	271	-252	9,944
62	11	2	16	269	-251	9,692
63	10	1	15	267	-250	9,442
64	9	1	15	265	-248	9,194
65	7	1	15	263	-247	8,947
66	6	1	15	260	-245	8,703
67	6	1	15	256	-241	8,462

Table A-23. FP 6 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	5	1	15	252	-237	8,225
69	4	1	15	248	-232	7,993
70	4	1	15	246	-231	7,762
71	3	0	15	244	-229	7,534
72	3	0	15	242	-227	7,307
73	2	0	15	240	-225	7,083
74	2	0	15	238	-223	6,860
75	2	0	15	236	-221	6,640
76	2	0	15	234	-219	6,421
77	1	0	15	230	-215	6,206
78	1	0	15	227	-212	5,994
79	1	0	15	223	-208	5,786
80	1	0	15	222	-207	5,579
81	1	0	15	221	-206	5,373
82	1	0	15	219	-204	5,169
83	1	0	15	218	-203	4,966
84	1	0	15	217	-202	4,764
85	0	0	15	215	-200	4,564
86	0	0	15	214	-199	4,365
87	0	0	15	211	-196	4,169
88	0	0	15	209	-194	3,975
89	0	0	15	206	-191	3,784
90	0	0	15	205	-190	3,595
91	0	0	15	203	-188	3,407
92	0	0	15	202	-187	3,219
93	0	0	15	201	-186	3,034
94	0	0	15	199	-184	2,849
95	0	0	15	198	-183	2,666
96	0	0	15	197	-182	2,484
97	0	0	15	194	-179	2,305
98	0	0	15	192	-177	2,128
99	0	0	15	190	-175	1,953
100	0	0	15	189	-174	1,780
101	0	0	15	187	-172	1,607
102	0	0	15	186	-171	1,436
103	0	0	15	185	-170	1,266
104	0	0	15	184	-169	1,097
105	0	0	15	183	-168	928
106	0	0	15	182	-167	762
107	0	0	15	180	-165	597
108	0	0	15	178	-163	434
109	0	0	15	176	-161	273
110	0	0	15	174	-160	114
111	0	0	15	173	-158	-45
112	0	0	15	172	-157	-202
113	0	0	15	171	-156	-358
114	0	0	15	170	-155	-514
115	0	0	15	169	-154	-668
116	0	0	15	168	-153	-821
117	0	0	15	166	-151	-973
118	0	0	15	165	-150	-1,122
119	0	0	15	163	-148	-1,270
120	0	0	15	162	-147	-1,417
121	0	0	15	161	-146	-1,563
122	0	0	15	160	-145	-1,708
123	0	0	15	159	-144	-1,853
124	0	0	15	158	-144	-1,996
125	0	0	15	158	-143	-2,139

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-24. GHG Emissions from Floodplain (FP) Alternative 7.
[631,000 cy of soil removed over 387 acre area, 24-yr duration]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF ACCESS ROADS/STAGING AREAS (TRANSPORTATION/CONSTRUCTION)
[NOTE: Emissions from excavating gravel materials from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF GRAVEL AND OTHER MATERIALS/EQUIPMENT TO/FROM SITE								
TO: Dump Truck (20 cy)	113	50	5,700	58	0.00016	0.00017	58	transportation
FROM: Dump Truck (20 cy)	113	50	5,700	58	0.00016	0.00017	58	transportation
Water Truck	4	50	200	2.0	0.0000057	0.0000060	2	transportation
CONSTRUCTION OF ACCESS ROADS / STAGING AREAS								
Water Truck	4,422	50	220,000	2,200	0.057	0.13	2,200	construction
						TOTAL EMISSIONS	2,300	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO EXCAVATION OF FLOODPLAIN SOILS (TRANSPORTATION OF EQUIPMENT AND EXCAVATION ACTIVITIES)

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION OF EQUIPMENT TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.000010	0.000011	4	transportation
Flat Bed Truck	7	50	350	4.0	0.000010	0.000011	4	transportation
Cargo Truck	1	50	50	1.0	0.0000014	0.0000015	1	transportation
ONSITE EXCAVATION ACTIVITIES								
Excavator - Removal	4,422	50	220,000	2,200	0.057	0.13	2,200	construction
Dump Trucks	8,844	50	440,000	4,500	0.11	0.26	4,500	construction
Excavator - Loading	4,422	50	220,000	2,200	0.057	0.13	2,200	construction
Water Pump	4,369	50	220,000	2,200	0.057	0.13	2,200	construction
						TOTAL EMISSIONS	11,100	

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF EXCAVATED MATERIALS TO STOCKPILE AREAS

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
Dump Truck - 20 cy	178	50	8,900	90	0.002	0.01	90	construction
						TOTAL EMISSIONS	90	

See Notes on Pages 2 & 3

Table A-24. GHG Emissions from Floodplain (FP) Alternative 7.
[631,000 cy of soil removed over 387 acre area, 24-yr duration]

ESTIMATED DIRECT GHG EMISSIONS (expressed as CO_2-eq) DUE TO PLACEMENT OF BACKFILL MATERIAL (TRANSPORTATION TO SITE/PLACEMENT/COMPACTION/GRADING)
[NOTE: Emissions from excavating backfill material from borrow pit are presented in *Off-Site* GHG Emissions Tables below]

Type of Vehicle/ Equipment Used	Total duration of vehicle operation (days)	Assumed gallons of diesel fuel utilized per vehicle per day	Total Quantity of Diesel Fuel Used (gal)	Tonnes of CO_2 emitted[1]	Tonnes of N_2O emitted[1]	Tonnes of CH_4 emitted[1]	Tonnes of CO_2-eq emitted[2]	Included as "transportation" or "construction" in summary table
TRANSPORTATION TO/FROM SITE								
Dump Truck - 20 cy	7	50	350	4.0	0.00001	0.00001	4	transportation
Flat Bed Truck	7	50	350	4.0	0.00001	0.00001	4	transportation
PLACEMENT/COMPACTION/GRADING								
Excavator - Fill	2,442	50	120,000	1,200	0.0312	0.0696	1,200	construction
Front-End Loader	2,442	50	120,000	1,200	0.0312	0.0696	1,200	construction
Dump Trucks	4,884	50	240,000	2,400	0.0624	0.1392	2,400	construction
						TOTAL EMISSIONS	4,800	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq)
► DUE TO EXCAVATION OF ACCESS ROAD BASE MATERIAL (GRAVEL), EXCAVATION OF BACKFILL MATERIAL FROM BORROW PIT, AND DIESEL FUEL REFINING

