WRRC-2003-01

Economic Impacts of Providing Secondary Treatment at the Sand Island Wastewater Treatment Plant, Oahu, Hawaii

James E.T. Moncur

October 2003

Prepared for

Department of Environmental Services
City and County of Honolulu

Report
for

"Cost of Secondary Treatment: Sand Island Wastewater Treatment Plant, City and County of Honolulu"

Project Period: 1 April 2003 – 30 September 2003

Principal Investigator: James E.T. Moncur

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF HAWAIʻI AT MĀNOA
Honolulu, Hawaiʻi 96822

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James E.T. Moncur
Water Resources Research Center
University of Hawaii at Manoa
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SUMMARY

Upgrading the Sand Island Wastewater Treatment Plant to provide secondary treatment has been estimated at $448 million, doled out over a period of several years. Such a project involves two opposite economic effects: stimulation as the builders pay labor and buy materials, and contraction as consumers divert money from other goods or services to pay for it. Moreover, the initial burst of spending will cause industries with no direct connection to the project to experience an increase or decrease in their business, causing subsequent ripples throughout the economy. With a truly large project, such as the roughly $448 million plant upgrade, these direct and indirect impacts can have serious repercussions on the entire local economy.

Stimulation and contraction can wield their impacts in different ways, depending on the type of resources purchased and their interconnections with other sectors of the economy. Clearly, the stimulative effect of the construction process impacts on very different industries than would an equal stimulus from, say, a rise in consumer spending on automobiles. This paper provides estimates of both positive and negative impacts of a secondary treatment project.

Input-output models provide a convenient, if in some ways imperfect, means of obtaining these estimates. Hawaii's IO model is produced by the state Department of Business, Economic Development and Tourism. IO models trace the sales of each product to other producing sectors (interindustry sales) as well as to final purchasers (households, investment, exports and government spending). Thus when a final demand sector, such as government, increases its spending, the effects can be traced throughout the model's interindustry structure, illuminating the indirect effects consequent on a given initial burst of spending.

Details of the estimation procedure are outlined in the following sections of this paper. By way of summary of the estimates, suppose first that the secondary treatment project is constructed as part of the "State and Local Government Construction" sector of final demand and that operation and maintenance costs are paid through higher household spending in fees to the "water and sewer" industry.

Construction of the plant will cost about $448 million, over a period of some eight years, with a discounted present value of $363 million. Operation and maintenance are estimated to cost $9 million per year throughout the assumed 50-year life of the plant, beginning eight years after the project is approved. This stream of costs has a discounted present value of $186 million. The IO model estimates that the expenditure of $549 (= $363 + $186) million on plant construction,

operation and maintenance generates additional output (indirect impacts) of $449 million, for a total of $988 million additional output over the 50-year life of the treatment plant.

At the same time, the extra sewer fees necessary to pay for construction, operation and maintenance of the facility will require a withdrawal of the same $549 million from other economic activities. This diversion, according to the IO model, will decrease output by $784 million once the indirect, as well as direct, impacts are accounted for. With these assumptions, the net impact of the investment is a positive $988 million - $784 million = $203 million.

Of course, sewer fees are only one means of underwriting the investment. If funded by decreases in other "State and Local Government Consumption," the IO model indicates a negative impact of $976 million in output, leaving a net positive impact of only $988 million - $976 million = $12 million. Similarly, various combinations of withdrawals through households and government are possible. For example, if 50% of the costs are underwritten by higher sewer fees and 50% absorbed by decreasing other State and Local Government Consumption, the net impact on output is a positive $119 million.

Similar estimates are given below for earnings and employment effects. In general, the net impacts on earnings and employment have more of a tendency to be negative than do those on output. Assuming the costs are financed entirely through higher sewer fees, estimated net impacts range from -$164 million to +$203 million in output, -$244 million to +$91 million in earnings and - 8403 to +530 in jobs.

INTRODUCTION

In pursuit of the "zero discharge" standard promulgated by Congress in the 1970s, the U.S. Environmental Protection Agency generally requires "secondary" treatment of sewage, to (nearly) eliminate suspended solids as well as biochemical oxygen demand on the water body receiving the effluent. The Clean Water Act Amendments (1977), however, recognize that in some cases adding secondary to primary treatment imposes an unnecessary and fruitless expense. Hence some cities may apply for a "section 301(h) waiver" from the secondary treatment requirement.

One such waiver permits Honolulu to treat sewage at its Sand Island Wastewater Treatment Plant to a primary level. Serving the largest part of Oahu's urban core, this plant produces some 75 million gallons of treated effluent daily. The effluent is discharged into the ocean through an 84-inch-diameter pipe about 9,000 feet offshore at a depth between 230 and 245 feet. It has been argued that the outfall's distance from shore, the depth of the discharge pipe, the lack of a continental shelf around the island, and the prevailing ocean currents, all combine to make near-shore fecal contamination or damage to marine biota extremely unlikely. Honolulu's 301(h) permit requires a substantial monitoring effort to ensure that the receiving waters continue to support a viable and healthy "balanced indigenous population" of marine life, despite the effluent discharge. This monitoring effort has shown, to date, no significant environmental degradation in the vicinity of the outfall.

IDENTIFICATION OF THE PROBLEM

Despite the lack of demonstrable harm to the environment, the City periodically comes under pressure to upgrade the Sand Island plant from primary to secondary treatment. The costs of doing so are huge, estimated at $448 million.[1] One need hardly note that this amount would be sufficient to underwrite any number of major government projects–mass transit, highways, urban renewal, hospitals, education, parks and so on. Diverting resources of this magnitude constitutes a major public decision. Hence it is important to investigate the effects of investing in upgraded treatment on basic economic variables.

