Impact of Federal Pollution Control and Abatement Expenditures on Manpower Requirements

Bulletin 1836

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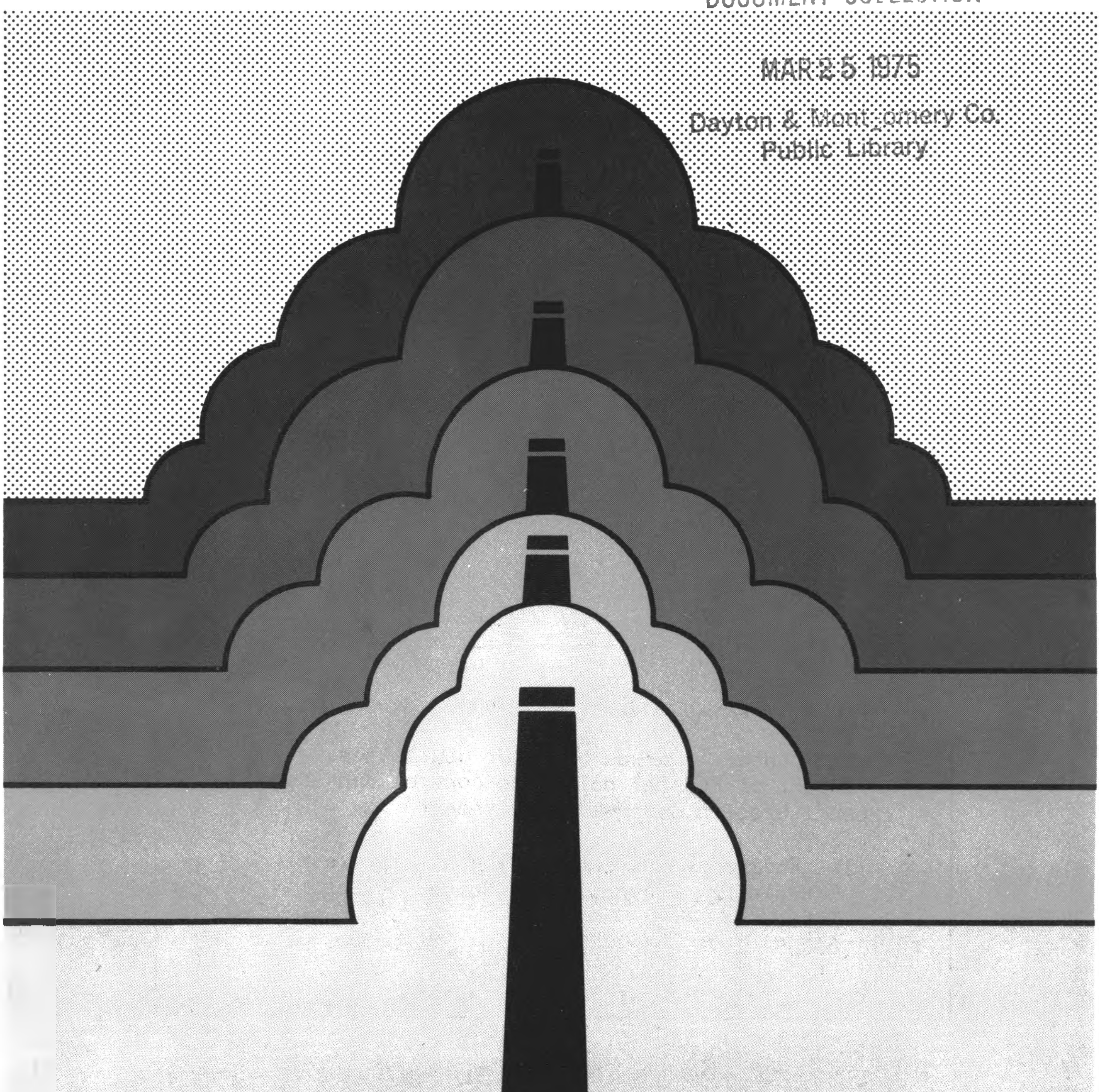

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U.S. Department of Labor
Peter J. Brennan, Secretary
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Julius Shiskin, Commissioner

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Preface

Cutbacks in Federal defense and research and development expenditures in the early 1970's and the resulting unemployment and dislocation of scientific and technical manpower, raised concern about the effects of shifting Federal expenditures and priorities on employment, especially of scientific, technical, and other "high level" manpower. Very soon it was discovered that a comprehensive system did not exist for estimating the potential effect of shifts in Federal spending and priorities on the creation or elimination of jobs.

The development of the research techniques and data necessary for the analysis of such shifts is of major importance to those responsible for determining national priorities, planning manpower training programs, and planning and operating labor market service programs. The National Science Foundation recognized the need for developing these techniques and data, especially in relation to requirements for scientists and engineers, and provided support to the Bureau of Labor Statistics for research in this area. This bulletin presents the results of that research. The focus of the research was placed on developing a method for measuring employment generated by expenditures for a specific Federal program. The method was also used to develop estimates of the employment generated by Federal expenditures for pollution control and abatement. Illustrative projections of the requirements for scientific and technical personnel in the pollution control fields also were developed as well as the information on skill transferability of scientists and engineers from defense and aerospace activities to work related to pollution control and abatement.

Much of the data generated in this study is based on information gathered from interviews with officials of organizations engaged in pollution control activities in approximately 100 universities, nonprofit organizations, private firms, and provided by numerous Federal officials in the Environmental Protection Agency and other Federal, State, and local government agencies. Because of the small sample size, the pilot nature of the study, and the limitations of the methods, estimates of employment generated by Federal expenditures for pollution control in this bulletin should be viewed as rough orders of magnitude, rather than as precise numbers.

The work underlying this bulletin represents the cooperative efforts of two divisions of the Bureau—the Division of Manpower and Occupational Outlook, Office of Manpower Structure and Trends, and the Division of Economic Growth. Michael Crowley of the Division of Manpower and Occupational Outlook coordinated and directed the study. Edith Andrews and Daniel Hecker of the same Division prepared this bulletin together with Kenneth R. Tyree of the Division of Economic Growth, who assisted in the development of the study design and research methods.

Within the National Science Foundation, Norman Seltzer, Study Director, Scientific Manpower Studies Group, and Morris Cobern have been active participants from the outset.

Contents

Introduction

The repercussions of Government actions and policies on employment are far reaching and exceedingly complex. Many Federal programs are developed without any real consideration or assessment of the consequences of their operations on the manpower resources of the country and while such an assessment perhaps would not solve any conflict in values or in priorities inherent in the operation of different programs, it would assist in the decisionmaking process.

"If this country is to move efficiently toward optimal trends, the manpower consequences of Government action in all fields should be projected and appraised on a continuing basis and in a much more comprehensive, integrated manner."[1] Several examples may serve as background to the need for the prior assessment of manpower implications before starting, stopping, or changing, the direction of Government programs.

Where the Government is the principal, sometimes only, purchaser of particular goods and services, and also supplies most of the investment for their production, any change in its spending or financial support to the program can have far reaching manpower implications. This situation is illustrated in spending for national defense, and particularly in Government-supported defense related research and development. Since the Government uses private companies and non-profit institutions as the principal channels for carrying on these activities, budget changes have extensive repercussions. Where the contractors and sub-contractors are concentrated in a few areas, the effects of either a rapid increase or decrease in Government spending are greatly magnified; and where the contractor's employees account for a large percent of the local labor force, the effect on the whole community is great. The cutback in defense orders in the early 1970's had marked effects in some areas, for example, in Seattle, Wash., and Huntsville, Ala., because layoffs by contractors working on such orders snowballed throughout the community. Failure to consider the manpower implications of Federal programs is somewhat akin to dumping pollutants in the river upstream and letting the people downstream worry about ways and means of cleaning up the environment.

Reductions in Government financed R&D at the university level have equally direct but perhaps less immediate manpower implications. Grants to universities to carry on certain kinds of R&D for, or connected with, particular Government programs have a dual impact in that they necessarily influence (1) the direction of the university's research and development potential, the specialization of its staff, and the character of its physical equipment for R&D purposes and, at the same time, (2) the training of the predoctoral graduate students who work on the project. A reduction in Government spending for R&D in a particular program will have an immediate fiscal effect on the university's income, but a certain timelag will occur in translating this into a manpower impact. Graduate students will probably continue in the same area of specialization they had chosen when Government-financed fellowships were available. Even at the undergraduate level the pipeline may be turning out specialists for nonexistent Government or Government-financed jobs.

In Government planning there are a multitude of considerations involved in choosing one program over another or in changing an existing program. If the manpower implications of a program, or program shift, often have been neglected or only imperfectly assessed, a major part of the reason for this neglect has been the lack of data necessary for such analysis and assessment.

As background for decisionmaking, information is needed on: (a) What industries would be most affected by any new program, (b) how much new employment would be generated, and the occupational mix of such employment, and (c) whether the manpower requirements of the new program could be satisfied without putting into jeopardy other aspects of the economy. Proper analysis of such information can put into focus possible manpower problems that would result from following various alternatives. Two contingencies might be noted: (a) where the supply of skills available for a program appears inadequate except at the risk of creating shortages or bottlenecks elsewhere in the economy, or impairing other Federal programs with higher priorities, and (b) where changes in an existing program could start substantial cutbacks in employment in particular industries, occupations, or areas which could snowball and precipitate a recession of significant local, if not regional or national, proportions. While forewarning alone will not eliminate either of these occurrences, it can mitigate the consequences through a careful phasing of a program, as well as the planning or adjustment of alternative or supplementary programs.

Objectives

The preceding discussion briefly examined some ways of looking at the manpower implications of Federal programs and policies, and is designed to show the possible range of interrelationships that must be considered when analyzing the manpower implications of Federal programs and policies.

In order to bring this study into manageable limits, "impact" is defined strictly in quantitive terms and is restricted to that traceable to Federal spending only. Thus, the primary objective of this study is to develop an analytical technique capable of measuring the manpower impact of Federal expenditures and use that technique to measure the employment requirements of Federal expenditures for pollution .control and abatement activities.

A second objective of the study is to examine the extent of skill transferability among fields of work for scientists and engineers, and specifically for ex-employees in aerospace and defense activities moving into professional jobs in the field of pollution control and abatement. Pollution control and abatement was a new and developing area to which the Government was giving increased priority in its allocation of funds at the time this study was initiated in 1972. The popular assumption was that unemployed scientists and engineers could be shifted easily to pollution related occupations and thereby help eliminate manpower problems associated with cutbacks in defense, space, and R&D support.

The study has placed primary emphasis on engineers, scientists, and technicians, both in response to NSF's sponsorship of the study and because these occupations are considered essential to economic growth. Any sudden or sharp increase or decrease in requirements for scientists and engineers poses problems because of the relatively long leadtime necessary to train these workers. Besides the 4-years plus of college training needed, there is also the preparatory work in student counseling and career guidance necessary to direct students to select engineering or science as a career. Moreover, society has a substantial financial investment in such training, so that unemployment or underutilization of such workers apart from the personal suffering of those involved, represents a capital loss and social waste for society.

Limitations of data

Employment impact data in the context of this study only refer to the estimated potential employment generated or lost by specific Federal spending programs. Employment includes those working directly on the program and on Federal Government payrolls (including recipients of Federal grants and contracts),[2] as well as the indirect employment represented in the goods and services purchased and used in the operation of the program.

It is important to emphasize that the data only quantify the jobgenerating capability of particular programs and have nothing to do with "good" or "better." The fact that one program shows a higher jobgenerating capacity per million dollars spent than another does not give it value—except insofar as the number itself has value. The value concept is tied up with the larger context of manpower implications, the full perspective of possible consequences by occupation, industry, or geographic area, along with analytical inferences, hypothetical conclusions, and value judgments as to the role of the program in furthering the broad goals and objectives of the government. Thus, employment impact data cannot and will not indicate whether (a) one program fulfills its purpose better than another, (b) has greater social-use value than another, or (c) yields better results executed under one category of performer or another (for example, a university, a nonprofit institution, private industry, state or local government, or the responsible Federal agency itself). All of these judgments would require additional data and criteria by decision makers.

Employment impact data can, however, represent a significant input to the decisionmaking process. The Government may and does undertake policies or programs for reasons quite removed from labor market consideration — for example, national defense. However, in many cases, employment impact data are or should be a prerequisite to the consideration of the economic and social costs (and benefits) of a given Federal program.

[1] *Manpower Report of the President*, March 1972. (U.S. Department of Labor, 1972.)

[2] In this report, a man year is equated with 2,080 man-hours paid for, except for onsite construction, where 1,800 man-hours constitute a man-year. This convention also was used to compute the man years of graduate students working on project at colleges and universities. However, most graduate students are paid for less than 2,080 hours per year, but it was not clear how many hours of work per year constitutes "full-time" employment for graduate students. Thus, a somewhat higher number of graduate student man years than indicated in this report could be supported if less than 2,080 man hours were considered a man year.

Highlights

Findings. An average of 66.9 jobs were generated for each million dollars expended by the Federal Government for pollution control and abatement. This compares with 49.8 civilian jobs generated per million dollars of defense expenditures (in 1972), and 73.9 for nondefense expenditures. For every million dollars of Federal pollution control and abatement expenditures, requirements were generated for 5 engineers, 8 scientists, and 6 technicians. The approximately $500 million of Federal pollution control and abatement funds in 1970 generated requirements for about 33,500 workers. Of these, approximately 2,600 were engineers, over 3,800 were scientists and 3,100 were technicians. In addition, requirements were generated for 5,300 clerical workers, 5,100 craftworkers, 5,300 operatives, 1,700 laborers, and 1,200 service workers.

In the aerospace and defense industries, respondents indicated that a fair number of skills were transferable, but they saw little incentive to hiring ex-aerospace or defense oriented workers since they were not having problems in meeting their manpower requirements. Only in an expanding economy where potential or real manpower shortages exerted pressure on the employer, did skill transferability really enter the picture. Furthermore, as far as the employer was concerned, technology bore a datemark, so there was not only a question of transferring a skill, but of updating a basic training.

However, many employers raised serious questions as to where, and how much, one could "retrain." Generally, retraining was more applicable, and easier, for engineers than for scientists, and in certain specialities. But, in no case was this a matter of a simple brush-up or a few weeks', or months', work. In most cases it meant going back to college and getting a graduate degree in another specialty – a matter of 1 to 2 years work plus a substantial capital outlay in addition to the earnings foregone in the interim.

Skill transferability does exist, but to be overly optimistic on the prospects of quick retraining and absorption of professionals into new jobs of comparable level in the labor market is unrealistic. It may appear negative to minimize the number of openings that may exist for the retrained professional, but it is unrealistic to encourage individuals to take up retraining at considerable cost and effort and still not be able to find suitable employment.

Of course, employers could view questions relating to skill transferability differently if, for example, a very large amount of money were introduced into the economy for energy R&D. In such a situation, the existing manpower supply might not be sufficient to meet demand without retraining of personnel.

Methods. Analysis of the effects of Federal expenditures on the generation of employment involves two tools in current use by manpower specialists: Input-output tables, and the industry-occupational matrix. Despite certain limitations, these tools provide the basis for a useful method of conducting "impact studies."

Using the method devised for this study, expenditures for a specific program are translated into estimates of employment generated in all major industries through input-output tables. These industry employment tables are then translated into occupational employment through the industry-occupational matrix.

Detailed expenditure information from a central source provided the most effective data for use in this study. However, the study found that expenditure data can be collected successfully when they are not from a central source. Although personal interviews were used in the study, respondents did indicate that data could have been provided in response to a mail survey.

Chapter I. Manpower Impacts—Federal Pollution Control and Abatement Expenditures

Federal funds

Federal outlays for pollution control and abatement activities totaled $751 million in 1970. These funds supported a variety of programs and activities ranging from grants to State and local governments for construction of municipal waste water treatment facilities, to manpower development programs to train workers for environmental protection activities.

As pointed out in Chapter I, not all activities labeled as Federal pollution control and abatement funds by OMB were within the scope of this study. In general, only those activities that could be considered as uniquely pollution control and abatement were retained. Thus, funds for manpower development in the environmental protection field were excluded since manpower development is not specifically or uniquely related to pollution control. In addition, minor amounts of monies were eliminated because the agencies involved could not provide needed data. Outlays for the activities within the scope of this study amounted to $501 million in 1970.

One further adjustment was made to the data. Radiation R&D, amounting to $78 million, as well as Radiation Abatement and Control Operations, amounting to $24 million, were separated and treated as a distinct activity as shown:

	Adjusted outlays	*Outlays for radiation activities*
Total	501	102
Financial aid to State and local governments	252	–
Research, development, and demonstration	180	78
Federal abatement and control operations	69	24
Radiation activities	–	–

This was done because radiation activities were, for the most part, carried out by one agency, the Atomic Energy Commission, and were thought to be somewhat unique. Furthermore, outlays for radiation R&D activities were far larger than those for any other media or type of pollution and would overshadow the others if included.

Employment impacts—interpretation of data

Employment impact of requirements data can be presented in two ways. The actual impact of total expenditures on a program can be given. In this study the $501 million of expenditures generated requirements for 33,530 jobs. Another way of looking at this impact is to say that 66.9 jobs (33,530 jobs divided by $501 million) were generated by each million dollars spent on the program.

Data on the manpower requirements generated by the total expenditures show the magnitude of the employment impacts, facilitate a comparison of the relative importance and employment impact of different programs, and provide a basis for placing a particular program within an overall economic framework and analyzing the manpower impact of a particular program on the overall demand for specific occupations or groups of occupations. Manpower data shown on a per million dollar basis facilitates a comparison of the employment impact of different types of activities or programs, since each activity has a common reference or expenditure level. Both presentations have merit and both are used in this report.

The direct and indirect manpower data in this study are not strictly comparable. The direct manpower data are on a man-years or full-time equivalent basis. Indirect manpower data, generated by the input-output system and the occupational matrix, represent the average number of full and part-time jobs supported throughout the remainder of the economy.

In the man-year concept, a man-year may be a combination of a number of part-time jobs, while under the jobs concept, each part-time job is counted as a job, just as is each full-time job. For Federal in-house activities almost all employees, particularly those in professional and technical jobs, were full-time employees who worked full-time on pollution control activities, so there is little difference between the total on a man-years basis and the total if it had been calculated on a jobs basis.

Extramural grants and contracts presented an additional problem. Data were collected on the number of man-hours supported by the grant or contract, as well as the total number of positions supported, if only in part. The number of positions supported by a grant or contract usually was substantially greater than the number of man-years supported. This was because most of those who worked on grants and contracts worked on them for less than a full year, or spent less than 40 hours of their time on them each week, even if they were full-time permanent employees of the grantee or contractor. The total number of position supported by the grants and contracts is clearly not the same thing as jobs used for indirect employment, and furthermore is extremely difficult to interpret in terms of manpower impact analysis. Therefore, it was decided that man-year data, which is more meaningful in terms of manpower impact analysis, should be used. The data collected does not indicate how many part-time positions were supported by these grants and contracts, and therefore there is no way of determining how much higher the total would be under a jobs concept.

Since the total employment impact data include data on both a jobs and on a man-years basis, there is no completely correct term to use to describe this total. However, for ease of presentation, the term jobs will be used in this report to refer to both types of manpower data.

Several points should be kept in mind when comparing the employment requirements, per million dollars, of different activities and programs. Differences in the number of jobs generated per million dollars reflect to some extent the occupational mix of the jobs supported. Because of salary differentials, fewer professional than clerical workers, for example, can be supported.

A second point which must be kept in mind is that R&D consists of a wide variety of projects. Basic research projects generally have a high percent of their costs going for direct labor input, which supports mostly professional and technical jobs, while demonstration projects have a high percent of their costs going for the purchases of goods and services, which usually generate a low proportion of professional and technical jobs. Differences in employment requirements between performer and media reflect, to some extent, differences in the type and mix of projects and do not necessarily reflect inherent differences in the operations by type of performer, or in the costs of doing similar projects for different media.

Data results

The $501 million of Federal pollution control and abatement expenditures in FY 1970 generated about 33,530 jobs. (See table 1.) Roughly a third, or 10,960, were professional and technical, including 2,600 engineers, 3,860 natural scientists, and 3,100 technicians. These represented less than one-half of 1 percent of the engineers and technicians employed in 1970, and less than 1 percent of all scientists.

Table 1. Total employment impact of Federal pollution control and abatement expenditures, by selected occupational groups

Selected occupational groups	Number	Percent distribution
Total	33,530	100.0
Professional and technical	10,960	32.7
Engineers	2,600	7.7
Natural scientists	3,860	11.5
Technicians	3,100	9.2
Other professional and technical, including medical workers	1,420	4.2
All other	22,570	67.3

NOTE: Detail may not add to totals because of rounding.

The largest number of engineering jobs generated were in civil engineering-1,130, and other engineering-590 mostly nuclear engineers. Within the natural sciences, 1,380 chemist and 1,040 biologist jobs were generated. (Appendix table A-1 provides considerably more occupational detail.)

Roughly 45 percent of the jobs generated by expenditures on the radiation program, on R&D, and on abatement and control operations were professional and technical. This compares to only about 15 percent of the jobs generated by grants for the construction of municipal waste water treatment facilities. (See table 2.) The proportion in each occupational group, however, differs by program.

About 47 percent of the jobs were generated directly–in-house on Federal payrolls or at grantees and contractors (tables 3 and 4)–and 53 percent were generated indirectly–through purchases of goods and services in support of inhouse operations and grant and contract work. However, about 83 percent of the professional and technical jobs were generated directly. From another perspective, 57 percent of the jobs generated directly were professional and technical, while only 11 percent of the job generated indirectly were professional and technical.

This impact can also be viewed on a per million dollar basis. The job generating capabilities of Federal pollution control and abatement activities, per million dollars, are somewhat less (66.9) than the 74.1 jobs generated per million dollars of Federal nondefense expenditures (1972), and significantly lower than the job generating capabilities of expenditure categories that do not involve construction activities. The relatively low number of jobs generated by Federal pollution control and abate-

Table 2. Total and professional and technical employment, by program

Group	Total		R&D		Abatement and control operations		Radiation		Municipal waste water treatment	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	33,530	100.0	7,820	100.0	3,550	100.0	8,610	100.0	13,550	100.0
Professional and technical	10,960	32.7	3,460	44.3	1,660	46.8	3,860	44.8	1,970	14.5
Engineers	2,600	7.7	800	10.2	490	13.8	700	8.1	610	4.5
Natural scientists	3,860	11.5	1,540	19.7	590	16.0	1,710	19.9	30	.2
Technicians	3,100	9.2	920	11.7	490	13.8	960	11.2	730	5.4

NOTE: Details may not add to totals because of rounding.