Quantity of gravel material required for access road construction (tons)	Pounds of CO_2-eq emitted per ton of gravel material excavated from borrow pit[3]	Tonnes of CO_2-eq emitted from gravel excavation activities	Quantity of backfill materials required (CY)	Pounds of CO_2-eq emitted per ton of backfill material excavted from borrow pit (assumes 1.5 ton/CY backfill)[4]	Tonnes of CO_2-eq emitted from backfill excavation activities	Gallons of diesel fuel required (from above-listed activities)	Pounds of CO_2-eq emitted per gallon diesel fuel refined[5]	Tonnes of CO_2-eq emitted from diesel refining
62,744	5.72	163	625,900	4.94	2,103	1,821,950	3.673	3,035

►DUE TO EXCAVATION OF SAND FROM BORROW PIT

Quantity of sand required for use in lining stockpile areas (tons)	Pounds of CO_2-eq emitted per ton sand excavated from borrow pit[6]	Tonnes of CO_2-eq emitted from sand excavation activities
1,716	4.94	3.8

Total Estimated Tonnes CO_2-eq emitted due to Off-Site Sources	5,300

Notes:

1. Calculations made with emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008).
   The following emissions factors are utilized for calculations involving transportation of materials to/from the work site(s):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
   The following emissions factors are utilized for calculations involving on-site material installation/excavation/construction and transportation of material from work-site to stockpile areas:
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Notes continued on page 3

Table A-24. GHG Emissions from Floodplain (FP) Alternative 7.
[631,000 cy of soil removed over 387 acre area, 24-yr duration]

Notes (continued):

2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.

Emissions factors associated with notes 3 through 6 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

3. Gravel is presumed to be 79% "gravel, round" and 21% "gravel, crushed", which is the typical mix for unspecified gravel.
4. Used gravel excavation process with material "Clay and soil, excavated for use" substituted for "Gravel, in ground".
5. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel), which includes emissions from refining and transportation of fuel from refinery to filling station (average distance), was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
6. Sand, at mine (or borrow pit).

Table A-25. FP 7 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2). (See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
0	42,504					
1	42,273	231	15	0	247	247
2	41,840	433	31	26	437	684
3	41,233	607	46	52	601	1,285
4	40,473	759	61	78	743	2,028
5	39,582	892	76	104	864	2,892
6	38,575	1,006	92	130	969	3,861
7	37,469	1,106	107	164	1,049	4,910
8	36,276	1,193	122	198	1,117	6,027
9	35,007	1,269	138	233	1,173	7,201
10	33,673	1,334	153	267	1,220	8,421
11	32,282	1,391	162	302	1,252	9,673
12	30,841	1,441	172	336	1,277	10,949
13	29,357	1,484	181	370	1,295	12,244
14	27,835	1,522	191	405	1,307	13,552
15	26,281	1,554	200	439	1,315	14,866
16	24,699	1,582	209	473	1,318	16,185
17	23,091	1,607	219	503	1,323	17,508
18	21,463	1,629	228	532	1,324	18,832
19	19,816	1,647	238	562	1,323	20,155
20	18,152	1,663	247	591	1,319	21,474
21	16,475	1,677	252	621	1,309	22,783
22	14,786	1,690	258	650	1,297	24,080
23	13,085	1,700	264	680	1,284	25,364
24	11,376	1,709	269	709	1,270	26,634
25	9,890	1,486	259	739	1,007	27,641
26	8,598	1,292	250	742	800	28,440
27	7,474	1,123	240	742	621	29,061
28	6,498	976	230	742	464	29,526
29	5,649	849	220	742	327	29,853
30	4,911	738	211	743	206	30,059
31	4,269	642	199	734	106	30,165
32	3,712	558	187	726	18	30,183
33	3,227	485	174	718	-58	30,125
34	2,805	422	162	709	-125	30,000
35	2,439	366	156	701	-178	29,822
36	2,120	319	150	693	-224	29,598
37	1,843	277	144	681	-260	29,338
38	1,602	241	138	669	-290	29,048
39	1,393	209	132	657	-316	28,732
40	1,211	182	125	645	-338	28,394
41	1,053	158	118	638	-362	28,032
42	915	138	110	631	-383	27,649
43	796	120	103	624	-402	27,247
44	692	104	95	617	-418	26,829
45	601	90	91	610	-428	26,401
46	523	79	88	603	-437	25,964
47	455	68	84	594	-441	25,523
48	395	59	80	584	-444	25,079
49	344	52	77	574	-446	24,633
50	299	45	73	565	-447	24,186
51	260	39	68	558	-451	23,735
52	226	34	64	552	-454	23,281
53	196	29	59	546	-457	22,825
54	171	26	55	539	-459	22,366
55	148	22	53	533	-458	21,908
56	129	19	51	527	-457	21,451
57	112	17	48	519	-453	20,997
58	97	15	46	511	-450	20,548
59	85	13	44	502	-446	20,102
60	74	11	42	494	-441	19,661
61	64	10	40	490	-440	19,221
62	56	8	38	485	-439	18,782
63	48	7	35	480	-438	18,344
64	42	6	33	476	-436	17,908
65	37	5	32	471	-433	17,474
66	32	5	32	467	-430	17,044
67	28	4	31	460	-425	16,619

Table A-25. FP 7 emissions and sequestration losses/gains from disruptions in forest carbon stocks (tonnes, CO_2).
(See general notes page prior to Table A-15)