This study provides estimates of economic impacts, specifically on output, earnings and employment. It is important to note at the outset what this study will *not* answer. The ultimate question is whether the benefits of secondary treatment at Sand Island *justify* using the resources that will be required. Justification of the project could be established only by a thorough benefit-

[1]Hawaii Pacific Engineers, Inc., *Sand Island Wastewater Treatment Plant Secondary Treatment Cost Estimates,* prepared for City & County of Honolulu Department of Environmental Services, March 28, 2003. The published figure was $453 million; City adjustments lowered this to $448 million.

cost study. Benefits are measured, in principle, by willingness-to-pay for the enhanced wastewater treatment capability the project offers. Since these benefits are largely of a non-market and non-monetary character, they would be difficult to measure even with the best of research resources, techniques and time. This study makes no attempt to do so. We examine only the cost side, by studying effects of this investment on output, earnings and employment, including both the direct effects of the project expenditures and the indirect effects induced by that added spending.

METHODOLOGY

Any increase in investment, in whatever line of economic activity, is experienced by recipients of the investment spending–businesses as well as households–as an increase in income. This addition to income is referred to as the "direct" effect of the investment. Given limited inventories, there will be a sequence of secondary effects as well: suppliers to the investment project must increase their output, their suppliers must increase output, and so on. These effects ripple through the economy indefinitely, and are referred to as the "indirect effects" of the initial investment outlay. Moreover, the direct and indirect effects will increase income to labor and other primary factors of production. This higher income induces additional spending, called, not surprisingly, "induced effects" of the initial outlay.

Because a part of each round of spending increase is diverted to savings, subsequent rounds of this spending-income-spending cycle eventually diminish to insignificance. Nevertheless, total output will have risen by a multiple of the initial investment.

One method of estimating the indirect effects involves the use of an input-output or interindustry or IO model. As the name implies, these models trace in detail the connections between industries or sectors of the economy. Output from any given industry goes either to other industries, which use it as an input to their production processes, or to "final demand." An IO model traces the interindustry and final demand connections in detail, and thus allows estimation of the indirect as well as the direct effects consequent on a change in final demand for the product of any given industry. Outputs of each industry, plus final demand for that industry, are conventionally displayed in a row of the IO table.

One could equally well trace the inputs purchased by a given industry from all other industries, plus the payments to labor and other factors of production. Again by convention, inputs and final payments are displayed in a column of the IO table. The model is set out mathematically in the appendix.

Final demand typically is composed of consumption, exports, investment and government expenditures. In some models, as in Hawaii's, each of these categories is decomposed further, for example to isolate visitor spending or separate government consumption from government investment.

One result of these models is a set of multipliers, each of which gives the total direct plus indirect impacts on, for example, output of the construction sector resulting from a change in final demand for, say, government expenditures, but also given unchanged levels of final demand for other sectors. These multipliers are of (at least) two types. "Type I" multipliers trace the effect of a change in final demand for some product throughout all the direct + indirect interindustry impacts noted above. The more comprehensive "type II" multipliers recognize that in addition to interindustry effects, household incomes rise and induce a further expansion of output from, in principle, all other industries. Type II multipliers incorporate direct, indirect and induced effects. This study uses mainly the type II multipliers.

Unfortunately, there is no input-output model specifically for the City and County of Honolulu. However, the Hawaii state input-output model[2], which was developed and is maintained by the state Department of Business, Economic Development and Tourism, serves as a principal tool in economic forecasting and analysis for the state. The dominance of Oahu in the state's economy makes the state model a much better representation of Honolulu than would be the case for most other state models.

The Hawaii model is available in two versions, a consolidated one dividing interindustry transactions into 20 sectors and a detailed one with 131 interindustry sectors. We use the detailed model.

DATA

This analysis takes as its starting point the engineering estimate that construction of secondary wastewater treatment facilities at Sand Island would cost $448 million[3] for a plant capable of processing 90 million gallons per day (mgd) of wastewater. This expenditure would be distributed over an eight-year design-and-construct period as shown in Table 1. In addition, once built the plant will cost $9 million annually for operation and maintenance. These costs include sludge disposal and externalities such as odor control.

Table 1
Sand Island Wastewater Treatment Plant Secondary Treatment Project
Schedule of Expenditures
(× 1,000)

FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	Total
$560	$2,400	$5,400	$7,040	$37,400	$128,600	$169,000	$97,600	$448,000

Source: City & County of Honolulu, Environmental Services Department.

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[2]Research and Economic Analysis Division, DBEDT. *The Hawaii Input-output Study: 1997 Benchmark Report*, March 2002. This publication, along with downloadable data files in spreadsheet format, is available at http://www.hawaii.gov/dbedt/97io/index.html .

[3]HPEI, op. cit., as adjusted by CCH to account for reduced facility needs.

However, the \$97.6 million scheduled for FY 2012 (for example) is not directly comparable to the same amount spent in FY 2005 or any other year. Each year's scheduled expenditure must be discounted to make the amounts comparable. We use a discount rate of 3% annually, which represents approximately the long run, risk-free real (no inflation) opportunity cost of rate payers' funds.[4] All costs in any given fiscal year are assumed to occur at the end of the calendar year and are discounted to the present (June 30, 2003) using the formula $PV_K = \sum_{t=2005}^{2012} \frac{K_t}{(1+r)^{(t-2003.5)}}$, where K_t is capital expenditure in year t, and r is the discount rate. The present value equivalent to this stream of future investment outlays is thus \$363.0 million.

