Regional Economic Impact Assessment: Evaluating Remedial Alternatives for the Portland Harbor Superfund Site, Portland, Oregon, USA

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ABSTRACT
The present paper describes a methodology for evaluating impacts of Superfund remedial alternatives on the regional economy in the context of a broader sustainability evaluation. Although economic impact methodology is well established, some applications to Superfund remedial evaluation have created confusion because of seemingly contradictory results. This confusion arises from failure to be explicit about 2 opposing impacts of remediation expenditures: 1) positive regional impacts of spending additional money in the region and 2) negative regional impacts of the need to pay for the expenditures (and thus forgo other expenditures in the region). The present paper provides a template for economic impact assessment that takes both positive and negative impacts into account, thus providing comprehensive estimates of net impacts. The paper also provides a strategy for identifying and estimating major uncertainties in the net impacts. The recommended methodology was applied at the Portland Harbor Superfund Site, located along the Lower Willamette River in Portland, Oregon, USA. The US Environmental Protection Agency (USEPA) developed remedial alternatives that it estimated would cost up to several billion dollars, with construction durations possibly lasting decades. The economic study estimated regional economic impacts—measured in terms of gross regional product (GRP), personal income, population, and employment—for 5 of the USEPA alternatives relative to the “no further action” alternative. Integr Environ Assess Manag 2018;14:32–42. © 2017 The Authors. Integrated Environmental Assessment and Management published by Wiley Periodicals, Inc. on behalf of Society of Environmental Toxicology & Chemistry (SETAC)

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INTRODUCTION AND OBJECTIVES
The US Environmental Protection Agency (USEPA) prepares detailed technical studies to assist in the evaluation of remedial alternatives at sites covered by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980; subsequently “Superfund” and “Superfund sites”). Key technical documents include the remedial investigation (RI) and feasibility study (FS) (USEPA 1998). The RI study characterizes site conditions, determines the nature of the waste, assesses risk to public health and the environment, and conducts tests to evaluate potential performance and cost of treatment technologies. The FS provides for the development, screening, and detailed evaluation of alternative remedial actions. Developing these studies at Superfund “mega-sites” (sites with expected cleanup costs greater than US$50 million; [NRC 2007]) can

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take many years and often require large budgets. Estimated costs for remedial alternatives at these mega-sites can be in the hundreds of millions—or even billions—of dollars.

Although the RI and FS studies provide an enormous amount of technical information on remedial alternatives—including detailed information on potential costs and their timing—the Superfund technical studies typically have not provided a comprehensive “sustainability analysis” of alternatives that integrates environmental, economic, and social considerations. The Portland Harbor Sustainability Project (PHSP) has filled this gap for the Portland Harbor Superfund Site (“Site”)—located along an approximately 10-mile stretch of the Lower Willamette River in Portland, Oregon, USA—by evaluating the sustainability of 5 remedial alternatives identified by USEPA in the FS relative to the “no further action” alternative (USEPA 2016a). Sustainability studies integrate information from 3 major categories or “pillars”: 1) environmental, 2) economic, and 3) social. The present paper addresses 1 important element of the economic information.

Economic assessment methods

Economic consequences of a remedial alternative can be evaluated and compared using 3 major methodologies:

1) Economic impact analysis. Comparisons of the impacts of remedial alternatives on the regional economy.
2) Cost-effectiveness analysis. Comparisons of the incremental gains in effectiveness (as measured by 1 or more metrics, such as avoided human health risk) with the incremental costs of increasingly expensive remedial alternatives.
3) Benefit-cost analysis. Comparisons of the net monetary benefits (i.e., monetary benefits minus monetary costs) of remedial alternatives, including assessments (typically qualitative) of benefits and costs that are not put into monetary terms.

Although the overall PHSP study includes information on the second and third economic methodologies, the present paper focuses on the first economic methodology—economic impact analysis—for 2 reasons. First, USEPA has recognized that the “public acceptability” of remedial alternatives depends in part on impacts on the regional economy (USEPA 2005). Second, 2 prior studies of the economic impacts of remediating the Site came to diametrically opposite conclusions—one concluded economic impacts to the Portland economy would be positive (ECONorthwest 2012) and the other concluded that the impacts would be negative (Brattle Group 2012). This situation was particularly confusing to the public because both studies used the same economic model—the IMPLAN model (IMPLAN Group 2017)—and similar cost estimates.