Table 3. Employment impact of pollution control and abatement expenditures, direct and indirect, by occupational group

Occupational group	Total	Direct		Indirect	
		Number	Percent	Number	Percent
Total	33,530	15,860	100.0	17,670	100.0
Professional and technical	10,960	9,050	57.1	1,910	10.8
Engineers	2,600	2,180	13.8	420	2.4
Natural scientists	3,860	3,790	23.9	70	.4
Technicians	3,100	2,740	17.3	360	2.0
Other professional and technical, including medical	1,420	360	2.3	1,060	6.0
All other	22,570	6,810	43.0	15,770	89.2

NOTE: Details may not add to totals because of rounding.

ment expenditures primarily reflects the relatively greater importance of construction within pollution control and abatement expenditures. Table 5 shows the manpower requirements per million dollars of expenditures for selected programs and components of demand.

Federal pollution control and abatement expenditures, however, generate a relatively high proportion of professional and technical jobs. The 22 professional and technical jobs generated per million dollars of expenditures for pollution control and abatement activities is considerably greater than the number generated per million dollars of Federal nondefense (except NASA) expenditures. (See table 6.)

Table 4. Percent distribution, direct and indirect employment, by occupational group

Occupational group	Total number	Percent distribution		
		Total	Direct	Indirect
Total	33,530	100.0	47.3	52.7
Professional and technical	10,960	100.0	82.6	17.4
Engineers	2,600	100.0	83.9	16.2
Natural scientists	3,860	100.0	98.1	1.8
Technicians	3,100	100.0	88.4	11.6
Other professional and technical, including medical	1,420	100.0	25.4	74.6
All other	22,570	100.0	30.2	69.8

NOTE: Details may not add to totals because of rounding.

Table 5. Manpower requirements per million dollars of selected program expenditures 1972

Program	Expenditures
Total public	94.2
Defense	74.2
Nondefense	74.1
NASA	62.5
Nondefense excluding NASA	74.6
State and local government	106.0
New construction	59.9
Excluding structures	116.4
Total private	69.0
Personal consumption	70.3
Durable goods	71.2
Nondurable goods	76.6
Services	63.8
Gross private domestic fixed investment	67.6

SOURCE: Adapted from *Manpower Factbook*, table 1 (U.S. Department of Labor, Bureau of Labor Statistics, in press).

Table 6. Employment impact, per million dollars of expenditures for Federal nondefense (except NASA), and pollution control and abatement activities

Occupational group	Non-defense	Pollution control and abatement activities
Total	74.6	66.9
Professional and technical	15.9	21.9
Engineers	1.4	5.2
Natural scientists	1.1	7.7
Technicians	2.6	6.2
Other professional and technical, including medical workers	10.8	2.8
All other	58.7	45.0

NOTE: Detail may not add to totals because of rounding.

There were considerable differences in the impact of expenditures per million dollars for programs within pollution control and abatement. Radiation expenditures generated the highest number of jobs per million while construction generated the lowest as shown below.

	Total	*R&D*	*Abatement and control operations*	*Radiation*	*Waste water treatment plants*
Total	66.9	76.7	78.4	84.1	53.6

The manpower impacts associated with the four programs or activities studied – research and development, abatement and control operations, radiation related activities and construction of municipal water treatment facilities – are discussed in more detail below.

Research and development

The 102 million dollars of outlays for pollution control and abatement research and development supported 7,820 jobs. About 2,490 of these were in air pollution R&D, 3,130 in water pollution R&D and 2,200 in all other R&D, including solid waste, and pesticide. About 3,460 jobs were professional and technical, and approximately 800 were engineers, 1,540 were natural scientists, and 920 technicians. (See table 7.)

The largest number of engineering jobs were in civil-290, chemical-170, and mechanical-160. Within the natural sciences, 700 chemist and 400 biologists jobs were generated. The other engineering and science technician category generated the largest number of technicians-470. (Tables A-2 to A-16 provide additional detail.)

About 53 percent of the jobs were generated directly and 47 percent were generated indirectly (table 7). However, 89 percent of the professional and technical jobs were generated directly on the payrolls of organizations carrying out the research grants and contracts.

Shown below is the employment impact of R&D outlays attributable to each performer. The data includes both direct and indirect employment.

Total	7,820
Inhouse	3,680
Extramural	4,140
State and local government	1,110
Universities	1,800
Nonprofit organizations	370
Private industry	880

Appendix tables A-5 to A-16 show a more detailed distribution between direct and indirect employment, by performer.

For each million dollars spent on pollution control and abatement R&D, 76.7 jobs were generated (table 10), more than the number generated by each million dollars spent on the entire program (66.9). The total employment impact was fairly similar for inhouse operations and for extramural activities. In-house R&D programs generated 78.3 jobs per million dollars, while

Table 7. Employment impact of research and development outlays, direct and indirect, by occupational group

Occupational group	Total	Percent	Direct: Number	Direct: Percent of occupational group	Indirect: Number	Indirect: Percent of occupational group
Total	7,820	100	4,130	52.8	3,690	47.2
Professional and technical	3,460	44.2	3,090	89.3	370	10.7
Engineers	800	10.2	720	90.0	80	10.0
Natural scientists	1,540	19.7	1,520	98.7	20	1.3
Technicians	920	11.7	850	92.4	70	7.6
Other professional and technical, including medical	210	2.7	20	10.0	190	90.0
All other	4,350	55.8	1,040	23.9	3,320	76.1

NOTE: Detail may not add to totals because of rounding.

Table 8. Employment impact of research and development outlays, per million dollars, by performer and occupational group

	Total	Inhouse	Total extramural	State and local government	Universities	Nonprofit organizations	Private industry
Total	76.7	78.3	75.3	67.9	94.5	64.0	62.6
Professional and technical	33.9	34.9	33.0	17.5	57.3	31.2	20.0
Engineers	7.8	6.9	8.5	4.2	13.8	7.3	6.7
Natural scientists	15.1	16.7	13.8	5.8	26.1	13.3	6.2
Technicians	9.0	9.1	8.9	4.8	15.8	6.6	5.2
Other professional and technical, including medical	2.1	2.2	1.9	2.6	1.6	3.9	1.7
All other	43.0	43.5	42.4	50.5	37.2	32.7	42.7

NOTE: Detail may not add to totals because of rounding.

extramural R&D programs generated 75.3. However, some difference between extramural performers was evident. Grants and contracts to colleges and universities generated 94.6 jobs per million dollars, considerably more than those of any other performer.

The number of professional and technical jobs for inhouse and for extramural R&D also was similar – 34.9 for inhouse and 33.0 for extramural (See table 8.) Here also, the number differed considerably between extramural performers. In addition to generating the greatest number of jobs, grants and contracts to colleges and universities also generated roughly 2 or 3 times as many professional and technical jobs as grants and contracts to the other performers.

Sources and effects R&D generated 83.4 jobs per million dollars, while Control Technology R&D generated 70.1 jobs. (See table 9.) Although generating only about 12 percent more jobs per million dollars, sources and effects R&D generated twice as many professional and technical jobs.

Table 9. Employment impact of research and development outlays, per billion dollars, by sources and effects and control technology

Occupational group	Sources and effects	Control technology
Total	83.4	70.1
Professional and technical	47.1	23.9
Engineers	6.7	9.6
Natural Scientists	27.4	4.8
Technicians	10.9	7.6
Other professional and technical, including medical	2.1	1.6
All other	36.2	46.2

NOTE: Only pertains to extramural employment since data on in-house activities and were not available by type of program. Details may not add to totals because of rounding.

Abatement and control operations

The 45.2 million dollars of Federal abatement and control expenditures, all for in-house operations, generated 3,550 jobs. (See table 10.) About 1,670 were professional and technical, including 490 engineers, 580 scientists, and 490 technicians.

The largest number of engineering jobs generated were in civil engineering-340. Within natural sciences 310 chemist jobs were generated. About 210 jobs were generated for other engineering and science technicians; as well as 210 for other technicians. (Table A-17 contains greater occupational detail.)

About 65 percent of all jobs were generated directly at Federal agencies, and 35 percent were generated indirectly. However, 90 percent of the professional and technical jobs were generated directly.

As shown, abatement and control operations generated 78.4 jobs, roughly the same as the number of jobs generated per million dollars of R&D:

Total	78.4
Professional and technical	36.9
Engineers	10.8
Natural scientists	12.9
Technicians	10.7
Other professional and technical, including medical	2.4
All other	41.6

Radiation programs

Data on the impact of Federal outlays for radiation pollution control and abatement include both R&D and abatement and control operations. Impact data for radiation programs were developed separately in this study for reasons explained earlier in this chapter. R&D

Table 10. Employment impact of abatement and control operations expenditures, direct and indirect, by occupational groups

Occupational group	Total		Direct		Indirect	
	Number	Percent distribution	Number	Percent distribution	Actual	Percent distribution
Total	3,550	100.0	2,300	100.0	1,250	100.0
Professional and technical	1,660	46.8	1,500	65.2	160	12.8
Engineers	490	13.8	470	20.4	20	1.6
Natural scientists	590	16.3	580	25.2	10	0.8
Technicians	490	13.8	460	20.0	30	2.4
Other professional and technical including medical	110	3.1	–	–	110	8.8
All other	1,890	53.2	800	34.8	1,090	87.2

NOTE: Detail may not add to totals because of rounding.

was performed at Government owned-contractor operated (GOCO) laboratories, at universities, non-profit organizations and private firms, as well as at Atomic Energy Commission (AEC), and Environmental Protection Agency (EPA) laboratories. Most abatement and control operations were performed inhouse, by AEC and EPA.

Outlays for radiation pollution in FY 1970 totalled 102.4 million dollars and generated approximately 8,610 jobs. (See table 11.) About 3,860 were professional and technical, including 710 engineers, 1,710 natural scientists, and 960 technicians. The largest number of engineering jobs generated were in the category other engineers-410, mostly nuclear. Within the natural sciences, 480 biologist, 460 physicist, and 340 chemist jobs were generated. The other engineering and science technicians category generated the largest number of technicians jobs–500. (Table A-18 provides greater occupational detail.)

On a per million dollar basis the radiation program generated 84.1 jobs, the highest of any program in the study:

Total	84.1
Professional and technical	37.7
Engineers	6.9
Natural scientists	16.7
Technicians	9.4
Other professional and technical, including medical	4.7
All other	46.4

Grants for construction of municipal waste water treatment facilities

Grants to State and local governments for construction of waste water treatment facilities amounted to $252.7 million, supporting 13,540 jobs. (See table 12.) About 2,040 were professional and technical including 610 engineers, 30 natural scientists, and 700 technicians. The largest number of engineering jobs generated were in civil-400. Draftsmen (330) and other engineering and science technicians were the technician categories with the most jobs generated. These expenditures generated the lowest proportion of professional and technical jobs of any program in this study.

Table 11. Employment impact of radiation program outlays, direct and indirect, by occupational group

Occupational group	Total		Direct		Indirect	
	Total	Percent distribution	Number	Percent distribution	Number	Percent distribution
Total	8,610	100.0	4,710	100.0	3,900	100.0
Professional and technical	3,860	44.8	3,420	72.6	440	11.3
Engineers	700	8.1	610	13.0	90	2.3
Natural scientists	1,710	19.9	1,690	35.9	20	0.5
Technicians	960	11.1	900	19.1	60	1.5
Other professional and technical, including medical	480	5.5	220	4.7	260	6.7
All other	4,740	55.1	1,290	27.4	3,460	88.7

NOTE: Detail may not add to totals because of rounding.

Table 12. Employment impact of grants for waste water treatment facilities, by occupational group

Occupational group	Total		Direct		Indirect	
	Number	Percent distribution	Number	Percent distribution	Number	Percent distribution
Total	13,550	100.0	4,730	100.0	8,820	100.0
Professional and technical	1,970	14.5	1,040	22.0	930	10.5
Engineers	610	4.5	380	8.0	230	2.6
Natural scientists	30	.2	—	—	30	0.3
Technicians	730	5.4	530	11.2	200	2.3
Other professional and technical, including medical	560	4.1	100	2.1	460	5.2
All other	11,580	85.5	3,690	78.0	7,890	89.5

NOTE: Detail may not add to totals because of rounding.

About a third of the jobs were generated directly, and two-thirds were generated indirectly, the opposite of other programs, where most jobs were generated directly. Slightly more than half of the professional and technical jobs were generated directly and slightly less were generated indirectly. On a per million dollar basis, the municipal waste water treatment program generated 53.6 jobs, also the lowest of any program within the scope of this study:

Total	53.6
Professional and technical	7.8
Engineers	2.4
Natural scientists	.1
Technicians	2.9
Other professional and technical, including medical	2.2
All other	45.8

The construction program involved both design services by engineering design firms and on-site construction by construction contractors. As would be expected, funds to design engineering firms generated a relatively high proportion of professional and technical jobs, particularly engineers and technicians, while on-site construction generated a relatively low proportion. Since most of the funds were for on site construction, the total more closely resembled the onsite construction pattern, with its low proportion of professional and technical jobs.

Separate occupational impact data for engineering design and for onsite construction are shown in tables A-19 to A-21.

Chapter II. Illustrative Projections: Manpower Implications of 1980 Federal Pollution Control and Abatement Expenditures

Pollution-energy interactions: Some caveats

Projections of Federal pollution control and abatement expenditures are difficult under the best of circumstances. Besides the obvious problems associated with estimating long term Federal priorities, and the relative lack of good historical data and relationships, the emergence of the "energy crisis" raises questions concerning possible trade offs between environmental concerns and energy concerns.

Frequently, trade offs may be called for because of cost considerations rather than purely technological limitations. For example, pollution control devices on automobiles—needed to meet Federal standards – have resulted in automobiles delivering less miles per gallon of gasoline. With increasing cost of gasoline, public opinion may view automotive pollution control standards as "luxuries" which cannot be afforded.

Many of the interfaces between Federal pollution expenditures and the energy crisis surface in questions relating to air pollution control and abatement. However, the bulk of Federal funds for pollution control and abatement activities are in the water pollution field. In 1972, for example, about 62 percent, $1.2 billion, of the $1.9 billion of Federal funds for pollution control and abatement activities were for water pollution control and abatement activities.[1] In addition, most of the monies for water pollution activities are in the form of grants to State and local governments for the construction of waste water treatment facilities.

The bulk of Federal funds for pollution control and abatement other than for the construction of waste treatment facilities are for research and development. In 1972, Federal R&D expenditures for air pollution control and abatement constituted 39 percent[2] of total R&D for all forms of pollution control and abatement. The interface between air pollution and the energy crisis makes any projections of Federal funds for pollution control and abatement research and development extremely tentative.

Another problem in projecting Federal R&D funds for pollution control and abatement concerns the labeling or re-labeling of Federal R&D funds. At one time, for example, R&D funds concerned with the problems of burning coal cleanly could be labeled pollution control research and at another time labeled energy research. How particular R&D funds are labeled depends to some extent on what is "popular" at a given time, and to some extent on the particular set of instructions and definitions used to report R&D expenditures.

Historic trends

Pollution control became a national issue in the late 1960's. Prior to that time, personal and local concerns with pollution problems existed, and ecologists periodically issued warnings of damage to the environment. Gradually, however, public dissatisfaction increased as it became evident that bad air, foul water, noise, undetermined effects of radiation, the overuse of pesticides, and solid waste—singly and in their cumulative effects—posed dangers to health and well being. The pollution issue emerged on the national scene with the public realization that pollution was not something that could be solved locally with piecemeal adjustments. The Federal Government, thus, came to be regarded as the primary source of funds and standards.

Factors which increased popular awareness of the pollution problem included the increasing urbanization of the population with the resultant concentration of pollution; rising standards of living resulting in increasing per capita waste; and scientific and medical findings which emphasized previously unknown dangers from pollution.

In response to this new national priority, the Environmental Protection Agency (EPA) was created in 1970 and charged with the mission of protecting and enhancing the environment. The creation of EPA resulted in the removal of a number of units previously concerned with some aspect of pollution control from existing Federal agencies and their consolidation into a single agency. Prior to the creation of EPA, pollution control activities of the Federal Government, and their associated dollars, were often buried in agency totals or

Table 13. Federal pollution control and abatement outlays in 1970

(In millions of dollars)

Component	Types of pollution							
	Total	Air	Water	Solid waste	Pesticides	Radiation	Noise	Other
Total	754.4	115.2	249.5	19.9	21.6	123.3	0.3	124.6
Financial assistance to State and local governments	287.5	20.5	258.7	–	–	1.6	–	6.7
Research, development and demonstration	294.0	57.0	50.3	16.1	18.4	94.0	.2	62.0
Abatement and control operations	73.6	11.9	26.2	1.7	1.5	23.7	–	8.6
Other	95.3	25.8	14.3	2.1	1.7	4.0	.1	47.3

SOURCE: Based on unpublished data from the Office of Management and Budget (OMB). Totals shown are slightly different from those published by OMB and from time series data on expenditures shown in this report. These data reflect minor adjustments made by Bureau staff to reconcile OMB and agency data.

classified on some other functional basis. Thus, for purposes of developing projections, statistics relating to Federal pollution control and abatement expenditures are not available prior to 1970.

Table 13 shows Federal pollution control and abatement outlays for 1970 distributed by programs and types of pollution. Table 14 shows Federal pollution control and abatement expenditure for the period 1970 to 1974.

Federal pollution control and abatement outlays over the 1970-74 period, showed large gains, with estimated 1974 outlays almost 4 times greater than 1970 outlays. Although these expenditures have grown rapidly, they still constitute a small proportion of total Federal expenditures – about 1 percent in 1974.

Federal R&D expenditures for pollution control and abatement also constitute a relatively small proportion of total Federal R&D funds. (See table 15.) As a proportion of total Federal R&D funds, those for pollution control and abatement have increased from almost 2 percent in 1970 to an estimated 3 percent for fiscal 1973.

The increasing relative importance of Federal expenditures for pollution control and abatement are part of a general shift of Federal expenditures from defense to nondefense related activities. (See table 16.) Along with a relative decline in defense expenditures, there have been relative declines in the share of Federal dollars for space exploration and related activities after a rapid build-up in the early 1960's. The "human resource" area has shown the greatest gains, due in large part to increasing transfer payments such as social security.

Table 14. Federal pollution control and abatement expenditures, 1970-74

(In millions of dollars)

Item	1970[1]	1971[1]	1972[1]	1973[1]	1974[2]
Budget authority	$1,432	$1,823	$3,196	$8,334	$1,554
Outlays	751	1,149	1,314	1,917	3,111

[1] = actual.
[2] = estimated.

SOURCE: *The Budget of the United States, Fiscal Year 1974, Special Analyses*, Special Analysis "Q", "Federal Environmental Programs."

Future trends in pollution control outlays

Present Federal legislation could significantly increase pollution control efforts in virtually all areas. Increasingly stringent clean air and water standards call for greater pollution control and abatement expenditures throughout the economy.

In addition to present legislation, there are many other factors that could affect Federal expenditures for pollution control and abatement. A waning of public enthusiasm or a shift in priorities to other areas could reduce Federal expenditures in this area. On the other hand, increased levels of Federal expenditures for pollution control and abatement could result from developments such as the discovery of previously unknown danger from certain kinds of pollutants.

The Water Pollution Control Act Amendments of 1972 require industries to use the "best practicable" technology to control pollution. Municipalities are to have secondary waste treatment capabilities by July 1, 1977. By July 1, 1983, municipalities and industries are to use the "best available technology economically achievable" to treat waste water, and by 1985 the goal is to eliminate all water pollution. To help meet this goal, the Act appropriates $18 billion for grants to State and local governments for construction of waste treatment facilities. In addition, $6.6 billion is authorized for water

Table 15. Federal pollution control R&D expenditures related to Federal R&D expenditures and total Federal purchases

(In millions of 1970 dollars)

Year	Federal purchases (GNP component)	Federal R&D expenditures		Federal pollution control R&D expenditures	
		Outlays	Percent of Federal purchases	Outlays	Percent of Federal R&D expenditures
1970	$96,500	$15,159	15.7	$296	1.95
1971	90,700	14,193	15.6	339	2.38
1972	91,900	13.895	15.1	350	2.52
1973	94,400	14,396	15.2	436	3.04

SOURCE: Executive Office of The President, Office of Management and Budget, and National Science Foundation.

pollution research, development, and demonstration projects, as well as other activities such as manpower training.

The Clean Air Act Amendments of 1970 are similar to the Water Pollution Act in that they set stringent air quality standards. Although the Act calls for significant increases in research and development, standard setting, and enforcement expenditures, Federal expenditures for air pollution control and abatement will not be as great as for water because of the absence of large construction grants. In addition, a significant portion of the R&D needed for air pollution control, such as the control of automobile emissions, will be financed by private industry. Many other legislative items and agency appropriations provide for expenditures on noise, pesticides, and radiation pollution control and abatement.

Illustrative projections of Federal pollution control expenditures

Since grants to State and local governments for construction of waste water treatment plants and lines, and research and development activities constitute the bulk of Federal expenditures for pollution control and abatement activities, only these two expenditure items were projected to illustrate possible manpower implications.

The actual and projected expenditure data shown below pertain only to Federal expenditures and do not reflect additional spending called for or resulting from the Federal expenditures. For example, Federal support for sewer plant construction amounts to about 75 percent of total costs, with the remainder coming from State and local agencies.

The major item of Federal pollution control expenditures now and in the future probably will be grants to States and localities for sewer plant and lines construction. Water pollution control acts prior to 1972 provided significant support to localities for sewer construction and the Federal Water Pollution Control Act Amendments of 1972 will control the amount of involvement and the level of expenditures of the Federal Government in water pollution control construction through the 1970's. This Act raises the level of Federal support to 75 percent of new State and local sewer plant and lines construction expenditures and appropriates $18 billion for this purpose. The bill provides that those funds be appropriated for fiscal years 1973-75.