Similarly, the \$9 million/year stream of O&M costs must be converted into a present value capital equivalent. Again basing the discounting process in mid-year 2003, the equation is $PV_{OM} = \sum_{t=2012}^{T} \$9/(1+r)^{(t-2003.5)}$, where T is the last year in which the plant will incur O&M costs, so that (T - 2012) is its operating life span. This computation assumes that the plant will come on line in 2012 and will not incur O&M costs prior to that year. The HPEI cost study gives no indication of how long the plant might last, so we do the calculations based on an assumed life of 50 years. Given these parameters, the present value of O&M costs is \$185.5 million. The cost data are summarized in Table 2.

Table 2. Present Values of Capital and Operating Costs (\$ million)

	Nominal	Discounted
Capital	448.0	363.0
O&M[(a)]	450.0	185.5
Total	998.0	548.5

(a) Assumes plant life of 50 years, \$9 million per year, discounted at 3%.

ECONOMIC EFFECTS OF THE INVESTMENT SPENDING

As with any investment, construction of a secondary treatment facility will have positive and negative effects. Such a project will raise incomes for those directly involved in the project. This direct increase will cause indirect effects, as already noted, rippling throughout the economy as it is spent. At the same time, the funds spent on the project must come from somewhere. Either sewer fees must be raised or other government expenditures must be cut, or some combination of

[4]Economists disagree about whether to use discount rates that represent (a) the rate of time preference of the individuals under consideration, or (b) the rate these individuals could earn in the best alternative investment of the funds. Since the funds to cover secondary treatment costs will come ultimately from households, we take the latter approach. This rate has remained remarkably steady in the 2% to 3% range, assuming no risk and no inflation. For a fuller discussion, see Barry C. Field, 2002. *Natural Resource Economics: An Introduction,* Boston: McGraw-Hill.

the two.[5] As ratepayers or government diverts expenditures from other activities, output, earnings and employment in those activities will decrease, both directly and indirectly.

In the context of the IO model, the net impact of these positive and negative changes in income could occur through several channels. Ideally, the model would include final demand sectors specifically for "Investment in Wastewater Treatment Facilities" and "Expenditures on Secondary Wastewater Treatment." Of course, such detail does not exist in the Hawaii model (nor in any other I am aware of). Obtaining the necessary data and fitting it into the IO model would require a major research effort in itself. Fortunately, however, several sectors in the detailed Hawaii IO model provide close approximations.

In the following, we present two types of analysis, first in terms of the capital stock amounts invested in the facility (and the capital equivalents of streams of O&M costs) and then in terms of annual cash flows.

Capital Stocks: Positive Effects

The effects of spending per se (whether for construction or O&M) are entirely positive. As resources are hired or purchased, payments flow out to suppliers, labor, profit and imports. To estimate these effects of capital spending, we use the following procedure, as suggested in the *Hawaii Input-Output Study*.[6] First, assume that investment in the secondary treatment facilities will be distributed across the IO model's sectors in the proportions indicated by the "State and Local Government Investment" (SLGI) sector of final demand. Let f_{si} denote final demand (in dollars) from SLGI for the output of sector *i*, as given in the published IO tables. Calculate the proportion of SLGI coming from each sector *i* as $\pi_{si} = f_{si} / \Sigma_i f_{si}$. Next, determine the direct change in output of sector *i* due to this secondary treatment investment ($363.0, as shown in Table 2) amongst sectors: $\Delta X_i = \pi_{si} \times 363.0$. Finally, multiply each ΔX_i by the published multiplier m_i for sector *i*, and sum the results: $\sum_{i=1}^{n} m_i \Delta X_i$. This is the total positive impact on output of the capital spending.

Consumers' expenditures to cover the cost of operating and maintaining the system amount to an increase, albeit an involuntary one, in final demand for "State and Local Government Enterprises: Water and Sewer" services. We use the published multipliers for this sector to estimate the indirect impacts of the higher sewer bills.

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[5] In principle, the project might also be funded by federal grants. Although widely available in the early years of National Environmental Protection Act, federal government policy and budgets in recent years have made wastewater treatment plant construction grants unlikely. If available, such funding, being mostly provided by citizens of other states, would be largely gravy to the city or state economy; it could be said to result only in positive effects.

[6] *The Hawaii Input-Output Study*, op. cit., Table 6.1, p. 45.

The situation just described is labeled scenario I in Table 3. In addition to the output effects mentioned, the Hawaii IO model calculates multipliers similar to m_i for earnings and employment, so impact estimates for all three variables are reported in Table 3.[7]

Table 3. Impacts of Spending for Secondary Treatment (Type II Multipliers)

	Direct Effect ($ millions)	Type II Multipliers: Output	Type II Multipliers: Earnings	Type II Multipliers: Employment	Total Impacts: Output ($ million)	Total Impacts: Earnings ($ million)	Total Impacts: Employment (Jobs)
I. Positive capital spending effects via "State and Local Government Investment" sector of final demand O&M effects via "State and Local Government Enterprises: water and sewer" (sector 127)							
Capital	363.0	*1.89*	*0.61*	*19.1*	684.8	223.1	6,918
O&M	185.5	1.63	0.44	13.4	303.0	81.6	2,484
Total	548.5				987.8	304.7	9,402
II. Positive effects via "Gross Private Domestic Investment" sector of final demand O&M effects via "State and Local Government Enterprises: Water and Sewer" (sector 127)							
Capital	363.0	*1.40*	*0.45*	*15.2*	509.3	162.7	5,534
O&M	185.5	1.63	0.44	13.4	303.0	81.6	2,484
Total	548.5				774.6	235.2	8,535
III. Negative effects via "Personal Consumption Expenditures" (final demand sector)							
	-548.5	*1.43*	*0.39*	*16.2*	-784.4	-214.3	-8,872
IV. Negative effects via "State and Local Government Consumption" (final demand sector)							
	-548.5	*1.78*	*0.89*	*29.9*	-976.2	-488.8	-16,421

As noted above, the SLGI sector defined in the Hawaii IO model is not the ideal representation of effects stemming from investment in secondary treatment. An alternative is to assume that the impacts behave as though the investment occurred through the model's Gross Private Domestic Investment (GPDI) sector of final demand. Using the same calculation as above, we estimate the impacts of an increase of $363.0 million in investment via GPDI. The results are shown in Table 3 as scenario II.