Objective of the present paper

The primary objective of the present paper is to provide a template methodology for evaluating the regional economic impacts of remedial alternatives at Superfund sites. This methodology is illustrated by developing estimates of regional economic impacts of remedial alternatives for the Site (see NERA Economic Consulting 2016 for additional information on this study, including detailed information on methodology and data). This methodological template reconciles the 2 prior economic impact studies and thus provides a means of avoiding the confusion illustrated by the opposing results of the 2 prior Portland studies.

BACKGROUND ON THE PORTLAND HARBOR SITE AND USEPA REMEDIAL ALTERNATIVES

Portland Harbor Superfund Site

The Site encompasses about 10 miles of the Lower Willamette River in Portland, Oregon, from the Broadway Bridge at river mile (RM) 11.8 to Sauvie Island at RM 1.9 (near the confluence of the Willamette and Columbia rivers). Sediment contamination includes PCBs, dioxins, and other substances from many sources over more than 100 y. The USEPA formally listed the Site on the National Priorities List in December 2000. (See USEPA 2016a and 2016b for additional background regarding the Site.)

US Environmental Protection Agency remedial alternatives for the Site

The USEPA developed, screened, and analyzed a set of remedial alternatives for the Site as part of its FS. Table 1 summarizes USEPA’s estimates of the remedial costs (measured by undiscounted expenditures over a 31-y period) and the duration of the construction phase of remediation activities—that is, the period including capital expenditures associated with dredging, capping, and other activities—for the 5 remedial alternatives developed by USEPA that are

| USEPA alternative expenditure estimates | B | D | I | E | F |
|----------------------------------------|---|---|---|---|---|
| Years of construction                  | 4 | 6 | 7 | 7 | 13|
| Total expenditures (millions of 2016 US$) | 642 | 953 | 1173 | 1240 | 2179|

Table 1. USEPA alternative expenditure estimates. USEPA = US Environmental Protection Agency.

aUndiscounted expenditure estimates over a 31-y period (2020–2050).

bUSEPA 2016a.
evaluated in the present study. The USEPA’s Proposed Plan (PP) for the Site, released at the same time as the draft final FS in June 2016, identified Alternative I as the “preferred” remedial alternative (USEPA 2016a, 2016c). The subsequent USEPA Record of Decision (ROD) issued in January 2017 identified a new alternative—Alternative F “Modified”—as the remedial plan for the Site (USEPA 2017). Alternative F Modified was estimated by USEPA to cost $1.7 billion and to require 13 y for construction. Because it was developed after our study was completed, our study does not include Alternative F Modified.

The USEPA’s cost estimates (undiscounted) for the 5 evaluated FS alternatives range from about $642 million to almost $2.2 billion, with construction durations ranging from 4 to 13 y. The total expenditures are based on a 31-y period that includes expenditures for design and construction activities, agency oversight, and postconstruction activities such as long-term monitoring, maintenance, and periodic Site reviews. Note that USEPA expenditure estimates do not include past expenditures on interim cleanup measures and source control activities, or past or future legal and other administrative expenses.

**METHODOLOGY**

*Nature of economic impact analysis*

Economic impact analyses evaluate the changes in economic activity in a given region caused by a certain “event,” which could be a business decision to build a new factory or a public policy decision to regulate some economic activity or (as in the case of Superfund) to require particular engineering remedies. The region could be a neighborhood, city, metropolitan region, state, or even a country as a whole. The change in economic activity can be measured by various parameters. The 2 most prominent regional measures are changes in 1) gross regional product (GRP), which measures the total size of the regional economy (i.e., similar to a nation’s gross domestic product), and 2) employment, which measures the total jobs in the region.

Changes in other economic impacts (e.g., population, taxes) can also be estimated. In addition, the economic impacts can be disaggregated into different categories. Employment impacts, for example, can be disaggregated by economic sector (e.g., oil and gas extraction sector or waste management and remediation services sector). The level of sectoral and other detail depends in part upon the specific modeling tool used, as discussed in the *Models to estimate economic impacts* section.

The full regional economic impacts depend upon how the decision or policy initially affects the regional economy (referred to as “direct impacts”), as well as on how these direct impacts are “multiplied” due to linkages in economic activity within the regional economy and how these multiplier effects are limited by leakages of economic demand outside the region. The overall impacts are typically divided into the 3 generic categories, although it is useful to think of these impacts as processes that are set in motion as a result of private or public decisions. (For convenience, the discussion of the methodology assumes a positive initial change; the effects would be reversed for a negative initial change.)

1) **Direct impacts.** These impacts relate to initial spending or other direct impacts. A new factory, for example, will involve direct local spending on construction. As emphasized in the *Importance of incorporating financing impacts* section, it is also critical to include the direct impacts from the local spending that is reduced because of the need to pay for this spending (i.e., the financing of project costs).

