8-1-1970

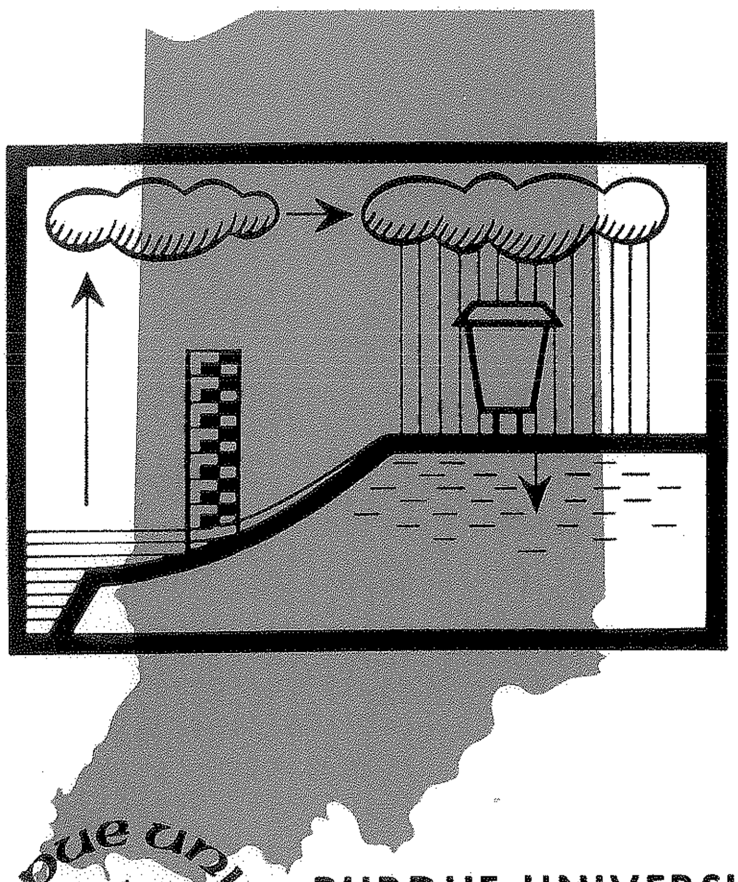
Manpower Supply In Wastewater Treatment Plants

L. N. Smith

W. L. Miller

TECHNICAL REPORT 15

MANPOWER SUPPLY IN WASTEWATER TREATMENT PLANTS



by

L. N. Smith

and

W. L. Miller

August 1970

PURDUE UNIVERSITY
WATER RESOURCES RESEARCH CENTER
LAFAYETTE, INDIANA

MANPOWER SUPPLY IN

WASTEWATER TREATMENT PLANTS

by

L. N. Smith

W. L. Miller

A completion report of OWRR Project No. A-011-IND (Agreement No. 14-31-0001-3014), Improved Methods for Estimating Manpower Needs for Water Resources Development". Period of project: July 1968 to June 1970. Principal investigator: W. L. Miller

Purdue University

Department of Agricultural Economics

Lafayette, Indiana

The work upon which this report is based was supported in part by funds provided by the United States Department of Interior, Office of Water Resources Research, as authorized by the Water Resources Act of 1964.

Technical Report No. 15

Purdue University Water Resources Research Center

Lafayette, Indiana

August 1970

Foreword

This study was conducted with the financial support of both the Agricultural Experiment Station at Purdue University and the United States Department of Interior. Research project A-011-IND entitled "Improved Methods for Estimating Manpower Needs for Water Resources Development" which was funded by the Department of Interior provided the major source of funds for this work. The administrative support for this project was provided by Dr. Dan Wiersma, Director of the Purdue Water Resources Center and Dr. C.E. French, Head Department of Agricultural Economics.

This report is based upon the research conducted by Mr. Lawrence N. Smith and reported in his Master of Science thesis. The research completes both objectives specified in the research project designated above. The work involves the application of regression analysis to determine the supply function for wastewater treatment plant operators in the State of Indiana. The supply function estimated provides the basis for forecasts of occupational supply in 1972. This methodological technique is in contrast to the more traditional employer survey approach to forecasting an industry's future manpower situation. It appears that the method utilized in this study has potential application to other occupational areas.

The authors would like to express their appreciation to personnel of the Indiana State Board of Health. Mr. Joseph C. Krieger, Mr. Oral H. Hert and Mr. Herbert A. Youmans were of great assistance to the authors. A special note of appreciation must be expressed to each superintendent of a wastewater treatment plant who completed a questionnaire which provided the primary data utilized for this study.

TABLE OF CONTENTS

Table of Contents (con't)

LIST OF TABLES

List of Tables (con't)

LIST OF FIGURES

ABSTRACT

Manpower Supply in Wastewater Treatment Plants

Lawrence N. Smith and W.L. Miller

Will there be enough skilled and trained men available who are willing to work in the wastewater treatment industry under present and projected economic conditions? Three research objectives were established to examine this question: (1) obtain information about operators employed during 1969, (2) estimate supply functions for plant operators in 1969, and (3) project the supply of operators for 1972.

The quantity of wastewater treatment plant operators was postulated to be a function of wages, alternative wages, population, unemployment, and recent hirings. Single equation, linear regression procedures based on cross sectional data were used to estimate the operator supply functions.

The analysis concludes that two variables appear to be significant in explaining the quantity of operators supplied, that is, wages and population. Projections for two regions in Indiana and for the State as a whole were made for 1972.

The conclusions suggest managers have several alternatives to insure enough skilled and trained operators will be available. These alternatives include the change in wages and population variables suggested by the analysis of the supply function in this study and other techniques, such as, employing one operator full time to service a few small plants in the same geographic area or the training of additional operators.

logic and utilize disaggregated data more generally available. The statistical results of the regression analysis suggest that it is possible to estimate operators supplied using wages, population, alternative wages and unemployment when suitable intercept shifters for size of location and quality of manpower are included in the estimating equation.

The analysis concludes that two variables appear to be significant in explaining the quantity of operators supplied, that is, wages and population. Higher wages offered within the wastewater treatment industry, other things being equal, can attract more manpower to the industry. For example, it is shown that for an increase of $50 per month in salary scale (about a 10% increase) at all treatment plants in Indiana the number of operators supplied would increase by about 25 men in the state. This study demonstrates that while an increase in population provides more demand for wastewater treatment facilities, it also provides the source of more operators to work at wastewater treatment plants. For example, a 50,000 person increase in population would provide one additional operator in the wastewater treatment industry.

Two regions of the state are projected for 1972. The operators supplied for both regions show increases in supply especially in the smaller locations. The state as a whole shows similar relative increase in operators supplied in the smaller locations. The estimate of labor supply available in 1972 gives planning personnel a basis for comparison with operators expected to be required in 1972.

The conclusions suggest that program administrators, planners, wastewater treatment plant supervisors, and other interested groups of people have several management alternatives to consider. These alternatives include the change in wages and population variables suggested by the analysis of the supply function in this study and other techniques, such as, employing one operator full time to service a few small plants in the same geographic area or the training of additional operators. Utilizing several of these manpower management techniques in a complementary manner can assist the wastewater treatment industry in the effective control of its labor supply during the decade of the 1970's.

CHAPTER I

NATURE AND SCOPE OF THE PROBLEM

> "The essence of the challenge to knowledge posed by the relations between water resources and economic development is the formulation of the questions that economics as a discipline must answer." 1/

The General Problem

The broad question of environmental quality is a critical social issue in the United States at the present time. One aspect of the environmental quality issue is the reduction of environmental degradation of the water resource. The fact that water pollution control is a central concern of government is verified by the recent committment of substantial funds and the construction of many public wastewater treatment plants. Table 1.1 indicates the large increase in investment during the decade of the sixties.

The total U.S. investment spending for watewater treatment plants increased approximately 36% during the years 1964-1968. In Indiana, the investment increased approximately

1/ Ciriacy-Wantrup, S.V., "Water Resources and Economic Development: The Challenge To Knowledge," Water Resources and Economic Development in the South, Agricultural Policy Institute, North Carolina State University, August, 1965, pp. 1-10.