Capital Stocks: Negative Effects

However, the effects are not all positive. Funds to pay suppliers, labor and so on do not fall off trees or leak out of the mint, but must be diverted from other activities. We estimate the negative impacts in two versions. First, assume that sewer service rates are raised so that consumers bear the full amount of (the present values of streams of) capital and O&M costs.

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[7] "Type II" multipliers are used here, incorporating direct effects, indirect effects via other sectors of the economy and effects induced by higher consumer incomes. These are defined mathematically in the appendix.

Further, suppose that consumers react by decreasing Personal Consumption Expenditures (PCE, another sector of final demand in the IO model) by an equivalent amount. Distribute this assumed decrease amongst IO sectors using the same procedure described above for capital costs. The results are shown in Table 3 as scenario III.

A second, perhaps less likely, possibility is that instead of assessing consumers to cover the full costs of the project, funds will be diverted from other government spending. We use the IO model's State and Local Government Consumption (SLGC) sector of final demand to represent this possibility. Results appear in Table 3 as scenario IV.

Net Impacts Since either of the positive impact estimates could combine with either of the negative figures, four separate estimates of the net impacts are given in Table 4. Each entry in Table 4 is simply the difference between total positive and total negative impacts, for a given combination of scenarios I or II, and scenarios III or IV in Table 3.

At one extreme, if the positive effects occur through the SLGI sectors (scenario I) while the negative effects occur via (i.e., the project is funded by) decreased PCE (scenario III), then the secondary treatment investment is estimated to increase output, earnings and employment respectively by $203.4 million, $90.5 million, and 530 jobs, over the 50-year life cycle assumed for the investment.

Table 4. Net Impacts of Spending Changes Induced by Investment in Secondary Treatment

	Negative Effects					
	Output ($ million)		Earnings ($ million)		Employment (No. of Jobs)	
Positive Effects	III	IV	III	IV	III	IV
I	$203.4	$11.6	$90.5	-$184.1	530	-7019
II	$(9.8)	-$201.6	$21.3	-$253.2	-337	-7886

At the extremes, estimates of net impacts on output range between -$201.6 million and +$203.4 million; on earnings, between -$253.2 million and +$90.5 million; and on employment, between -7886 and +530 jobs.

One could argue that sewer rate payers might balk at paying the increased sewer fees necessary to cover secondary treatment costs and that some of these costs would be covered by decreasing other government consumption. This amounts to a combination of scenarios III and IV. Suppose, for example, that sewer fees are hiked enough to cover half the costs, while other government consumption is diverted to cover the other half. Table 5 displays the result:

Table 5. Net Impacts of Spending Changes: Costs Split Evenly Between Households and Government

	Negative Effects		
Positive Effects	Output ($ million)	Earnings ($ million)	Employment (No. of Jobs)
I	$119.2	-$41.0	-3048
II	-$56.3	-$101.4	-4432

Other possibilities were investigated but are not reported here. For example, we tried assuming that the plant life extends indefinitely. In this case, the present value of the stream of future O&M costs rises to $300 million. Results were qualitatively the same. We also did the calculations using type I multipliers rather than the more inclusive type II multipliers; and we used a higher discount rate. For all these alternatives, the net impacts were qualitatively similar.

Which outcome is most likely? Only a partial and uncertain answer can be given. First, in principle any wastewater treatment facility could be built and operated by either government or private entities. Neither government nor private investment as defined in the IO model precisely describes the situation at hand. However, government invests for unique purposes and under unique constraints. Assuming that this investment would be carried out under the direction of the City government, the SLGI sector (scenario I) perhaps is a better representation than is the GPDI sector (scenario II). Further, one might argue that the government investment sector is more narrowly focused (and thus a better representation of reality) than the private investment sector, considering the vast array of products and activities covered by the latter. All things considered, while neither scenario is completely implausible, scenario I seems somewhat more likely to be the outcome than scenario II.

The choice between representations of negative impacts, scenarios III and IV, is even less clear. Faced with an increase of $x in sewer bills, consumers are unlikely to maintain the distribution of expenditures over sectors, contrary to IO model assumptions. Instead, they are likely to adjust their behavior in ways that would decrease water consumption and therefore (given Honolulu's method of calculating sewer fees) decrease their sewer bills–which would necessitate a further hike in sewer fees to cover the costs of secondary treatment.

Cash Flow Analysis

The estimates above come from calculating the discounted present value of the streams of spending over the lifetime of the project, applying IO multipliers and subtracting the resulting negative effects from the positives. This procedure describes the project in terms of the lump sum equivalents injected into or withdrawn from the economy. Alternatively, one may view the project in cash-flow terms: estimate spending in each year, apply the multipliers from Table 3 as appropriate to calculate the stream of annual net impacts and finally calculate the present value of that stream. This procedure has the advantage of forcing explicit consideration of interest costs as well as the O&M and capital expenditures.