2) **Indirect impacts.** These impacts are the result of the business-to-business transactions indirectly caused by the direct impacts. The regional spending on construction, for example, will result in additional spending in the region by the companies providing construction services.

3) **Induced impacts.** These impacts result from the increased personal income caused by the direct and indirect impacts. Businesses will hire more workers (or increase hours for their existing workforce) and these workers will, in turn, increase spending at regional businesses.

Note that the overall regional impacts resulting from the direct impacts depend upon the linkages between sectors as well as the fraction of each sector’s purchases that is supplied by firms within the region (versus those outside the region); these fractions are referred to as “regional purchase coefficients” (RPCs) and reflect the extent to which expenditures stay in (versus “leak out of”) the regional economy in successive rounds. When a consumer buys a car, for example, much of the increased demand goes outside the region to regions where the car is assembled and where parts are manufactured. In general, the larger the region, the larger the RPCs are likely to be.

*Models to estimate economic impacts*

Economic impact analyses typically use 1 of 2 basic modeling frameworks, the second of which is a more complex version of the first. The first method involves the use of an Input-Output (I-O) model of the economy. Wassily Leontief is credited with developing and implementing I-O analysis (see, e.g., Leontief 1986); he received a Nobel Prize in 1973 for this major contribution to economics. Input-Output tables represent the interindustry relationships within the economy, showing how the output of 1 sector requires inputs from all sectors (including its own). Each I-O matrix has columns for inputs to each industrial sector and rows for outputs for each sector. These I-O models also include RPCs that provide measures of the extent to which increased demand translates to demand within the region. Based upon data for the I-O table and the RPCs, multipliers can be calculated that measure the total effect of a change in direct expenditures on the regional economy. An output multiplier of 2.0, for example, means that an increase of $10 million in direct spending within the region would lead to a total increase of $20 million in regional output when all of the direct, indirect, and induced effects are taken into account.
The second modeling framework builds upon the I-O modeling methodology but includes additional economic simulations that allow for the estimation of economic impacts over time. These are more complex econometric and general equilibrium models that include modeling of regional labor markets and other dynamic elements of regional economies. In contrast to I-O–based models, these models can be used to project the time path of the regional economy and thus the time path of changes due to a project or policy. The model developed by Regional Economic Models, Inc. (REMI) is a prominent example of this more complex modeling framework. For example, REMI models the dynamic effects of policies on labor markets, including impacts on labor in-migration and out-migration. The basic modeling approach behind REMI is explained in Treyz (1980) and the REMI website (www.remi.com). The present study uses the REMI model.

Importance of incorporating financing impacts

Economic impact studies are often used to evaluate the effects of major public or private projects, such as highways and sports stadiums. These studies typically emphasize the positive effects of increased expenditures (e.g., jobs), using either static I-O based models or more complex models such as REMI that trace the effects of additional expenditures over time.

An important criticism of many economic impact studies, however, is their failure to take into account the negative effects of paying for the expenditures, and thus the costs that are borne by those within the region (see, e.g., Mills 1993 and Hefner 1997). Such local financing considerations are not likely to be significant for a large new factory coming into a metropolitan region because the costs would be financed by company shareholders, most of whom do not reside within the region. Similarly, local financing impacts would not be significant for a federal project paid for by the federal government. The situation is very different, however, for a typical local public project, such as a highway improvement or sports facility for which local taxpayers pay much of the costs. Because localities must balance their budgets, paying for the new project would mean increases in taxes or decreases in other local government expenditures (or some combination).

Financing can be particularly complex for large sediment sites in which cleanup costs are paid for by many parties—some private, some public, some local, and some nonlocal. The critical point is that local financing (whether public or private) would lead to reductions in regional economic activity that would offset (or could indeed exceed) the positive effects of the expenditures on the regional economy.

The net economic impacts of a particular project depend upon both the positive impacts of increased expenditures as well as the negative impacts of the financing of these expenditures; thus, there is a need to evaluate both these effects in order to properly evaluate the economic impacts of a policy or program.

The REMI model developed for Portland Harbor study

We used the REMI Policy Insight Plus Model (Pi+) to develop estimates of the net economic impacts of USEPA’s remedial alternatives at the Portland Site. The REMI Pi+ is a state-of-the-art regional economic model that is used by public agencies in virtually every state as well as numerous governments abroad. In addition to including multiplier effects due to I-O relationships and RPCs, the REMI Pi+ model incorporates various important market effects, including effects on local wage rates, prices, and other economic variables. Moreover, in contrast to the IMPLAN model—which estimates a “snapshot” of the potential impacts of a project at 1 point in time—the REMI Pi+ model provides for dynamic modeling that allows the estimation of regional economic impacts over time. Although other dynamic regional economic models might be used, the REMI model is the most widely used of these models.