Table 1.1. Annual Public Investment For Wastewater Treatment Plants and Ancillary Works. 1962-1975 a/

Year	United States millions of dollars	Indiana millions of dollars
1962-66 Average	$ 508.9	$ 16.8
1967-69 Average	691.7 b/	20.6
Percentage Increase From 1962-66 to 1967-69	36%	23%
1970-75 Average Planned	2,043.4	30.5
1970-75 Average Suggested Needs	1,694.7 to 2,392.1	56.5 to 67.5

a/ "The Economics of Clean Water," Summary Report of the Federal Water Pollution Control Administration, U.S. Department of Interior, March 1970 (Washington: U.S. Government Printing Office, 1970) p. 25.

b/ 1969 estimated.

23% from 1964 to 1968 reaching a level of 20.6 million dollars per year at the end of the decade. Total U.S. investment intentions for the period 1970-75 will apparently fall within the range programmed by the Federal Water Pollution Control Administration (FWPCA). Indiana's planned annual average investment of 30.5 milion dollars during the period will not reach the level of 56.5 to 67.5 million dollars per year which FWPCA suggests may be the desirable needed level of investment.

The increase in wastewater treatment plants planned during the 1970-1975 period will increase the demand for more trained personnel to operate these plants. Forward planning requires analysis of the anticipated changes in the supply of men in the sewage treatment industry and the economic factors which will influence this supply. The program to improve water quality by building more plants would be delayed if significant manpower shortages developed when the plants become operational.

The Specific Problem

The question posed in the wastewater treatment industry during the decade of the 1970's is, will there be enough men available with the skill and training necessary, who are willing to work in the wastewater treatment industry under the anticipated economic conditions?

There are two impacts on the labor force that occur as the sewage treatment facilities expand. The first impact is upon the number of operators required while the second is upon the skill level of the operator. As more plants are added, new operators are needed and the increased number of plants adds to the number of replacements required due to death and retirement. When treatment plants are expanded to meet increased population loads or to achieve higher levels of water quality, additional personnel are needed. Both new plants and larger plants generally require more highly skilled operators which could increase the time required to train competent operators. Upgrading plants from the primary treatment classification to secondary treatment requires both more manpower and more skill due to the complexity of the operations involved. In those plants where automation can be introduced manpower needs may be reduced but the skills needed probably will be greater.

It appears in Indiana that the most immediate impact of sewage plant expansion will be upon the number of operators required for small treatment plants. At the end of 1968 there were still 82 communities in Indiana which had sewage collection systems but no treatment facilities.[2/] Municipal waste facilities were planned for construction in 76 communities with less than 5,000 population by 1972. No construction of plants was listed for larger cities (over 5,000 in population) but large amounts of money had been allocated for the improvement and upgrading of existing plants.[3/] A comparison of recommendations by sanitary engineers for sewage plant personnel with existing employess indicated a shortage of employees in the smaller population groups.

In this specific problem setting it seems appropriate to examine at the industry level of aggregation the supply for wastewater treatment plant operators in Indiana. Furthermore, it would be helpful if improved methods for analyzing and predicting this occupational labor supply could be provided so these methods would be available for industry use in the future.

Little research has been completed on occupational labor

2/ "The Economics of Clean Water," Summary Report of the Federal Water Pollution Control Administration, U.S. Department of Interior, March 1970 (Washington: U.S. Government Printing Office, 1970) p. 25.

3/ Ibid.

supply functions at the state and local level. The historic demand for the services of public employment agencies has been predominately concerned with the issue of unemployment. This has meant that the public agencies have allocated much more of their available funds to the unemployment problem rather than being concerned with occupational supply issues. Although manpower planning programs have developed during the decade of the 1960's, there are substantial gaps in knowledge about what projections should accomplish, how they should be conducted and how the results of the projections should be interpreted.

The traditional methods for estimating manpower usually obtain employer forecasts of the number of workers that will be available in the time period of interest. This number is compared with the number of jobs employers expect to be available by the industry in the same time period. If the number of workers anticipated is less than the expected jobs which will be available training plans can be made to correct this gap.

There are two difficulties with this approach. First, studies of employer forecasts have found them to be inaccurate. The issue appears to involve the difficulty of projecting the employer's short term response to market forces. One study in 1958 evaluated the accuracy of the bimonthly employment forecasts of more than 1,000 Indiana employers. Out of 130 firms sampled for the study, only one quarter were estimating changes better than could be done by a straight projection of current employment.[4/]

Second, the traditional approach does not consider that the occupational situation with regard to labor supply is directly related in part to several economic factors. For example, if industry wages are set below the wage which prevails in other industries, with demand for the same kind of labor, then an employment gap could persist in spite of training and recruitment programs designed to eliminate the gap.

Objectives

The general objective of this study is to analyze the supply of operators for Indiana wastewater treatment plants. This general objective has three specific parts which are identified below:

1) to obtain information about operators employed during 1969,

2) to estimate supply functions for plant operators in 1969, and

3) to project the supply of operators for 1972.

An economic model of the treatment plant, operator labor market is proposed. The model is defended with appropriate theory and presented in statistical form. The single equation model is then confronted with data collected on a cross

---

4/ Andrews, W.H. and Booker, G.S., Forecasts of Future Labor Requirements by Indiana Employers, Indiana University, Bloomington, 1968, p. 1.

sectional basis from both primary and secondary sources to obtain estimates of the parameters for the variables judged to be significant for prediction purposes. The supply function estimated for 1969 forms the basis for predicting the operator supply for the State of Indiana and representative economic regions within the state in 1972.

Review of Labor Projection Methods

There are several labor projection approaches in current use by economic planners. Although in this study the interest is in an occupational level within a single industry, an appreciation and understanding of labor projection methods can be gained by reviewing other projection studies.

Swerdloff lists four techniques for labor projection: 1) Input-output analysis, 2) Economic model building, 3) Employer forecasts and 4) Factor analysis.[5/] Fishman, in a 1966 publication, surveyed methods used by others to forecast or project employment.[6/] His thorough review includes labor projection attempts at the national, state and local level as well as projections by occupation, industry and total employment.

5/ Swerdloff, S., "Manpower Projections: Some Conceptual Problems and Research Needs," Monthly Labor Review, Vol. 89, No. 2, February, 1966, p. 138.

6/ Fishman, L., Roberts, W.E., Franks, C.M. and McCormick, W.W., Methodology for Projection of Occupational Trends in the Denver Standard Metropolitan Statistical Area, Bureau of Economic Research, Institute of Behavioral Science, University of Colorado, Boulder Colorado, March 1966, pp. 1-57.

Fishman lists four types of methods for projecting employment which are similar to the Swerdloff techniques: 1) Ask employers to predict their employment, 2) Extrapolate historical data, 3) Relate estimates of total economic activity to individual industries, 4) Analyze the characteristics of demand and develop projections through statistical relationships of the factors having the greatest influence on demand. Secondary studies reviewed by Fishman point out that employer forecasts are usually shortrun guesses subject to substantial errors and often overly optimistic in predicting employment.

The method of projection used by the Fishman group in the Denver study combines the historical approach with economic activity analysis. Two naive methods are used as benchmarks for comparison with their more sophisticated proposals. The overall approach is in matrix form with the first benchmark a no change prediction and the second a local projection simply proportional to national projections. It was the conclusion of the groups that small changes in economic activity result in large changes in employment prospects leading to inaccurate projections without the added historical comparisons.

The same Denver study concluded that data quality and quantity are crucial problems in labor projections. Vocational programs and educational policies require regional and specific information if they are to be guided by more than current demand and supply conditions and experienced guesses. These researchers feel that it is wrong to legitimize present data-gathering methods by using employer surveys and census data presently existing and suggesting they are useful in policy planning when the accuracy of the data does not justify such use.