In any given year, economic impacts of the project may derive from (a) construction outlays (b) operation and maintenance spending and (c) repayment, with interest, of capital costs.[8] For present purposes, assume that:

- construction outlays follow the schedule given in Table 1 above
- O&M spending will be $9 million per year, starting the year after construction is completed and continuing throughout the 50 year lifetime of the plant
- construction is financed by issuing bonds in each year of the construction cycle in amounts needed to cover that year's construction outlays
- bonds have a 30 year maturity and 6% interest rate
- all costs are underwritten by sewer charges, thus decreasing the Personal Consumption Expenditures portion of final demand
- economic impacts of expenditures are estimated by applying the multipliers displayed in Table 3 above
- the social rate of time preference, used for discounting the stream of net economic impacts, is 3% per annum

Results, calculated on a spreadsheet, appear in Table 6. Column 9 displays the stream of net economic impacts over the life of the secondary treatment installation. Discounting at the assumed 3% time preference rate (column 10) the results indicate that the project subtracts about $41 million more output than it adds, over the life of the facility.

Similar calculations could be made in terms of the earnings and employment variables. The discounted stream of earnings impacts is slightly positive, while the impacts (undiscounted) on employment appear to be strongly negative. However, such results are very sensitive to the discount rate used. For example, any rate greater than 3.5% makes the net impact on output positive. At 4%, the secondary treatment project is estimated to inject about $37 million more than it withdraws.

DISCUSSION AND CONCLUSIONS

In one sense, the question addressed here is irrelevant. To justify an investment in secondary treatment, *benefits* of the project should exceed *costs.* The preceding analysis has dealt only with costs; the positive impacts mentioned above are not at all the same as benefits. The benefits would be measured by the willingness of sewer service consumers to pay for secondary

[8]Note that even if the project is funded from, say, tax revenues or accumulated net revenues of the sewer enterprise, so that no "repayment" as such is necessary, the expenditure incurs a cost in terms of foregone uses of these funds. Even though no out-of-pocket cash flows are generated in this case, the expenditures on sewer plant incur opportunity costs, i.e., other projects foregone in order to expand wastewater treatment.

Table 6. Cash Flow Analysis

Fiscal Year	O&M $	Capital $	Amortization Total	Total (O&M +Amort)	Negative Effect: Output Impact* × 1.43	Positive Effects: Capital flows Impact* × 1.89	Positive Effects: O&M Impact* × 1.63	Net Output Impact	Present Values at 3%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2005	0	560000	40683	40683	58177	1058400	0	1000223	1000223
2006	0	2400000	215041	215041	307508	4536000	0	4228492	4105332
2007	0	5400000	607345	607345	868503	10206000	0	9337497	8801486
2008	0	7040000	1118793	1118793	1599874	13305600	0	11705726	10712397
2009	0	37400000	3835863	3835863	5485283	70686000	0	65200717	57929992
2010	0	128600000	13178513	13178513	18845273	243054000	0	224208727	193404417
2011	0	169000000	25456179	25456179	36402335	319410000	0	283007665	237014464
2012	0	97600000	32546712	32546712	46541799	184464000	0	137922201	112143371
2013	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-35319589
2014	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-34290863
2015	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-33292100
2016	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-32322427
2017	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-31380997
2018	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-30466988
2019	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-29579600
2020	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-28718058
2021	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-27881610
2022	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-27069524
2023	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-26281091
2024	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-25515623
2025	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-24772449
2026	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-24050921
2027	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-23350409
2028	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-22670300
2029	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-22010000
2030	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-21368932
2031	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-20746536
2032	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-20142268
2033	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-19555600
2034	9000000	0	32546712	41546712	59411799	0	14670000	-44741799	-18986020
2035	9000000	0	32506029	41506029	59353621	0	14670000	-44683621	-18409060
2036	9000000	0	32331672	41331672	59104290	0	14670000	-44434290	-17773145
2037	9000000	0	31939367	40939367	58543295	0	14670000	-43873295	-17037625
2038	9000000	0	31427919	40427919	57811924	0	14670000	-43141924	-16265638
2039	9000000	0	28710850	37710850	53926515	0	14670000	-39256515	-14369647
2040	9000000	0	19368200	28368200	40566526	0	14670000	-25896526	-9203195
2041	9000000	0	7090534	16090534	23009463	0	14670000	-8339463	-2877385
2042	9000000	0		9000000	12870000	0	14670000	1800000	602969
2043	9000000	0		9000000	12870000	0	14670000	1800000	585407
2044	9000000	0		9000000	12870000	0	14670000	1800000	568356
2045	9000000	0		9000000	12870000	0	14670000	1800000	551802
2046	9000000	0		9000000	12870000	0	14670000	1800000	535730
2047	9000000	0		9000000	12870000	0	14670000	1800000	520127
2048	9000000	0		9000000	12870000	0	14670000	1800000	504977
2049	9000000	0		9000000	12870000	0	14670000	1800000	490269
2050	9000000	0		9000000	12870000	0	14670000	1800000	475990
2051	9000000	0		9000000	12870000	0	14670000	1800000	462126
2052	9000000	0		9000000	12870000	0	14670000	1800000	448666
2053	9000000	0		9000000	12870000	0	14670000	1800000	435598
2054	9000000	0		9000000	12870000	0	14670000	1800000	422911
2055	9000000	0		9000000	12870000	0	14670000	1800000	410593
2056	9000000	0		9000000	12870000	0	14670000	1800000	398634
2057	9000000	0		9000000	12870000	0	14670000	1800000	387023
2058	9000000	0		9000000	12870000	0	14670000	1800000	375751
2059	9000000	0		9000000	12870000	0	14670000	1800000	364806
2060	9000000	0		9000000	12870000	0	14670000	1800000	354181
2061	9000000	0		9000000	12870000	0	14670000	1800000	343865
2062	9000000	0		9000000	12870000	0	14670000	1800000	333849
Totals		**$448,000,000**						**-$459,533,960**	**-$41,022,290**