The specific REMI model developed for the Portland Harbor study was a 4-region model based on version 1.7 of REMI’s Pi+ application (REMI 2015). The 4 regions were needed to specify the location of the direct effects (expenditures and financing). Figure 1 shows the geographic scope and resolution of the Portland REMI Pi+ model. The 4 regions were these:

1) “City of Portland”
2) Five Oregon counties in the Portland metropolitan statistical area (“Rest of Oregon MSA Counties”)
3) Two Washington state counties in the Portland metropolitan statistical area (“Rest of Washington MSA Counties”)
4) “Rest of Oregon” state.

This model was used to develop estimates of economic impacts of the 5 Portland remediation alternatives in the 7-county Portland MSA. This estimation illustrates the general methodology for estimating regional economic impacts of Superfund remediation alternatives.

Direct effects of expenditures (positive) and local financing (negative)

Expenditures entailed in USEPA’s remedial alternatives lead to positive impacts because they increase demand for local goods and services. The size of the overall impacts depends upon the size of the direct expenditures and their interactions in the regional economy, including the RPCs for the various spending components. But, as emphasized above (see Importance of incorporating financing impacts), it is critical to take into account the financing of these expenditures. To the extent that remediation expenditures are paid for by businesses and governments within the region, financing leads to negative impacts that offset the positive effects of expenditure. When local or regional governments incur these expenses, the expenditure must come from either increased local taxes or reduced local government services. Moreover, remedial costs borne by local or regional businesses reduce the money
available for other activities and make these businesses less competitive relative to companies in other regions, leading to reduced sales and thus to reduced regional economic activity as firms cut back on employees and other costs.

The 2 prior studies in Portland were both deficient because each of them considered only 1 of the 2 (opposing) effects, which explains why they came to opposite conclusions on the effects of a large remediation program on the local economy. ECONorthwest (2012, p. 4) estimated cleanup would add annual jobs of between 723 and 1119 per year, while Brattle (2012, p. 27) estimated that cleanup would reduce annual jobs by 913 jobs per year. Note that the main point here is not the difference in the level of the estimated impacts but rather the difference in the direction of the effect, a difference that is driven by each of the studies focusing on 1 of the 2 potential effects of remediation expenditures. ECONorthwest (2012) evaluated only the positive impacts of expenditures and found positive impacts, while Brattle (2012) evaluated only the negative impacts of local financing and found negative impacts. In essence, each of the 2 studies only examined 1 side of the coin. To avoid the incomplete assessment in both reports, the modeling approach developed for the present study includes both positive and negative effects, providing a balanced assessment of the economic impacts of the remedial alternatives.

Inputs to REMI model for Portland Harbor expenditures

The USEPA developed detailed remedial cost information in their FS (USEPA 2016a) that provided the basis for estimates of direct expenditure inputs. The inputs were developed for the 31-y period from 2020 to 2050 (based on the information on the timing of expenditures provided in USEPA’s FS). These expenditure estimates were inputted into the relevant REMI PI+ regions, sectors, and years.

Inputs to REMI model for financing of Portland Harbor expenditures

The financing inputs were developed by combining the USEPA expenditure information with assumptions on the fraction of costs borne by different groups and the specific financing methods for the relevant groups. Note that, within the CERCLA process, potentially responsible parties (PRPs) organize to apportion financial responsibility for site remediation costs and negotiate with the USEPA; this process is commonly termed “allocation” and is described in general terms in USEPA (1994). The allocation process has not yet been completed for the Site, but USEPA has named more than 100 local, national, and international public and private entities as PRPs that may be liable for remediation costs (EPA 2014). We use information on the nature of these entities as well as our understanding of expectations regarding the general nature of the allocation to develop financing scenarios.

For purposes of developing the REMI inputs, the groups that might finance remediation expenditures were divided into the following 3 groups: 1) local governments, 2) local businesses, and 3) nonlocal national or international businesses and the federal government. Remediation costs are assumed to be borne equally by these 3 major groups (i.e., one-third each), an assumption supported by the composition of the PRP group and by opinions expressed by local stakeholders. The implications of this assumption are discussed in the context of the modeling results and sensitivity analyses.