Table 17 shows actual and projected levels of Federal financial aid to State and local governments, 1970 to 1980. The major portion of these funds are for the construction of sewage plants and lines, but also included are relatively small expenditures for support to State and local administrative efforts in setting standards and other minor aid programs.

The path of the expenditures shown in table 17 assumes that the $18 billion called for in the legislation (Clean Water Act Amendments of 1972) will be "spread out" over a number of years rather than expended by

Table 16. Percent distribution of Federal budget outlays by function, selected years

Function	1955	1960	1965	1970	1974	1975
Total	100.0	100.0	100.0	100.0	100.0	100.0
National defense	58.7	49.8	41.9	40.8	30.2	29.7
Human resources	21.1	27.6	29.9	37.0	46.7	46.8
Physical resources	8.3	10.9	12.3	10.7	9.6	10.1
Interest	8.8	9.0	8.7	9.3	9.2	8.8
Other	3.1	2.7	7.2	2.2	4.3	4.6

SOURCE: The Budget of the United States, Fiscal Year 1974.

Table 17. Federal financial assistance to State and local governments for pollution control, 1970-80

(In millions of 1970 dollars)

Year	Outlays
1970[1]	$ 288
1971[1]	516
1972[1]	433
1973[2]	738
1974[3]	1,724
1975[3]	1,915
1976[3]	2,151
1977[3]	2,600
1978[3]	3,087
1979[3]	3,718
1980[3]	4,426

[1] = Actual.
[2] = Estimated.
[3] = Projected.

SOURCE: 1970-73 actual and estimated, Office of Management and Budget. 1974-80 projected, Bureau of Labor Statistics.

Table 18. Federal pollution control R&D expenditures, 1970-74 and projected 1975-80

(In millions of 1970 dollars)

Year	Total
1970[1]	$296
1971[1]	341
1972[1]	356
1973[2]	444
1974[2]	522
1975[3]	546
1976[3]	571
1977[3]	598
1978[3]	625
1979[3]	654
1980[3]	685

[1] = Actual.
[2] = Estimated.
[3] = Projected.

SOURCE: 1970-74 actual and estimated, Office of Management and Budget. 1975-80 projected, Bureau of Labor Statistics.

the mid-1970's as called for in the legislation. This path is more in line with administration goals in 1973 and was developed by the Bureau of Labor Statistics in a special study for the Environmental Protection Agency.[3]

A pattern of steadily increasing expenditures, from $1.7 billion in 1974 to $4.4 billion in 1980 is shown in table 17. This pattern seems more likely to reflect what will actually occur for several reasons. (1) The legislation calls for obligation of the grants now and in the near future. However, the actual expenditures will occur as the construction progresses. Therefore, as more and more projects are approved and begin construction, the outlays will increase since most projects approved earlier will still be under construction into the late 1970's, and (2), attempting to accomplish the level of construction provided for in the bill in a few years might be difficult because of manpower and construction industry capacity constraints.

Another major component of Federal pollution control expenditures is support for pollution control research and development. Table 18 indicates actual, estimated, and projected Federal pollution control R&D spending, 1970 to 1980. Pollution control R&D has risen rapidly in the last few years, from $296 million in fiscal year 1970 to an estimated $522 million in fiscal year 1974. Much of this rapid rise has been for research into pollution sources and effects, and for standards setting. Since much of this research has been completed, R&D expenditures will rise less rapidly in the future. Also, the decision was made in 1973 to shift emphasis to a reliance on the capabilities of the private sector to meet the technology requirements of a more intensive enforcement program.

Attempting to project pollution control R&D from legislation is difficult because of the many sources of funds and the many agencies that expend the funds. There is also the problem of labeling – funds spent on development of clean energy sources, for example, also are partially pollution control R&D. In the absence of any other clear indications of the pattern of Federal pollution control R&D expenditures, outlays were assumed, for illustrative purposes only, to increase at the same rate as the projected increases in GNP implied in the Bureau's Economic model for 1980. However, as pointed out (in chapter III), only $102 million of the $296 million of pollution control R&D funds fell within the scope of R&D for this study (another $78 million of the $296 million was radiation R&D, which was considered separately). If this same relationship were assumed for 1980, the comparable amount would be $236 million.

Illustrative manpower requirements

Assuming Federal outlays of $4,426 million for construction of municipal waste treatment facilities, and $236.7 million for research and development projects for 1980, manpower requirements would total 179,000 for the construction program and about 14,100 for the R&D program. (See table 19.)

The research and development projects would generate requirements for 6,260 professional and technical jobs, while the construction program would generate requirements for 26,030 professional and technical jobs.

These projected 1980 requirements attributable to the selected pollution control and abatement programs

Table 19. Projected employment requirements for selected Federal pollution control and abatement activities, by selected occupations, 1980

Selected occupation	Research and development	Waste water treatment plant construction
Total	14,140	179,510
Professional and technical	6,260	26,030
Engineers	1,440	8,080
Natural scientists	2,790	360
Technicians	1,654	9,690

represent only a small part of the professional and technical manpower requirements projected for the total economy. The R&D program represents about 0.04 percent and the construction program about 0.10 percent of total professional and technical manpower requirements for 1980.

The projected 1980 requirements for scientists and engineers attributable to the selected pollution control and abatement programs represents a larger proportion of the scientist and engineer requirements projected for the total economy than do requirements for all professional and technical manpower combined. Although larger, these programs would still have a relatively insignificant impact on total requirements for scientists and engineers. The approximately 9,500 engineers projected to be required for pollution control and abatement activities in 1980 only represent about 0.7 percent of the estimated requirements for engineers in the total economy.

Openings for engineers in the total economy resulting from both growth in requirements and the need to replace those who die, retire, or leave the labor force for other reasons are projected to average about 57,000 per year through the 1970's. Assuming that engineers in pollution control and abatement activities have death and labor force separation rates similar to those for all engineers, openings for engineers in pollution control and abatement activities would average about 850 per year through the 1970's, or about 1.5 percent of total openings.

Requirements for scientists show a pattern similar to that for engineers. Thus, requirements for scientists in pollution control and abatement activities in 1980 total about 2,800, compared to requirements of 650,000 for the total economy. Through the 1970's, openings for scientists in the economy are expected to average about 30,000 per year. In the pollution control and abatement field, openings are projected to average 200 per year, or 0.6 percent of the total openings for scientists.

The 1980 employment requirements have been adjusted for productivity increases – 2.5 percent per year in R&D and 1.5 percent per year in waste water treatment plant construction. The projected requirements are based on an assumption that the "mix" of projects within R&D will be the same in 1980 as it was in 1970, and that engineering design costs will represent the same percent of construction costs. The occupational distribution, which depends on the patterns for individual projects and industries, as well as on the "mix", is also assumed to be the same as in 1970.

–FOOTNOTES–

[1] *Special Analysis, Budget of the U.S. Government*, Fiscal Year 1974, p. 274 (Office of Management and Budget), 1973.

[2] *Environmental Quality–The Fourth Annual Report of the Council on Environmental Quality* (The Council on Environmental Quality), 1973.

[3] *Manpower Implications of Alternative Levels of Sewer Works Construction* (U.S. Department of Labor, Bureau of Labor Statistics, 1973), Unpublished.

Chapter III. Hiring Standards and Skill Transferability

In sample interviews of employers in the pollution control field information was obtained on hiring standards, skill transferability, and any barriers to hiring scientific and technical manpower with aerospace or defense experience, or both.

Purpose and scope of survey

At the time this study was conducted, unemployment among professional and technical workers with defense-oriented experience focused attention on the question of how much and what kind of retraining would be required to qualify them for employment in other fields.

To help focus on this and related concerns, a series of questions were raised during the course of the interviews underlying this study. (See interview guide in appendix B.)

Although specifically concerned with the transferability of ex-aerospace-defense workers into the pollution control field, the study has served as a vehicle for investigating basic questions on the relationship of academic qualifications and work experience for engineers, scientists, and technicians. (EST occupations.) Whether, and to what extent, specialization is a hindrance to job transfer was an important part of the discussions with respondents. These questions and the problems they raise are prevalent wherever modern technology is used. While the answers received were keyed to pollution control activities, they are indicative of a wide area of responses from government, industry, and universities.

For analytical purposes, responses were initially classified by (1) performer, (2) program, and (3) media or area of pollution—air, water, radiation, pesticides, and solid waste. However, a preliminary analysis of the data suggested that responses should be classified by performer. (See table 20.) Apart from the fact that certain programs are dominantly identified with certain performers (for example, construction is exclusively private industry, abatement and control is almost entirely Federal inhouse, and the greater part of R&D sources and effects is performed by universities), there were certain basic similarities in occupational and hiring patterns found among similar performers regardless of the program or media or area of pollution. As a generalization, the differences between categories of performers researching in the same media or a related field usually exceed their similarities. Conversely, the similarities between performers of the same category exceed whatever differences may be imposed by working with different media and in different programs.

Sample observations covered almost 3,000 EST employees of whom approximately 33 percent were engineers, 39 percent scientists, and 28 percent technicians. Of these, private industry employed the bulk of the engineers, because of its emphasis on construction and design programs, while universities and nonprofit institutions were more research-oriented and employed a large percent of scientists. (See table 21.)

The R&D sources and effects program (in which most of the university work fell) deals exclusively with research projects and employed 90 percent of the scientists and 64 percent of all EST's covered in the

Table 20. Distribution of respondents and engineer, scientist, and technician employment covered in sample, by performer category

(In percent)

Performer category	Number of respondents	Number of EST positions reported
Total number	81	2,870
Percent	100	100
State and local governments	17	5
Universities	32	31
Nonprofit institutions	9	7
Private industry	40	50
Federal in-house[1]	2	7

[1] The 2 respondents reported for Federal inhouse refer to field interviews of regional Federal facilities engaged in abatement and control operations. Their inclusion is somewhat accidental since it was not the intention to collect in-house employment data in such interviews, only regional response to skill transferability questions. In-house employment and cost data had been obtained on a universe basis, covering both headquarters and field offices, from each sponsoring agency. However, because two of the interviews for this program did provide detailed staff breakdowns to support statements on training and work experience requirements, these have been included to give a broader base to the tabulations with the representation of Federal inhouse.

Table 21. Engineer, scientist, and technician positions covered in sample, distributed by occupational group and performer category of respondent

Performer category	Number of respondents	Number of EST positions reported			
		Total	Engineers	Scientists	Technicians
Total	81	2,870	934	1,108	828
State and local governments	14	134	53	30	51
Universities	26	872	66	550	256
Nonprofit institutions	7	209	29	71	109
Private industry	32	1,434	680	397	357
Federal inhouse[1]	2	221	106	60	55

[1] See footnote, table 20.

sample. In contrast, construction design and building programs together employed roughly 20 percent of the engineers and 23 percent of the technicians, but only one-tenth of 1 percent of the scientists. These construction programs employed 13 percent of all EST employees covered in the sample and were represented under a single performer category—private industry.

Hiring standards

Universities and nonprofit institutions had stringent criteria for prospective employees, and many universities hire professionals only as faculty members, a status which usually requires a Ph. D. degree. Universities, and nonprofit institutions aligned with universities, have a ready source of employment candidates in their graduate schools and seek to widen the education of the graduates with actual work experience in their specialty to supplement the classroom.

Most employers require that engineers have a basic engineering degree, although in some specialized engineering occupations, a master's degree or even a doctorate may be required. An advanced degree in engineering appeared to be a prerequisite for employment by some of the nonprofit institutions (notably in openings as program chiefs with administrative responsibilities). In a few selected cases involving the on-site construction of waste water treatment facilities, there were no firm academic requirements for an engineering position. These employers appeared reluctant to hire overqualified people for positions which they felt did not demand their specialized skills.

Educational standards for technicians were broadly based, depending on the particular job and, to some extent, the category of the employer. The fact that universities had the highest overall level of educational requirements may be due to the extensive science training needed for their research.

For computer technicians and others, formal training is a requirement in most employment areas. The specialized knowledge expected of many engineering and science technicians necessitates an educational background beyond a high school diploma. However, some technicians are hired without stringent educational requirements where the nature of their job is relatively uncomplicated and requires basically manual skills. Examples of this practice occurred in some radiation labs concerned with the care and testing of animals' reactions to radiation. Here, employers were more concerned with the attitude, personality, and experience of their technicians. State and local governments and private industry involved in water pollution control activity likewise expressed their desire to hire technicians who were dedicated to this type of work.

Work experience requirements

Requirements for work experience were closely aligned to educational background and to a limited extent interchangeable. For example, many respondents in private industry would accept a combination of education plus work experience to substitute for a higher degree, and for certain engineering jobs work experience was an essential prerequisite for employment. Many firms look for specific experience in such areas as combustion and work with radiants, and allow more flexibility in educational requirements for persons with the desired experience. A period of from 2 to 5 years' work experience was common in the survey, although a few employers demanded up to 10 years of specialized experience in engineering.

It is difficult to stipulate work experience requirements for scientists when dealing with Ph. D.'s who have been involved in one field for much of their professional lives. Some pollution projects do call for very specific skills requiring an experienced individual in a particular area: exceptional weight may then be put on experience in selecting candidates.

Technicians generally are required to fill educational requirements and also have job experience. For them practical experience may in some cases substitute for formal education, but the reverse holds true where the performer is a university. Here the experience requirements may be dropped if the applicant has the necessary skills plus a good educational background.

In assessing their past experience in matching qualifications to job vacancies, more than half (63 percent) of the respondents expressed no difficulty in hiring EST's. (See table 22.) Many respondents alluded to the situation in recent times as a "buyer's market" in which there existed a surplus of talented people looking for positions. Some employers foresaw a tightening in supply of qualified personnel, but felt that the prestige of their institutions enabled them to choose from the "cream of the crop," although they expressed the opinion that other employers might encounter difficulty.

Less than one-third of the employers reported any difficulty in filling specialized jobs. In private industry, these employers reported shortages of environmental researchers; sanitary, civil, and mechanical engineers; design engineers and drafters; and, in air pollution projects, applicants with experience in combustion. In the university sector, shortages also were noted of qualified applicants with combustion experience, as well as pathologists, biological scientists, environmentalists, foresters with mathematical skills, and lab technicians.

Of the remaining respondents, some had developed a "calculated risk approach" in which they combined training with selected prior experience to develop qualified applicants. Others showed a "no compromise approach" in maintaining rigid requirements for employees. And, finally, some only accepted contracts for which the work qualifications complemented those available in their present staff. The "no compromise approach" was conspicuous among nonprofit institutions and embodied the philosophy that, "We sit and wait and do without rather than hire (the academically unqualified)."

Lack of experience was cited as the principal drawback by those employers who had trouble in finding qualified engineers. But there were other deterrents to hiring, peculiar to individual respondents. Some researchers engaged in field assignments for pollution studies cited the location of the work as a hindrance. In radiation studies, the danger of work with radioisotopes was cited as a problem in hiring professionals, especially women. Some respondents detected a marked reluctance on the part of some qualified people to work for universities, institutions, or industries which were closely associated with defense projects and bore the "stigma of weaponry."

Of all performers, construction design firms in private industry apparently had the most difficulty in filling

Table 22. Respondents' assessment of hiring experiences for professional and specialized job openings

Degree of difficulty experienced	Percent of respondents
No difficulty	63
Some difficulty in highly specialized jobs—	29
Have adopted a calculated risk approach—willing to accept or try substitute combinations of training and experience	2
Have had to adopt a no-compromise approach because of rigid requirements	2
Seek and accept only work (projects) which fit skill capabilities of present staff	4

their staffing requirements. Adequately trained designer drafters were at a premium with many of these firms, and others had perceived shortages in design, hydraulic, and pollution control engineers. State and local governments competing for pollution control grants reported problems in finding sufficiently trained minority workers to fill quotas and, in some cases, had been forced to reduce their normal standards. Many respondents bemoaned the general lack of training funds. Lack of funds was also cited as the principal reason by many respondents for not being able to expand their existing staffs. State and local governments listed low pay scales as hindrances to drawing better qualified people into pollution control occupations.

Staffing patterns and current labor market conditions

Respondents were asked—in the context of today's (1972-73) labor market situation—what changes, if any, they would make in their staffing patterns in work done in the past year or two. At least four possible categories of revisions were anticipated prior to conducting the interviews:

1. Different combinations of scientific and engineering manpower. For example, substituting chemists where physicists had been employed, or mathematicians for engineers.
2. Increases or decreases in the number of scientific and technical personnel.
3. Changes in the proportion of technicians relative to scientists or engineers.
4. Substituting professional and technical staff for capital investments, or vice versa.

Respondents generally had difficulty discussing this area, either because retrospective program planning had not been previously conducted, or, if it had, there was a reluctance to suggest that the way the project was staffed in the past was incorrect. Thus, of those who replied, 80 percent would have made *no* changes in staffing pattern. Of the remaining 20 percent who would have made changes, the majority would have increased the number of engineers, technicians, and scientists in that order.

Respondents were also asked if they were considering any deliberate upward revision of the qualifications of their scientific and technical staffs in light of the reported availability of highly educated manpower. "Revision" was not understood in the negative sense of automatically upgrading educational requirements, but as a positive and deliberate move to reverse whatever dilution of skills might have occurred as a matter of necessity during past periods of skill shortages.[1]

Two-thirds of the respondents replied negatively, or did not offer any opinion, on possible upgrading of their existing staff. Of the remainder, a selected few stressed raising minimum educational qualifications. The private industry respondents wanted higher standards for engineers, while universities sought the same for scientists. Little or no attention was given to increasing the ratio of technical support to scientists or engineers, but other changes specifically mentioned included: Need for instrumentation experience for engineers; need for project and plant operation managers, and need for reorganization of staff assignments.

Skill transferability—defense and aerospace to pollution control

All respondents were asked to help pinpoint areas of possible skill transferability in engineering, scientific, and technical occupations between aerospace and defense industries and their own work in the pollution control field. At the time the interviews were conducted—mid 1972—this was a particular point of interest since many in engineering, scientific, and technical occupations recently had been laid off by aerospace and defense firms, and unemployment rates were relatively high for these workers. Similarities and dissimilarities or actual barriers were considered under four major headings: (a) academic qualifications, (b) work experience, (c) retraining possibilities, and (d) economic, social, and other barriers.

While all respondents cooperated in this exercise, almost half (45 percent) reported that they had not been approached for employment by any ex-aerospace or defense industry personnel. Their comments were, therefore, based on judgment and personal opinion only. It should be noted in this connection that the sample had not been specifically designed to elicit a high response from employers who had employed, or at least had received a substantial number of applications from, ex-aerospace and defense industry employees. As a result, many of the respondents, in the Middle West and in the South particularly, were insulated by distance from the job-hunting which pervaded the West Coast and parts of the East Coast. While their opinions and, in some cases, their prejudices, might have been changed in the process of interviewing and evaluating specific job applicants, the overriding consideration was that they were, or spoke for, employers in the specific areas and programs under investigation.

Nonprofit organizations found similarity and transferability of academic training among mechanical, aerospace, electrical, chemical, and combustion engineers. A science degree also was useful, especially in physics and chemistry.

Inhouse programs, as reported by EPA regional offices, looked for staff with an engineering background, and especially civil and mechanical engineers. Administrative skills in manpower planning also were an asset.

Finally, private industry employers in the sample reported the academic qualifications for mechanical, electrical, and civil engineers with water management training, as those most in demand in the pollution control field. Next in order of preference were construction, aeronautical, and instrumentation engineers. Other engineering fields with similarities in academic qualifications, also in demand, were: Architectural, electronic, chemical, industrial, and process and control engineering, as well as skills in radiation, stress analysis, thermodynamics, and systems and project management. In the science field, chemists and mathematicians were occupations cited most where there was an identity in background training (for pollution control work). For technicians, similarities and carryover in training existed for design draftsmen, computer technicians, programers, and those knowledgeable in particle technology.

Academic qualifications and work experience. Concerning the similarity or equivalence of the academic qualifications of their own staff and of personnel most commonly employed in aerospace/defense industries, some respondents found no similarity; others felt that while their particular project was totally dissimilar to aerospace work, a particularly gifted individual might make the transition; one respondent felt sure there must be some similarity but just could not think of any.

State and local government respondents found greater similarity and transferability among the less specialized occupations, notably, civil and mechanical engineers. Systems and computer technical skills also were found transferable as well as any skills in interviewing other technically qualified persons.

Universities listed a variety of engineering backgrounds as common to, or transferable to, pollution control work, namely: Combustion; electronic, civil, chemical, electrical, and mechanical engineering. System analysis also were considered transferable. Among the science professions, the transferability of academic training was high for: Biologists, physical chemists, life scientists and mathematicians, and, to a lesser degree, for physiologists, statisticians, physicists, and those experienced in instrumentation and air-flow inhalation chambers. Among easily acclimated technicians were: Labor technicians, computer personnel, technical editors, and persons experienced in radar and infra-red technology.

In their totality, the responses indicated a decided majority (58 percent) supporting the view that there was some skill carryover for scientific and technical occupations. (See table 23.) Nonprofit institutions showed a higher proportion of "considerable" carryover skill ratings and State and local governments were at the other extreme with the highest proportion of "none" or "negligible."

Retraining possibilities. Where the skill carryover from jobs in aerospace and defense-industries to pollution control is negligible, can retraining bridge the gap? This was an obvious question even before knowing that a considerable minority (42 percent) of EST occupations covered in the sample were rated in this "none" or "negligible" skill carryover category. Considering all EST occupations together,[2] and tabulating responses for all respondents, the results showed:

60 percent felt retraining was possible.
15 percent felt retraining was feasible but costly.
18 percent felt retraining was difficult and ill-advised.
7 percent felt retraining was not possible.