*Each number in column (6) is column (5) times the relevant multiplier (from table 3, the value noted just above the column number). Likewise, columns (7) and (8) are columns (3) and (2), respectively, times the relevant muliplier.

treatment. This study has not dealt with willingness to pay at all. However, years of monitoring by marine scientists, as mandated by EPA, have established that effluent from the existing primary treatment plant has had little, if any, effect on marine life in the vicinity of the ocean outfall.[9] If no negative impacts have occurred, then what benefit, what "willingness-to-pay" could arise from a secondary upgrade? Perhaps ratepayers and taxpayers would benefit from some vague perception of added certainty that the effluent is in fact not damaging the environment and that it will not damage the environment in the future. But this benefit could be provided at far less cost by expanding or modifying the existing monitoring program. If in fact the benefits are zero, then *no* positive expenditure for secondary treatment, no matter how small, is justified.

That said, Hawaii's IO model has been used to estimate the indirect and induced positive effects of an increase in spending required to upgrade the Sand Island Wastewater Treatment Plant to a secondary level of treatment, as well as the negative impacts of diverting funds away from other goods and services in order to pay for secondary treatment costs. Depending on which final demand sector best represents the effects of spending for this project (government or private investment), and on the source of revenues to finance the spending (personal consumption or government spending), the estimates of net impacts can be negative or positive. As seen in Table 4 above, these impacts range from −$202 million to +$203 million in output, from −$254 million to +$91 million in earnings and from −7,900 to +530 in jobs. In terms of cash flows (Table 6), the estimates again may be either positive or negative.

Sewage Bills Even without the costs of secondary treatment, sewer rates are scheduled to increase, as shown in Table 7. Assuming a continuation of present policy mandating that user fees should cover all costs of wastewater treatment, the presently planned increases, *not* including secondary treatment costs, will result in average bills in FY 2016 that are nearly 2.5 times the FY 2005 amount, as seen in table 7, second column.

Secondary treatment would require direct capital costs totaling some $448 million plus operation and maintenance costs of $9 million annually. To cover these costs,[10] average sewage bills would rise an *additional* 3% to 10%, above and beyond what is planned without secondary treatment, in each of the years 2008 through 2013. By FY 2016, this will result in an average bill of $124.88–some 3.5 times the projected FY 2005 bill of $37.02 (table 7, fourth column). Thus secondary treatment will add to the average sewer bill an amount roughly equal to the current average bill.

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[9]See for example the papers for Session 35, "Ocean Outfall Monitoring in Hawaii," in *Oceans 2001 MTS/IEEE Conference Proceedings*, November 5-8, 2001, Honolulu, HI. Papers are J.H. Bailey-Brock, B. Paavo, B.M. Barrett, and J. Dreyer, "Changes in Pollution Indicators at the Sand Island Sewage Outfall," pp. 1401-1407; R.C. Swartz, J.H. Bailey-Brock, W.J. Cooke and E.A. Kay, "Macrobenthos Monitoring Near the Sand Island and Barbers Point Ocean Outfalls, Oahu, Hawaii," pp. 1408-1416; R. Fujioka, C. Fujioka and R. Oshiro, "Development and Assessment of a Fecal Bacterial Monitoring Program to Determine the Impact of Ocean Sewage Outfall on Shoreline Water Quality," pp. 1417-1423; and J.N. Miller, R.H. Wilkens, and P. Wathern, "Video Transects and Their Use in the Environmental Assessment of Deep Water Marine Disposal Sites," pp. 1424-1427.

[10]Note that sewer fees do not need to cover the indirect or induced costs.

Table 7. Projected Increases in Sewer Bills*

Fiscal Year	Current Projected Average Bill	% Change	Projected Average Bill with Secondary	% Change
FY05	$37.02	–	$37.02	–
FY06	41.83	13.0%	41.83	13.0%
FY07	46.85	12.0%	46.85	12.0%
FY08	51.06	9.0%	52.47	12.0%
FY09	55.66	9.0%	60.34	15.0%
FY10	60.67	9.0%	71.50	18.5%
FY11	66.13	9.0%	85.09	19.0%
FY12	72.74	10.0%	100.83	18.5%
FY13	77.11	6.0%	107.89	7.0%
FY14	81.73	6.0%	114.36	6.0%
FY15	85.82	5.0%	120.08	5.0%
FY16	89.25	4.0%	124.88	4.0%
Total		141%		237%

*Data provided by City and County Division of Environmental Services

Secondary Treatment and the State's Economy In 2001, the Hawaii Gross State Product (roughly the same concept as "output" in the IO model) was $43,710 million[11] and the civilian labor force was roughly 600,000.[12] That said, the $448 million to be invested in secondary treatment amounts to more than 1% of the entire state's GSP. At its height (in 2011) the construction phase raises state GSP by $283 million (table 6) or about 0.6% of GSP. Subsequent withdrawals to pay for it lower GSP by $44.7 million per year (about 0.1% of current GSP) over most of the years 2013 to 2041, when all bonds are retired. By any measure, this is a significant project.

While these figures are to be taken only as rough orders of magnitude, they establish the significance of a secondary treatment project for Hawaii's economy. A secondary treatment project, along with several other large construction projects recently announced,[13] and continuing pressure in housing and other construction can be expected to strain the availability of labor and other construction resources. Tight labor markets tend to stimulate wage increases, as well as housing and other prices associated with rapid growth.