Bruno Stein in a survey of 300 different local, regional and state manpower studies also emphasizes the data problem.[7/] For analytical purposes he grouped the studies into eight categories: 1) Manpower requirement and 2) Potential labor force surveys, 3) Wage surveys, 4) Studies of technological and structural change, 5) The long term unemployed, 6) Economic base reports, 7) State plans and overall economic development plans, and 8) Miscellaneous studies including job vacancy surveys.

Stein's comments about projection methods are similar to those of Fishman. Employer projections of their needs cannot be given much weight although they continue to be an excellent source of information. Greater hope appeared to be in the direction of sectoral models that can be disaggregated by region.

In 1962 Schuh analyzed the national market for hired labor in agriculture.[8/] His model assumed the simultaneous

---

7/ Stein, B. and Leung, C., Local Manpower Data Programs, Office of Manpower Policy, Evaluation and Research, U.S. Department of Labor, August 1966, pp. 6-115.

8/ Schuh, G.E., "An Econometric Investigation of the Market for Hired Labor in Agriculture," Journal of Farm Economics, Vol. 44, May 1962, pp. 307-321.

determination of hired wages and hired employment by the interaction of the forces of supply and demand. A distributed lag model was used in an effort to obtain estimates of both long-run and short-run elasticities.

Gisser in a sectoral analysis of a labor market, used a cross-sectional study to show that, Ceteris paribus, raising the level of schooling of farm employees will shift the supply curve of farm labor to the left.9/ The following labor supply equation indicates the variables Gisser found to be significant:

$$W = b_0 + b_1 L + b_2 \overline{W} + b_3 S + b_4 R \qquad (1.1)$$

The symbols W and L stand respectively for farm wages and labor input per farm. The symbol $\overline{W}$ stands for alternative wages, and the symbols S and R stand for schooling and race. This model, using simultaneous demand and supply equations is an example of the sectoral analysis recommended by Stein. It shows the method of model formulation and the type of variables which might be included in a supply function.

In a later article Gisser attempts to identify variables which the government might alter to influence labor supply for policy reasons.10/ This analysis included the examination

9/ Gisser, M., "Schooling and the Farm Problem," Econometrica, Vol. 33, July 1965, pp. 582-592.

10/ Gisser, M., "Needed Adjustments in the Supply of Farm Labor," Journal of Farm Economics, Vol. 49, No. 4, November 1967, pp. 806-815.

of population growth and relative wages as major influences on farm labor supply.

Tyrchniewics and Schuh have developed a regional agricultural labor supply model.[11/] Their study applies a national model to regional analysis. The supply equation expresses hired farm employment as a function of: real wages of hired farm labor, a measure of income earned in non-agricultural employment, the amount of unemployment in the economy and the size of the civilian labor force. Their model also uses an interesting trend variable in the supply function. This trend variable appears to pick up many of the factors researchers would like to specifically include in labor supply functions, such as, the taste for certain kinds of employment because of better working conditions, the availability of jobs, improved transportation, improved communication, the secular increase in level of education and the possibility of a consistent measurement error.

Eddleman in a resource development context attempts to devise a framework for evaluating the separate employment effects of variables influencing factor demand and supply in a region.[12/] Employment by industry was used as the

---

11/ Tyrchniewics, E.G., and Schuh, G.E., "Regional Supply of Hired Labor to Agriculture," Journal of Farm Economics, Vol. 48, August 1966, pp. 537-556.

12/ Eddleman, B.R., "Estimating the Effects of Resource Development Programs on Regional Employment," American Journal of Agricultural Economics, Vol. 51, No. 5, December 1969, pp. 1434-1441.

dependent variable in his analysis. The explanation of how employment is formed and how it varies by industry leads to a useful structural description of a region. For the study undertaken here this method of analysis is revealing. In the factor analysis of employment demands, percentage changes in exogenous shifters, such as, current education expenses, highway construction investments, and the cumulative construction expenditures for water resource development are used to represent the changes in important factor supplies in an area. A comparison of the estimated coefficients of the exogenous shifters from separate multiple regressions indicates the specific types of variables (shifters of factor supplies, product demands, firm production possibilities or change in firm numbers) that explain the largest proportion of total employment variation. This type of analysis can be undertaken for a single industry with a single equation approach. Eddleman uses the general relationships established to provide the conceptual framework for analyzing proportional changes in the demand for labor within given industries.

A common theme found in labor projection literature is that there are many critical needs for better data. Kaufman, Farr and Shearer point out that even where aggregate data do exist, there is a lack of data disaggregated to levels most relevant for the scope of decision making.13/ For example, even in industrial states, information is not available about the numbers of public high school graduates from various specialities within vocational education. National estimates of the anticipated demand for certain skills would have little relevance for guiding the decisions of local school boards.

Fishman recommends occupational groupings due to the planning needs of educational authorities. He goes on to say, "Clearly accurate industry break-downs are important and, if available, they would add immeasurably to projections."14/ Unlike the Eddleman model where many factors in a region are evaluated for their influence on the demand for employment, Fishman's group found the labor supply for supportive industries to be more clearly related to population than the activity of supplying industries or markets. Supportive industries appear to bear predictable relationships to population or to sub-regions of the total economy.

Lisacks surveyed the manpower needed for pollution control and water resources in Indiana on the basis of broad occupational needs.15/ This extensive survey samples

---

13/ Kaufman, J.J., Farr, G.N., and Shearer, J.C., The Development and Utilization of Human Resources, A Guide for Research, Pennsylvania State University, University Park, Pennsylvania, July 1967, pp. 13-16.

14/ Fishman, L., et. al., op. cit., p. iii.

15/ Lisack, J.P., Manpower Requirements for Pollution Control and Water Resources in Indiana and a Related Pollution Control Technology Curriculum, Office of Manpower Studies, School of Technology, Purdue University, Lafayette, Indiana, February 1969, pp. 1-21.

employer estimates of: present employment, current job vacancies and their projected manpower needs for the next five years for all related professional and technician level occupations. Lisacks compared his findings with national FWPCA projected manpower requirements in the same occupational area. The national data are disaggregated to the Indiana level on the basis of Indiana population as a proportion of national population. He concludes that more recruitment of students is necessary into related pollution control disciplines with additional pay recommended for technicians in pollution control jobs. Lisacks appears to have carried out the Fishman recommendations:

> Pure statistical research into occupational projections are not enough. If the personnel and vocational studies show that five or six main streams of vocational and technical training serve to prepare the student for most of the blue collar occupations, then we should group these production jobs according to the five or six occupational streams and project needs by these major groups' skills. 16/

A 1967 Senate Report attempts a national estimate of manpower needs in pollution control.17/ The report gives the impression that the current supply of trained operators is inadequate but admits to the lack of data to validate the impression.

16/ Ibid., p. 41.

17/ Manpower and Training Needs in Water Pollution Control, Report of the Department of Interior, Federal Water Pollution Control Administration to the Congress of the United States, Document No. 49, 90th Congress, 1st Session, August, 1967, pp. 1-15.

> Problems encountered in the conduct of this study indicate there is a dearth of information on current and projected employee needs and skills and on employment conditions. There is no readily available information on salaries, length of time required to fill vacancies, or employee turnover rates. Such information would be exceedingly helpful in maintaining a continuing understanding of manpower resources and training problems during the period of rapid expansion of the Nation's clean water efforts. 18/

The report was helpful in suggesting specific pollution control industry trends which will influence projections. For example, the following trends are pointed out: Demands for operating personnel lag well behind construction appropriations, technology influences, manpower requirements (automation increases skills needed but decreases manpower needed), and economies of scale in large plants may be offset by demands for a greater degree of reliability and more complete treatment.

The Senate report is based upon the following assumptions for projection purposes which are specific for the wastewater treatment industry: assume that 80% of the communities now discharging sewage without treatment will have constructed treatment plants by 1972, assume that 50% of today's primary plants will be upgraded to secondary, assume that additions to present plants will be sufficient to service 2/3 of estimated population increases, and assume that the improvements in technology and automation, plus economies of scale will balance demands for increased reliability and demands for tertiary treatment.