And, where it is possible, how different is such "retraining" from that normally given to college graduates entering the labor market for the first time, with the same academic qualifications but without the work experience of the aerospace-defense-industry applicant? A plurality (47 percent) of the responses indicated the same level for "retraining" and "job-entry training" for new graduates, but the remainder were divided between two extremes of much (23 percent) and little (30 percent) retraining required, and there was great divergence on the issue of retraining itself. Some did not have the funds or the time for retraining, or cited special difficulties in retraining aerospace and defense personnel; in contrast, a few saw no retraining needed at all

Table 23. Responses to extent of possible skill carryover in engineer, scientist, and technician occupations in pollution control from aerospace-defense employment

Estimated extent of possible skill carryover	Percent of total responses[1]
Total:[1] Number	198
Percent	100
None	14
Negligible	28
Some	41
Considerable	17

[1] Responses refer to estimates for the individual EST occupations, not to respondents as the employer-establishments. Conceivably, a single respondent could provide three responses, one each for engineers, scientists and technicians, and all different. Some did, and some did not reply at all. The distribution of responses by performer in their totality only is shown below:

	Percent
Total	100
State and local governments	18
Universities	31
Nonprofit institutions	11
Private industry	35
Federal	5

Table 24. Kinds of barriers cited as deterrent to hiring ex-aerospace-defense personnel and relative importance as a percent of total responses

Barrier characteristics	Percent of total responses[1]
Total responses:	
Number	160
Percent	100
Labor market supply:	
No shortages—other recruits available	16
Economic costs:	
Higher wages expected	26
Entry at higher grade levels	2
Costs of retraining	5
Skill deficiencies:	
Dated technology (age gap)	4
Retraining an abbreviated substitute	4
Experience factor:	
Not cost-conscious	4
Not competitive market-minded	1
Psychological factors:	
Disappointment over wage cut	6
Age-adjustment problem	4
Domestic and social problems in area move	1
Other, n.e.c.[2]	27

[1] Response was a count of each barrier cited by a respondent, so that it was possible for a single respondent to account for several responses. Moreover, almost one-fifth of the respondents sampled either did not answer this question or did not cite any specific barriers.

[2] This was an unstructured question in which the respondent formulated the barrier himself, rather than checked what was given him. As a result there was great variety in the responses and only the most repetitive could be isolated and tabulated above.

and reported large numbers of ex-aerospace-defense workers already on their staff.

Economic, social, and other barriers. The most common barriers respondents cited against recruiting or hiring ex-aerospace or defense-industry scientific and technical personnel were that: (1) They demanded or expected too high a salary, and (2) other recruits were available without this or other barriers. Among the "other" barriers cited were: Dated technology, lack of cost-consciousness, problems involved in moving to a new area, and, as psychological barriers, disappointment and bitterness over wage cuts, and adjustments to working with or under those junior in age. (See table 24.) It must be remembered that this discussion is based on responses from a limited number of interviews. Thus, responses summarized in this report may not be indicative of the views held by all establishments in the pollution control field.

Some employers felt that if the aerospace industry picked up again, they would lose any ex-aerospace workers they had; others felt the aerospace-defense worker was too specialized and did not have sufficiently broad experience within a given technical specialty; and a few were very negative, labeling aerospace workers as "conference types," over-specialized and lazy, not responsible, spoiled, and so forth.

State and local governments sometimes have residency requirements for hiring which would be a barrier for many aerospace workers. Universities often demand that their professionals qualify as faculty members. Some employers do not wish to hire "over-qualified" personnel for technical positions that need little training. Other respondents simply generalized that it would be "uncomfortable" for all concerned to hire ex-aerospace workers, while a few saw no reason to go out of their way as they wanted to avoid problems.

Ex-aerospace engineers were sometimes felt to have difficulty in acquiring new skills, and as one private industry respondent put it, "We can't train engineers." The underlying question in essence was: Is he qualified for the job? While many respondents saw no barriers to employment, apart from the individual problem of wages, the fact remains that most employers were quite able to meet their staffing requirements without pursuing ex-aerospace-defense workers.

—FOOTNOTES—

[1] Upgrading entry qualifications without reference to the skill requirements for job performance is an easy but negative way of reducing the number of job applicants who have to be sorted through, e.g., a municipality may "up" the qualifications of its garbage collectors to include a high school diploma, or department stores may make a college degree a prerequisite for any salesman's job. Screening applicants for high academic qualifications merely to reduce the number of applicants to more manageable proportions, or to add to degree of social prestige to the establishment, or to circumvent anti-discrimination laws by restricting applicants to particular social and income groups who have had the economic resources to complete more years of schooling than others, are all examples of negative upgrading — this is not what is meant.

[2] Responses varied for each occupation. The data, however, are too thin to cross-classify by each occupation and performer.

Chapter IV. Study Design and Methods

The method used in this study to analyze the employment impact of Federal Government expenditures, is designed around two analytical tools in current use by the Bureau of Labor Statistics: (1) input-output tables (and associated interindustry employment tables), and (2) the industry-occupational matrix. The input-output tables show what each industry in the economy purchases from every other industry, as well as from itself, in order to produce its own output. They provide a tool for measuring the effect on the production system, industry by industry by a specific amount of final demand such as Federal Government expenditures. When converted through the use of industry productivity ratios, these input-output tables also yield employment requirements by industry related to the same Federal Government expenditures. The industry-occupational matrix shows the average occupational distribution of each industry's total employment. Employment estimates by occupation are generated by applying the matrix to estimates of industry employment requirements.

The preparation of employment impact or requirements data, therefore, does not represent any radical deviation from current BLS programs. Rather, such data may be viewed as a natural evolution since the techniques used in this study use and expand upon established ones. Thus, the method used is neither revolutionary or wholly new. What is new is the method's application to a very specific Federal program, complex in subject matter and structure.

Input-output table and the occupational matrix—their limitations

Input-output tables are marked by the ability to identify the intermediate sales and purchases, that is, outputs and inputs, that carry goods and services from industry to industry, from manufacturer to distributor and on to their final purchaser in the market. The pressures of World War II stimulated the application of the technique by forcibly illustrating the pitfalls that building production for one goal could run into in the way of material or manpower shortages at earlier or intermediate stages of the production.

The technique rests on the interdependency of a highly integrated economy where each output from one industry is the input into another, where every sale is also a purchase until the product reaches the stage of final demand. On this basis the output of an industry is the sum of all of its inputs (plus, of course, the "value added" entry for the industry's own wage bill and other prime factor changes which represents the industry's own contribution to GNP). At the time this study was under way, the input-output table for 1963 constructed by the Bureau of Economic Analysis, U.S. Department of Commerce, showing inter-industry relationships for the U.S. economy was aggregated to 134 sectors and updated to 1970 by the Bureau of Labor Statistics.[1]

This technique is valuable in analyzing the employment impact of a Federal expenditure because once the final demand, in this case the bill of goods, is known, the system can identify the output needed to be generated in each industry to produce this final demand. The relationship of employment by industry to output by industry in 1970 was used to translate the data on output needed to produce the final demand into data on jobs needed to produce the final demand.

The industry-occupational matrix is a comprehensive set of data on the occupational employment composition of all industry sectors in the economy for 1970. These data are set up to form a matrix, or table, of about 160 specific occupations cross-classified with 116 industries which shows the proportion each occupation is of total employment in an industry. Initially, work on the industry-occupation matrix grew out of concern by the Department of Defense for anticipating the economic problems that might arise from various defense programs. In recent years, a strong interest has developed in determining manpower needs for other purposes. The latter have included training new workers, retraining displaced workers, and providing information to counselors and to students making career decisions. Data for the industry-occupational matrix are brought together from a wide variety of sources.[2]

Limitations. There are certain limitations, however, in both the input-output and industry-occupational matrix systems which should be kept in mind when evaluating the indirect employment impact data.

1. Average vs. Marginal

Employment requirements generated by the input-output system reflect the average employment required to produce the total annual output of each industry. These requirements are based upon overall or average interindustry relationships, productivity ratios, and occupational distribution for a particular year. As such, they most appropriately reflect the employment requirements of the total purchases from an industry. In most instances, however, these relationships are used to determine the employment requirements of a change in a given program or an increment in purchases from a particular industry. For these purposes, marginal employment requirements would be more appropriate. The use of average requirements imply that employment will increase in proportion to this increase in output.

At any point in time, however, average and marginal manpower requirements are likely to be different. Where an industry is operating at less than capacity, there may be a certain margin of under-employed staff. With an increase in production, staff and skills are more fully utilized and this margin can be expected to narrow. Other possibilities exist in (1) recourse to more overtime or (2) organizational changes with further streamlining of the production process. Any of these could account for greater output without an increase in employment.

Even if employment were to increase, the occupational composition of this increase may differ considerably from the *average* occupational composition of the industry or industries. Depending on the specific circumstances, most of the increase might take place in semi-skilled operative positions, with little or no increase in the employment of professional and other white-collar workers. For example, an increase in the demand for automobiles would result, at least in the short run, in increased employment of production related (blue-collar) workers, with little or no increase in the employment of nonproduction (white-collar) workers.

2. Aggregate industry classification

The analytical framework used in the input-output systems divides all purchases into 134 industry sectors. Most sectors include more than one kind of product or service and the inputs to these sectors reflect the production and employment requirements of a number of products or services. In some cases, a program may require just one of several products produced in an industry sector. However, the interindustry model can not differentiate among the products or services within a sector. Thus, a purchase will create requirements for employment in all industries supporting the overall sector, although some of the manpower generated may not be related to the product purchased. Despite this difficulty, generated requirements for each sector will generally be close to the actual requirements for a single purchase since the industry sectors are defined to include related or homogeneous products. This problem also exists with the Industry Occupational Matrix. Occupational patterns are average for an entire sector and may not be representative of the occupations used to produce the specific goods and services purchased.

3. Generated employment requirements does not include multiplier and accelerator effects.

Employment requirements include the primary employment required in the industries producing the goods or services actually purchased and the supporting labor required to produce the materials, parts, services, and other items embodied in these final products. They do not take into account the multiplier effect, which generates additional jobs as workers spend their earnings for consumer goods and services. Also excluded is the accelerator effect, which would increase jobs when business people expand their investment in plant and equipment in response to the increased demand for output.

Program selection and basic data sources

In order to use these analytical tools to measure the impact of a specific Federal program, cost data are necessary to construct a "bill of goods." This represents a listing of an agency's expenses, for a given program, arranged according to the producer industry responsible for supplying the goods and services purchases. Once the parameters of a specific program's operations are reasonably well defined, and the necessary cost data have been obtained, it is possible to develop a usable gauge of the job-creating or job-reducing potential of that program.

The Federal program to be studied had to meet certain criteria. Among these was the availability of cost data that could be gathered in a statistical sampling technique, and activity in major industry sectors of the economy. Also, the program had to have a potential to affect the employment market for scientists and engineers if it were to expand or contract significantly.

Pollution control and abatement expenditures were selected as the program to study. Several factors influenced this choice. At the time the project was started, "pollution" was high in public consciousness, and "pollution control" was high on the list of priorities that might be expected to absorb funds released because of the end of the Vietnam War. In addition, the sharp increase in unemployment among scientific and technical manpower in the early 1970's raised the possibility of aerospace and defense-related scientists and engineers transfering their skills to pollution control and abatement activities.

Another reason reflects data availability. The Office of Management and Budget (OMB) had completed an analysis of Federal expenditures in fiscal year 1970 for pollution control and abatement activities. The OMB study furnished a reference point from which a "universe" of all Federal spending relating to specific pollution control activities could be developed.

Study parameters and concepts

The data collection phase of the study had three basic parameters: (1) the time dimension; (2) the specific nature of the activities to be studied; and (3) the scope of the coverage.

1. Time dimension

The Office of Management and Budget, in its Special Analysis[3], had collected fiscal year 1970 data on Federal pollution control expenditures under three different categories:

	In millions of dollars
Budget authority	$1,432
Obligations	1,071
Outlays	751

Before any data collection could begin, it was necessary to determine which of these categories was most appropriate for impact analysis. Budget authority was excluded since this included the total funds available for the program authorized by legislation. Such funds could be authorized to run over a number of years and would not necessarily, or even likely, be spent during fiscal year 70.[4]

In contrast, obligations represent funds committed for a single fiscal year, and outlays, payments actually made during the fiscal year. Either category might be appropriate for analyzing in-house Federal expenditures since there is usually no extensive timelag between purchase, delivery, and payment for goods and services supporting inhouse operations. However, this is not true for extramural work, and in the case of construction and R&D grants and contracts, considerable timelags can and do occur between project performance and payment. Obligations contracted in fiscal year 1970 would not necessarily result in project performance and payment in fiscal year 1970. Outlay data, therefore, were more closely related to delivery of goods and services (including direct labor) and data were obtained on that basis wherever possible. Fiscal year 1970 was selected as the reference period because it was the only year for which outlays were reported (fiscal year 1971 and fiscal year 1972 were still estimates at the time this study was begun).

2. Specific nature of activities

In its fiscal year 1970 survey, OMB had listed 16 different activities under pollution control and abatement on which agencies were asked to supply data. Each of these activities was further broken out for seven media or pollutants – air, water, radiation solid waste, pesticides, noise, and multimedia) – but not all agencies performed all 16 activities in all seven media.

After investigation, certain deletions appeared necessary in order to concentrate the limited research resources available on the more important programs, and to eliminate programs of a dual or multipurpose nature where the pollution control component could not be isolated or quantified. Accordingly, activities were eliminated where they were too small, involved a great many heterogeneous activities, or contained some unmeasurable portion of activities other than pollution control. The remaining activities were consolidated into three activities (table 25) as illustrated and discussed below.

Under *financial aid to State and local governments*, only grants for construction of municipal waste water treatment facilities were included within the scope of the study. These grants were included in contracts and subcontracts to private construction firms and engineering design firms. Excluded were approximately $36 million for planning and control agency support because of the difficulty of isolating and identifying such funds with specific pollution control activities or programs.

Approximately $116 million of the outlays reported by OMB for *research, development and demonstration (R&D)* were excluded from this category. Of this, about $86 million were excluded because they were allocated to a primary purpose other than pollution control, although they contributed to pollution control. The excluded R&D funds were an important category for many agencies. A conspicuous example was coal research where in the course of finding more economic methods for processing coal, or processing a finer quality, ways might be discovered for reducing the sulphur content and, thereby, the air-polluting character of coal as fuel. How much of the cost of such research should then be charged to pollution control? Because of the difficulties of quantifying the proportionate share of costs attributable to pollution control where that was not the primary purpose of the research, all expenditures reported under this category were deleted.

Another $30 million reported by various agencies as pollution control R&D had to be excluded because the

Table 25. Expenditures for pollution control and abatement, adjusted fiscal year 1970

(in millions of dollars)

Activity	OMB reported total 1970 Federal outlays	Adjusted outlays within scope of study	
		Dollars	Percent
Total	$751	$501	100
Financial aid to State and local governments for municipal waste water treatment facilities	288	252	50.5
Research, development, and demonstration	296	180	35.8
Federal abatement and control operations	72	69	13.7
Other—includes manpower development, reduction of pollution from Federal facilities and program direction and support	96	—	—

agencies were unable to supply the detail necessary on the actual projects. In many R&D projects, pollution control conceptually was an important constraint, yet impossible to quantify except as an across-the-board percent of total costs for any given project.

Research and development was the most complicated of the three activities included in the study because of its structure and ramifications. All R&D work fell into two subprograms, either R&D sources and effects or control technology. Sources and effects R&D is concerned with detecting and measuring various sources of pollutants, and studying their movements as well as evaluating their effects. Control technology R&D is concerned with discovering, developing and testing methods to prevent, control, and manage pollution problems. Research and development in each program on five media were considered in the study: air, water, radiation, solid waste, and pesticides.

The flow of Federal funds and the framework for collecting data on how such funds were spent are illustrated in chart 1.

An additional consideration was the actual performer of the R&D. R&D was split between (1) in-house and (2) extramural grants and contracts, which in turn were distributed among State and local governments, universities, nonprofit institutions, and private industry (profit-making firms). This is illustrated in chart 2.

But further detail was necessary in order to identify differences in the employment effects of R&D funds spent by each performer, by subprogram, and by media. This detail is illustrated for private industry in chart 3, but the same detail applies as well to the other extramural performers and in-house operations.

Abatement and control operations were treated as a single activity or program, thereby consolidating four component activities which had been treated separately in the OMB survey: (1) planning, (2) monitoring and surveillance, (3) standard-setting and enforcement, and (4) technical support. All of these operations were conducted by Government agencies at Government installations. About $3 million had to be excluded because the agencies could not provide the needed detail and breakdown of cost data.

Other included several smaller programs totaling $96 million. All of these were excluded from the scope because they could not be considered uniquely pollution control and abatement activities. For example, "manpower development" was considered a generic title that could apply to any program. Likewise, some of the outlays reported for reducing pollution from Federal facilities were used to purchase "cleaner" heating units. There was some question as to how much of these expenditures were for normal replacements and how much for pollution control purposes.

Scope of coverage–data collection. As indicated earlier, to measure the manpower impact of Federal expenditures it is necessary to trace the entire "chain reaction" of purchases through the economy, starting with salaries paid by the Federal Government and ending with purchases from mining and agriculture. Input-output tables can be used to simulate these transactions once a bill of goods is constructed, that is, a list of purchases of goods or services for a program classified by the industry producing the goods or services. However, greater accuracy would be obtained if data could be collected at each step for each particular bill of goods being analyzed because of the aggregation problem discussed earlier. Because of resource limitations, however, tradeoffs are necessary between collecting data and relying on input-output techniques to generate employment. Also, there are practical limitations as to how far actual purchases can be traced throughout the economy. Thus, data collection in this study was restricted to one, and in a few cases, two levels removed from the sponsoring Federal agency. These levels are described below.

First level included all activities performed by the Federal agency itself under any of the three pollution control programs. These activities varied greatly among agencies. Most agencies, for example, contracted out much of their R&D work, while some performed a significant amount of R&D work in-house.

Second level included all extramural work, whether on a grant or contract basis, classified into four performer categories:[5]

State and local governments
Universities
Nonprofit institutions
Private profitmaking firms

Third level covered contractors, subcontractors, and suppliers to performers at the second level. Theoretically, subcontractors exist in some form and to some degree, in every program, but the problems of identifying and quantifying their costs quickly becomes very involved.

With each step away from the Federal agency responsible for funding an activity, the data collection problems multiply and it becomes increasingly difficult for suppliers to relate a fraction of their total output to a specific government program. Nevertheless, this level was explored to some extent in the case of grants to State and local governments who functioned primarily as financial administrators and contracted out actual operations. This generally was the rule for grants for waste water treatment plants and demonstration projects.

Data availability

An initial investigation was conducted to determine if some or most of the needed cost data for the second level Federal extramural projects could be obtained from agency records.

Federal agencies require grantees and contractors to submit proposals and keep records using a fairly standardized format, which includes a detailed listing of direct manpower payroll costs and goods and services purchased. The financial summary of a typical proposal format specifies cost data for R&D projects for the following categories:

Salary and wages
Fringe benefits

Chart 1

Structure for Collecting R&D Data

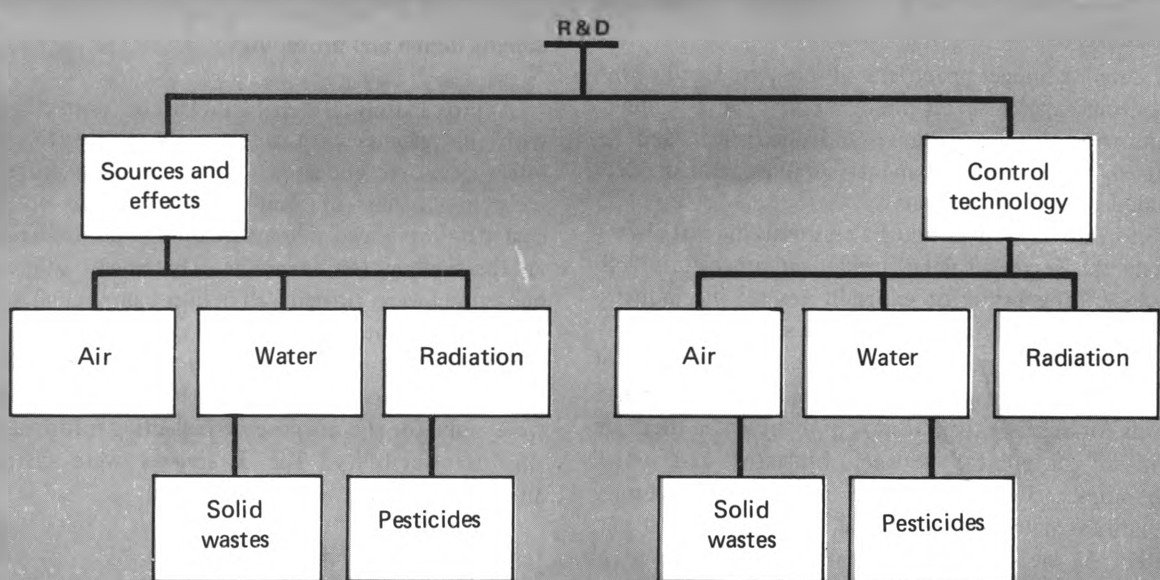
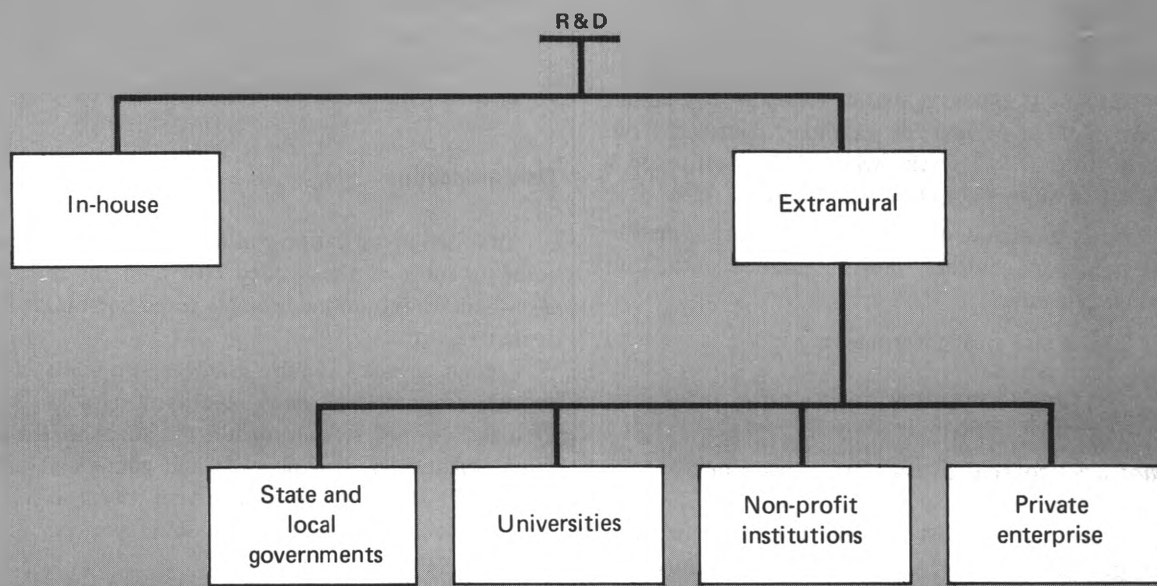


Chart 2

Performers of R&D



Consultant services
Equipment
Supplies
Travel
Publication costs
Other
Indirect costs (at a fixed percent of salary and wage)

A detailed budget proposal is also required, indicating names and salaries of all directly employed personnel, specifications of consultants and their fees, and an itemized listing of equipment, supplies, and services included within the summary.