year (end)	Carbon (as CO_2) remaining sequestered in trees/mulch[1]	Annual CO_2 emissions from decay of mulch[1]	Annual CO_2 Sequestration assumed lost from removed trees[2]	Annual CO_2 Sequestration of newly planted trees[3]	Annual Net emissions [emissions(+), sequestration (-)]	Annual Cumulative emissions [emissions(+), sequestration (-)]
68	24	4	30	454	-420	16,199
69	21	3	29	447	-415	15,784
70	18	3	28	441	-410	15,375
71	16	2	28	437	-407	14,968
72	14	2	27	433	-404	14,564
73	12	2	26	429	-401	14,162
74	10	2	25	426	-399	13,764
75	9	1	25	422	-395	13,369
76	8	1	25	418	-392	12,977
77	7	1	25	413	-387	12,590
78	6	1	25	408	-382	12,209
79	5	1	25	403	-377	11,832
80	4	1	25	398	-372	11,460
81	4	1	25	395	-369	11,091
82	3	1	25	392	-366	10,725
83	3	0	25	388	-363	10,362
84	3	0	25	385	-360	10,003
85	2	0	25	382	-357	9,646
86	2	0	25	379	-354	9,292
87	2	0	25	375	-349	8,943
88	1	0	25	370	-345	8,598
89	1	0	25	366	-341	8,257
90	1	0	25	362	-336	7,921
91	1	0	25	359	-334	7,587
92	1	0	25	357	-332	7,255
93	1	0	25	355	-329	6,926
94	1	0	25	352	-327	6,600
95	1	0	25	350	-324	6,275
96	0	0	25	347	-322	5,953
97	0	0	25	344	-318	5,635
98	0	0	25	340	-315	5,320
99	0	0	25	337	-312	5,008
100	0	0	25	333	-308	4,700
101	0	0	25	331	-306	4,394
102	0	0	25	329	-304	4,090
103	0	0	25	327	-302	3,789
104	0	0	25	325	-299	3,489
105	0	0	25	322	-297	3,192
106	0	0	25	320	-295	2,897
107	0	0	25	317	-292	2,605
108	0	0	25	314	-289	2,317
109	0	0	25	311	-286	2,031
110	0	0	25	308	-282	1,749
111	0	0	25	306	-281	1,468
112	0	0	25	304	-279	1,190
113	0	0	25	302	-277	913
114	0	0	25	300	-275	638
115	0	0	25	298	-273	366
116	0	0	25	296	-271	95
117	0	0	25	293	-268	-173
118	0	0	25	291	-265	-439
119	0	0	25	288	-263	-701
120	0	0	25	285	-260	-961
121	0	0	25	283	-258	-1,219
122	0	0	25	282	-256	-1,476
123	0	0	25	280	-255	-1,730
124	0	0	25	278	-253	-1,983
125	0	0	25	277	-251	-2,235

Note:
1. Highlighted value indicates emissions expected through the end of the project.

Table A-26. Direct GHG Emissions from tree removal and chipping activities.

TOTAL HOURS OF EQUIPMENT RUN-TIME BY DBH[1] CLASS FOR TREE REMOVAL (See Note 2).

Dbh[1] class (inches)	2.3-hp saw	3.7-hp saw	7.5-hp saw	Bucket truck	Chipper	Stump grinder
1-6	0.3	NA	NA	0.2	0.1	0.25
7-12	0.3	0.2	NA	0.4	0.25	0.33
13-18	0.5	0.5	0.1	0.75	0.4	0.5
19-24	1.5	1	0.5	2.2	0.75	0.7
25-30	1.8	1.5	0.8	3	1	1
31-36	2.2	1.8	1	5.5	2	1.5
36+	2.2	2.3	1.5	7.5	2.5	2
average:	1.26	1.22	0.78	2.79	1.00	0.90

TOTAL CARBON EMISSIONS FOR VARIOUS TREE REMOVAL EQUIPMENT (See Note 2).

Equipment	Total C emission (kg/hr)
Aerial lift / bucket truck	3.2
Chain saw < 4 hp	1.5
Chain saw > 4 hp	3.2
Chipper / stump grinder	5.4

ESTIMATED DIRECT EMISSIONS (CO_2) DUE TO TREE REMOVAL ACTIVITIES.

			Estimated Number of Hours of Operation				Estimated CO_2 emissions (tonnes)				
	Assumed number of forested acres[3]	Assumed number of trees[4]	chain saw < 4 hp	chain saw > 4 hp	bucket truck/ aerial lift	chipper / stump grinder	chain saw < 4 hp	chain saw > 4 hp	bucket truck/ aerial lift	chipper / stump grinder	Total
FP 2	11	6,215	15,375	4,848	17,358	11,791	85	57	204	233	580
FP 3	23	12,870	31,838	10,039	35,944	24,416	175	118	422	483	1,200
FP 4	53	28,875	71,431	22,523	80,644	54,780	393	264	946	1,085	2,700
FP 5	44	23,980	59,322	18,704	66,973	45,493	326	219	786	901	2,200
FP 6	110	60,225	148,985	46,976	168,200	114,255	819	551	1,974	2,262	5,600
FP 7	185	101,640	251,438	79,279	283,866	192,826	1,383	930	3,331	3,818	9,500

Notes:
1. dbh - diameter at breast height.
2. From tables 1 and 2 of Nowak et al. 2002.
   • Nowak, D.J., Stevens, J.C., Sisinni, S.M. and J. Luley. 2002. Effects of urban tree management and species selection on atmospheric carbon dioxide. *Journal of Arboriculture* . 28(3):113-122. May 2002.
3. Assumed number of forested acres requiring clearing for each alternative was determined by comparing the horizontal extent of anticipated floodplain soil removal (for each FP alternative), as well as the anticipated footprints of access roads and staging areas (for each FP and SED alternative) with data presenting the extent of various natural communities considered to be forests within the area of interest (Woodlot Alternatives, Inc. 2002).
   • Woodlot Alternatives, Inc. 2002. Ecological Characterization of the Housatonic River. Prepared for U.S. Environmental Protection Agency, Region 1. Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, MA. September 2002.
4. Uses value of 550 trees/acre based on 2005 USDA Forest Service Inventory of Massachusetts (Forest area: 3,166,400 acres; Number of live trees: 1,583,395,000) adjusted to include standing dead trees (from Table 2 of COLE Carbon Report) [dead trees comprise ~11% of live trees].
   • Cole Development Group. 2008. Cole 1605(b) Report for Massachusetts. http://ncasi.uml.edu/COLE/ (December 19, 2008).

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Appendix A - Carbon Footprint/Greenhouse Gas Inventory Analysis for Sediment, Floodplain, and Treatment/Disposition Alternatives

Response to EPA Interim Comments on CMS Report

Treatment/Disposition Alternatives

Table A-27. GHG Emissions from Treatment/Disposition (TD) Alternative 1.
[TD 1 - Disposal in an off-site permitted landfill or landfills]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF MATERIALS FOR DISPOSAL AT OFF-SITE FACILITY

		Estimated number of Truck Trips	Approximate Miles to High Acres Landfill	Approximate Miles to Model City Landfill	Tonnes of CO_2 emitted in travel[1]	Tonnes of N_2O emitted in travel[1]	Tonnes of CH_4 emitted in travel[1]	Tonnes of CO_2-eq emitted in travel[2]
Lower-Bound Volume	SED 3, FP 2 TSCA	3,500	--	340	4,100	0.011	0.012	14,000
	SED 3, FP 2 Non-TSCA	11,800	250	--	10,100	0.028	0.030	
Upper-Bound Volume	SED 8, FP 7 TSCA	51,900	--	340	61,000	0.17	0.18	220,000
	SED 8, FP 7 Non-TSCA	183,800	250	--	160,000	0.44	0.47	