18/ *Ibid.*, p. 34.

Fein uses a labor projection method similar to the approach contemplated by this study.[19/] In projecting the supply of physicians he uses as explanatory variables: population growth, age and sex distribution of the population, regional migration trends, urbanization, color, education, income and the impact of medicare. Fein seeks to compare a measure of the demand for health services with the projected supply of physicians available to meet those demands. The study identifies a gap between predicted and needed supplies of physicians which must be altered by educational and training institutions. Fein also recommends the improved management of trained personnel in the health occupations. Part of the gap between the predicted and actual rates of supply and demand which he identifies is attributed to the non-additive character of the impact of the variables studied.

Within the pollution control context where the adequacy of future plant operator supply is uncertain, the problem is one of reducing the large set of factors which affect operator supply down to a meaningful set for supply projection purposes. The projection methods examined revealed the need for disaggregated data and more objective techniques. Independent relations are sought which will remain valid under differing circumstances. In the next chapter economic

---

19/ Fein, R., The Doctor Shortage, An Economic Diagnosis, The Brookings Institution, Washington, D.C., May 1967, p. 79.

theory is used to develop an economic model as a framework to analyze operator supply. Later, data are used from a cross sectional survey to verify and quantify the economic relationships postulated. These relationships as verified are then used to project operator supply and suggest policy implications.

CHAPTER II

METHODOLOGY

In developing improved manpower projections ideas may be drawn from labor economics and general economic theory. The first part of this chapter examines those theoretical concepts which are appropriate for a better understanding of the wastewater treatment plant operator supply. This initial theoretical section is followed by a more specific economic specification of the model which includes a description of each variable which will be included in the model. The final section of this Chapter specifies the statistical model that will be used to estimate the economic model in section two.

Economic Theory

The theory which applies to the supply function for labor depends in part on the level of aggregation and concept of time which is of interest. At the family level the supply of labor is conceived to be developed from the utility function which compares two goods, i.e., wages and leisure. For competitive industries the most important labor supply determinant may be wages. At the national level of aggregation the fiscal and monetary policies of the government are important determinants of labor participation and supply.

For a single industry, such as, wastewater treatment, the theory of labor supply to competitive industries appears to be the most applicable. The relative wages paid by an industry are indicated by theory to be a most important determinant of the quantity of men supplied in the work force. For public service industries which support the growth of other sectors of the economy a variable such as population may be closely related to supply. Unemployment, which at the national level may be an indication of the degree of excess demand for labor, at the disaggregated level becomes a measure of the availability of the wages offered.

Aggregating labor supply by occupation becomes important for keeping the distinction between short and long-run time periods clear. Workers are placed in separate occupational categories because they are not perfect substitutes for each other. This may be because of their training, education and innate ability or because of their attitudes toward work and job status. To change occupations is not costless and usually involves time. Training takes time as does migration and the search for alternative employment.

Fleisher defines the short run, "A period of time in which decisions are made about whether to sell labor services and how much to sell."1/ This differs from the long run which allows time for decisions involving education, occupational choice, and migration. In his study, plant operators are measured in the short run concept. In economic theory the short run is that period during which fixed investment can't be changed while in the long run all costs become variable. In the analysis of the supply of labor, investment in the human factor can be in terms of health, apprenticeship, on-the-job-training, and family size.

The instantaneous labor supply curve may be a series of points, showing the amount of labor forthcoming at all possible earning levels at a given moment of time. Only the size of the active labor force is known at the prevailing earnings level. Inferences about the shape of the total function might be based upon measurements at different moments in time as earnings vary or simultaneous measurements of the labor force and earnings in different labor markets.2/

A given level of wastewater treatment can be achieved in alternative ways, using various combinations of the productive factors. The demand for labor in this study is assumed to be derived from plant production functions for each plant or location.3/

1/ Fleisher, B.M., Labor Economics, Theory and Evidence, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1970, pp. 106-107.

2/ Cohen, S., "The Supply Curve of Labor Re-examined," Industrial and Labor Relations Review, Vol. 13, October, 1959, pp. 64-71.

3/ The demand function was not estimated in this study.

Phelps views demand (at going real wage rates) as being composed of all those members of the work force who are employed and all known vacancies.4/ Maki defines demand or requirements as the number of persons who would be employed at given wage rates if there were no shortage of available trained personnel and the amount of resources available to pay them.5/

The concept of a labor market is important for the development of projection methods because it relates the demand and supply concepts described above. There are three possible definitions of a labor market: 1) The widest area within which employees with fixed addresses would accept employment, 2) the market in which wage structures and levels within an industry are fairly uniform, and 3) the process in which buyers and sellers of a particular "brand" of human services meet and bid and take.6/

For projection purposes what is needed is a measure of the demand for plant operators and the supply of operators available to meet those demands in the time period of interest.

4/ Phelps, E.H., "Money-Wage Dynamics and Labor Market Equilibrium," Journal of Political Economy, Vol. 76,4, Part V, July/August, 1968, pp. 678-711.

5/ Maki, D.R., A Forecasting Model of Manpower Requirements in the Health Occupations, Industrial Relations Center, Ames, Iowa, 1967, p. 4.

6/ Cartter, A.M., and Marshall, R.F., Labor Economics: Wages, Employment, and Trade Unionism, Richard D. Irwin, Inc., Homewood, Illinois, 1967, pp. 198-205.

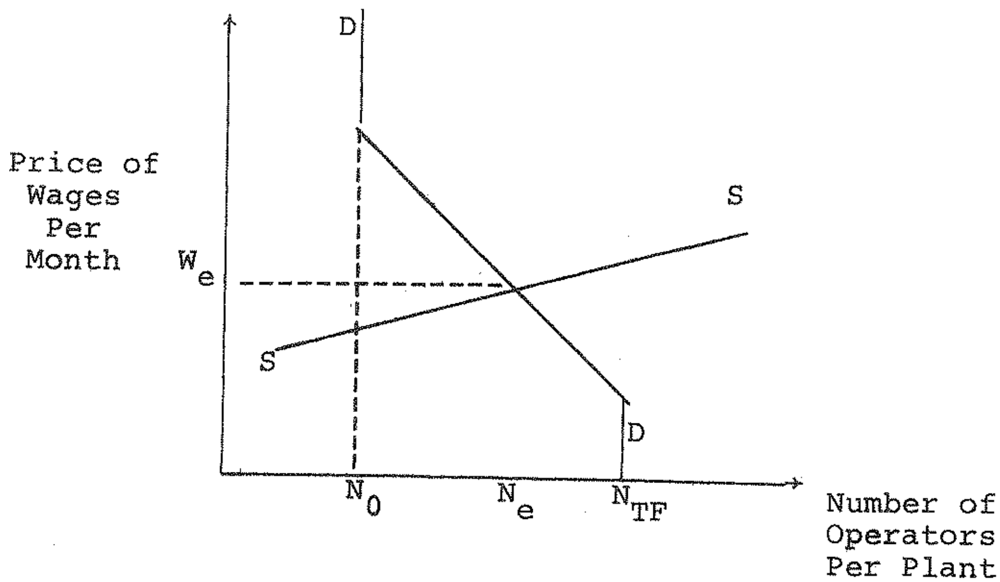


Figure 2.1. Market for Wastewater Treatment Plant Operators

Key: SS = Supply function

DD = Demand function

N_0 = Minimum employees needed per plant

N_e = Equilibrium number of men

N_{TF}= Technically fixed maximum number of men per plant

W_e = Equilbrium wage

Figure 2.1 which illustrates the labor market for wastewater plant operators is helpful for integrating several ideas important in labor theory. The demand curve is shown with two vertical segments with a length between which slopes downward from the left to the right. The downward sloping segment of the demand function assumes some substitution is possible in sewage plants between labor and other productive factors. The demand for operators at each location is a derived demand from the communities utility function for supportive services relative to other uses of their resources. It is postulated that demand can be determined by an analysis of important factors such as relative wages, design capacity, plant age, plant capital, the technology used and working conditions as reflected by turnover rates.