Unfortunately, these budget proposals did not always contain the degree of detail needed to construct a "bill of goods," the listing of expenditures by the industry producing or supplying the goods or services purchased, required for the input-output system. Also, the type of detail needed generally was not available from agency records for actual expenditures; in many cases there are significant differences between budgeted and actual expenditures. Because of the limitations, necessary expenditure data were collected from extramural performers. At the same time information was obtained on skill transferability and hiring standards. In doing this, a sample survey was designed and implemented. A personal visit survey was considered to be more appropriate than a mail survey because of the experimental nature of this overall study. However, one of the key items on the survey was to identify if the data could be collected by mail, since mail surveys are much less expensive than personal interviews.

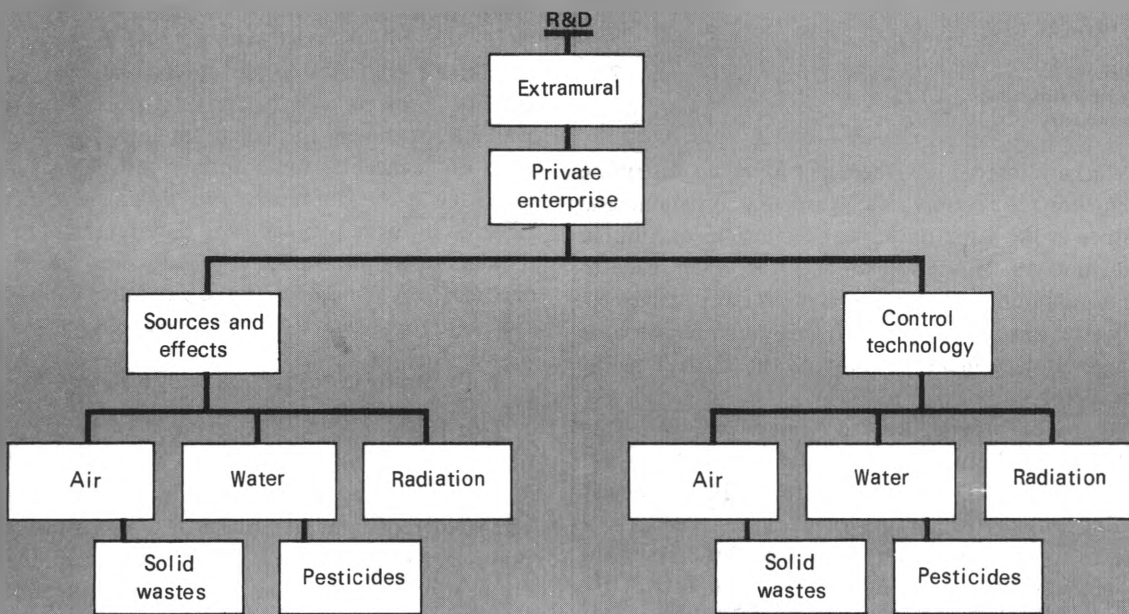
Sample design and procedures

Approximately 100 field interviews were conducted with the resources available for this study. In general, interviews were allocated to each program proportionately to its share of total dollar outlays except where cost data were available either on a total program basis at the agency (for example, abatement and control oeprations were virtually all in-house programs), or were available from other sources (for example, an earlier BLS survey of sewer works construction supplied both labor and cost data for that program). In such cases interviews were only for the purpose of collecting information on skill transferability. The interviews were distributed among the three programs as follows:

1. Grants and contracts for R&D 75
2. Grants for construction of sewage works 23
3. Abatement and control operations (in-house) 8

Chart 3.

Private Industry R&D — Program and Media



The procedure and basis for selecting these interviews is described below for each program.

1. R&D programs

Interviews for the R&D program were selected on the basis of a probability sample proportionate to program size (in dollar value) and first consideration was given to a valid sample of the R&D program in its entirety. To insure fully representative coverage, all performers and all media were represented in the sample but the design called for the development of data only for the total of the three largest media (air, water, and radiation) because the size of the sample would not warrant detail on the two smallest (solid waste and pesticides).

A sample stratified by dollar value of outlays was judged most appropriate since each project could be easily classified into several distinct categories. Stratification in this manner would also make possible the provision of data for each of the categories stratified, that is, program, sub-program, media, and performer.

A first step in constructing the sample was to develop an overview showing total outlays for each media and performer within each of the subprograms – R&D sources and effects, and R&D control technology. However, difficulties were encountered. Some agencies did not have data available on fiscal year 70 outlays; there were no lists of projects on which money had been spent in fiscal year 70; and even where a project was known to have been active in fiscal year 70, it was impossible to determine what actual outlays were in fiscal year 70 without a thorough inspection of the project file.

As a result of this impasse, the most acceptable procedure was to use a surrogate universe, the dollar value of projects funded during fiscal year 1970.[6]

Because of the disproportionate weight of one media, radiation, any attempt to distribute total outlays by media and program, and from this to allocate interviews, showed a marked imbalance. Radiation outlays made up slightly more than one-half of all extramural R&D and 75 percent of the subprogram, R&D sources and effects. Most of this R&D was performed at a small number of government-owned, contractor-operated laboratories. A test interview at one of these sites indicated the possibility of collecting data on all pollution control and abatement projects at the site, that is, on a universe basis, and that this could be done in a single interview. Since a small number of interviews could thus provide data for a substantial proportion of all radiation R&D performed, it was not necessary to assign interviews for this media in proportion to dollar value of outlays. Ten interviews were allocated for this aspect of the study, with the remaining 65 interviews distributed among the other four media. These 10 interviews (radiation) were split, proportionate to dollar outlays, between on-site and off site categories as follows:[7]

	Total	Onsite	Offsite
Total	10	8	2
Universities	8	6	2
Nonprofit institutions	1	1	–
Private industry	1	1	–

A working matrix was then developed to distribute the remaining 65 interviews by media, program, and performer in the same proportion that each contributed to total outlays. Minor adjustments were then made to assure a minimum of three interviews for any active cell. Solid waste was an exception to this minimum because one large project included most of the outlays in the private sector.

In terms of program, the 65 interviews were split almost 2 to 1 between R&D-control technology (41 interviews) and R&D-source and effects (24 interviews). (See table 26.)

The next step was to develop a sampling frame. The Environmental Protection Agency provided lists of the R&D projects being funded during fiscal year 70. However, due to time-lags and to the fact that a number of projects funded were active over a number of years, these lists were not considered representative of fiscal year 70 outlays. Instead, an appropriate list of projects active during fiscal year 70 had to be developed along with estimated outlays for each during this period. This was done by: (1) Adding projects funded in previous years which extended into fiscal year 70, (2) dropping fiscal year 70 funded projects not scheduled to being until after June 30, 1970, and then (3) prorating total costs of those projects which extended beyond fiscal year 70. Information needed for these adjustments was furnished by the Environmental Protection Agency. Grants and contracts were then randomly selected from these lists in accordance with the sample design.

In the case of the Atomic Energy Commission's (radiation) contracts at on-site laboratories, complete lists of projects active during fiscal year 70 were available. Although the dollar amounts for each project were not available, total outlays for all projects combined at each laboratory were known. Since these laboratories were handled as if they represented a single project, this total outlays figure was all that was necessary. A complete list of off-site contracts was available from which interviews were selected.

2. Grants for construction of sewer works

This program covered both costs of actual construction and design engineering costs. While the results of an earlier BLS survey on sewage plant construction material and labor requirements[8] could be used for the construction segment, these were not applicable to the design engineering part. A limited sample, therefore, was necessary to develop both manpower and expenditure data for the design element. The 23 interviews allotted to this program were split with 12 marked for full collection of data from design engineering firms (occupational and cost data as well as information on skill transferability) and 11 for skill transferability data only from construction contractors. The interviews were paired, that is, the same construction project supplied both.

As part of another project, the BLS had received from EPA a complete listing of all grants for construction of waste water treatment facilities. From this list,

Table 26. Distribution of interview sample, by program and performer, fiscal year 1970

Programs and performers	Total	Air	Water	Solid waste	Pesticides
Total—all program	65	13	32	12	8
State and local governments	20	–	10	6	4
Universities	22	5	8	5	4
Nonprofit institutions	7	4	3	–	–
Private industry	16	4	11	1	–
Sources and effects—total	24	9	7	–	8
State and local governments	4	–	–	–	4
Universities	13	5	4	–	4
Nonprofit institutions	4	4	–	–	–
Private industry	3	–	3	–	–
Control technology—total	41	4	25	12	–
State and local governments	16	–	10	6	–
Universities	9	–	4	5	–
Nonprofit institutions	3	–	3	–	–
Private industry	13	4	8	1	–

23 projects were selected subject to the following constraints:

1. Project costs to be between $1 million and $5 million (to eliminate very small projects as well as exceptionally large ones).
2. A sizable portion of the work to have been done in fiscal year 70.
3. The project to include a treatment plant.
4. Projects to be distributed in 11 designated location.[9]

EPA was then asked to supply the name of the engineering design firm and principal general contractor for each grant. In choosing between alternates, consideration was given to avoiding contacting firms which supply information to BLS data collection programs, and preference was given to the larger design firms and building contractors specializing in sewer works.

3. Abatement and control operations

These programs were conducted in-house with manpower and cost data available in Washington. The eight interviews allocated to these programs were for the purpose of collecting information on hiring standards and skill transferability. These interviews were conducted at various EPA regional offices and AEC installations.

Interviews

As an aid in interviewing, an Interview Guide (appendix B) was developed. The guide provided interviewers with a series of questions in sequence but as the title suggests, it was primarily a guide to dialogue and not a questionnaire. Many of the questions required thoughtful evaluation—especially those relating to skill transferability. Several pretest interviews were made to decide on the actual phrasing of the guide and to insure that the kinds of information wanted were understood and available.

All interviewers were provided with written background material describing the purpose of the study, the scope of the data to be analyzed, a definition of terms used, the reasons behind each question, and the type of data being sought. In addition, several training sessions were conducted at which these materials were discussed and problems ironed out.

Because the structure of the interview guide had been deliberately left open, a good part of the success of any interview depended upon the interviewer's skill and initiative in determining what data were available and how they should be evaluated.

In addition to recognizing internal inconsistencies in the data, interviewers had to be able to judge whether respondents provided data in sufficient detail to fill the requirements of the input-output technique. Moreover, with reference to transferability questions, interviewers were encouraged to probe and discuss these complex issues rather than accept what might be termed "standard" answers.

Data collection and operational problems

Specific data collection and operational problems centered on the types of accounting systems and associated detail maintained by the various performers; the allocation of overhead costs; the time frame for the data collected; and the comparability of in-house and extramural Federal R&D costs.

Since the availability of needed data from Federal agencies was an issue in this study, all Federal agencies reporting pollution control and abatement expenditures for fiscal year 1970 were contacted to obtain information on how the funds were used. However, half of the fiscal year 1970 outlays attributed to the Environmental Protection Agency (EPA) were in fact spent by other agencies since EPA did not come into existence until December 1970. While accounts were transferred, there was, however, a physical problem of transferring files (in some cases this had barely been completed at the time of our research in mid-1972). To overcome these problems many interviews were held with agency staff and internal records and work sheets were reviewed.

Some agencies were unable to identify specific programs corresponding to the dollar amounts reported (to OMB) because they had developed their data by taking a fixed percent of the work in a program as being in the pollution control field. For example, virtually all of NASA's research projects included a pollution control component. Conceivably one could make an across-the-board estimate of the amount to be attributed to pollution control. While these procedures may be quite satisfactory for developing estimates of the amount of funds expended for Federal pollution control and abatement activities, they are unsatisfactory for the purpose of this study. Because of this, the category was eliminated from consideration.

Records were kept in different manners in each of the sectors of the economy and each had special problems as indicated below:

Accounting records

Federal agencies—In collecting data for manpower impact analysis, it seemed reasonable to use existing data systems as much as possible. But, in many cases it was very difficult to use existing Federal data for nonpayroll expenditures. Since expenditures had to be identified in sufficient detail to permit assignment to a particular industry at the three or four digit SIC level as a first step in distributing and aggregating such costs into a "bill of goods," a great deal of work had to be done in interviewing and digging out records which would make such identification possible. The man hours devoted to this effort were substantial, and the results frequently frustrating.

The OMB has prescribed a uniform system to be used by Federal agencies in classifying financial transactions for budget estimates and budget reports to OMB and Congress. Under this system, expenditures for any given Federal program are identified by code with the particular project or program to which they relate, and to the object class which describes their activity or purposes. Object classes reflect a functional structure for recording expenditures: They classify and describe expenditures in terms of what they do or are used for, but rarely provide the detail necessary to identify the producer industry which supplies the goods or services. Among major object classes in the Federal system, under which practically all equipment and goods or services purchased, or contracted for, fall, are:

Travel
Transportation of things
Rent, communications and utilities
Printing and reproduction
Other services
Supplies and materials
Equipment

Under this system, each agency can set up sub-object classes providing further detail on these major classifications to suit its own particular needs. In some cases these sub-object classes provided data which permitted identification of producer industries, but in other cases the sub-object classes aggregated items from a wide range of industries which could not be separated out. Where this occurred, however, it was sometimes possible to determine the producer industry either from data in purchasing records or from information obtained in personal interviews.

State and local governments—Federal grants to States and local governments for pollution controls fall under two programs: (1) capital investments and (2) research and development. Despite differences of titles, there is a close relationship, if not identity, in their final product and expenditures patterns. Grants under capital investments are intended almost entirely for regional and municipal sewage plants and lines. The bulk of funds for research and development to State and local governments has thus far been largely for control technology in water pollution and has almost invariably involved the construction of a "demonstration" sewage plant.

In almost all cases, the actual work is contracted out to private industry—design engineers and construction firms. State and local governments are in effect "performers" in name only. While they may contribute general administrative services, and varying amounts of supervision and inspection of work in process to maintain standards and fulfill the specifications of the contract, these charges generally represent only minimal costs in relation to the general magnitude of total costs for the construction work itself.

Since the Bureau had made an intensive survey (in 1963) of costs in sewage plant construction, it was decided to exploit further the results of that survey and develop (with necessary adjustments for changes in prices and productivity during the interim) the data needed for running the fiscal year 70 outlays for the "construction" program through the input-output system.

The sewage plant construction bill of goods so developed and used for State and local governments is, in effect, the pattern of expenditures typical of private industry; no account has been taken (because no data were available) of the cost of State and local government's own inputs in the form of project administration and supervision.

Universities—In many respects universities were the easiest performer from which to collect data. The projects funded by Federal agencies fell exclusively under the R&D program, and the great majority were in the sources and effects category, commonly identified with basic and applied research. These projects were fairly small, with the greater part of outlays for direct labor rather than materials and supplies, so that their employment impact, outside the direct measurements of faculty and graduate students employed on the project, was minimal.

Overhead is often the most significant nonpayroll cost for university research projects and for this study could not be ignored despite major difficulties in trying to break it down as an expense item. For this purpose a standard distribution pattern was ultimately developed from a variety of sources. (See *Allocation of Overhead* below.)

Private industry—Since the overall sample was selected on the basis of expenditure size, it included a large number of "big" projects. In many cases, this meant "big" establishments. Because of various management, marketing, and legal pressures, large establishments have developed fairly sophisticated accounting and retrieval systems. Thus, cost data are available in different ways for a variety of purposes, and the retrieval of data relating to a specific project, or collecting projects under a given program, did not present a significant problem for large establishments. Smaller establishments sometimes had difficulty in providing the requested data.

Allocation of overhead

Overhead normally includes a large number of functions, such as general administration, plant operation and maintenance, security, library facilities, equipment depreciation and so forth. Together these functions comprise sizable amounts of payroll and purchases of goods and services. Thus, overhead averaged around 23 percent of total costs on projects performed by universities, somewhat less for State and local governments, and considerably more for nonprofit institutions and private industry.

Overhead charges are a particular concern where the project is less than an organization's entire operation and overhead costs must be prorated. On the other hand, where an organization is taken as a whole, the items normally within overhead are included as part of the organization's direct costs split between payroll and nonpayroll categories.

However, there is no way of applying input-output techniques to overhead *per se*; it must be broken down into the various expense items. This was very difficult to do. To generalize from the sample responses, those with low overhead rates generally itemized most costs as direct, but details on overhead costs were generally poor for those organizations with large overhead costs. Engineering design firms were an exception: For the most part they classified everything except direct technical manpower cost as overhead, but were able to itemize (based on an average computed for all projects) all of the expenses included in overhead.

Overhead at universities is normally treated as a fixed charge, but there can be wide variations in the rate charged as well as the method of computation. Many research laboratories compute overhead as a fixed charge per professional employed on a project; other institutions base the charge on total payroll for a project. Considerable variation also exists in the rate charged.[10]

At universities and nonprofit institutions the overhead charge is basically an allocation of general costs over a number of projects with no attempt to allocate specific costs to specific projects. Moreover, overhead is generally charged at a standard rate applicable to all projects. Even though pollution control projects may use more than the average of one overhead resource and less of another, such distinctions are not reflected in overhead costs. The result is that any type of research performed at these institutions would show virtually the same manpower impact for a substantial portion of each dollar expended.

On the basis of available information from all sources, standard patterns were developed for breaking down overhead into expense categories for each of the performer categories.

Time frame for data collection

Cost data for this project were collected for fiscal year 1970. There is, however, a problem with using data for just 1 year for Federal in-house operations since variations exist in the distribution of obligations by object class from 1 year to the next. Use of these single year data for any estimating purposes assumes that the distributions of purchases in any year will be the same as in the base year. However, there may be changes over time as methods of operation change or the base year may be atypical. Certain categories are more subject to variation than others, particularly expenses which can be more easily cut back or deferred, for example, travel or equipment purchases. On the other hand, equipment purchases may be unusually high if a new laboratory or facility is being furnished.

The problem of taking data for a 1-year period to represent the impact of Federal in-house programs which run for more than 1 year is also found in Federal extramural programs. Many extramural projects likewise run for more than 1 year, so that cost data for any 1-year period gives a picture of only a segment of the project. A review of project proposals together with information obtained during interviews indicates that many projects go through various stages, each requiring different resource inputs.

Two extreme patterns of phased expenditures were noted in extramural projects. (1) In Research, Development, and Demonstration (RD&D) sources and effects projects, all major purchases for equipment, materials and supplies were usually made in the first year of the project; payroll costs for direct labor, plus overhead and maintenance charges, were usually the only costs in the second and third years of a 3-year cycle. However, (2) in RD&D control technology projects, the reverse pattern occurred. Here, and in all projects involving considerable construction (notably sewage plants and lines), costs in the first year were almost entirely compensation for engineering-design services; in the second year were purchases for heavy equipment, materials, and supplies to get the work under way; in the third year such purchases fell off and costs again were largely compensation for actual construction work, supervision, and testing, involving few professional occupations in contrast to the first year. In this study, these problems were reduced (if not eliminated) since the sampling frame included projects active in fiscal year 1970. These projects represented the entire pattern of phased expenditures and the resulting data can be considered as "average."

In the case of the engineering design part of construction grants, this data collection problem did not occur. Design costs could not be given for a single year, so cost data for the entire project were obtained and then prorated for 1 year and applied to fiscal year 1970. Furthermore, since all costs in design engineering, except direct payroll, are treated as overhead, the distribution pattern applied in breaking overhead down into specific expense accounts tends to be an average for a large number of projects.

4. Comparability of in-house and extramural R&D expenditures

In-house R&D activities involved two fairly distinct types of operations: (1) performance of research at Federal laboratories, and (2) monitoring of extramural research performed by grantees and contractors. The latter is actually a cost of doing extramural research. The level of monitoring expenses is tied to the level of extramural R&D and conceptually should be added to extramural research. However, cost data were generally not available separately for the two operations.[11]

It would seem reasonable to assume that the cost patterns of the two operations differ. Monitoring of extramural research, for example, involves a greater proportion of certain costs, like communications and travel, and less of other, like equipment and supplies. Because of the inability to identify the component costs of the two operations, data for in-house R&D and extramural R&D are not strictly comparable.[12]

–FOOTNOTES–

[1]For a discussion of the uses of input-output data see forthcoming BLS Bulletin on the Structure of the U.S. Economy, 1980 and 1985.

[2]See *Occupational Employment Statistics*, 1960–70, Bulletin 1738, (U.S. Department of Labor, Bureau of Labor Statistics, 1972).

[3]Special Analyses, Budget of the U.S. Government, Fiscal Year 1974, Special Analysis Of Federal Environmental Programs, pp. 219-29, (Office of Management and Budget), 1973.

[4]The duration of a Budget Authority depends on the legislative act to which it is tied but normally runs up to 5 years, sometimes up to 10 years, and in a few cases the duration is unlimited.

[5]Contract work performed for one Federal agency by another conceptually constituted another type of performer but was disregarded on the assumption that the occupational pattern and cost structure would not differ significantly from work done by other Federal agencies.

[6]The sum of inhouse outlays or obligations (which were felt to be quite close to actual outlays) plus totals of grants and contracts let during Fiscal Year 70 for each agency, differed considerably in most cases from total outlays reported for the agency. This was not surprising considering the usual timelags between the letting of grants and contracts (obligations) and actual performance and payment (outlays). Therefore these grant and contract totals, distributed by media and performer, were "forced" into total Fiscal Year 70 outlays. In effect, they were assumed to be the difference between total outlays and inhouse outlays. These "forced" extramural figures formed the basis for the design of the sample.

[7]More than two-thirds of the research was carried on at "on-site" laboratories owned by, or operated for AEC. The remainder of the program consisted of support to work performed "off-site" in university laboratories, hospitals, other nonprofit institutions, commercial organizations, and other government agencies. Because of the concentration of R&D at the Oak Ridge Laboratory, the private industry sector would have been allocated two interviews based on dollar outlays. This "extra interview," was added to the on-site university category.