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**Figure 1.** Map of REMI model regions. REMI = Regional Economic Models, Inc.
The REMI inputs for scenarios regarding local financing

In addition to depending on the allocation of costs among local and nonlocal entities, the economic impacts of financing depend on how local groups would pay for their shares of the costs. As noted, local governments could pay for their costs by either increasing taxes or reducing other local government expenditures. Moreover, the payments could be made when the costs are incurred or they could be spread out by selling bonds (and thus paying for the costs over the lifetime of the bonds). Timing is important because remedial expenditures vary greatly over time, with large costs incurred during initial construction and smaller costs incurred during later periods for monitoring and other maintenance expenses. Local governments could finance the costs as they are incurred, or they could create a more constant annual cost burden by selling municipal bonds with long-term payback terms (e.g., 20 y). Note that local businesses would have similar options to finance their costs by obtaining long-term loans.

The REMI results were developed based on 2 “methods” for local government financing (i.e., either increased taxes or decreased expenditures) and 2 financing timing assumptions (i.e., contemporaneous payments or spreading costs over time through issuing 20-y bonds) for both local government and local businesses. These assumptions lead to 4 financing cases for local government and 2 financing cases for local business.

Impacts of remediation alternatives on Portland economy relative to baseline conditions

The net effect of each remediation alternative is calculated as the difference between the Portland regional economy—
as indicated by employment and other measures of the regional economy—assuming the alternative is implemented, and the Portland regional economy under baseline conditions. The REMI PI+ baseline conditions for the Portland regional economy are based on extensive local and regional data, as summarized in REMI (2015). The baseline is assumed to be consistent with USEPA Alternative A, the “No Further Action” alternative.

RESULTS AND DISCUSSION

The REMI model results

The REMI model results included total impacts on the regional economy as well as details on how different sectors and groups (e.g., income groups) within the Portland region would be affected. Although the emphasis of the present paper is on the methodology, it is useful to summarize the study’s results.

Overall Portland regional economic impacts. The results lead to 3 major conclusions. First, all of the 5 USEPA remedial alternatives modeled are predicted to lead to net negative impacts on the Portland regional economy in terms of the 4 categories—jobs, GRP, personal income, and population—over the 31-y period from 2020 to 2050 (see Table 2 for average annual and cumulative economic impacts to the Portland regional economy). Put another way, these results indicate that the negative impacts from local financing are greater than the positive expenditure effects. Second, the net negative impacts differ substantially among the alternatives, with the negative impacts substantially greater for the more

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**Table 2. Economic impacts of USEPA alternatives on Portland, Oregon, USA, regional economy**

| Economic impact                  | USEPA alternative |
|----------------------------------|-------------------|
|                                 | B     | D     | I     | E     | F    |
|                                 | Min   | Max   | Min   | Max   | Min  | Max  | Min  | Max  | Min  | Max  |  |
| GRP (millions of 2016 US$)      |       |       |       |       |      |      |      |      |      |      |  |
| Average annual                   | −$18  | −$49  | −$28  | −$74  | −$36 | −$93 | −$39 | −$99 | −$71 | −$178 |  |
| Cumulative (3% DR)               | −$381 | −$815 | −$575 | −$1233| −$747| −$1544| −$821| −$1648| −$1432| −$3030|  |
| Personal income (millions of 2016 US$) |       |       |       |       |      |      |      |      |      |      |  |
| Average annual                   | −$13  | −$39  | −$20  | −$59  | −$26 | −$73 | −$29 | −$78 | −$53  | −$142 |  |
| Cumulative (3% DR)               | −$261 | −$632 | −$401 | −$962 | −$528| −$1206| −$585| −$1289| −$1027| −$2388|  |
| Total employment (jobs/job-years)|       |       |       |       |      |      |      |      |      |      |  |
| Average annual                   | −110  | −340  | −170  | −510  | −230 | −640 | −250 | −680  | −460  | −1250 |  |
| Cumulative                       | −3430 | −10430| −5290 | −15780| −7020| −19810| −7800| −21180| −14150| −3860 |  |
| Population (persons/person-years)|       |       |       |       |      |      |      |      |      |      |  |
| Average annual                   | −290  | −470  | −440  | −710  | −570 | −890 | −620 | −950  | −1100 | −1750 |  |
| Cumulative                       | −9010 | −14540| −13770| −22150| −17690| −27690| −19270| −29530| −34160| −54220|  |

DR = discount rate; GRP = gross regional product; USEPA = US Environmental Protection Agency.

*Cumulative and average annual values over a 31-y period (2020–2050). Cumulative GRP and personal income impacts calculated as present values as of 1 January 2016 using a 3% real discount rate. Minimum and maximum values correspond to alternative assumed financing mechanisms for local governments and local businesses. (For additional detail regarding financing cases see NERA Economic Consulting [2016]). The Portland region corresponds to the 7-county metropolitan area around the City of Portland.
expensive alternatives. Third, the ranges in Table 2 for a given USEPA alternative illustrate that the magnitudes of these impacts are sensitive to uncertainties in how the local government and local business costs might be financed (with respect to financing timing and method).