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO DIESEL FUEL REFINING

		Gallons of diesel fuel required (for above-listed transportation)[1]	Pounds of CO_2-eq emitted per gallon diesel fuel refined[3]	Tonnes of CO_2-eq emitted from diesel refining
Lower-Bound Volume	SED 3, FP 2 TSCA	402,200	3.673	670
	SED 3, FP 2 Non-TSCA	997,100	3.673	1,661
Upper-Bound Volume	SED 8, FP 7 TSCA	5,964,300	3.673	9,935
	SED 8, FP 7 Non-TSCA	15,531,100	3.673	25,871

See Notes on Page 2

Table A-27. GHG Emissions from Treatment/Disposition (TD) Alternative 1.
[TD 1 - Disposal in an off-site permitted landfill or landfills]

Notes:

1. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. Determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report).
   Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel) provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org). This emission factor includes emissions from refining and transportation of fuel from refinery to filling station (average distance), and was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-28. GHG Emissions from Treatment/Disposition (TD) Alternative 2.
[TD 2 - Disposition in a local in-water Confined Disposal Facility (CDF) or Facilities]
"Lower-Bound Volume" herein refers to SED 6 hydraulically dredged sediments (300,000 cy)
"Upper-Bound Volume" herein refers to SED 8 hydraulically dredged sediments (1,240,000 cy)

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF CONFINED DISPOSAL FACILITY:

TRANSPORTATION OF BACKFILL TO SITE OF CONFINED DISPOSAL FACILITY

	Estimated number of Truck Trips[1]	Estimated Miles from Landfill to Backfill Pit	Tonnes of CO_2 emitted in travel[2]	Tonnes of N_2O emitted in travel[2]	Tonnes of CH_4 emitted in travel[2]	Tonnes of CO_2-eq emitted in travel[3]
Lower-Bound Volume	11,200	25	960	0.00269	0.00286	960
Upper-Bound Volume	22,900	25	2,000	0.0055	0.0058	2,000

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF CONFINED DISPOSAL FACILITY:

VEHICLE EMISSIONS FROM CONSTRUCTION ACTIVITIES

	Estimated hours of diesel vehicle operation	Assumed gallons of diesel fuel usage[4]	Tonnes of CO_2 emitted in landfill construction[2]	Tonnes of N_2O emitted in landfill construction[5]	Tonnes of CH_4 emitted in landfill construction[5]	Tonnes of CO_2-eq emitted in landfill construction[3]
Lower-Bound Volume	19,782	120,000	1,200	0.03	0.07	1,200
Upper-Bound Volume	87,129	500,000	5,000	0.13	0.29	5,000

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO DIESEL FUEL REFINING AND MANUFACTURE OF STEEL SHEET PILING

	Gallons of diesel fuel required (from above-listed activities)[2]	Pounds of CO_2-eq emitted per gallon diesel fuel refined[6]	Tonnes of CO_2-eq emitted from diesel refining	Quantity of steel sheet piling required (sq. ft.)	Pounds of CO_2-eq emitted per pound of steel sheet piling produced[7] (assumes 24.19 lbs/sq. ft)	Tonnes of CO_2-eq emitted from steel sheet piling manufacture
Lower-Bound Volume	210,000	3.673	300	27,840	2.16	660
Upper-Bound Volume	700,000	3.673	1,200	39,960	2.16	947

See Notes on Page 2

Table A-28. GHG Emissions from Treatment/Disposition (TD) Alternative 2.
[TD 2 - Disposition in a local in-water Confined Disposal Facility (CDF) or Facilities]
"Lower-Bound Volume" herein refers to SED 6 hydraulically dredged sediments (300,000 cy)
"Upper-Bound Volume" herein refers to SED 8 hydraulically dredged sediments (1,240,000 cy)

Notes:

1. From CMS Report (pg. 7-27), construction trucks to deliver materials to site for building landfill (assume 12-cy capacity trucks).
2. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
3. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
4. Based on assumption of 50 gallons used per 8 hour day per piece of equipment.
5. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)

Emissions factors associated with notes 6 and 7 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report). Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

6. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel) provided by Ecoinvent 2.0 database includes emissions from refining and transportation of fuel from refinery to filling station (average distance), and was converted to 3.673 lb CO2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
7. Presumes low-alloyed steel, sheet rolled (as specified for the majority of steel sheet pile manufactured by Skyline Steel, http://www.skylinesteel.com).

Table A-29. GHG Emissions from Treatment/Disposition (TD) Alternative 3.
[TD 3 - Disposition in a local on-site Upland Disposal Facility]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF UPLAND DISPOSAL FACILITY:
TRANSPORTATION OF BACKFILL TO SITE OF UPLAND DISPOSAL FACILITY

	Estimated number of Truck Trips[1]	Estimated Miles from Landfill to Backfill Pit	Tonnes of CO_2 emitted in travel[2]	Tonnes of N_2O emitted in travel[2]	Tonnes of CH_4 emitted in travel[2]	Tonnes of CO_2-eq emitted in travel[3]
Lower-Bound Volume	1,400	25	120	0.00034	0.00036	120
Upper-Bound Volume	13,200	25	1,130	0.0032	0.0034	1,130

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF UPLAND DISPOSAL FACILITY:
VEHICLE EMISSIONS FROM CONSTRUCTION ACTIVITIES

	Estimated hours of diesel vehicle operation	Assumed gallons of diesel fuel usage[4]	Tonnes of CO_2 emitted in landfill construction[2]	Tonnes of N_2O emitted in landfill construction[5]	Tonnes of CH_4 emitted in landfill construction[5]	Tonnes of CO_2-eq emitted in landfill construction[3]
Lower-Bound Volume	74,522	470,000	4,800	0.12	0.27	4,800
Upper-Bound Volume	205,957	1,300,000	13,000	0.34	0.75	13,000

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF MATERIALS FOR DISPOSAL

	Estimated number of Truck Trips[6]	Assumed Miles to Disposal Facility	Tonnes of CO_2 emitted in travel[2]	Tonnes of N_2O emitted in travel[2]	Tonnes of CH_4 emitted in travel[2]	Tonnes of CO_2-eq emitted in travel[3]
Lower-Bound Volume	20,400	10	700	0.0020	0.0021	700
Upper-Bound Volume	314,267	10	10,800	0.030	0.032	11,000

See Notes on Page 2

Table A-29. GHG Emissions from Treatment/Disposition (TD) Alternative 3.
[TD 3 - Disposition in a local on-site Upland Disposal Facility]

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO DIESEL FUEL REFINING

	Gallons of diesel fuel required (from above-listed activities)[2]	Pounds of CO_2-eq emitted per gallon diesel fuel refined[7]	Tonnes of CO_2-eq emitted from diesel refining
Lower-Bound Volume	550,000	3.673	920
Upper-Bound Volume	2,500,000	3.673	4,200

Notes:
1. From CMS Report (pg. 7-43), construction trucks to deliver materials to site for building landfill (assume 12-cy capacity trucks).
2. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
3. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4]) Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
4. Based on assumption of 50 gallons used per 8 hour day per piece of equipment.
5. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - N_2O emission factor for diesel construction equipment: 0.26 g N_2O/gallon (Table A-6 of above referenced document)
   - CH_4 emission factor for diesel construction equipment: 0.58 g CH_4/gallon (Table A-6 of above referenced document)
6. Number of truck trips is equal to that of TD 1 adjusted to account for smaller trucks being used (12-cy capacity trucks for local disposal (TD 3) vs. 16-cy capacity trucks for off-site disposal (TD 1)).
7. Determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report). Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel) provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org). This emission factor includes emissions from refining and transportation of fuel from refinery to filling station (average distance), and was converted to 3.673 lb CO_2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).