Additional Comments Several caveats apply to the IO estimates. First, by using the PCE sector of final demand, we assumed costs to be borne entirely by households and distributed among interindustry sectors in proportion to PCE. In reality, many ratepayers are businesses rather than households. Their expenditures are distributed across sectors in a very different way.

Second, the IO model is static in nature, assuming production technologies and household consumption patterns remain unchanged. This is not strictly true of most activities, including

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[11] *The State of Hawaii Data Book 2002*, online at http://www.hawaii.gov.dbedt .

[12] Data from State of Hawaii Department of Business, Economic Development and Tourism, available at http://www.state.hi.us/dbedt/sea/index.html.

[13] *Honolulu Star-Bulletin*, "UH Construction Plan Could Mean 1000 New Jobs," Sunday September 28, 2003, p.

wastewater treatment technologies. People and businesses change over time and, faced with changes in relative costs, will innovate to cut these costs, in ways not reflected in the IO structure and in ways that are largely unforeseeable.

Similarly, the existing billing procedures and rate structures provide one path for wastewater customers to cut their bills. Since Honolulu's sewer fees are keyed to water use, higher sewer fees will induce households and businesses to cut water use. Decreased usage may, in turn, induce the City to increase sewer fees which, in turn, will induce consumers to decrease usage, though by how much is not known. There is a large literature dealing with consumer responsiveness to increases in the price of water.[14] Assuming sewer ratepayers react to the increased water-plus-sewage bill as they would to an increase in the price of water, the literature indicates that a 1% increase in price would lead to a decrease in water consumption of about 0.3% or 0.4%. Thus the quantity-based portion of their sewage bills would also decline by 0.3% to 0.4%. This would alter the IO coefficients at several points and might well change the impacts estimated above.

Third, this is not a benefit/cost analysis. "Benefits" implies some measure of willingness of those affected by the project to pay for the services it provides. This analysis covers only the cost side, estimating the net impact on output, earnings and job counts of the given investment. Hence we cannot say whether the project is "worthwhile," only what the impacts of its costs are.

Fourth, the output, earnings and employment impacts assume that the supplies of labor and other resources are not binding. This assumption may or may not be met in Hawaii's labor market, given the magnitude of this project, but the possibility of migration from other states makes it less critical. Such a large project might well put upward pressure on prevailing wage rates. The linear production function implied by the IO table does not account for such effects.

Fifth, no account has been taken of financing beyond whatever was built into the engineering cost estimates used as data. Among other things, selling bonds to finance such a large project might affect the City's credit rating, requiring higher interest costs on this and all other financing and thus higher O&M costs.

Finally, IO models have inherent limitations, some of which have already been noted. Although no technique is entirely unimpeachable, econometric and computable general equilibrium models provide greater scope for flexibility in simulating the situation at hand. Developing such models and applying them to the immediate question would, however, require a larger research budget and longer time frame than provided for this project.

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[14]See, for example, J.M. Dalhuisen, R.J.G.M. Florax, H.L.F. de Groot and P. Nijkamp, 2003, "Price elasticities of residential water demand: A meta-analysis," *Land Economics* 79(2) (May), pp. 292-308. For Honolulu specifically, see J.E.T. Moncur, 1987. "Urban water pricing and drought management," *Water Resources Research* 23(3) (March), pp. 393-398; and J.E.T. Moncur, 1989, "Drought episodes management: the role of price," in *Water Resources Bulletin* 25(3) (June), pp. 499-505.

GLOSSARY

Direct effect – out-of-pocket spending in exchange for a good or service, for example the wages paid to a carpenter or the cost of concrete.

Discount rate – a factor used to make future monetary values comparable to present values. If intended to represent the rate at which an individual or society is willing to exchange a dollar today for an amount to be received at a later date, the discount rate is a *personal (or social) rate of time preference*. If intended to represent alternative returns foregone due to spending in a certain activity, the discount rate is the *opportunity cost* of the chosen investment. These two concepts can lead to widely disparate discount rates. This study adopts the latter approach.

Final demand – a purchase not intended for resale or incorporation into another product or service. The detailed Hawaii IO model includes final demand sectors for households (personal consumption expenditure), visitors, state and local government consumption, state and local government investment, four types of federal government spending and exports.

GPDI – Gross Private Domestic Investment; a sector of final demand in the Hawaii IO model.

Indirect effect – An extra dollar in final demand for, say, sugar requires an extra dollar's worth of output by the sugar industry. To produce that extra dollar's worth of sugar, the sugar industry must purchase more agricultural chemicals, but more trucks and so on. These interindustry reverberations are the *indirect* effects of the initial increase in final demand.

Induced effect – To satisfy an extra dollar's worth of final demand for, say, sugar requires hiring more labor. If the resulting higher labor income is spent on, say, additional clothing, housing or the like, that spending can be satisfied only by increasing the outputs of the clothing industry and housing construction industry. These reverberations are the *induced* effects of the initial increase in final demand.

Industry – one of the 131 sectors into which the Hawaii IO model decomposes the state's economy. These range from "sugarcane" to "federal government: postal services" and include in particular "state and local government enterprises: water and sewer."

Interindustry transaction – sales from one industry to another for incorporation into the purchaser's final product or service.

Opportunity cost – the goods and services foregone in order to purchase some given item. The opportunity cost of the sewer fees necessary to support a secondary treatment plant is, for example, the investment return ratepayers might have earned by investing in, for example, a low-risk stock.

Personal Consumption Expenditures (PCE) – roughly speaking, purchases by households for consumption; a sector of final demand in the IO model.

Present value (or *discounted present value)* – the value today of an amount to be received or spent in some future year.

Sector – an industry or a segment of final demand.