[8]*Labor and Material Requirements for Sewer Works Construction*, Bulletin 1490 (United States Department of Labor, Bureau of Labor Statistics, 1966).

[9]In order to give representative geographic coverage for construction in the entire country and at the same time fit in with known areas of sampling for other programs, 11 areas were designated as follows: District of Columbia, Raleigh-Durham, Boston, New York, Pittsburgh, Philadelphia, Chicago, Detroit, Knoxville-Oakridge (Tenn.) Austin-Houston-San Antonio, and San Francisco.

[10]According to a National Science Foundation study of several thousand scientific research projects funded throughout the country in a variety of disciplines, the average project cost for Fiscal Year 70 was $43,833 of which 52.6 percent was for payroll (direct labor); 25.1 percent for equipment, materials, and services, and 22.3 percent for overhead.

[11]For Federal inhouse operations certain agencies reported a substantial portion of their expenditures under "Program Direction and Support," which includes activities normally considered overhead. Other agencies instead included them as part of either of two other programs, that is, R&D or abatement and control operations. Since Program Direction and Support expenditures are not included in this study or allocated to other programs, overhead on certain inhouse operations is to that extent understated.

[12]Several agencies with R&D activities classified as "Other than primary purpose but contributes to pollution control," and thereby excluded from detailed analysis in this study, contracted out or gave grants for all of their R&D. An analysis of their inhouse monitoring costs could possibly given an indication of the impact of this type of program.

Appendix A. Detailed Tables

The following detailed tables present data on direct and indirect actual expenditures for Federal pollution control and abatement activities, by type of program, and the direct and indirect employment generated for each million dollars of expenditures under each of the programs.

Table A-1. Federal pollution control and abatement activities: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	33,530	15,860	17,670	66.9	31.7	35.3
Professional and technical	10,960	9,050	1,910	21.9	18.1	3.8
Engineers	2,600	2,180	420	5.2	4.3	.9
Aeronautical	10	10	—	—	—	—
Chemical	240	240	—	.5	.5	—
Civil	1,130	1,050	80	2.5	2.1	.2
(Sanitary)[1,2]	(460)	(460)	—	(.9)	(.9)	—
Electrical	210	130	80	.4	.2	.2
Industrial	60	10	50	.1	.1	—
Mechanical	300	210	90	.6	.4	.2
Other	590	500	90	1.2	1.0	.2
Natural Scientists	3,860	3,790	70	7.7	7.5	.2
Agricultural	150	150	—	.3	.3	—
Biological	1,040	1,040	—	2.1	2.1	—
(Microbiologists)[3]	(40)	(40)	—	(.1)	(.1)	—
(Zoologists)[3]	(10)	(10)	—	—	—	—
Medical	230	230	—	.5	.5	—
Mathematicians	80	80	—	.2	.2	—
Systems analysts	60	60	—	.1	.1	—
Chemists	1,380	1,330	50	2.8	2.7	.1
(Biochemists)[3]	(50)	(50)	—	(.1)	(.1)	—
Geologists and geophysicists	30	30	—	.1	.1	—
Physicists	430	430	—	.9	.9	—
Meteorologists	70	70	—	.1	.1	—
Other natural scientists	330	330	—	.7	.7	—
Technicians, except medical and dental	3,100	2,740	360	6.2	5.5	.7
Drafters	420	210	210	.8	.4	.4
Surveyor	50	30	20	.1	—	—
Electrical and electronic	330	260	70	.7	.6	.1
Other engineering and science	1,430	1,360	70	2.9	2.8	.1
Computer programmers	100	100	—	.2	.2	—
Other	800	800	—	1.6	1.6	—
Medical and other health workers	250	180	70	.5	.4	.1
Other professional and technical	1,170	180	990	2.3	.4	1.9
Accountants	240	30	210	.5	.1	.4
Pilots	70	40	30	.1	—	—
Architects	20	—	20	—	—	—
Designers	80	30	50	.1	—	.1
Editors and reporters	40	—	40	.1	—	.1
Lawyers	190	—	190	.4	—	.4
Personnel and labor relations workers	50	—	50	.1	—	.1
Other	490	90	400	1.0	—	—
Managers and administrators	2,820	1,000	1,820	5.6	2.0	3.6
Clerical workers	5,310	1,920	3,390	10.6	3.8	6.8
Sales workers	810	—	810	1.6	—	1.6
Craft workers	5,130	2,160	2,970	10.2	4.3	5.9
Operatives	5,300	840	4,460	10.6	1.7	8.9
Service workers	1,200	200	1,000	2.4	.4	2.0
Laborers	1,740	640	1,100	3.5	1.3	2.2
Farmers and farm workers	200	—	200	.4	—	.4

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

[3] Detail available for direct extramural employment only.

NOTE: Detail may not add to totals because of rounding
— represents less than 5 or none.

Table A-2. Federal pollution control and abatement activities, research, development and demonstration: Generated employment by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	7,820	4,130	3,690	76.7	40.5	36.2
Professional and technical	3,460	3,090	370	33.9	30.3	3.6
Engineers	800	720	80	7.8	7.0	.8
Aeronautical	10	10	—	.1	.1	—
Chemical	170	170	—	1.7	1.7	—
Civil	290	280	10	2.8	2.7	.1
(Sanitary)[1,2]	(170)	(170)	—	(1.7)	(1.7)	—
Electrical	40	20	20	.4	.2	.2
Industrial	20	10	10	.2	.1	.1
Mechanical	160	150	10	2.6	1.5	1.1
Other	100	90	10	1.0	.8	.2
Natural scientists	1,540	1,520	20	15.1	14.9	.2
Agricultural	130	130	—	1.3	1.3	—
Biological	400	400	—	3.9	3.9	—
(Microbiologists)[3]	(40)	(40)	—	(.4)	(.4)	—
(Zoologists)[3]	(10)	(10)	—	(.1)	(.1)	—
Medical	130	130	—	1.3	1.3	—
Mathematicians	50	50	—	.5	.5	—
Systems analysts	20	20	—	.2	.2	—
Chemists	700	690	10	6.9	6.8	.1
(Biochemists)[3]	(10)	(10)	—	(.1)	(.1)	—
Geologists and geophysicists	20	20	—	.2	.2	—
Physicists	10	10	—	.1	.1	—
Meteorologists	20	20	—	.2	.2	—
Other natural scientists	50	50	—	.5	.5	—
Technicians, except medical and dental	920	850	70	9.0	8.3	.7
Drafters	50	20	30	.5	.2	.3
Surveyor	—	—	—	—	—	—
Electrical and electronic	40	20	20	.4	.2	.2
Other engineering and science	470	450	20	4.6	4.4	.2
Computer programmers	30	30	—	.3	.3	—
Other	320	320	—	3.1	3.1	—
Medical and other health workers	10	—	10	.1	—	.1
Other professional and technical	200	20	180	2.0	.2	1.8
Accountants	30	—	30	.3	—	.3
Pilots	10	—	10	.1	—	.1
Architects	—	—	—	—	—	—
Designers	10	—	10	.1	—	.1
Editors and reporters	10	—	10	.1	—	.1
Lawyers	20	—	20	.2	—	.2
Personnel and labor relations workers	10	—	10	.1	—	.1
Other	100	—	100	1.0	—	1.0
Managers and administrators	520	120	400	5.1	1.2	3.9
Clerical workers	1,350	540	810	13.2	5.3	7.9
Sales workers	170	—	170	1.7	—	1.7
Craft workers	710	60	650	7.0	.6	6.4
Operatives	890	90	800	8.7	.9	7.8
Service workers	310	30	280	3.0	.3	2.7
Laborers	370	200	170	3.7	2.0	1.7
Farmers and farm workers	60	—	60	.6	—	.6

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-3. Federal pollution control and abatement activities, air research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	2,490	1,340	1,150	78.1	42.0	36.1
Professional and technical	1,180	1,060	120	36.9	33.3	3.6
Engineers	300	270	30	9.3	8.4	.9
Aeronautical						
Chemical	50	50	—	1.7	1.7	—
Civil	30	30	—	1.1	1.0	.1
(Sanitary)[1,2]	(30)	(30)		(1.0)	(1.0)	—
Electrical	20	10	10	.6	.4	.2
Industrial	10	—	10	.3	.1	.2
Mechanical	140	130	10	4.3	4.1	.2
Other	30	20	10	.9	.6	.3
Natural scientists	470	460	10	14.6	14.4	.2
Agricultural	10	10	—	.3	.3	—
Biological	90	90	—	2.7	2.7	
(Microbiologists)	(10)	(10)	—	(.4)	(.4)	
(Zoologists)						
Medical	70	70		2.2	2.2	
Mathematicians	20	20		.5	.5	
Systems analysts	—	—		.1	.1	
Chemists	250	250		7.7	7.7	
(Biochemists)						
Geologists and geophysicists						
Physicists	—	—	—	.1	.1	
Meteorologists	25	25	—	.8	.8	
Other natural scientists	0	0		0	0	
Technicians, except medical and dental	350	330	20	11.0	18.4	
Drafters	20	20	—	.6	.6	
Surveyor	—	—	—			
Electrical and electronic	20	20	—	.5	.5	
Other engineering and science	210	210	—	6.5	6.5	
Computer programmers	10	10		.4	.4	
Other	80	80		2.5	2.5	
Medical and other health workers						
Other professional and technical	70	10	60	2.0	.2	1.8
Accountants	10	—	10	.2	—	.2
Pilots	—		—	.1	—	.1
Architects						
Designers	—		—	.1		.1
Editors and reporters	—		—	.1		.1
Lawyers	10		10	.2		.2
Personnel and labor relations workers	—		—	.1		.1
Other	30		30	1.0		1.0
Managers and administrators	190	60	130	5.9	1.9	4.0
Clerical workers	430	180	250	13.5	5.6	7.9
Sales workers	60	—	60	2.0	—	2.0
Craft workers	190	10	180	5.8	.2	5.6
Operatives	300	30	270	9.3	.9	8.4
Service workers	90	—	90	2.7	—	2.7
Laborers	50	—	50	1.5	—	1.5
Farmers and farm workers	20	—	20	.5	—	.5

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-4. Federal pollution control and abatement activities, water research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	3,130	1,670	1,460	73.5	39.3	34.2
Professional and technical	1,290	1,160	130	30.4	27.2	3.2
Engineers	300	270	30	7.0	6.3	.7
Aeronautical	10	10	—	.2	.2	—
Chemical	50	50	—	1.2	1.2	—
Civil	160	160	—	3.7	3.6	.1
(Sanitary)[1,2]	(90)	(90)	—	(2.1)	(2.1)	—
Electrical	10	—	—	.2	.1	.1
Industrial	—	—	—	.1	—	.1
Mechanical	20	20	—	.5	.4	.1
Other	40	40	—	1.1	1.0	.1
Natural scientists	670	660	10	15.8	15.6	.2
Agricultural	60	60	—	1.5	1.5	—
Biological	230	230	—	5.5	5.5	—
(Microbiologists)[3]	(10)	(10)	—	(.3)	(.3)	—
(Zoologists)[3]	(10)	(10)	—	(.3)	(.3)	—
Medical	30	30	—	.6	.6	—
Mathematicians	10	10	—	.3	.3	—
Systems analysts	10	10	—	.2	.2	—
Chemists	300	300	—	7.0	7.0	—
(Biochemists)[3]	(4)	(4)	—	(.1)	(.1)	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—		—	.1	.1	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	20	20	—	.4	.4	—
Technicians, except medical and dental	60	20	30	6.0	5.4	.1
Drafters	10	—	10	.6	.1	.2
Surveyor	—	—	—	.1	—	.1
Electrical and electronic	10	10	—	.3	.2	.1
Other engineering and science	140	140	—	3.3	3.2	.1
Computer programmers	—		—	.1	.1	—
Other	90	90	—	2.0	2.0	—
Medical and other health workers	—	—	—	.1	—	.1
Other professional and technical	60	—	60	1.5	—	1.5
Accountants	—	—	—	.2	—	.2
Pilots	10	—	10	—	—	—
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	.1	—	.1
Lawyers	10	—	10	.2	—	.2
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	30	—	30	.7	—	.7
Managers and administrators	170	30	140	4.0	.6	3.4
Clerical workers	540	220	320	12.7	5.2	7.5
Sales workers	60	—	60	1.5	—	1.5
Craft workers	330	50	280	7.2	1.1	6.1
Operatives	350	50	300	8.2	1.2	7.0
Service workers	100	10	90	2.3	.2	2.1
Laborers	285	185	100	.5	—	.5
Farmers and farm workers	—	—	—	—	—	—

[1] Data available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

[3] Detail available for direct extramural employment only.

Table A-5. Federal pollution control and abatement activities, inhouse research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	3,680	1,950	1,730	78.3	41.5	36.8
Professional and technical	1,640	1,450	190	34.9	30.9	4.0
Engineers	320	280	40	6.9	6.0	.9
Aeronautical	—	—	—	—	—	—
Chemical	80	80	—	1.7	1.7	—
Civil	120	120	—	2.6	2.5	.1
(Sanitary)[1,2]	(100)	(100)	—	(2.2)	(2.2)	—
Electrical	20	10	10	.4	.2	.2
Industrial	10	—	—	.2	.1	.1
Mechanical	30	20	10	.6	.4	.2
Other	60	50	10	1.4	1.1	.3
Natural scientists	780	770	10	16.7	16.5	.2
Agricultural	60	60	—	1.3	1.3	—
Biological	180	180	—	3.9	3.9	—
(Microbiologists)[3]	—	—	—	—	—	—
(Zoologists)[3]	—	—	—	—	—	—
Medical	100	100	—	2.2	2.2	—
Mathematicians	20	20	—	.4	.4	—
Systems analysts	10	10	—	.1	.1	—
Chemists	340	330	10	7.2	7.1	.1
(Biochemists)[3]	—	—	—	—	—	—
Geologists and geophysicists	10	10	—	.3	.3	—
Physicists	10	10	—	.1	.1	—
Meteorologists	20	20	—	(.4)	(.4)	—
Other natural scientists	30	30	—	.9	.9	—
Technicians, except medical and dental	430	400	30	9.1	8.4	.7
Drafters	10	—	10	.3	—	.3
Surveyor	—	—	—	—	—	—
Electrical and electronic	30	20	10	.6	.4	.2
Other engineering and science	170	160	10	3.7	3.5	.2
Computer programmers	10	10	—	.3	.3	—
Other	200	200	—	4.2	4.2	—
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	100	—	100	2.2	—	2.2
Accountants	10	—	10	.3	—	.3
Pilots	10	—	10	.1	—	.1
Architects	—	—	—	—	—	—
Designers	10	—	10	.1	—	.1
Editors and reporters	10	—	10	.1	—	.1
Lawyers	10	—	10	.2	—	.2
Personnel and labor relations workers	10	—	10	.1	—	.1
Other	60	—	60	1.3	—	1.3
Managers and administrators	280	100	180	6.0	2.1	3.9
Clerical workers	700	360	340	14.8	7.6	7.2
Sales workers	90	—	90	1.9	—	1.9
Craft workers	300	30	270	6.3	.6	5.7
Operatives	400	10	390	8.5	.2	8.3
Service workers	170	—	170	3.6	—	3.6
Laborers	80	10	70	1.6	.2	1.4
Farmers and farm workers	40	—	40	.8	—	.8

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-6. Federal pollution control and abatement activities, inhouse air research development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,480	710	770	77.4	36.9	40.5
Professional and technical	590	510	80	30.8	26.6	4.2
Engineers	150	130	20	7.8	6.7	1.1
Aeronautical	–	–	–	–	–	–
Chemical	50	50	–	2.8	2.8	–
Civil	30	30	–	1.8	1.7	.1
(Sanitary)[1,2]	(30)	(30)	–	(1.7)	(1.7)	–
Electrical	10	10	–	.7	.4	.3
Industrial	10	–	–	.2	.1	.1
Mechanical	20	10	–	.9	.7	.2
Other	30	20	10	1.3	1.0	.3
Natural scientists	250	250	–	13.1	12.9	.2
Agricultural	10	10	–	.5	.5	–
Biological	20	20	–	.9	.9	–
(Microbiologists)[3]	–	–	–	–	–	–
(Zoologists)	–	–	–	–	–	–
Medical	70	70	–	3.6	3.6	–
Mathematicians	20	20	–	.8	.8	–
Systems analysts	–	–	–	.1	.1	–
Chemists	110	110	–	5.9	5.8	.1
(Biochemists)	–	–	–	–	–	–
Geologists and geophysicists	–	–	–	–	–	–
Physicists	–		–	.2	.2	–
Meteorologists	(20)	(20)	–	(1.0)	(1.0)	–
Other natural scientists	–	–	–	–	–	–
Technicians, except medical and dental	150	130	20	7.8	7.0	.8
Drafters	–	–	–	–	–	–
Surveyor	–	–	–	–	–	–
Electrical and electronic	10	10	–	.7	.7	–
Other engineering and science	80	80	–	4.0	4.0	–
Computer programmers	10	10	–	.6	.6	–
Other	30	30	–	1.7	1.7	–
Medical and other health workers	–	–	–	–	–	–
Other professional and technical	40	–	40	2.1	–	2.1
Accountants	–	–	–	.3	–	.3
Pilots	–	–	–	.1	–	.1
Architects	–	–	–	–	–	–
Designers	–	–	–	.1	–	.1
Editors and reporters	–	–	–	.1	–	.1
Lawyers	–	–	–	.2	–	.2
Personnel and labor relations workers	–	–	–	.1	–	.1
Other	20	–	20	1.2	–	1.2
Managers and administrators	140	60	80	7.5	3.1	4.4
Clerical workers	280	130	150	14.5	6.8	7.7
Sales workers	40	–	40	2.3	–	2.3
Craft workers	120	–	120	6.6	.2	6.4
Operatives	200	–	200	10.4	–	10.4
Service workers	60	–	60	2.9	–	2.9
Laborers	30	–	30	1.7	–	1.7
Farmers and farm workers	10	–	10	.5	–	.5

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-7. Federal pollution control and abatement activities, inhouse water research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,240	810	430	78.0	51.0	27.0
Professional and technical	640	580	50	40.1	36.7	3.4
Engineers	140	130	10	8.7	8.1	.6
Aeronautical	—	—	—	—	—	—
Chemical	30	30	—	1.6	1.6	—
Civil	80	80	—	5.0	5.0	—
(Sanitary)[1,2]	(70)	(70)	—	(4.3)	(4.3)	—
Electrical	10	—	—	.3	.1	.2
Industrial	—	—	—	.1	—	.1
Mechanical	10	—	—	.3	.2	.1
Other	20	20	—	1.3	1.2	.1
Natural scientists	330	330	—	21.1	20.9	.2
Agricultural	10	10	—	.8	.8	—
Biological	140	140	—	8.6	8.6	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	10	10	—	.7	.7	—
Mathematicians	—	—	—	.2	.2	—
Systems analysts	—	—	—	.2	.2	—
Chemists	150	150	—	9.4	9.3	.1
(Biochemists)	—	—	—	—	—	—
Geologists and Geophysicists	—	—	—	.1	.1	—
Physicists	—	—	—	.1	.1	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	10	10	—	.9	.9	—
Technicians, except medical and dental	130	120	10	8.2	7.7	.5
Drafters	—	—	—	.2	—	.2
Surveyor	10	10	—	.4	.3	.1
Electrical and electronic	10	10	—	.4	.3	.1
Other engineering and science	70	70	—	4.2	4.1	.1
Computer programmers	—	—	—	—	—	—
Other	50	50	—	3.3	3.3	—
Medical and other health workers	10	—	10	.3	—	.3
Other professional and technical	20	—	20	1.4	—	1.4
Accountants	—	—	—	.2	—	.2
Pilots	—	—	—	.1	—	.1
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	.1	—	.1
Lawyers	—	—	—	.2	—	.2
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	10	—	10	.9	—	.9
Managers and administrators	70	20	50	4.6	1.6	3.0
Clerical workers	260	160	90	16.2	10.3	5.9
Sales workers	20	—	20	1.4	—	1.4
Craft workers	80	20	60	5.3	1.5	3.8
Operatives	90	10	80	5.5	.4	5.1
Service workers	50	—	50	2.9	—	2.9
Laborers	20	10	10	1.5	.6	.9
Farmers and farm workers	10	—	10	.6	—	.6

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-8. Federal pollution control and abatement activities, extramural research, development and demonstrations: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	4,140	2,180	1,960	75.3	39.6	35.7
Professional and technical	1,820	1,640	180	33.0	29.8	3.2
Engineers	470	430	40	8.5	7.8	.7
Aeronautical	10	10	—	.1	.1	—
Chemical	90	90	—	1.7	1.7	—
Civil	170	160	10	3.0	2.9	.1
(Sanitary)[1,2]	(70)	(70)	—	(1.3)	(1.3)	—
Electrical	20	10	10	.4	.2	.2
Industrial	10	—	10	.1	—	.1
Mechanical	140	130	10	2.5	2.4	.1
Other	40	30	10	.7	.5	.2
Natural scientists	760	750	10	13.8	13.6	.2
Agricultural	70	70	—	1.3	1.3	—
Biological	210	210	—	3.8	3.8	—
(Microbiologists)[3]	(40)	(40)	—	(.7)	(.7)	—
(Zoologists)[3]	(10)	(10)	—	(.2)	(.2)	—
Medical	30	30	—	.6	.6	—
Mathematicians	30	30	—	.6	.6	—
Systems analysts	10	10	—	.2	.2	—
Chemists	360	360	—	6.5	6.5	—
(Biochemists)[3]	(10)	(10)	—	(.2)	(.2)	—
Geologists and geophysicists	10	10	—	.1	.1	—
Physicists	10	10	—	.1	.1	—
Meteorologists	(10)	(10)	—	(.1)	(.1)	—
Other natural scientists	10	10	—	.2	.2	—
Technicians, except medical and dental	490	450	40	8.9	8.2	.7
Drafters	30	20	10	.6	.4	.2
Surveyor	—	—	—	—	—	—
Electrical and electronic	20	10	10	.3	.1	.2
Other engineering and science	300	290	10	5.4	5.2	.2
Computer programmers	10	10	—	.2	.2	—
Other	130	130	—	2.3	2.3	—
Medical and other health workers	10	—	10	.1	—	.1
Other professional and technical	100	20	80	1.8	.3	1.5
Accountants	10	—	10	.2	—	.2
Pilots	10	—	10	.1	—	.1
Architects	—	—	—	—	—	—
Designers	10	—	10	.1	—	.1
Editors and reporters	10	—	10	.1	—	.1
Lawyers	10	—	10	.2	—	.2
Personnel and labor relations workers	10	—	10	.1	—	.1
Other	40	—	40	.7	—	.7
Managers and administrators	240	30	210	4.3	.5	3.8
Clerical workers	650	190	460	11.8	3.4	8.4
Sales workers	90	—	90	1.6	—	1.6
Craft workers	420	30	390	7.6	.6	7.0
Operatives	490	80	410	8.8	1.4	7.4
Service workers	140	30	110	2.5	.5	2.0
Laborers	300	190	110	5.4	3.4	2.0
Farmers and farm workers	20	—	20	.4	—	.4