Table A-30. GHG Emissions from Treatment/Disposition (TD) Alternative 4.
[TD 4 - Chemical extraction of PCBs from removed sediment/soil]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION OF CHEMICAL EXTRACTION FACILITY

	Estimated tonnes of CO_2 emitted due to construction of chemical extraction facility and building[1]	Tonnes CO_2-eq due to construction of chemical extraction facility and building[2]
Lower-Bound Volume	1,700	1,700
Upper-Bound Volume	1,700	1,700

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF MATERIALS FOR DISPOSAL

	Estimated number of Truck Trips[3]	Approximate Miles to Disposal Facility (High Acres Landfill in Fairport, NY)	Tonnes of CO_2 emitted in travel[4]	Tonnes of N_2O emitted in travel[4]	Tonnes of CH_4 emitted in travel[4]	Tonnes of CO_2-eq emitted in travel[2]
Lower-Bound Volume	15,300	250	13,100	0.037	0.039	13,000
Upper-Bound Volume	235,700	250	200,000	0.57	0.60	200,000

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO OPERATION OF CHEMICAL EXTRACTION FACILITY - PURCHASED ELECTRICI

	Estimated Total Electricity Costs to Run BioGenesis[SM] System[5]	Total number of kWh used based on utility cost of $0.11/kWh[6]	Tonnes of CO_2 associated with purchased electricity[7]	Tonnes of N_2O associated with purchased electricity[7]	Tonnes of CH_4 associated with purchased electricity[7]	Tonnes CO_2-eq associated with purchased electricity[2]
Lower-Bound Volume	$1,944,386	17,676,236	6,600	0.14	0.69	6,700
Upper-Bound Volume	$24,227,530	220,250,273	83,000	1.7	8.6	84,000

See Notes on Pages 2 & 3

Table A-30. GHG Emissions from Treatment/Disposition (TD) Alternative 4.
[TD 4 - Chemical extraction of PCBs from removed sediment/soil]

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO DIESEL FUEL REFINING

	Gallons of diesel fuel required (from above-listed activities)[4]	Pounds of CO_2-eq emitted per gallon diesel fuel refined[8]	Tonnes of CO_2-eq emitted from diesel refining
Lower-Bound Volume	1,300,000	3.673	2,200
Upper-Bound Volume	20,000,000	3.673	33,000

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CEMENT/CONCRETE PRODUCTION FOR BUILDING CONSTRUCTION

	Assumed mass of concrete required for construction of building to house chemical extraction system (cy)	Pounds of CO_2-eq emitted per cubic yard of concrete produced[9]	Tonnes of CO_2-eq emitted from cement/concrete production
Same for both lower- and upper-bound volumes	1,500	443	300

Notes:

1. From http://buildcarbonneutral.org; for 30,000 sq ft building, 1 story above grade, mixed construction, in eastern temperate region, tall grass existing vegetation, tall grass installed vegetation, 50,000 sq ft disturbed landscape, 1,000 sq ft installed landscape. The value of 850 tonnes CO_2 emissions from above computation was doubled to approximate emissions from construction of both building and system.
2. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4]) Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
3. From CMS Report (Table 7-1, pg. 7-99), truck trips for off-site disposal (assume 16-cy capacity trucks), updated to reflect changes in removal volumes.
4. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
5. From Appendix A of CMS Report: *Chemical Extraction Treatability Study Report* , Tables 5-3 and 5-5.
6. From Appendix A of CMS Report: *Chemical Extraction Treatability Study Report* , page 5-12.
7. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
   - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
   - N_2O annual output emission rate: 17.01 lb N_2O/GWh
   - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Notes continued on page 3

Table A-30. GHG Emissions from Treatment/Disposition (TD) Alternative 4.
[TD 4 - Chemical extraction of PCBs from removed sediment/soil]

Emissions factors associated with notes 8 and 9 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report). Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

8. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel) provided by Ecoinvent 2.0 database includes emissions from refining and transportation of fuel from refinery to filling station (average distance), and was converted to 3.673 lb CO2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
9. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.

Table A-31. GHG Emissions from Treatment/Disposition (TD) Alternative 5.
[TD 5 - Thermal desorption of PCBs from removed sediment/soil]

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONSTRUCTION AND OPERATION OF THERMAL DESORPTION FACILITY

	Estimated tonnes of CO_2 emitted due to construction of thermal desorption apparatus and building[1]	Natural Gas Consumption (MMBtu)[2]	Tonnes of CO_2 emitted due to Natural Gas Consumption[3]	Tonnes of N_2O emitted due to Natural Gas Consumption[3]	Tonnes of CH_4 emitted due to Natural Gas Consumption[3]	Direct tonnes CO_2-eq emitted due to construction and operation[4]
Lower-Bound Volume	1,700	380,090	20,000	0.038	1.9	22,000
Upper-Bound Volume	1,700	5,709,460	300,000	0.57	29	300,000

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO TRANSPORTATION OF MATERIALS FOR DISPOSAL

		Estimated number of Truck Trips[5]	Approximate Miles to Disposal Facility (High Acres Landfill in Fairport, NY)	Tonnes of CO_2 emitted in travel[6]	Tonnes of N_2O emitted in travel[6]	Tonnes of CH_4 emitted in travel[6]	Direct tonnes of CO_2-eq emitted in travel[4]
Lower-Bound Volume	50% Reuse of Floodplain soils	12,800	250	11,000	0.031	0.033	11,000
	No Reuse	13,800	250	11,800	0.033	0.035	12,000
Upper-Bound Volume	50% Reuse of Floodplain soils	180,000	250	150,000	0.43	0.46	150,000
	No Reuse	212,100	250	180,000	0.51	0.54	180,000