The vertical segments of the demand curve derive from the fact that the usefulness of marginal workers at the point of technical plant capacity may fall to zero. At the point of plant shutdown the usefulness of marginal workers could rise to infinity. Between the two vertical segments a community has some range of prices over which it is willing to employ operators. The community can choose to operate the plant in strict compliance with all social and legal requirements including processing, maintenance, testing and record keeping. Alternatively, the municipality may elect to meet minimum processing requirements while eliminating other work.

The interesting question posed by Figure 2.1 is what level of wages is associated with no excess of the quantity of operators supplied over the quantity of operators demanded or visa versa? Shifts in the demand function or the supply function would change the equilibrium wage and the size of the work force.

The operator supply function in Figure 2.1 is an upward sloping curve reflecting the increased wage level required to attract additional workers into the treatment plant operator occupational field. In addition to wages it is anticipated that the number of operators supplied would be influenced by wages in other industries, the population, and other economic variables. The model used analyzes wages and relative wages separately although they could have been formulated as a single difference variable. The operator wage itself is determined by underlying factors, such as the operator's previous occupation, previous wage, educational level, age and region of residence.

As more years of schooling and training are required wage levels are higher. If occupational choice is a long run decision then economic theory suggests that the most appropriate assumption is that relative occupational earnings will tend to remain a rather fixed relationship. This suggests that if the industry can be divided into discrete classes by level of training required more meaningful results may be obtained.

In framing operator supply in the market concept certain assumptions are necessary to have conditions permitting the comparison of wage rates and employment levels in the respective sectors of the local or regional economy. Some mobility between sectors is assumed to be possible with a balance of economic costs affecting men viewing alternative possible employment. For example, this would mean that fringe and non-wage benefits in the wastewater treatment sector were similar to other sectors employing workers with comparable skills. Units of labor for mobility to be possible would have to be homogeneous within some occupational range.

The economic function of the labor market mechanism is to solve the complex problem of matching demand and supply. The value of product per production man hour helps determine wage values. Wage values help determine the demand for and supply of labor. The purpose of labor projections is to facilitate the smooth short term operation of the market mechanism and to help achieve other long term social goals. By reshaping or shifting the supply or demand functions through policy actions, unemployment can be reduced and output increased thereby improving community satisfaction with resource allocation.

Economic Model

The economic model developed for the operator market makes use of variables which theory suggest are related to the market. By then confronting the model with data, if the model is properly identified, the market structure will be revealed. Major emphasis in the study is on the supply side of the market, however, work has been done both for identification and estimation purposes on the demand aspects of the operator market.[7/] Further justification for estimation of

---

7/ See pages 26 and 27.

a single equation supply model in this study rather than a multi-equation supply and demand model appears later in this Chapter.[8/]

I. Supply equation:

$$q_S = f(W, AW, P, U, H, C) \tag{2.1}$$

Definitions:

q_S = the quantity of qualified operators employed in each plant. [9/]

W = the wage of wastewater treatment plant superintendents in each plant.

AW = county alternative opportunity wage in manufacturing.

P = the municipal population of the community where the plant is located.

U = the unemployment in the county where the plant is located.

H = the number of men hired during Sept., Oct., and Nov. 1969.

C = the class of plant which reflects both the size of plant and the skills and experience of employees.

II. Demand equation:

$$q_D = f(W, K, D, A, T) \tag{2.2}$$

Definitions:

q_D = the quantity of qualified operators employed in each plant.

W = the operators wage at the plant.

8/ See pages 37 and 38.

9/ "Operator" is defined as any person who performs any function, other than labor only, which does or could affect the treatment process.

K = the cost of the capital used for plant construction.

D = the millions of gallons per day design of the plant.

A = the age of the plant.

T = the type of plant, i.e., primary or secondary.

III. Institutional constraint:

$$q_S = q_D \tag{2.3}$$

The observed operator force is the amount supplied and demanded.

Economic Relevance of Variables

To develop an improved method for labor projection, wastewater treatment operators were used since they represented a homogenous, skill level within an occupation. Information about operators was available; broad differences in wages, population, alternative opportunities and employment conditions could be sampled on local and regional levels and; the group appeared to be important to study relative to the current emphasis on pollution problems.

The following description of variables is limited to those included in the supply function, Eq. 2.1, since that is the equation that will be estimated in this study. The description of each variable includes information about the economic significance of the variable, the alternative statistical data series considered for measuring the variable, and the data selected to represent the economic concept.

Number of Operators

The number of operators supplied were obtained directly from survey data. These data were entered directly as number of operators employed for each plant since plants are the unit of observation for the development of the cross sectional data. Three alternative methods for describing the operator variable were investigated but they were less satisfactory than the direct measurement used. One alternative approach considered specifying the q_S variable as vacancy or no vacancy. With this specification the analysis would indicate the probability of vacancy with respect to change in exogenous variables. This approach was not elected because few vacancies were reported in the survey. Another approach considered specifying q_S as operators supplied per thousand of population. Other density factors might have been used but this method, after trial runs, apparently lacked sufficient variation to allow the explanation of supply to reach reasonable levels. A third approach considered involved the inclusion of all wastewater treatment plant employees instead of operators alone. Analysis by this method has been done, but was not used in this study because data available for it are from larger municipalities only and the development of wastewater treatment plants in the smaller towns in Indiana is of considerable importance during this decade.

Wage

The wage differential is one way by which the labor supply is allocated among various types of employment. Wages usually are the most conspicious employment feature a prospective jobholder sees. The proportion of the population which participates in the labor force within a given labor market responds positively to wage levels. Since migration is at least partly a result of wage and employment trends, even local population size can be affected by wage levels. The quantity of operators offered is expected to increase as wages rise with a positive regression coefficient anticipated for the wage variable.

Wage levels were determined by the 1969 survey. The wage used was reported in each case for plant superintendent. Superintendent's wages were used partly because operators wages were not reported for all data points. By using only superintendent's wages a degree of wage homogeneity is assumed between operator and superintendent wage levels which is not entirely correct, but for all locations this appeared to be the most appropriate wage to use for comparative purposes. Furthermore, the ratio between operator and superintendent wage levels appears to be relatively constant across the State which reinforces the appropriateness of using superintendents' wages in this study. In small towns the operator and superintendent are the same because few plants hire more than one operator. In large towns and cities the superintendent's wage was uniformly reported and appeared to offer a reliable measure to use for relative wage differences among plants. A more accurate and homogeneous measure of wages for statistical analysis would have been preferred but one was not available.

The most recent survey of wastewater treatment plant operators' wages was taken by the Indiana Water Pollution Control Association in 1960.[10/] This survey is useful for comparative purposes but was considered out of date for the present analysis. The 1967 Census of Local Governments includes wages for all Indiana wastewater treatment workers, but the figure is presented only as part of the broader local government wages category.

Alternative Wages

In this cross sectional study, wages in occupations which would require levels of skill similar to those required by the wastewater treatment industry were obtained for the county area where the treatment plant was located. Economic theory suggests that as the wage rates in occupations requiring skills similar to wastewater treatment rise the number of people employed in wastewater treatment plants should fall, *ceteris paribus*. It would therefore be anticipated that the sign of the regression coefficient associated

---

10/ Indiana Water Pollution Control Association, "Salary Survey in Municipal Treatment Plants in Indiana - 1960," *Journal of Water Pollution Federation*, Vol. 33, July 1961, pp. 734-747.

with the independent variable called alternative wages (AW) would be negative.