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-9. Federal pollution control and abatement activities, extramural air research, development, and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,010	630	380	78.9	49.5	29.4
Professional and technical	590	560	30	46.1	43.4	2.7
Engineers	150	140	10	11.5	10.9	.6
Aeronautical	–	–	–	–	–	–
Chemical	20	20	–	1.6	1.6	–
Civil	–	–	–	–	–	–
(Sanitary)[1,2]	–	–	–	–	–	–
Electrical	10	–	–	.5	.3	.2
Industrial	–	–	–	.1	–	.1
Mechanical	120	120	–	9.2	9.1	.1
Other	–	–	–	.1	–	.1
Natural scientists	210	210	–	16.8	16.6	.2
Agricultural	–	–	–	–	–	–
Biological	70	70	–	5.5	5.5	–
(Microbiologists)[3]	(10)	(10)	–	(.9)	(.9)	–
(Zoologists)[3]	–	–	–	–	–	–
Medical	–	–	–	–	–	–
Mathematicians	–	1	–	.1	.1	–
Systems analysts	–	–	–	–	–	–
Chemists	130	130	–	10.5	10.4	.1
(Biochemists)[3]	–	–	–	–	–	–
Geologists and geophysicists	–	–	–	–	–	–
Physicists	–	–	–	–	–	–
Meteorologists	10	10	–	(.6)	(.6)	–
Other natural scientists	–	–	–	–	–	–
Technicians, except medical and dental	210	200	10	15.8	15.4	.4
Drafters	20	20	–	1.6	1.5	.1
Surveyor	–	–	–	–	–	–
Electrical and electronic	–	–	–	.2	.1	.1
Other engineering and science	130	130	–	10.3	10.2	.1
Computer programmers	–	–	–	–	–	–
Other	50	50	–	3.6	3.6	–
Medical and other health workers	–	–	–	–	–	–
Other professional and technical	30	10	20	1.9	.5	1.4
Accountants	–	–	–	.1	–	.1
Pilots	–	–	–	.1	–	.1
Architects	–	–	–	–	–	–
Designers	–	–	–	.1	–	.1
Editors and reporters	–	–	–	.1	–	.1
Lawyers	–	–	–	.2	–	.2
Personnel and labor relations workers	–	–	–	.1	–	.1
Other	10	–	10	.6	–	.6
Managers and administrators	40	–	40	3.4	.1	3.3
Clerical workers	150	50	100	11.9	3.8	8.1
Sales workers	20	–	20	1.6	–	1.6
Craft workers	60	–	60	4.4	.1	4.3
Operatives	100	30	70	7.7	2.2	5.5
Service workers	30	–	30	2.3	–	2.3
Laborers	20	–	20	1.3	.1	1.2
Farmers and farm workers	10	–	10	.4	–	.4

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-10. Federal pollution control and abatement activities, extramural water research, development, and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,890	860	1,030	70.7	32.3	38.4
Professional and technical	660	580	80	24.6	21.6	3.0
Engineers	160	140	20	5.9	5.2	.7
Aeronautical	10	10	–	.3	.3	–
Chemical	20	20	–	.9	.9	–
Civil	80	80	–	2.9	2.8	.1
(Sanitary)[1,2]	(20)	(20)	–	(.8)	(.8)	–
Electrical	10	–	–	.2	.1	.1
Industrial	–	–	–	.1	–	.1
Mechanical	10	10	–	.6	.5	.1
Other	–	–	–	.9	.8	.1
Natural scientists	330	320	10	12.5	12.3	.2
Agricultural	50	50	–	1.9	1.9	–
Biological	100	100	–	3.6	3.6	–
(Microbiologists)[3]	(10)	(10)	–	(.4)	(.4)	–
(Zoologists)[3]	(10)	(10)	–	(.5)	(.5)	–
Medical	10	10	–	.5	.5	–
Mathematicians	10	10	–	.3	.3	–
Systems analysts	10	10	–	.2	.2	–
Chemists	150	150	–	5.7	5.6	.1
(Biochemists)[3]	(10)	(10)	–	(.2)	(.2)	–
Geologists and geophysicists	–	–	–	–	–	–
Physicists	–	–	–	.1	.1	–
Meteorologists	–	–	–	–	–	–
Other natural scientists	–	–	–	.1	.1	–
Technicians, except medical and dental	130	110	20	4.7	4.1	.6
Drafters	10	–	10	.3	.1	.2
Surveyor	–	–	–	.1	–	.1
Electrical and electronic	10	–	–	.2	.1	.1
Other engineering and science	70	70	–	2.7	2.6	.1
Computer programmers	–	–	–	.1	.1	–
Other	30	30	–	1.2	1.2	–
Medical and other health workers	–	–	–	–	–	–
Other professional and technical	40	–	40	1.5	–	1.5
Accountants	10	–	–	.2	–	.2
Pilots	–	–	–	–	–	–
Architects	–	–	–	–	–	–
Designers	–	–	–	.1	–	.1
Editors and reporters	–	–	–	.1	–	.1
Lawyers	10	–	10	.2	–	.2
Personnel and labor relations workers	–	–	–	.1	–	.1
Other	20	–	20	.7	–	.7
Managers and administrators	100	–	100	3.7	.1	3.6
Clerical workers	290	60	230	10.7	2.2	8.5
Sales workers	40	–	40	1.6	–	1.6
Craft workers	240	20	220	9.1	.9	8.2
Operatives	260	40	220	9.9	1.7	8.2
Service workers	50	10	40	2.0	.3	1.7
Laborers	240	150	90	8.8	5.6	3.2
Farmers and farm workers	10	–	10	.4	–	.4

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

[3] Detail available for direct extramural employment only.

Table A-11. Federal pollution control and abatement activities, extramural research, development and demonstration by State and local governments: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,110	330	780	67.9	20.2	47.7
Professional and technical	280	200	80	17.5	12.5	5.0
Engineers	70	50	20	4.2	3.3	.9
Aeronautical	—	—	—	—	—	—
Chemical	—	—	—	.1	.1	—
Civil	50	50	—	3.1	2.9	.2
(Sanitary)[1,2]	—	—	—	(.1)	(.1)	—
Electrical	10	—	—	.4	.2	.2
Industrial	—	—	—	—	—	—
Mechanical	—	—	—	.1	.1	—
Other	10	—	—	.2	.1	.1
Natural scientists	90	90	—	5.8	5.6	.2
Agricultural	—	—	—	—	—	—
Biological	10	10	—	.8	.8	—
(Microbiologists)[3]	—	—	—	—	—	—
(Zoologists)[3]	—	—	—	—	—	—
Medical	10	10	—	.6	.6	—
Mathematicians	10	10	—	.6	.6	—
Systems analysts	—	—	—	.1	.1	—
Chemists	60	50	—	3.4	3.3	.1
(Biochemists)[3]	(10)	(10)	—	(.5)	(.5)	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	10	10	—	.3	.3	—
Technicians, except medical and dental	80	60	20	4.8	3.5	1.3
Drafters	10	—	10	.2	.1	.1
Surveyor	—	—	—	.1	—	.1
Electrical and electronic	10	—	10	.4	.1	.3
Other engineering and science	40	30	10	2.6	2.1	.5
Computer programmers	10	10	—	.4	.4	—
Other	10	10	—	.8	.7	.1
Medical and other health workers	—	—	—	.2	—	.2
Other professional and technical	40	—	40	2.4	—	2.4
Accountants	—	—	—	.2	—	.2
Pilots	—	—	—	—	—	—
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	—	—	—
Lawyers	—	—	—	.2	—	.2
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	30	—	30	1.8	—	1.8
Managers and administrators	90	20	70	5.6	1.0	4.6
Clerical workers	180	40	140	11.1	2.3	8.8
Sales workers	30	—	30	1.6	—	1.6
Craft workers	190	10	180	11.7	.3	11.4
Operatives	200	20	180	12.0	.9	11.1
Service workers	50	20	30	2.9	1.1	1.8
Laborers	90	40	50	5.4	2.2	3.2
Farmers and farm workers	—	—	—	.2	—	.2

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-12. Federal pollution control and abatement activities, extramural research, development, and demonstration by universities: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,800	1,290	510	94.5	67.6	26.9
Professional and technical	1,090	1,050	40	57.3	55.0	2.3
Engineers	260	250	10	13.8	13.2	.6
Aeronautical	—	—	—	—	—	—
Chemical	60	60	—	2.9	2.9	—
Civil	100	100	—	5.2	5.1	.1
(Sanitary)[1,2]	(60)	(60)	—	(3.1)	(3.1)	—
Electrical	—	—	—	.2	—	.2
Industrial	—	—	—	.1	—	.1
Mechanical	90	90	—	4.8	4.7	.1
Other	10	10	—	.6	.5	.1
Natural scientists	500	500	—	26.1	26.0	.1
Agricultural	70	70	—	3.8	3.8	—
Biological	150	150	—	7.6	7.6	—
(Microbiologists)[3]	(30)	(30)	—	(1.3)	(1.3)	—
(Zoologists)[3]	(10)	(10)	—	(.7)	(.7)	—
Medical	20	20	—	1.0	1.0	—
Mathematicians	10	10	—	.7	.7	—
Systems analysts	10	10	—	.5	.5	—
Chemists	220	220	—	11.8	11.7	.1
(Biochemists)[3]	—	—	—	—	—	—
Geologists and geophysicists	10	10	—	.3	.3	—
Physicists	—	—	—	.1	.1	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	10	10	—	.3	.3	—
Technicians, except medical and dental	300	290	10	15.8	15.4	.4
Drafters	10	10	—	.8	.7	.1
Surveyor	—	—	—	—	—	—
Electrical and electronic	—	—	—	.1	—	.1
Other engineering and science	180	180	—	9.5	9.5	—
Computer programmers	10	10	—	.3	.3	—
Other	100	100	—	5.1	5.0	.1
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	30	10	20	1.6	.5	1.1
Accountants	—	—	—	.1	—	.1
Pilots	—	—	—	.1	—	.1
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	.1	—	.1
Lawyers	—	—	—	.1	—	.1
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	10	—	10	.5	—	.5
Managers and administrators	60	10	50	3.3	.4	2.9
Clerical workers	220	100	120	11.4	5.1	6.3
Sales workers	30	—	30	1.5	—	1.5
Craft workers	90	—	90	4.6	—	4.6
Operatives	110	—	110	5.7	—	5.7
Service workers	40	10	30	2.1	.4	1.7
Laborers	150	130	20	7.9	6.7	1.2
Farmers and farm workers	10	—	10	.7	—	.7

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-13. Federal pollution control and abatement activities, extramural research, development and demonstration by non-profit organization: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	360	180	190	64.0	32.8	31.2
Professional and technical	180	160	20	31.2	27.3	3.9
Engineers	40	40	—	7.3	6.9	.4
Aeronautical	10	10	—	.9	.9	—
Chemical	20	20	—	3.3	3.3	—
Civil	10	10	—	2.0	2.0	—
(Sanitary)[1,2]	(10)	(10)	—	(1.8)	(1.8)	—
Electrical	10	4	—	.8	.7	.1
Industrial	—	—	—	.1	—	.1
Mechanical	—	—	—	.1	—	.1
Other	—	—	—	—	—	—
Natural scientists	70	70	—	13.3	13.1	.2
Agricultural	—	—	—	—	—	—
Biological	10	10	—	2.0	2.0	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	—	—	—	—	—	—
Mathematicians	10	10	—	1.1	1.1	—
Systems analysts	—	—	—	—	—	—
Chemists	50	50	—	8.4	8.4	—
(Biochemists)	—	—	—	—	—	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	.3	.3	—
Meteorologists	(10)	(10)	—	(1.3)	(1.3)	—
Other natural scientists	—	—	—	.0	.0	—
Technicians, except medical and dental	40	40	—	6.6	6.3	.3
Drafters	—	—	—	.6	.5	.1
Surveyor	—	—	—	—	—	—
Electrical and electronic	—	—	—	.2	.1	.1
Other engineering and science	20	20	—	4.4	4.3	.1
Computer programmers	—	—	—	—	—	—
Other	10	10	—	1.4	1.4	—
Medical and other health workers	—	—	—	.1	—	.1
Other professional and technical	20	—	20	3.8	1.0	2.8
Accountants	—	—	—	.1	—	.1
Pilots	—	—	—	.1	—	.1
Architects	—	—	—	—	—	—
Designers	—	—	—	—	—	—
Editors and reporters	—	—	—	.1	—	.1
Lawyers	—	—	—	—	—	—
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	30	10	20	1.0	—	1.0
Managers and administrators	20	—	20	3.7	.1	3.6
Clerical workers	60	20	40	10.6	3.4	7.2
Sales workers	10	—	10	1.7	—	1.7
Craft workers	20	—	20	4.2	—	4.2
Operatives	30	—	30	4.5	—	4.5
Service workers	20	—	20	4.3	—	4.3
Laborers	20	10	10	3.0	1.9	1.1
Farmers and farm workers	—	—	—	.7	—	.7

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-14. Federal pollution control and abatement activities, extramural research, development and demonstration by private industry: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	880	380	500	62.6	27.1	35.5
Professional and technical	280	230	50	20.0	16.7	3.3
Engineers	90	80	10	6.7	6.0	.7
Aeronautical	—	—	—	—	—	—
Chemical	20	20	—	1.4	1.4	—
Civil	10	4	—	.4	.3	.1
(Sanitary)[1,2]	—	—	—	.1	.1	—
Electrical	10	—	—	.5	.3	.2
Industrial	—	—	—	.1	—	.1
Mechanical	40	40	—	2.8	2.8	—
Other	20	20	—	1.4	1.1	.3
Natural scientists	90	80	—	6.2	6.0	.2
Agricultural	—	—	—	—	—	—
Biological	40	40	—	2.7	2.7	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	10	10	—	.5	.5	—
Mathematicians	—	—	—	.3	.3	—
Systems analysts	—	—	—	—	—	—
Chemists	40	40	—	2.6	2.5	.1
(Biochemists)	—	—	—	(.1)	(.1)	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	—	—	—	—	—	—
Technicians, except medical and dental	70	70	10	5.2	4.7	.5
Drafters	10	10	—	.6	.4	.2
Surveyor	—	—	—	—	—	—
Electrical and electronic	—	—	—	.2	.1	.1
Other engineering and science	50	50	—	3.4	3.3	.1
Computer programmers	—	—	—	—	—	—
Other	10	10	—	.8	.8	—
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	20	—	20	1.7	—	1.7
Accountants	—	—	—	.2	—	.2
Pilots	—	—	—	.1	—	.1
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	.1	—	.1
Lawyers	—	—	—	.3	—	.3
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	10	—	10	.8	—	.8
Managers and administrators	60	10	50	4.2	.4	3.8
Clerical workers	180	40	140	12.5	2.5	10.0
Sales workers	20	—	20	1.7	—	1.7
Craft workers	120	30	90	8.2	2.0	6.2
Operatives	160	60	90	11.1	4.5	6.6
Service workers	30	—	30	2.0	—	2.0
Laborers	40	10	30	2.7	.9	1.8
Farmers and farm workers	—	—	—	.3	—	.3

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-15. Federal pollution control and abatement activities, extramural sources and effects research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,820	1,190	630	83.4	54.7	28.7
Professional and technical	1,030	960	70	47.1	44.1	3.0
Engineers	150	140	10	6.7	6.2	.5
Aeronautical	—	—	—	—	—	—
Chemical	10	10	—	.4	.4	—
Civil	40	40	—	1.7	1.6	.1
(Sanitary)[1,2]	(10)	(10)	—	(.6)	(.6)	—
Electrical	10	10	—	.4	.2	.2
Industrial	—	—	—	.1	—	.1
Mechanical	90	90	—	4.0	3.9	.1
Other	10	—	—	.3	.2	.1
Natural scientists	600	590	—	27.4	27.2	.2
Agricultural	30	30	—	1.2	1.2	—
Biological	190	190	—	8.5	8.5	—
(Microbiologists)[3]	(30)	(30)	—	(1.2)	(1.2)	—
(Zoologists)[3]	(10)	(10)	—	(.6)	(.6)	—
Medical	40	40	—	1.6	1.6	—
Mathematicians	30	30	—	1.3	1.3	—
Systems analysts	—	—	—	—	—	—
Chemists	300	300	—	13.9	13.8	.1
(Biochemists)[3]	—	—	—	(.2)	(.2)	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	(10)	(10)	—	(.5)	(.5)	—
Other natural scientists	10	10	—	.5	.5	—
Technicians, except medical and dental	240	230	10	10.9	10.5	.4
Drafters	20	10	—	.7	.6	.1
Surveyor	—	—	—	—	—	—
Electrical and electronic	—	—	—	.1	—	.1
Other engineering and science	120	120	—	5.4	5.3	.1
Computer programmers	10	10	—	.4	.4	—
Other	90	90	—	4.2	4.2	—
Medical and other health workers	—	—	—	.1	—	.1
Other professional and technical	40	10	40	2.0	.3	.7
Accountants	—	—	—	.1	—	.1
Pilots	—	—	—	.1	—	.1
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	.1	—	.1
Lawyers	—	—	—	.1	—	.1
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	20	—	20	1.1	—	1.1
Managers and administrators	90	20	70	4.0	.7	3.3
Clerical workers	280	110	170	12.7	5.0	7.7
Sales workers	40	—	40	1.6	—	1.6
Craft workers	100	10	90	4.8	.5	4.3
Operatives	110	—	110	4.8	—	4.8
Service workers	70	10	60	3.1	.5	2.6
Laborers	170	90	80	4.8	3.9	.9
Farmers and farm workers	10	—	10	.4	—	.4

[1] Detail available for direct employment only.
[2] Does not include detail for grants for waste water treatment plant construction.
[3] Detail available for direct extramural employment only.

Table A-16. Federal pollution control and abatement activities, extramural control technology research, development and demonstration: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	2,330	990	1,340	70.1	29.8	40.3
Professional and technical	790	680	110	23.9	20.5	3.4
Engineers	320	290	30	9.6	8.8	.8
Aeronautical	10	10	—	.2	.2	—
Chemical	90	90	—	2.6	2.6	—
Civil	130	130	—	3.9	3.8	.1
(Sanitary)[1,2]	(60)	(60)	—	(1.8)	(1.8)	—
Electrical	10	10	10	.4	.2	.2
Industrial	—	—	—	.1	—	.1
Mechanical	50	50	10	1.6	1.4	.2
Other	30	20	10	.9	.7	.2
Natural scientists	160	150	10	4.8	4.6	.2
Agricultural	50	50	—	1.4	1.4	—
Biological	20	20	—	.7	.7	—
(Microbiologists)[3]	(10)	(10)	—	(.3)	(.3)	—
(Zoologists)	—	—	—	—	—	—
Medical	—	—	—	—	—	—
Mathematicians	10	10	—	.2	.2	—
Systems analysts	10	10	—	.3	.3	—
Chemists	60	60	—	1.9	1.8	.1
(Biochemists)	—	—	—	(.1)	(.1)	—
Geologists and geophysicists	10	10	—	.2	.2	—
Physicists	—	—	—	.1	.1	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	—	—	—	—	—	—
Technicians, except medical and dental	250	220	30	1.6	6.7	.9
Drafters	20	10	10	1.1	.3	.8
Surveyor	—	—	—	—	—	—
Electrical and electronic	10	—	—	.3	.1	.2
Other engineering and science	180	170	10	5.4	5.1	.3
Computer programmers	—	—	—	.1	.1	—
Other	40	40	—	1.1	1.1	—
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	50	10	40	1.6	.3	1.3
Accountants	10	—	10	.2	—	.2
Pilots	—	—	—	—	—	—
Architects	—	—	—	—	—	—
Designers	—	—	—	.1	—	.1
Editors and reporters	—	—	—	—	—	—
Lawyers	10	—	10	.2	—	.2
Personnel and labor relations workers	—	—	—	.1	—	.1
Other	20	—	20	.5	—	.5
Managers and administrators	150	10	130	4.4	.4	4.0
Clerical workers	350	80	270	11.2	2.4	8.8
Sales workers	50	—	50	1.6	—	1.6
Craft workers	310	20	290	9.5	.7	8.8
Operatives	380	80	300	11.4	2.3	9.1
Service workers	70	20	50	2.1	.5	1.6
Laborers	180	100	80	5.5	3.0	2.5
Farmers and farm workers	20	—	20	.5	—	.5