ESTIMATED *DIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO COMPLETE CONVERSION OF TOC IN SED/SOIL TO CO_2

	Sediment / Floodplain Soil	In-Situ Volume (cy)	Average TOC[7]	Average Dry Bulk Density[8] (g/cm^3)	Mass of Carbon (short tons)	Tonnes of CO_2 emitted	Direct tonnes of CO2-eq emitted from TOC[4]
Lower-Bound Volume	SED 3	167,000	4.0%	0.78	4,400	15,000	15,000
	FP 2	22,000	8.4%	1.2	1,800	6,000	6,000
Upper-Bound Volume	SED 8	2,285,000	4.0%	0.78	60,000	200,000	200,000
	FP 7	631,000	8.4%	1.2	51,000	170,000	170,000

See Notes on Pages 3 & 4

Table A-31. GHG Emissions from Treatment/Disposition (TD) Alternative 5.
[TD 5 - Thermal desorption of PCBs from removed sediment/soil]

ESTIMATED *INDIRECT* GHG EMISSIONS (expressed as CO_2-eq) DUE TO OPERATION OF THERMAL DESORPTION FACILITY - PURCHASED ELECTRICITY

	Estimated total number of kWh used[9]	Tonnes of CO_2 associated with purchased electricity[10]	Tonnes of N_2O associated with purchased electricity[10]	Tonnes of CH_4 associated with purchased electricity[10]	Tonnes CO_2-eq associated with purchased electricity[4]
Lower-Bound Volume	664,230	250	0.0051	0.026	250
Upper-Bound Volume	9,977,700	3,800	0.077	0.39	3,800

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO DIESEL FUEL REFINING AND NATURAL GAS DRILLING/DISTRIBUTION

		Gallons of diesel fuel required (from above-listed activities)[6]	Pounds of CO_2-eq emitted per gallon diesel fuel refined[11]	Tonnes of CO_2-eq emitted from diesel refining	MMBtu of natural gas required (from above)	Pounds of CO_2-eq emitted per MMBtu natural gas[12]	Tonnes of CO_2-eq emitted from natural gas production/ distribution
Lower-Bound Volume	50% Reuse of Floodplain soils	1,080,000	3.673	1,800	380,090	50	8,600
	No Reuse	1,200,000	3.673	2,000			
Upper-Bound Volume	50% Reuse of Floodplain soils	15,000,000	3.673	25,000	5,709,460	50	130,000
	No Reuse	18,000,000	3.673	30,000			

ESTIMATED *OFF-SITE* GHG EMISSIONS (expressed as CO_2-eq) DUE TO CONCRETE PRODUCTION FOR BUILDING CONSTRUCTION

	Assumed mass of concrete required for construction of building to house thermal desorption system (cy)	Pounds of CO_2-eq emitted per cubic yard of concrete produced[13]	Tonnes of CO_2-eq emitted from cement/concrete production
Same for both lower- and upper-bound volumes	1,500	443	300

See Notes on Pages 3 & 4

Table A-31. GHG Emissions from Treatment/Disposition (TD) Alternative 5.
[TD 5 - Thermal desorption of PCBs from removed sediment/soil]

Notes:

1. Assumes similar size building as that needed for chemical extraction process. From http://buildcarbonneutral.org; for 30,000 sq ft building, 1 story above grade, mixed construction, in eastern temperate region, tall grass existing vegetation, tall grass installed vegetation, 50,000 sq ft disturbed landscape, and 1,000 sq ft installed landscape.
   The value of 850 tonnes CO_2 emissions from above computation was doubled to approximate emissions from construction of both building and system.
2. Based on supplier estimate of 100,000 cubic feet per hour of natural gas consumed for approximately 90 tons per hour of sediment/soil processed. A conversion factor of 1 cubic foot to approximately 1,030 Btu was assumed.
3. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Stationary Combustion Sources" (May 2008):
   - CO_2 emission factor per mmBtu natural gas: 53.06 kg CO_2/mmBtu (Table B-3 of above referenced document)
   - N_2O emission factor per mmBtu natural gas (commercial): 0.1 g N_2O/mmBtu (Table A-1 of above referenced document)
   - CH_4 emission factor per mmBtu natural gas (commercial): 5 g CH_4/mmBtu (Table A-1 of above referenced document)
4. As presented in Tables 6-3 and adjacent discussion in the Design Principles, CO_2-eq are calculated by multiplying the mass of individual GHG times their associated global warming potential (GWP) per the following expression: Total CO_2-eq = mass CO_2(GWP[CO_2]) + mass N_2O(GWP[N_2O]) + mass CH_4(GWP[CH_4])
   Where GWP[CO_2] = 1; GWP[N_2O] = 310; GWP[CH_4] = 21.
5. From CMS Report (Table 7-1, pg. 7-99), truck trips for off-site disposal (assume 16-cy capacity trucks), updated to reflect changes in removal volumes.
6. Calculations made with the following emission factor information presented in EPA guidance document "Direct Emissions from Mobile Combustion Sources" (May 2008):
   - CO_2 emission factor from a gallon of diesel fuel: 10.15 kg CO_2/gallon (Table B-1 of above referenced document)
   - N_2O emission factor for diesel heavy-duty trucks: 0.0048 g N_2O/mile (Table 2 of above referenced document)
   - CH_4 emission factor for diesel heavy-duty trucks: 0.0051 g CH_4/mile (Table 2 of above referenced document)

   Fuel economy assumed to be equal to that of "Combination Trucks" (0.169 gallons diesel fuel/mile), as presented in Table 4 of above referenced document.
7. Average floodplain soil total organic carbon (TOC) is average of Arithmetic Mean from Reaches 5A, 5B, 5C, and 6 for Floodplain, Riverbank, and Vernal Pool Soils taken from Table 5-4 of the 2003 RFI Report. Average sediment TOC is average of Arithmetic Mean from within the top 5 feet in Reaches 5A, 5B, 5C, backwaters, and Reach 6 from Table 4-3 of the 2003 RFI Report.
8. Average floodplain soil bulk density is average of bulk densities listed in Table 5-9 of the 2003 RFI Report for Reaches 5A, 5B, 5C, and Reach 6. Average sediment bulk density is average of Arithmetic Means for Reaches 5A, 5B, 5C, backwaters, and Reach 6 as listed in Table 4-7 of the 2003 RFI Report.
9. Based on an estimate of 2.0 kWh required per ton of soil/sediment fed to thermal desorber.
10. Year 2005 GHG Annual Output Emission Rates from Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID2007 Version 1.0), subregion: NEWE (NPCC New England). EPA's eGRID website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
    - CO_2 annual output emission rate: 829.41 lb CO_2/MWh
    - N_2O annual output emission rate: 17.01 lb N_2O/GWh
    - CH_4 annual output emission rate: 86.49 lb CH_4/GWh

Notes continued on page 4

Table A-31. GHG Emissions from Treatment/Disposition (TD) Alternative 5.
[TD 5 - Thermal desorption of PCBs from removed sediment/soil]

Emissions factors associated with notes 11 through 13 below were determined using IMPACT 2002+ assessment method customized with 100-yr global warming potentials (IPCC Fourth Assessment Report). Emissions factors provided by Ecoinvent 2.0 database developed by the Swiss Centre for Life Cycle Inventories (http://www.ecoinvent.org).