The source of data for this variable was the average weekly manufacturing earnings by county collected by the Indiana Employment Security Division. This series was selected because the survey questionnaire asked plant superintendents about the types of employment which men they hired had previously held or the types of new employment accepted by men who had left the industry. The survey indicated that 60 per cent of all men hired or separating from plants were associated with manufacturing employment either prior to or subsequent to their work at the wastewater treatment plants.11/ Since the manufacturing work was indicated as the most closely related competing occupation in the community, the average weekly manufacturing earnings provide a sound data series for comparison.

The average weekly earnings in manufacturing are computed from the quarterly earnings and average employment of all employees in manufacturing establishments covered by the Indiana Employment Security Act. The figures were computed from total payrolls and include all employees -- janitors, company officials, factory workers -- instead of only production workers.

Since at the time of the survey current average weekly earnings in manufacturing were not available from secondary

11/ See Chapter III, p. 48.

sources, a linear projection to 1969 from the 1967 and 1968 weekly earnings by county was calculated.

An alternative source of primary data would have been to have the supervisors who responded provide alternative wage information from their own knowledge of local areas. However it appeared that the Employment Security data provide more broadly based estimates of wages throughout each county than would be provided by using supervisor estimates of alternative wage levels. Government employee secondary wage data were not used because survey respondents did not identify government jobs as alternatives.

Population

The economic relevance of the population variable in a labor supply function for plant operators is complex. Population can be considered as the upper constraint on the number of people who could be supplied. Obviously population which includes men, women, and children greatly overstates the number of people that would be available to work. Conceptually, the actual additions possible to supply are of more interest than the potential additions represented by population, but the former magnitude is very difficult to estimate even when labor force data are available by city. It could be argued that supply for the industry is unconstrained yet research indicates that the public service industry employment may be closely related to population in the area.

Population and participation are major building blocks for most labor projections. In this study population relationships are analyzed in detail with the sign on the population variable postulated to be positive.

This study uses population data for the municipality within which the plant is located to represent the population variable. An exception to this procedure occurs if the plant is located in a Standard Metropolitan Statistical Area (SMSA) which is larger than a single county. In that case the population of the SMSA is used.

The 1960 census is used as a data source.[12/] Population estimates were available from Public Health statistics for many locations in 1968 but to be consistent and to be able to include more of the smaller locations 1960 data were used. Since this study is cross sectional in nature, the relative size of communities is more important than the absolute size. Therefore, the higher accuracy of the 1960 census was considered to be a better data source than the population estimates made for 1968 even though relative changes may have occurred among population levels between 1960 and 1968.

Unemployment

In the context of this study unemployment was included to measure the effect of the availability of alternative

---

12/ U.S. Census of Population: 1960, Number of Inhabitants, Indiana. Final Report PC(1)-lbA. U.S. Government Printing Office, Washington, D.C., 1961.

jobs. When comparing the single industry of wastewater treatment with the economy of the locality, it is postulated that when unemployment is low, the alternative opportunity wage becomes available as a job rather than only being a price which does not reflect actual employment opportunities. As unemployment rises, operator supply should rise. Classical theory assumed labor supply to be exogenously determined by demographic factors with wages equating supply with endogenously determined demand. This study is specifically interested in the other exogenous supply determining factors and so must include unemployment in the context of the availability of alternatives. In this sense unemployment is a proxy variable for the degree of excess demand for operators in other similar occupations.

The annual unemployment data by counties for 1967 and 1968 was provided by the Indiana Employment Security Division of Research and Statistics.[13/] The percentage of unemployment in metropolitan areas was taken for the same time periods from standard metropolitan statistical area tables.[14/] The unemployment figure used in the analysis was prepared by averaging the 1967 and 1968 annual unemployment percentages for each of the counties or SMSA's. Other more recent data series are available from the Division of Employment Security

---

13/ Heller, M.W., Indiana Regional Employment Projections 1967-1975, State of Indiana, Indiana Employment Security Division, May 1970, pp. 13-18.

14/ *Ibid.*, p. 12.

but to determine unemployment for each county it is necessary to use the older data sources.

Number Hired

In a reversal of Say's Law, it can be said that demand for labor creates its own supply. This simply suggests that there is occupational mobility of labor. It is postulated that as more operators are hired, more are supplied which indicates a positive regression coefficient should be equated for this variable. The number of operators hired in the three months of September, October, and November of 1969, were taken from the survey of wastewater treatment operators.

Class

Indiana law requires that the operator in charge of each wastewater treatment plant have a certificate of competence equal to the class of treatment plant where employed.[15] Therefore, the variable class reflects both the size of plant and the competence of operators. In one sense the class variable can be considered to be a proxy variable for educational and training levels of the operators. By partitioning the data into classes and examining each class, it may be possible to obtain more accurate estimates of the structural equations.

15/ Chapter 273, Acts of 1967, Indiana General Assembly.

Statistical Theory

This study utilized cross sectional data from a specially designed survey and from published accounting reports. One advantage of using cross sectional studies is that the parameters established do not have time as an added burden of error.[16/] Parameters established from time series data are measures of time variability; parameters in cross section analysis assume two units (plants) have different dependent values (operator supply) only because they have different independent values apart from random disturbance. This does not avoid the problems of measurement which are characteristic of primary data collection regardless of whether cross sectional or time series data are collected. However, the "all other things equal" situation is more closely realized when the time dimension is held constant in a cross sectional study.

To avoid error, attempts to get operators of uniform quality (homogeneity) are more important in cross sectional studies. This is because they have different independent values. Consistent errors can be measured by the Durbin-Watson statistic by either ordering the data by size or some other meaningful order such as geography.[17/] Prices throughout the state and other variables usually thought to be

---

16/ Klein, L.R., An Introduction to Econometrics, Prentice-Hall Inc., Englewood Cliffs, N.J., 1962, p. 55.

17/ Schuh, G.E., Class Notes, Econometrics, Purdue University, 1970.

endogenous are held constant at the time of the survey except for geographical differentials. Some variables which are endogenous for the entire population of operators can be taken as given for the individual units, e.g., wages.

One problem common to cross sectional data is that for projection purposes the sampling point for an economic unit may have been one of intermediate adjustment. This may also be true in time series data but the researcher may be able to note the adjustments by examining changes in the data over time.

An inherent problem in any projection is the lack of certainty that the true slopes of the regression surface have been detected. The data are used to develop the parameters on the related variables which have been chosen on the basis of *a priori* reasoning. The possibility exists for error in the data collection, in the estimation procedure and the *a priori* reasoning.

Statistical Model

The economic model proposed for the operator market was rather careful in its assumptions about the degree of simultaneity between wages and quantity supplied and demanded. It could be postulated that wages and the number of operators are jointly determined in which case the estimation procedure would necessarily involve simultaneous procedures. The case was hypothesized, however, in terms of quantity supplied adjusting to wages exogenously determined at each location.

For this reason, single equation, ordinary least squares regression procedures are used to estimate the supply function only.

On this basis the supply equation to be estimated is:

$$S: \quad q_S = Y_1 = b_0 + b_1W + b_3AW + b_4P + b_5U + b_6H + b_7D_1 + b_8D_2 + b_9D_3 + E_1 \qquad (2.4)$$

For identification purposes the demand equation is:

$$D: \quad q_D = Y_1 = b_0 + b_2W + b_{10}K + b_{11}D + b_{12}A + b_{13}G + E_2 \qquad (2.5)$$

All variables indicated in these equations have been defined previously except E_1 which represents the error term.

Economic theory was used to develop the equations, the task now is to infer from the cross sectional observations the nature of the structure which is capable of generating the observations numerically. Identification can occur if these observations permit estimation of the parameters of the structural equation.

Identification

The necessary condition for identification states: For any given equation the variables excluded from the equation but appearing in the system must be at least one less than the number of endogenous variables (structural equations) in the system. Examination of the model reveals that the necessary conditions for identification have been met for each equation. The supply equation is identified by the existince of variables that appear in the demand equation but not in the supply equation, in this case capital (K), design (D), age (A) and technology (T).