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-17. Federal pollution control and abatement activities, abatement and control operations: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	3,550	2,300	1,250	78.4	50.7	27.7
Professional and technical	1,660	1,500	160	36.9	33.3	3.6
Engineers	490	470	20	10.8	10.3	.5
Aeronautical	–	–	–	–	–	–
Chemical	60	60	–	1.4	1.4	–
Civil	330	330	–	7.4	7.3	.1
(Sanitary)[1,2]	(270)	(270)	–	(5.7)	(5.7)	–
Electrical	10	10	–	.2	.1	.1
Industrial	–	–	–	.1	–	.1
Mechanical	40	30	10	.9	.8	.1
Other	30	30	–	.8	.7	.1
Natural scientists	590	580	10	12.9	12.7	.2
Agricultural	20	20	–	.4	.4	–
Biological	160	160	–	3.6	3.6	–
(Microbiologists)	–	–	–	–	–	–
(Zoologists)	–	–	–	–	–	–
Medical	10	10	–	.2	.2	–
Mathematicians	–	–	–	.1	.1	–
Systems analysts	30	30	–	.6	.6	–
Chemists	310	310	–	6.9	6.8	.1
(Biochemists)	–	–	–	–	–	–
Geologists and geophysicists	–	–	–	.1	.1	–
Physicists	–	–	–	–	–	–
Meteorologists	(30)	(30)	–	(.7)	(.7)	–
Other natural scientists	10	10	–	.2	.2	–
Technicians, except medical and dental	490	460	30	10.7	10.2	.5
Drafters	10	–	10	.2	–	.2
Surveyor	–	–	–	–	–	–
Electrical and electronic	40	40	–	.9	.8	.1
Other engineering and science	210	210	–	4.6	4.5	.1
Computer programmers	10	10	–	.3	.3	–
Other	210	210	–	4.6	4.6	–
Medical and other health workers	20	–	20	.4	–	.4
Other professional and technical	90	–	90	2.0	–	2.0
Accountants	10	–	10	.3	–	.3
Pilots	–	–	–	.1	–	.1
Architects	–	–	–	–	–	–
Designers	–	–	–	.1	–	.1
Editors and reporters	10	–	10	.2	–	.2
Lawyers	10	–	10	.2	–	.2
Personnel and labor relations workers	–	–	–	.1	–	.1
Other	50	–	50	1.1	–	1.1
Managers and administrators	410	260	150	9.0	5.8	3.2
Clerical workers	770	490	280	16.9	10.8	6.1
Sales workers	60	–	60	1.4	–	1.4
Craft workers	200	30	170	2.5	.7	7.8
Operatives	200	–	200	4.5	–	4.5
Service workers	160	–	160	8.5	–	8.5
Laborers	40	–	40	.9	–	.9
Farmers and farm workers	30	–	30	.6	–	.6

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-18. Federal pollution control and abatement activities, radiation programs: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	8,610	4,710	3,900	84.1	46.0	38.1
Professional and technical	3,860	3,420	440	37.7	33.4	4.3
Engineers	700	610	90	6.9	6.0	.9
Aeronautical	–	–	–	–	–	–
Chemical	30	30	–	.3	.3	–
Civil	100	90	10	1.0	.9	.1
(Sanitary)[1,2]	(20)	(20)	–	(.2)	(.2)	–
Electrical	110	80	30	1.1	.8	.3
Industrial	10	–	10	.1	–	.1
Mechanical	40	20	20	.4	.2	.2
Other	410	400	10	4.0	3.8	.2
Natural scientists	1,710	1,690	20	16.7	16.5	.2
Agricultural	30	30	–	.3	.3	–
Biological	480	480	–	4.7	4.7	–
(Microbiologists)	–	–	–	–	–	–
(Zoologists)	–	–	–	–	–	–
Medical	90	90	–	.9	.9	–
Mathematicians	20	20	–	.2	.2	–
Systems analysts	10	10	–	.1	.1	–
Chemists	340	330	10	3.3	3.2	.1
(Biochemists)	(40)	(40)	–	(.4)	(.4)	–
Geologists and geophysicists	10	10	–	.1	.1	–
Physicists	420	420	–	4.1	4.1	–
Meteorologists	(20)	(20)	–	(.2)	(.2)	–
Other natural scientists	270	270	–	2.6	2.6	–
Technicans, except medical and dental	960	900	60	9.4	8.8	.6
Drafters	30	10	20	.3	.1	.2
Surveyor	–	–	–	–	–	–
Electrical and electronic	170	150	20	1.7	1.5	.2
Other engineering and science	500	480	20	4.9	4.7	.2
Computer programmers	30	30	–	.3	.3	–
Other	230	230	–	2.2	2.2	–
Medical and other health workers	200	160	40	2.0	1.6	.4
Other professional and technical	280	60	220	2.7	.6	2.1
Accountants	20	–	20	.2	–	.2
Pilots	50	40	10	.5	.4	.1
Architects	–	–	–	–	–	–
Designers	10	–	10	.1	–	.1
Editors and reporters	20	–	20	.2	–	.2
Lawyers	10	–	10	.1	–	.1
Personnel and labor relations workers	10	–	10	.1	–	.1
Other	140	–	140	1.4	–	1.4
Managers and administrators	660	240	420	6.4	2.3	4.1
Clerical workers	1,510	690	820	14.7	6.7	8.0
Sales workers	190	–	190	1.9	–	1.9
Craft workers	750	70	680	7.3	.7	6.6
Operatives	890	60	830	8.7	.6	8.1
Service workers	480	160	320	4.7	1.6	3.1
Laborers	230	60	170	2.3	.6	1.7
Farmers and farm workers	30	–	30	.3	–	.3

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-19. Federal pollution control and abatement activities, construction of waste water treatment plants: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	13,550	4,730	8,820	53.6	18.7	34.9
Professional and technical	1,970	1,040	930	7.8	4.1	3.7
Engineers	610	380	230	2.4	1.5	.9
Aeronautical	—	—	—	—	—	—
Chemical	—	—	—	—	—	—
Civil	400	350	50	1.6	1.4	.2
(Sanitary)[1,2]	—	—	—	—	—	—
Electrical	50	30	20	.2	.1	.1
Industrial	30	—	30	.1	—	.1
Mechanical	50	—	50	.1	—	.1
Other	50	—	50	.2	—	.2
Natural scientists	30	—	30	.1	—	.1
Agricultural	—	—	—	—	—	—
Biological	—	—	—	—	—	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	—	—	—	—	—	—
Mathematicians	—	—	—	—	—	—
Systems analysts	—	—	—	—	—	—
Chemists	30	—	30	.1	—	.1
(Biochemists)	—	—	—	—	—	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	—	—	—	—	—	—
Technicians, except medical and dental	730	530	200	2.9	2.1	.8
Drafters	330	180	150	1.3	.7	.6
Surveyor	50	30	20	.2	.1	.1
Electrical and electronic	80	50	30	.3	.2	.1
Other engineering and science	250	230	20	1.0	.9	.1
Computer programmers	30	30	—	.1	.1	—
Other	50	50	—	.2	.2	—
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	560	100	460	2.2	.4	1.8
Accountants	180	30	150	.7	.1	.6
Pilots	—	—	—	—	—	—
Architects	30	—	30	.1	—	.1
Designers	50	20	30	.2	.1	.1
Editors and reporters	—	—	—	—	—	—
Lawyers	150	—	150	.6	—	.6
Personnel and labor relations workers	30	—	30	.1	—	.1
Other	150	50	100	.6	.2	.4
Managers and administrators	1,240	380	860	4.9	1.5	3.4
Clerical workers	1,690	200	1,490	6.7	.8	5.9
Sales workers	380	—	380	1.5	—	1.5
Craft workers	3,460	2,000	1,460	13.7	7.9	5.8
Operatives	3,310	680	2,630	13.1	2.7	10.4
Service workers	250	—	250	1.0	—	1.0
Laborers	1,090	380	710	4.3	1.5	2.8
Farmers and farm workers	80	—	80	.3	—	.3

1 Detail available for direct employment only.

2 Does not include detail for grants for waste water treatment plant construction.

Table A-20. Federal pollution control and abatement activities, engineering design of waste water treatment plants: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	1,020	690	330	65.1	43.8	21.3
Professional and technical	720	620	100	45.6	39.2	6.4
Engineers	360	330	30	22.9	21.0	1.9
Aeronautical	—	—	—	—	—	—
Chemical	10	10	—	.6	.6	—
Civil	300	300	10	19.7	19.1	.6
(Sanitary)[1,2]	—	—	—	—	—	—
Electrical	20	10	—	1.1	.9	.2
Industrial	—	—	—	.1	—	.1
Mechanical	10	10	—	.7	.4	.3
Other	10	—	10	.6	—	.6
Natural scientists	2	—	2	.1	—	.1
Agricultural	—	—	—	—	—	—
Biological	—	—	—	—	—	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	—	—	—	—	—	—
Mathematicians	—	—	—	—	—	—
Systems analysts	—	—	—	—	—	—
Chemists	—	—	—	—	—	—
(Biochemists)	—	—	—	—	—	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	—	—	—	—	—	—
Technicians, except medical and dental	310	280	40	20.0	17.8	2.2
Drafters	140	120	20	9.0	7.5	1.5
Surveyor	10	—	10	—	—	.4
Electrical and electronic	—	—	—	.1	—	.1
Other engineering and science	120	110	—	7.3	7.2	.1
Computer programmers	—	—	—	—	—	—
Other	50	50	—	3.2	3.1	.1
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	30	10	30	2.5	.4	2.1
Accountants	20	10	10	1.0	.4	.6
Pilots	—	—	—	—	—	—
Architects	10	—	10	.4	—	.4
Designers	—	—	—	.3	—	.2
Editors and reporters	—	—	—	.2	—	.2
Lawyers	10	—	10	.4	—	.4
Personnel and labor relations workers	—	—	—	—	—	—
Other	—	—	—	.2	—	.2
Managers and administrators	40	10	30	2.6	.4	2.2
Clerical workers	150	70	80	9.3	4.2	5.1
Sales workers	30	—	30	1.7	—	1.7
Craft workers	30	—	30	2.1	—	2.1
Operatives	30	—	30	2.0	—	2.0
Service workers	20	—	20	1.0	—	1.0
Laborers	10	—	10	.5	—	.5
Farmers and farm workers	—	—	—	.2	—	.2

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Table A-21. Federal pollution control and abatement activities, onsite construction of waste water treatment plants: Generated employment, by selected occupations

Occupation	Actual expenditures			Per million dollars		
	Total	Direct	Indirect	Total	Direct	Indirect
Total	12,510	4,030	9,490	52.8	17.0	35.8
Professional and technical	1,260	430	830	5.3	1.8	3.5
Engineers	240	50	190	1.0	.2	.8
Aeronautical	—	—	—	—	—	—
Chemical	—	—	—	—	—	—
Civil	100	50	50	.4	.2	.2
(Sanitary)[1,2]	—	—	—	—	—	—
Electrical	20	—	20	.1	—	.1
Industrial	20	—	20	.1	—	.1
Mechanical	50	—				
Other	50	—	50	.2	—	.2
Natural scientists	20	—	20	.1	—	.1
Agricultural	—	—	—	—	—	—
Biological	—	—	—	—	—	—
(Microbiologists)	—	—	—	—	—	—
(Zoologists)	—	—	—	—	—	—
Medical	—	—	—	—	—	—
Mathematicians	—	—	—	—	—	—
Systems analysts	—	—	—	—	—	—
Chemists	20	—	20	.1	—	.1
(Biochemists)	—	—	—	—	—	—
Geologists and geophysicists	—	—	—	—	—	—
Physicists	—	—	—	—	—	—
Meteorologists	—	—	—	—	—	—
Other natural scientists	—	—	—	—	—	—
Technicians, except medical and dental	430	260	170	1.8	1.1	.7
Drafters	170	50	120	.7	.2	.5
Surveyor	50	20	20	.2	.1	.1
Electrical and electronic	70	50	20	.3	.2	.1
Other engineering and science	140	120	20	.6	.5	.1
Computer programmers	20	20	—	.1	.1	—
Other	—	—	—	—	—	—
Medical and other health workers	—	—	—	—	—	—
Other professional and technical	520	90	430	2.2	.4	1.8
Accountants	160	20	140	.7	.1	.6
Pilots	—	—	—	—	—	—
Architects	20	—	20	.1	—	.1
Designers	50	20	20	.2	.1	.1
Editors and reporters	—	—	—	—	—	—
Lawyers	140	—	140	.6	—	.6
Personnel and labor relations workers	20	—	20	.1	—	.1
Other	140	50	90	.6	.2	.4
Managers and administrators	1,210	380	830	5.1	1.6	3.5
Clerical workers	1,560	140	1,420	6.6	.6	6.0
Sales workers	360	—	360	1.5	—	1.5
Craft workers	3,410	1,990	1,420	14.4	8.4	6.0
Operatives	3,290	690	2,600	13.9	2.9	11.0
Service workers	240	—	240	1.0	—	1.0
Laborers	1,090	380	710	4.6	1.6	3.0
Farmers and farm workers	70	—	70	.3	—	.3

[1] Detail available for direct employment only.

[2] Does not include detail for grants for waste water treatment plant construction.

Appendix B. Interview Guide

BLS 3021

Office of Management and
Budget No. 44-S-72013
Approval expires 12-31-72

Employment Impact of Federal Expenditures
for Pollution Control and Abatement

Interview conducted at ______________________
(company)

____
(address)

with ______________________ (   )
(official's name) (Telephone)

on ______________________
(date)

A. Introduction

This interview is being conducted by the BLS as part of a study to assess the employment impact of Federal pollution control and abatement expenditures. The study is being made for the National Science Foundation. It is designed to develop a methodology to assist Federal agencies in evaluating the employment impact of new programs. It will also provide information on the industrial and occupational transferability of skills at the professional and technical levels. The basic expenditure data on which this study is based was originally collected from Federal agencies by the Office of Management and Budget. In this interview, we will be asking respondents for information on their employment and other costs connected either directly or indirectly with Federal pollution control and abatement projects in which they are engaged. All sources of data and information obtained in the interview will be held in strict confience by the BLS, and any published information will not permit identification of individual organizations.

B. Site Information

1. /Verify or obtain the following information (some entries are already known based on data received from OMB and other Federal agencies) for those who are directly receiving Federal funds./

   1. Name of Federal agency funding project.

   2. Project title or identification.

   3. Activity.

Financial assistance to State and local governments for capital investment (primarily sewage plant/pipeline construction) __________

Research, development and demonstration where the primary purpose is pollution control and abatement: __________

Pollution sources and effects
- Basic research __________
- Development __________

Pollution control technology
- Development __________
- Demonstration __________

Abatement and control operations (at Federal facilities) __________

- Planning __________
- Monitoring and surveillance __________
- Standard setting and enforcement __________
- Technical support __________

Manufacturers and/or suppliers of goods and services used in pollution control and abatement projects __________

4. Brief description of project
/In two or three sentences, describe purpose and nature of the project and identify media involved./

5. Starting date

6. Scheduled completion date (if open-ended, indicate).

7. Total cost of project

8. Total cost of project, FY-1970

9. Federal funds for project received in FY 1970.

Obtain the following from all respondents

10. Was any part of this project subcontracted for? (Obtain dollar amounts and names and addresses of subcontractors.)

11. Industry and SIC code of respondent.

12. Is the particular type of work in question different from your normal type of work? If yes, how?

13. How long has the organization been working in the pollution control and abatement field?

C. Payroll costs

1. What were the total payroll costs related to the project for FY 1970? (Include wages, salaries, and all employer financed benefits, exclude overhead and fees to consulting firms, but include individuals who are consultants.)

2. How many workers were supported by this payroll?

   a. List number of workers by occupation in Col. A.

   b. List man-hours or man-years in Col. B.

   /Individual items should add to total/

Occupations	No. of Positions	No. of man-years or man-hours
Total all occupations		
Professional, Technical and Kindred Occupations, Total		
Engineers		
Mechanical		
Electrical and Electronic		
All other engineers		
Mathematicians		
Systems Analysts		
Physical Scientists		
Chemists		
Physicists		
*All other physical scientists		
Life Scientists		
Biological scientists		
Medical scientists		
Agricultural scientists		
All other life scientists		
Technicians		
Computer Programmers		
Draftsmen		
Electrical and electronic technicians		
All other engineering technicians		
Science Technicians (exclude medical and dental technicians)		
All other technicians (Include medical and dental technicians in research and development exclude those who primary function is care or treatment of patients)		
Managerial occupations		
Sales occupations		
Clerical occupations		
Craftsmen		
Operatives		

3. If you received additional contracts in the same areas, what would be the effect on employment? (Discuss specific information relating to scientific and technical manpower. For example, if the contract were doubled, would employment of scientists and engineers double?)

D. Non-Payroll Costs

/Non-payroll costs include all charges to the project other than payroll reported under C-1. The following questions are designed to relate such expenditures to particular categories and industries in order to help measure the indirect employment resulting from this project./

1. Apart from payroll costs, what were the total outlays for the project in FY 1970? (Accept budget costs if actual outlays are not available.)

2. a. What kinds of capital equipment are (were) needed for this project? /Machinery or other durable goods lasting one year or longer. Include items purchased specifically for the project as well as existing items of capital equipment./

   b. What were the charges to the project for each item of capital equipment?

Item	Charge
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

3. What are the dollar amounts and kinds of goods and services charged to the project? (Include services of consulting firms and obtain names and addresses of such firms. Individual consultants included under payroll costs should not be included here.)

4. What were the total overhead costs charged to this project?

   a. Payroll costs - include dollar amounts and occupations supported by this overhead charge.

   b. Non payroll costs - include dollar amounts and types of services and supplies charged to overhead.

E. Skill Transferability

1. In filling scientific and technical vacancies related to pollution control projects, what qualifications do you seek? /Discuss relationship between education and general and/or specialized work experience./

2. How have your actual hiring experiences related to the qualifications you were seeking?

3. Has your organization experienced difficulty in expanding current projects or initiating new ones because of a shortage of manpower with the desirable training or skills? /Discuss time frame--past and current occupational shortages./

4. In the context of today's labor market situation:

   a. If you were starting now the work you have done in the past year or two, would you change your staffing patterns.? /Determine expected occupational variations and/or manpower/capital variation and discuss reasons for any variations./

   b. Are you considering any staffing changes--for example, an upgrading of scientific qualifications in light of the reported availability of highly educated manpower?

5. Skill Transferability from Defense and Aerospace Industries

   /This series of questions is designed to obtain the respondent's views concerning the transferability of defense and aerospace skills to the area under discussion./

   Have you had any experience in hiring or interviewing people from the aerospace industry? We would like you to answer the following questions based on your experience, or if you have had no experience along these lines we would like your opinions about this subject.

a. Are there any similarities in academic qualifications between your scientific and technical personnel and those personnel most commonly employed in aerospace and defense? (For example, B.S. degree in electrical engineering.)

b. Does the academic preparation and past experience of scientific and technical personnel in the defense and aerospace industries have any carryover to the work your organization is doing (in pollution control.)

c. If the technologies are so different that skill carryover would be negligible, can retraining bridge this gap? How different is the retraining necessary for displaced areospace and defense personnel from what would normally be given to new college graduates with the same academic qualifications?

d. Are there any barriers which could discourage your organization from recruiting or hiring displaced scientific and technical personnel from the defense and aerospace industries? (Include economic and social barriers to recruiting these personnel.)

F. What types of information obtained in this interview could you, and would you, have supplied in a mail questionnaire? [Be specific and cover items included under section C through E.]

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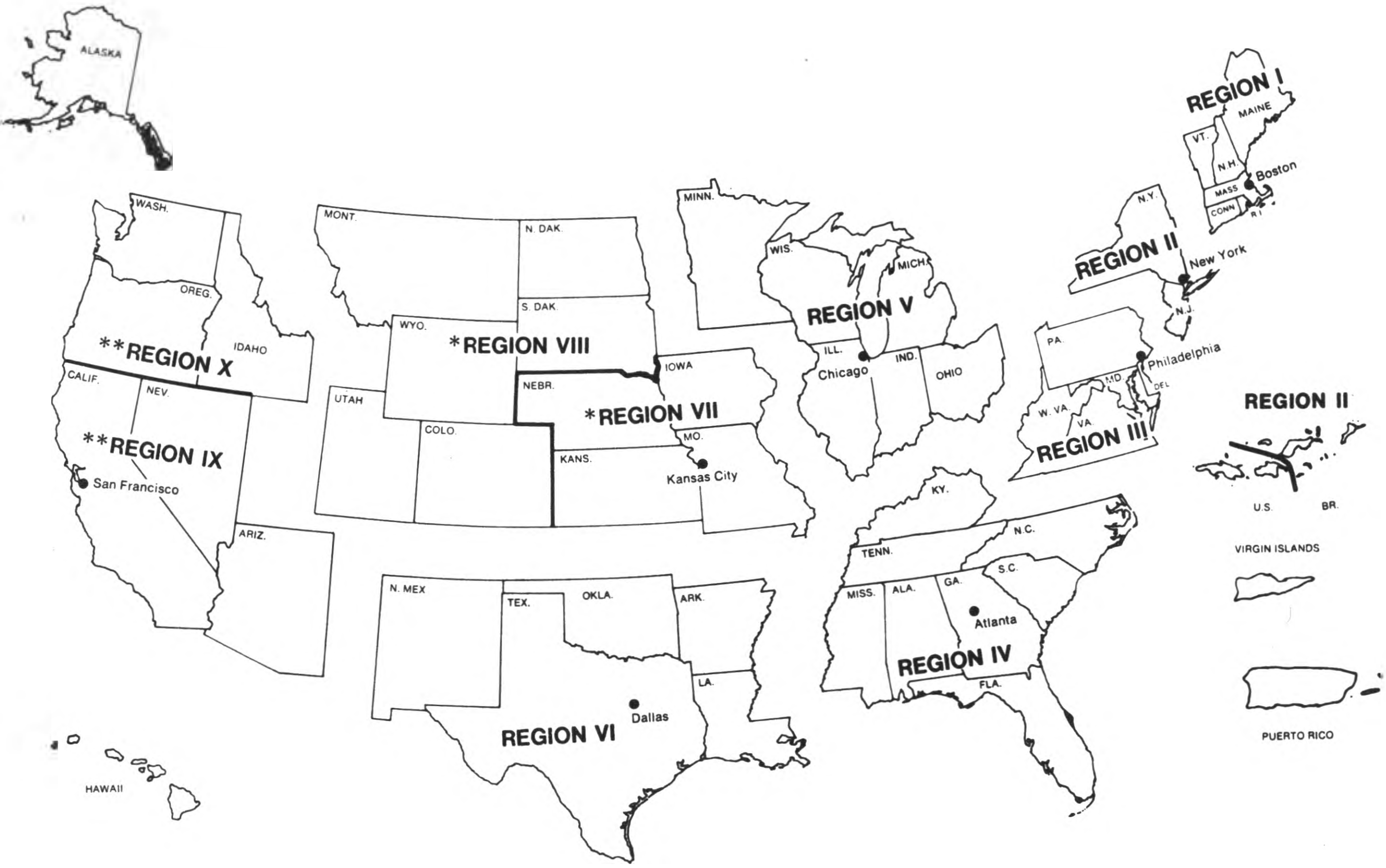
REGIONAL OFFICES



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