11. Diesel fuel refining emission factor (0.524 lb CO2-eq /lb low sulfur diesel fuel) provided by Ecoinvent 2.0 database includes emissions from refining and transportation of fuel from refinery to filling station (average distance), and was converted to 3.673 lb CO2-eq/gal using an average density for diesel fuel of 0.84 g/mL (7.01 lb/gal) (provided by Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
12. Emissions factors are considered "cradle-to-gate" and include all emissions associated with the supply chain, from raw materials extraction to finished fuel. The emissions factor presented is the sum of the following: 0.024 lbs CO_2-eq / ft^3 (converted to lbs CO_2-eq / MMBTU based on 1 ft^3 ~ 1,030 Btu) used for fuel production and 26.727 lbs CO_2-eq / MMBtu used for distribution.
13. Emissions factor of 443 lb CO_2-eq/cy concrete, considers emissions due to production of normal concrete at plant.

FIGURES

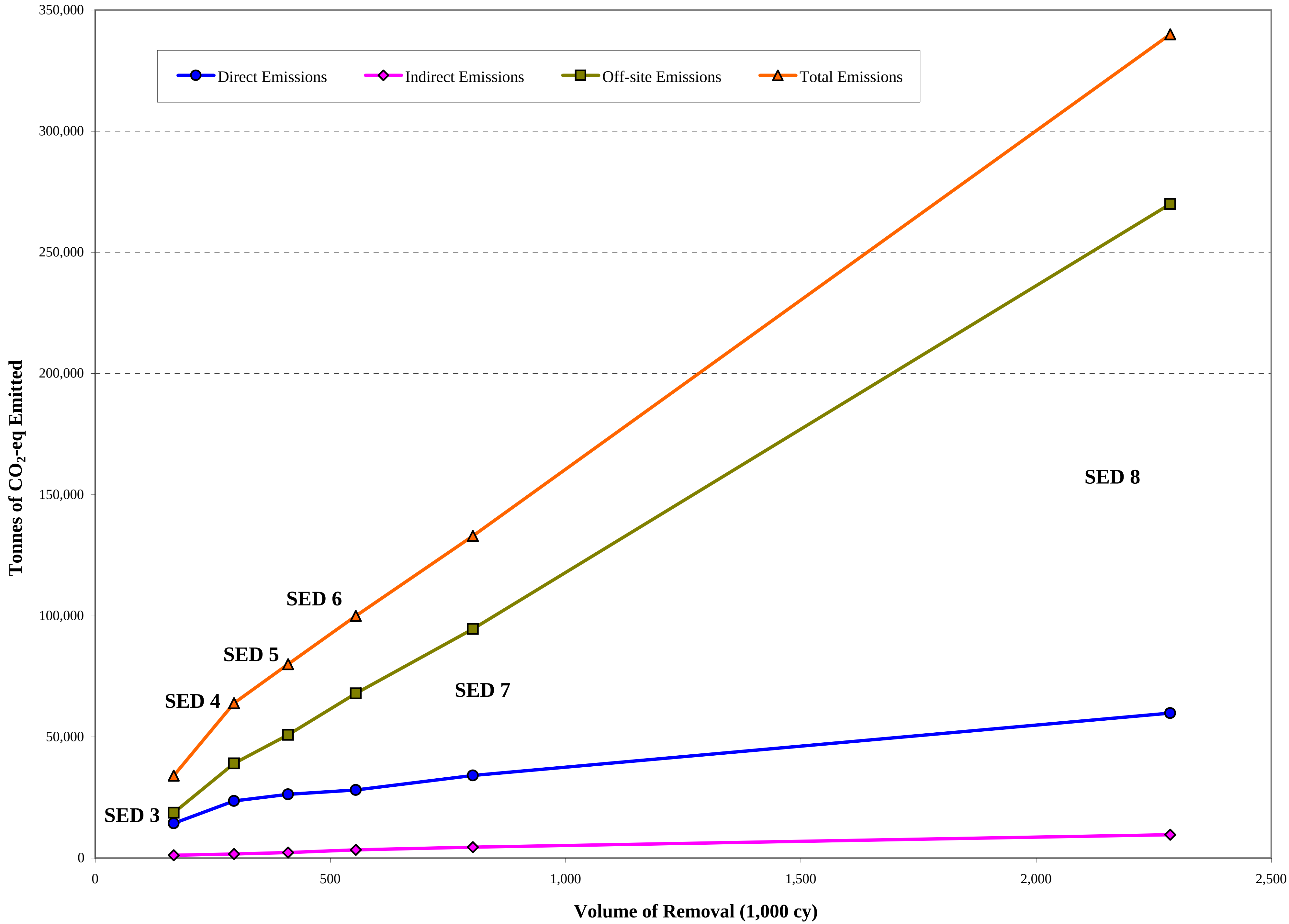

Figure A-1. Sediment alternatives, tonnes CO_2-eq emitted vs. volume of sediments removed.