The necessary and sufficient conditions for identification are met if at least one non-vanishing determinant of order G-1 (number of endogenous structural equations minus one) can be formed from the coefficients of the variables excluded from the equation of interest which appear in the other structural equation. In this model the equation of interest is the supply equation and the necessary and sufficient conditions are met by forming non-vanishing determinants with the K,D,A, and T coefficients. Since the model proposed and estimating technique used are both single equation, the identification procedure outlined above is not fully applicable. A single equation model is always identified providing the right model is used.

CHAPTER III

ANALYSIS OF DATA

Introduction

This chapter contains three major sections which examine the three objectives indicated in Chapter I. The first section describes the results of the operator survey with special emphasis upon the economic characteristics associated with the employment of the operators. This section is followed by an analytical section which incorporates data from the survey and secondary data from other sources to develop supply functions for the operators during 1969. The final section of this chapter utilizes the 1969 supply functions to develop labor supply projections for 1972. These 1972 projections provide the basis for the policy implications section which appears in Chapter IV.

Survey Response

To obtain primary information about wastewater treatment plant operators in Indiana in 1969, a questionnaire was prepared in cooperation with the State Board of Health. The survey was mailed to 245 superintendents of wastewater treatment plants. The response to this survey is described in Table 3.1 below. The high response to the mail questionnaire

Table 3.1. Response to Wastewater Treatment Plant Survey 1969

Class[a/]	Number of Plants[b/]	Number Responding	Percentage Response
I	62	26	42%
II	117	51	44
III	45	34	76
IV	21	18	86
All Classes	245	129	53

a/ Wastewater treatment class reflects the design load for which the plant was constructed. Class I plants have a design load equivalent to serve a population of 2,000 people. Class II plants are designed to serve 2,000 to 10,000 people. Class III plants serve 10,000 to 40,000 people and Class IV plants are designed to serve population equivalents in excess of 40,000 people.

b/ Total plants indicated by the Indiana State Board of Health.

was extremely gratifying. Fifty-three per cent of the questionnaires were returned as a result of a single mailing. This unusually high response attests to the interest of the superintendents of the sewage treatment plant in this research. The conclusions reached in this study are possible only due to the excellent cooperation of these men in completing and returning the questionnaires.

Notice that Table 3.1 indicates the questionnaire response by each class of wastewater treatment plant as well as the total response from all classes. The concept of wastewater treatment plant class is important here and is utilized throughout this chapter to organize and present the data. The plants in Indiana are assigned a class on the basis of a design load equivalent which is related to expected population over the design period. This expected population includes industrial loads. Plants which are designed to serve a population equivalent load of 2,000 people are classified as Class I plants. As the size of the design load population equivalent increases the class of the plant increases. Class II plants are designed to serve a population equivalent of from 2,000 to 10,000 people. Class III plants are designed to serve 10,000 to 40,000 people, and Class IV plants are designed for population equivalents which exceed 40,000 people.

It is important to recognize that the four plant classes are not homogeneous categories which group firms with identical production functions. There is variability in the production functions within each class. For example, Class IV includes some plants with only primary treatment facilities while other plants in the same class have both primary and secondary treatment facilities. However, the four classes do provide groups of plants that are roughly comparable in terms of the labor inputs required. For this reason the class groupings are quite helpful for analysis and interpretation of the data in a disaggregated form to identify important differences between classes that would be concealed in an aggregate analysis of all plants.

Furthermore, the state certification law defined operator classes to correspond with plant classes. Class I certification matches Class I plants in terms of training and experience requirements. As the plant class increases in size from Class I to Class IV the training and experience required for certification of the operator becomes more rigorous.

Table 3.2 shows the number of operators reported by class. The number reported is extended in proportion to the percentage response appearing in Table 3.2 in order to obtain an estimate of total number of operators in the State. Approximately two thirds of the total operators in the state appear to be covered by the survey response. The survey sample is influenced by the slightly higher response in

Table 3.2. Wastewater Treatment Plant Operators in Indiana, 1969

Class	Number Identified in Survey a/	Number Estimated in State b/
I	11	26
II	55	121
III	115	152
IV	124	144
All Classes	305	443

a/ This represents full time man equivalents when part time operators are employed.

b/ This estimate is obtained by assuming the average number of operators employed in those plants not responding to the survey are the same as those plants responding to the survey. See Table 3.1 for the percent of each class which responded to the survey.

Classes III and IV. The higher response from the survey in Class III and IV should improve the statistical reliability of the results for predicative purposes. The eleven operators reported in Class I represents the full time man equivalents employed in Class I plants. Since most Class I plant operators are part time workers, the number of men involved in wastewater treatment plant operations is understated by the eleven man equivalents. They represent the total man equivalents for approximately 30 to 40 part time operators.

Table 3.3 indicates the distribution of the sample by class in comparison to the distribution of the population by class for both plants and operators. The sample response of useable questionnaires weights more heavily the representation of large, Class III and IV plants than it does the smaller Class I and II plants. For example, 31 percent of

Table 3.3. Percentage Distribution of Plants and Operators Among Classes in Indiana, 1969

Class	Plants in Population	Sample Plant Questionnaires Usable	Operators in Population	Sample Operators Information Usable
I	25%	18%	6%	4%
II	48	40	27	15
III	18	31	34	40
IV	9	11	33	41
Total	100	100	100	100

the questionnaires returned were usable for Class III plants while only 18 percent of the population of plants in Indiana is composed of Class III plants. However, the distribution of operators among classes in the sample is alined more closely with the distribution of operators among classes in the population than was the case for the plant distribution. The sample contains 40% of the operators in Class III plants while the population includes 34% of the operators in Class III plants. In general, it appears that the sample data collected is representative of the population for the purposes of further analysis.

Survey Results

Information about wages of plant superintendents and operators was obtained from the survey conducted in 1969. By combining information from a 1960 Indiana Water Pollution Control Association salary survey with the 1969 operator study, it is possible to observe salary trends over time (see Table 3.4). The 1969 survey data were organized into classes to conform as closely as possible to the descriptions of the 1960 salary survey. In order to be consistent with the 1960 survey, 1960 population census data were used to group the plants from the 1969 survey into classes.

The average annual increase in wages per year for all categories is 4.7%. Wages in the primary plants increased more slowly than secondary plants. Wage increases for plants serving 2500-10,000 population exceeded those of the plants

Table 3.4. Monthly Superintendent and Operator Wages in Indiana Wastewater Treatment Plants, 1960 and 1969

Class		1960[a/]	1969	Average Annual Increase 1960-69
Secondary Serving More than 24,000 People	Supt.	$753	$1093	$45
	Oper.	417	564	35
Primary Serving More than 25,000 People	Supt.	612	743	21
	Oper.	346	498	44
Secondary Serving 10,000-25,000 People	Supt.	477	730	53
	Oper.	338	483	43
Primary Serving 10,000-25,000 People	Supt.	458	580	26
	Oper.	333	439	31
Primary and Secondary Serving 5,000-10,000 People	Supt.	341	620	81
	Oper.	293	495	69
Primary and Secondary Serving 2500-5000 People	Supt.	347	539	55
	Oper.	253	456	80

a/ Indiana Water Pollution Control Association, "Salary Survey in Municipal Treatment Plants in Indiana - 1960," Journal of Water Pollution Federation, Vol. 33 (July, 1961), pp. 734-737.

serving larger population centers. However, since wages in smaller plants were considerably lower than those of larger plants in 1960 the wages of smaller plants were still below the larger plants in 1969 even though the average annual rate of increase had been greater for the smaller plants.

In order to determine the employment opportunities which are alternatives for wastewater treatment plant operators, some questions were included in the survey to examine this issue. Information was obtained about the previous employment experience of the operators before they started work at the wastewater treatment plant. The superintendent was asked what jobs in the local community required skill levels similar to work at the treatment plant. He also was asked about the new jobs which former treatment plant operators had accepted when they terminated employment at the plant. The response to these questions were grouped into occupational categories (see Table 3.5).