SLGC – State and Local Government Consumption; a final demand sector in the Hawaii IO model.

SLGI – State and Local Government Investment; a final demand sector in the Hawaii IO model.

SLGEWS – State and Local Government Enterprises: Water and Sewer; one of the 131 "industries" defined for the Hawaii IO model.

Total output – in the IO model, the sum of interindustry sales and sales to all final demand sectors.

Type I multiplier – the ratio of direct + indirect effects to direct effects alone.

Type II multiplier – the ratio of direct + indirect + induced effects to direct effects alone. Instead of considering households to be "final" demanders of goods and services, consider them to be another industry, thus treating household incomes as "endogenous" to the model and adding income-induced effects to the direct and indirect effects. These are the multipliers used or calculated in Table 3.

Willingness-to-pay – the maximum amount a buyer is willing to pay for a good or service rather than go without it.

APPENDIX: INPUT-OUTPUT COMPUTATIONS[15]

Leontief, or input-output, or interindustry models begin by separating the economy into several industries, or sectors, and characterizing output, in dollar terms, of any one of the industries as the sum of what is sold to other industries and what is sold to "final demand," consisting of households, government, investment, and net imports:

$$X_i = \sum_{j=1}^{n} x_{ij} + f_i \,, \quad i=1,2,\ldots,n \qquad (1)$$

where

- X_i denotes the total output of industry i (in dollars)
- x_{ij} is the output from industry i used as input to industry j (i.e., sales from industry i to industry j)
- f_i is final demand (by households, government, investment and foreign trade) for the output of industry i
- n is the number of industries, or sectors, in the economy

The Hawaii IO model is available in a condensed format with $n = 20$ interindustry and 7 final demand sectors, as well as a detailed version with 131 interindustry sectors and 11 final demands. We use the detailed version, which includes separate final demand sectors for households ("Personal Consumption Expenditures"), for "State and Local Government Investment," for "State and Local Government Consumption," and for "Gross Private Domestic Investment," among others.

Equation (1) shows the distribution of industry i 's output to other industries and to itself. These numbers form a *row* of the IO table. In similar fashion, one could also list the same industry's *inputs*:

$$X_j = \sum_{i=1}^{n} x_{ij} + p_j \,, \quad j=1,2,\ldots,n \qquad (1')$$

where the summed values form a *column* of the IO table, and

- X_j is the sum of values of all inputs to industry j from other sectors of the economy
- x_{ij} is the same as in (1)
- p_j denotes "final payments" to labor, capital, certain taxes and profit

Thus the summation in (1) gives the values of outputs of a given industry, including deliveries to final demand, while that in (1') gives the values of all inputs. By definition, these must be the same for a given industry.

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[15]Based on *The Hawaii Input-Output Study*, op. cit., pp. 61-63.

Now, suppose the "production function" for industry i is linear, so that industry i requires a constant proportion of j's output:

$$x_{ij} = a_{ij} X_j$$

Thus (1) can be expressed as

$$x_i = \sum_{j=1}^{n} a_{ij} X_j + f_i \qquad (2)$$

or, in matrix notation,

$$X = AX + F \qquad (3)$$

where

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}; \quad A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}; \quad F = \begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{bmatrix}$$

A is referred to as the "direct requirements" matrix.

Solving (3) for total outputs gives

$$X = (I-A)^{-1} F \qquad (4)$$

where I denotes an $n \times n$ identity matrix. The inverse matrix $(I-A)^{-1}$ is called the "Leontief inverse" or final demand output multiplier matrix, as described below. With (4), one may specify any desired level of deliveries to final demand (including, e.g., personal consumption expenditures, visitor expenditures or any other element of final demand) and solve for the level X of total output necessary to produce the specified final demands. Of course, whether the economy can produce the resulting X depends on the availability of labor, capital and other primary resources. Limits on these are specified by the p_j values defined in (1').

Now, let α_{ij} be the element in row i, column j of the Leontief inverse matrix $(I-A)^{-1}$. Note that if final demand for some sector j increases we have

$$\frac{\partial X_i}{\partial f_j} = \alpha_{ij}$$

Interpreting this derivative as a ratio of small changes in the variables, the elements α_{ij} of $(I-A)^{-1}$ reveal the change in total output (sales, in dollars) of industry i per dollar increase in final demand for industry j. Thus the total increase in output of all sectors due to a one dollar increase in final demand for product *j* is

$$m_j^Q = \sum_{i=1}^{n} \alpha_{ij}$$ Type I **Output** Multiplier

The earnings multiplier table *C* is then obtained as

$$C = L(I-A)^{-1}$$

where *L* is an $n{\times}n$ matrix with zeros everywhere except the i^{th} diagonal element, which is the earnings coefficient from the final payments row of the direct requirements matrix. The Type I earnings multiplier for sector *j* is constructed from the *C* matrix as follows:

$$m_j^Y = \sum_{i=1}^{n} c_{ij}$$ Type I **Earnings** Multiplier

where c_{ij} is the ij^{th} element of the matrix *C*.

Employment effects emerge in similar fashion:

$$D = E(I-A)^{-1}$$

where E is an $n{\times}n$ matrix with the sector *i* direct employment coefficient (employment ÷ total output) as its i^{th} diagonal element and zeros elsewhere. The employment multiplier is then

$$m_j^N = \sum_{i=1}^{n} d_{ij}$$ Type I **Employment** Multiplier

where d_{ij} is, as before, the ij^{th} element of the matrix *D*.

Type II multipliers are derived in the same way as type I, except that the "PCE" column of final demands and the "employee compensation" row of final payments are incorporated into the x_{ij}'s. Thus households and employees are treated as just another industry.