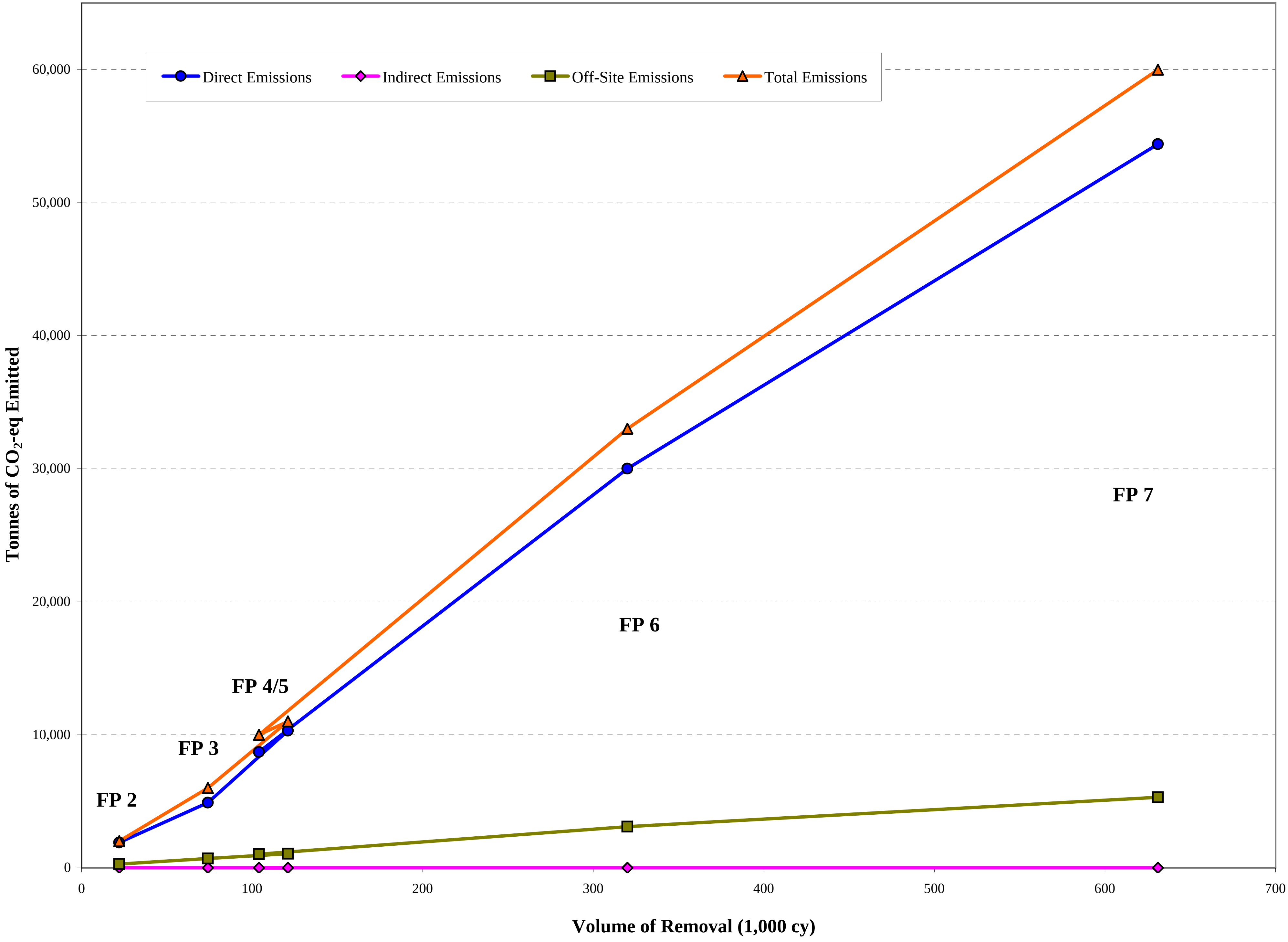

Figure A-2. Floodplain alternatives, tonnes CO_2-eq emitted vs. volume of removal.

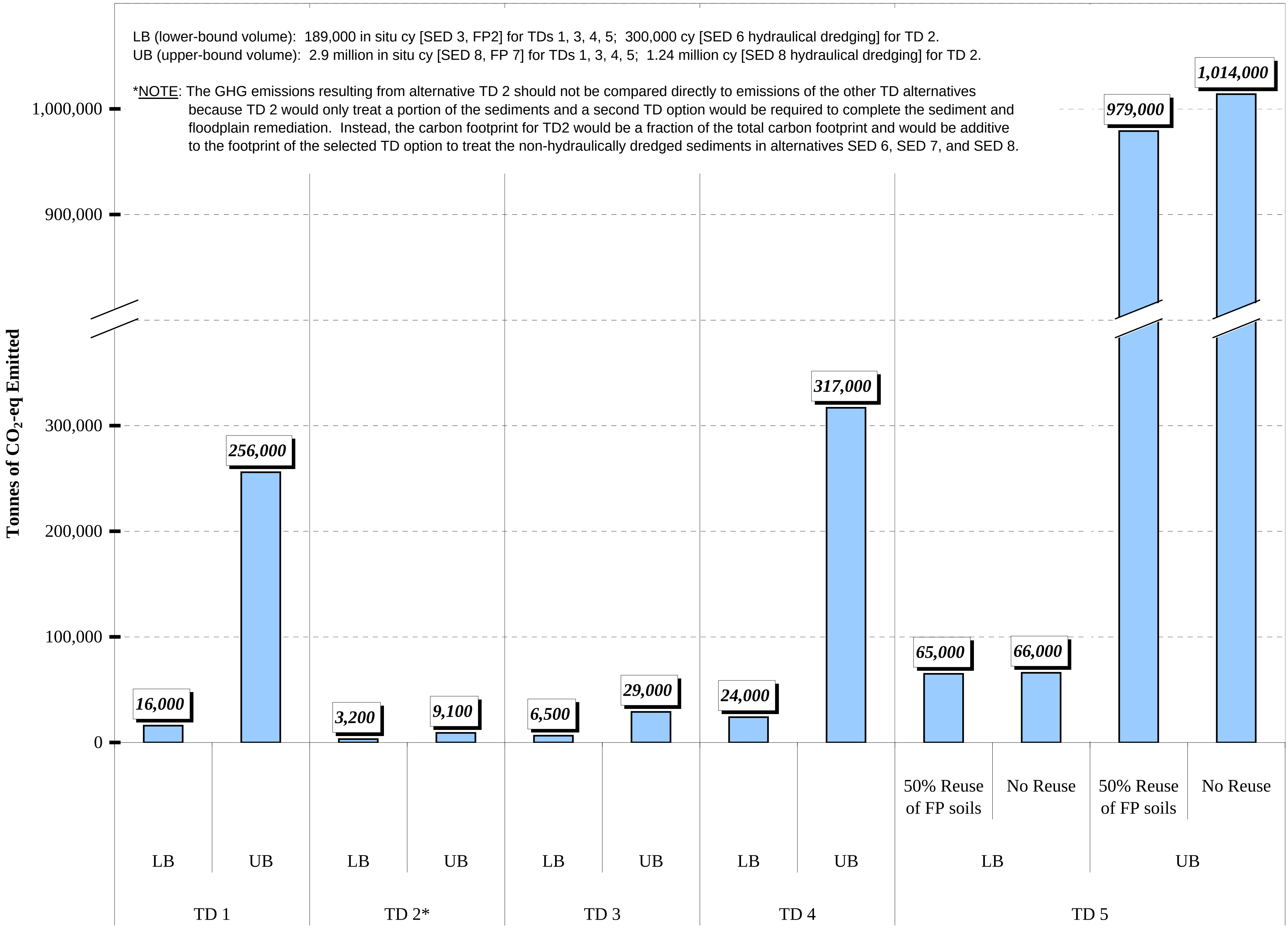

Figure A-3. Treatment/Disposition alternatives, tonnes CO_2-eq emitted.