The first conclusion—that remediation alternatives all lead to negative impacts on the Portland economy—depends in part on which groups ultimately would pay for expenditures, particularly on the ultimate split between local businesses, local governments, and nonlocal entities. The results assume each of these groups is responsible for one-third of the expenditures. One can consider the qualitative significance of this assumption by considering the effects of 2 extreme cases: 1) assuming costs would be borne entirely by the local entities (local businesses and local governments) and 2) assuming that costs would be borne completely by nonlocal entities (national or international businesses or the federal government).

Under the first extreme case, the estimated economic impacts would be more negative than presented in the present results. Because the net effect with some burden borne by nonlocal entities is negative, increasing the local cost burdens would tend to increase the negative financing effect and thus increase the overall negative impacts. In contrast, under the second extreme case, the estimated economic impacts would tend to be positive. Removing all financing responsibility from both local business and local governments implies that only the positive expenditure effects would impact the regional economy. Note, however, that this conclusion would not follow if some costs imposed on national or international businesses would ultimately be borne by the local subsidiaries of these companies. Thus, it would be necessary to consider precisely which balance sheets are affected by the cost allocation to assess the extent of local burdens even in this extreme case. Note that all of these financing considerations could be explored in more detail in further applied research.

**Ranges of potential impacts on the Portland region.** Figure 2 summarizes the ranges of average annual job and GRP impacts for the 5 USEPA alternatives evaluated, and Figure 3 shows ranges for cumulative impacts over the 31-y period. Using the maximum values based on the different financing assumptions, the average annual job loss over the period from 2020 through 2050 ranges from about 340 jobs under Alternative B to 1250 jobs for Alternative F. With regard to the equivalent GRP values, the losses range from $49 million under Alternative B to $178 million for Alternative F.

The wide range of job losses within each alternative scenario indicates that the potential losses could differ substantially depending on how the expenditures are financed. For example, the estimated job loss over the 31-y period for Alternative I ranges from 230 to 640 on an average annual basis and from 7020 to 19,810 on a cumulative basis (measured in job-years); however, net impact under each alternative is negative, across all cases considered.

**Detailed sectoral and wage-level impacts to the Portland region.** Virtually all sectors of the Portland regional economy would be negatively affected by the USEPA remedial alternatives (due to the multiplier effects). Table 3 summarizes employment impacts on individual sectors.

Impacts on individual sectors will lead to different job losses for various income groups. Job losses are predicted to lead to disproportionate losses in relatively high-wage jobs (e.g., government and health care) in the Portland region. The only sector showing a consistent net job gain across alternatives and financing cases is the professional, scientific, and technical services sector. Table 4 shows estimates of the range of average annual job losses divided into low-wage, medium-wage, and high-wage sectors. These results are based upon the employment results by sector and average sector wages. The loss in high-wage jobs makes up 34% to 49% of the total average annual job losses due to the USEPA remedial alternatives (Figure 4).

**Potential business disruption and “stigma” effects.** These results do not reflect all possible regional economic effects of the remediation alternatives. For example, the remedial alternatives could have additional effects on the regional
Figure 3. Cumulative economic impacts of USEPA alternatives on Portland, Oregon, USA, regional economy. Cumulative values over a 31-y period (2020–2050). Cumulative GRP impacts calculated as present values as of 1 January 2016 using a 3% real discount rate. Minimum and maximum values correspond to alternative assumed financing mechanisms for local governments and local businesses. (For additional detail regarding financing cases, see NERA Economic Consulting [2016].) The Portland region corresponds to the 7-county metropolitan area around the City of Portland. GRP = gross regional product (millions of 2016 US$).

Table 3. Average annual employment impacts by sector of USEPA alternatives on Portland, Oregon, USA, regional economy

| Employment sector                      | Average annual employment impact (jobs) per USEPA alternative |
|----------------------------------------|-------------------------------------------------------------|
|                                        | Min  | Max  | Min  | Max  | Min  | Max  | Min  | Max  | Min  | Max  |
| Forestry, fishing, and related activities | 0    | -10  | -10  | -10  | -10  | -10  | -10  | -20  | -10  | -20  |
| Mining                                | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Utilities                             | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Construction                          | 0    | -20  | 0    | -30  | 0    | -40  | 0    | -40  | 10    | -80  |
| Manufacturing                         | -10  | -20  | -20  | -30  | -20  | -30  | -30  | -40  | -50  | -70  |
| Wholesale trade                       | -10  | -10  | -10  | -10  | -10  | -10  | -10  | -20  | -20  | -30  |
| Retail trade                          | -20  | -30  | -30  | -50  | -40  | -60  | -40  | -70  | -70  | -120 |
| Transportation and warehousing        | -20  | -30  | -20  | -40  | -30  | -50  | -30  | -50  | -50  | -80  |
| Information                           | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | -10  | -10  |
| Finance and insurance                 | -10  | -10  | -10  | -10  | -10  | -10  | -10  | -20  | -20  | -30  |
| Real estate and rental and leasing    | -10  | -10  | -10  | -20  | -10  | -20  | -10  | -20  | -20  | -40  |
| Professional, scientific, and technical services | 30    | 20    | 40    | 20    | 40    | 10    | 40    | 10    | 40    | -10  |
| Management of companies and enterprises | 0    | 0    | 0    | 0    | 0    | 0    | 0    | -10  | -10  | -10  |
| Administrative and waste management services | 0    | -10  | 0    | -20  | 0    | -20  | 0    | -20  | 0    | -40  |
| Educational services                  | 0    | 0    | -10  | -10  | -10  | -10  | -10  | -10  | -20  | -20  |
| Health care and social assistance     | -20  | -30  | -30  | -50  | -40  | -60  | -40  | -70  | -80  | -120 |
| Arts, entertainment, and recreation   | 0    | 0    | -10  | -10  | -10  | -10  | -10  | -10  | -10  | -20  |
| Accommodation and food services       | -10  | -20  | -20  | -30  | -20  | -30  | -20  | -40  | -40  | -70  |
| Other services, except public administration | -10  | -20  | -20  | -30  | -20  | -30  | -20  | -40  | -40  | -60  |
| Total government employment           | -10  | -130  | -20  | -190  | -30  | -230  | -30  | -240  | -60  | -430  |
| Farm employment                       | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Total                                 | -110  | -340  | -170  | -510  | -230  | -640  | -250  | -680  | -460  | -1250  |

USEPA = US Environmental Protection Agency.

*Average annual values over a 31-y period (2020–2050). Rows may not sum to totals due to rounding. Minimum and maximum values correspond to alternative assumed financing mechanisms for local governments and local businesses. (For additional detail regarding financing cases see NERA Economic Consulting [2016].) The Portland region corresponds to the 7-county metropolitan area around the City of Portland.
economy through effects on riverfront activities that are not included in the REMI modeling. A business questionnaire was prepared that asked riverfront businesses (on the condition of anonymity) to assess 2 major potential impacts: 1) negative impacts related to business disruption and 2) positive impacts related to contaminated site stigma removal.

Questionnaire respondents were also asked about effects of increased noise (this was reported not to be a concern in general) and increased truck traffic (this was reported to be of some concern).

Virtually all respondents indicated that changes in their river operations were “very likely” if access to the river were disrupted during in-water construction. Expected changes depended on the nature of the available options.

- Participants with nearby alternative facilities with port access (e.g., on the Columbia River in Washington) would likely consider relocating operations.
- Participants without nearby facilities—particularly those with highly specialized and stationary equipment—would consider shipping by other higher-cost means in the near term (e.g., relying more on rail or trucks); eventually, this group might eliminate local production altogether.

Most participants responded that remedial alternatives with longer durations would lead to greater disruption and more severe reactions (i.e., relocation or permanent shutdown of riverfront facilities).

Most respondents believed there was a stigma associated with the listing of Portland Harbor as a Superfund site and that this stigma affected business. A majority of respondents believed that remediation might remove this stigma; however, participants cautioned that stigma removal would require 2 major changes: 1) legal certainty for new entrants fearing liability and 2) long-term perception of remediation success.

In summary, the questionnaire results suggest that the net effect of Superfund remediation on riverfront businesses is ambiguous (i.e., both positive and negative effects were identified). It seems likely that the net result of these offsetting effects is small relative to the direct effects from

Table 4. Average annual employment impacts by wage group of USEPA alternatives on Portland, Oregon, USA, regional economy

| Wage group      | Average annual employment impact (jobs) per USEPA alternative |
|-----------------|-------------------------------------------------------------|
|                 | B              | D              | I              | E              | F              |
| Low wage        | –20            | –30            | –30            | –50            | –40            | –60            | –50            | –70            | –80            | –130           |
| Medium wage     | –40            | –140           | –70            | –210           | –100           | –270           | –120           | –290           | –220           | –550           |
| High wage       | –40            | –160           | –70            | –240           | –80            | –300           | –90            | –320           | –160           | –570           |
| Total           | –110           | –340           | –170           | –510           | –230           | –640           | –250           | –680           | –460           | –1250          |

USEPA = US Environmental Protection Agency.

*Average annual values over a 31-y period (2020–2050). Low-wage jobs correspond to jobs in sectors with average annual incomes less than or equal to US $30 000; medium-wage jobs correspond to jobs in sectors with average annual incomes greater than $30 000 and less than or equal to $80 000; high-wage jobs correspond to jobs in sectors with average annual incomes greater than $80 000. Rows may not sum to totals due to rounding. Minimum and maximum values correspond to alternative assumed financing mechanisms for local governments and local businesses. (For additional detail regarding financing cases, see NERA Economic Consulting [2016].) The Portland region corresponds to the 7-county metropolitan area around the City of Portland.

Figure 4. Average annual employment impacts by wage group of USEPA alternatives on Portland, Oregon, USA, regional economy. Average annual values over a 31-y period (2020–2050). Low-wage jobs correspond to jobs in sectors with average annual incomes less than or equal to US $30 000; medium-wage jobs correspond to jobs in sectors with average annual incomes greater than $30 000 and less than or equal to $80 000; high-wage jobs correspond to jobs in sectors with average annual incomes greater than $80 000. Rows may not sum to totals due to rounding. Minimum and maximum values correspond to alternative assumed financing mechanisms for local governments and local businesses. (For additional detail regarding financing cases, see NERA Economic Consulting [2016].) The Portland region corresponds to the 7-county metropolitan area around the City of Portland. USEPA = US Environmental Protection Agency.

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the remedial expenditures and financing. Thus, we consider the quantitative REMI estimates to be robust to the inclusion of these additional impact categories. Note that one could imagine other pathways by which the remediation alternatives could affect the regional economy (e.g., if any health effects of remediation made the Portland region more attractive to workers and thus lowered the wages they would be willing to accept to work in the region, the local economy may be stimulated); but these more speculative effects do not seem likely to be significant relative to the expenditure and financing effects that are included in traditional economic impact analyses.

CONCLUSIONS

The present study illustrates a methodology for evaluating the regional economic impacts of Superfund remedial alternatives, an important consideration in evaluating alternatives at complex sediment sites with large potential costs. Regional economic impacts can be used—along with other economic, environmental, and social information—to develop a broad assessment of Superfund remediation alternatives (see Apitz et al. this issue; Fitzpatrick et al. this issue; McNally et al. this issue; Ruffle et al. this issue).

Conclusions regarding the economic impact methodology can be summarized in terms of several elements that are important to developing reliable estimates of regional economic impacts.

- Dynamic model. A dynamic economic model such as the REMI model is useful in showing changes over time in the potential economic impacts. Although 1-period models such as IMPLAN can be used to develop impact estimates, dynamic models provide advantages by taking into account how the expenditures and costs change over time and also how these changes propagate through the regional economy over time.
- Inputs specific to time, location, and sector. Detailed estimates of the different types of expenditures—including the time they are incurred, the sectors that are involved, and their location—are important in providing accurate assessments. Where the expenditures are made and where the entities paying the costs are located are important, for example, because expenditures and payments outside the region do not lead to local economic impacts.
- Inclusion of both positive and negative impacts. Taking into account the negative effects of local financing of expenditures as well as the positive impacts of expenditures is critical to provide a complete assessment of local economic impacts. Indeed, this element seems particularly important to avoid misleading results.
- Acknowledgement of uncertainties. It is useful to note uncertainties in the estimated economic impacts. Results are affected by assumptions on which entities pay the costs and how these payments are made. Thus, it is useful to provide quantitative estimates of how results would change with different assumptions.
- Qualitative assessments of other direct impacts. Remediation effects other than expenditures and financing could affect the regional economy, although in most cases it would be difficult to develop reliable quantitative estimates of these other effects and thus qualitative assessments seem more appropriate. Effects of the remediation on businesses along the river can be addressed qualitatively, for example, as one indication of effects that are omitted from the quantitative estimates.

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Data Accessibility—While the majority of input data used in this analysis is from the USEPA Portland Harbor Superfund Feasibility Study, which is publicly available data, the REMI model was used to evaluate economic impacts associated with these costs. This REMI PI v.1.7 model was leased from Regional Economic Models, Inc. (remi.com). The authors’ lease for this model has expired; therefore, the model and its proprietary data are not available. USEPA cost data can be found publicly in the Portland Harbor Draft Final Feasibility Study: Appendix G Detailed Analysis Cost Estimates (Published 06/08/2016, Doc ID #840010).

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