Other comparable jobs mentioned included: mechanics, truck driver, construction worker, telephone or electric utility lineman, and other public utility jobs. The largest percentage of the replies indicated factory work as the most comparable job. The large number of returns with no response to these questions was surprising. It reduces the confidence about the generality of the conclusion which can be derived from these questions. It is possible that the questions were unanswered more often in the Class I than the Class IV

Table 3.5. Occupational Alternatives for Wastewater Treatment Plant Operators in Indiana, 1969.

Class		Employment Prior to Treatment Plant	Employment Subsequent to Treatment Plant	Suggested Most Comparable Alternative Job
I	Factory	100%	0%	60%
	Other	0	100	40
	No response	96	90	80
II	Factory	25	50	60
	Other	75	50	40
	No response	90	95	70
III	Factory	60	70	80
	Other	40	30	20
	No response	60	60	50
IV	Factory	60	50	100
	Other	40	50	0
	No response	75	90	40

plants because there are fewer alternatives in the smaller communities. The low response may reflect low turnover rates at the treatment plants which would result in little recent information about alternative employment opportunities. As a result of the predominate importance of factory employment in the survey response, it was decided to use all manufacturing earnings as the most comparable alternative wages for wastewater treatment plant operators.

Table 3.6 assumes that wages in manufacturing plants represent a real alternative employment opportunity for waste treatment plant operators. It compares the wages in manufacturing with the average wages found in the survey for operators of wastewater treatment plants. The comparison

Table 3.6. Monthly Wages in Treatment Plants and Manufacturing Industries in Indiana, 1969 a/

Class	Wastewater Plant Operator Wages	Wages in Manufacturing Plants c/
I	b/	$551
II	$479	532
III	464	551
IV	538	665

a/ Care must be taken in interpreting the data presented in this table. The two series are not directly comparable. The operator wages in the smaller Class II plants reflect both management and part time employment because one operator may be the only employee. The Class III and IV plants include only operator wages. Manufacturing wages in contrast reflect supervisory salaries, line workers wages, and low skill wages, such as, cleaning workers.

b/ Since most Class I plant operators are part time, it was not possible to develop a meaningful full time man equivalent monthly wage for this class.

c/ This series is composed of the average county manufacturing wages for the counties in which the corresponding class treatment plants were located.

suggests operator wages may be lower in the wastewater treatment industry than in comparable manufacturing types of employment at the same location. However, this comparison must be interpreted with caution because these two data series are not directly comparable. The operator series excludes the superintendent salaries while the manufacturers wages include the salaries of supervisors, as well as, workers. All wages of operators are lower than production workers in manufacturing, this could result in higher turnover rates in the wastewater treatment industry than occurs in the manufacturing industry.

The operator survey obtained information about vacancies existing at the time of the study for sewage plant operators in Indiana. Labor theory suggests that job vacancy data can reveal the disequilibrium between supply and demand of labor in a stock sense. The vacancies can disclose the unmet needs for labor which serves as an index of the performance of the labor market.

Vacancies and their duration are shown in Table 3.7 for operators in charge from survey results for Sept., Oct. and Nov. 1969. There were 7 full time vacancies occurring for

Table 3.7. Operator in Charge Vacancies, Indiana, Sept., Oct. and Nov. 1969

Class	Number of Vacancies	Ave. Duration of Vacancy
I	3[a/]	6 months
II	0	---
III	5	2 months
IV	2	2 years
Total	10	

a/ The Class I positions vacant are three part time positions not three full time man equivalents.

operators who would be in responsible charge. Since all full time vacancies were in classes III and IV, the 7 were out of a possible total of 43 plants. There were 3 part-time vacancies reported in the Class I plants. This means 10 plants or 7% of the 129 in the survey which reported this category of information, were looking for an operator in charge.

There were several positions unfilled in the skill level operator and/or trainee category. Four part-time positions were open for operators and trainees at the time of the survey. The wastewater treatment plants in the 12 largest cities surveyed were looking for operators and trainees. For example, the city of Indianapolis hires several new operators each year.

Another aspect of the employment situation in wastewater treatment plants which provides insight into training issues is the labor turnover rate. Table 3.8 summarizes the data obtained during the survey about separations and accessions to the labor force in the plants.

Table 3.8. Labor Turnover in Indiana Wastewater Treatment Plants during Sept., Oct., and Nov. 1969.

Class	Separation Rate a/	Accession Rate a/
I b/	3.6	7.0
II	3.6	4.3
III	5.6	6.6
IV	5.6	6.6
All Manufacturing Plants c/	4.7	3.1

a/ Separation and Accession rates are calculated by dividing the number of separations or new hires respectively by the total number of employees and multiplying the quotient so derived by 100.

b/ Class I and II plants reflect full time man equivalent rates.

c/ Manpower Trends in Indiana, Indiana Employment Security Division, November and December, 1969, and January, 1970.

The separation rate of 5.6 in Classes III and IV is relatively high but not unreasonably higher than the separation rate for all manufacturing plants of 4.7 during the same time period. Accession rates varied from a low of 4.3 in Class II plants to a high of 7.0 in Class I plants. This high rate of accession in all classes in relation to the 3.1 indicated for all manufacturing plants could be an indication of new plants coming into operation, as well as, replacements due to retirement and other causes. For best results in terms of reliable plant operations, it would be desirable to see both rates lower, perhaps in the 2.0 range.

It is not known how the turnover rates in wastewater treatment plants vary seasonally. Since the survey covered only the three month period of September, October, and November, they might inaccurately depict the annual turnover situation if this factor has high seasonal variation. However, there was no indication that this coefficient does have a high seasonal component in the wastewater treatment plants.

Functional Form: Supply

There is no *a priori* basis which suggests the labor supply function should be considered linear or non-linear. For analysis of a supply function with numerical parameters, linearity in quantity supplied, relative price, and other exogenous variables gives a simplified form of the equation that facilitates analysis. After data computation was completed using a linear relationship the residuals were examined which confirmed the use of the linear relationship.[1/]

Since the model used was designed primarily for prediction purposes, the interest was not so much in determining causality but more in using the relationships existing within the equations for future prediction. The equation is specified as if causality was unidirectional from the exogenous variables to the endogenous variable, operators supplied. In economic theory if one takes the view that the firm hiring the labor factor purchases it in a purely competititve market structure, then quantities purchased are adjusted to given prices. The individual firm is thought to have little or no effect on the price and so must generally adjust quantity taken to the given array of prices. With cross sectional data which provide observations taken from individual firms, prices are assumed to be exogenously determined and quantity taken (operators) as endogenously determined.

The data obtained from each location were used to establish numerical values for the coefficients of the statistical models. The data were analyzed in a multiple variable, linear, stochastic, equation. Three forms of the relationships among variables were estimated and compared in an effort to find the method most useful for projection purposes. A stacked approach with classes run separately was used to

---

1/ The residuals exhibited no systematic non-linear pattern.

examine relationships within plant classes.

The first method tried used the following functional form:

$$Y = F\ (W, AW, P, U, H,) \qquad (3.1)$$

This is estimated in the statistical equation:

$$Y = B_0 + B_1W + B_2AW + B_3P + B_4U + B_5H + E \qquad (3.2)$$

The prediction equation for the first form can be stated:

$$\hat{y} = B_0 + b_1W + b_2AW + b_3P + b_4U + b_5H \qquad (3.3)$$

The symbols used have been previously defined but restated they are: wages, alternative wages, population, unemployment, hirings and error.

The second method used dummy variables to identify class relationships because this disaggregation of classes might have additional benefits for labor projection when applied to different sizes of communities. Tomek argues that at least two conditions must be satisfied before dummy variables can appropriately be used in regression analysis.[2/] First, it must be possible to divide the original observations into mutually exclusive classes, and second, the effect of the class difference is to change the Y-intercept level of the regression equation without changing the slope coefficients.

The data used for this study appear to satisfy these

2/ Tomek, W.G., "Using Zero-One Variables with Time Series Data in Regression Equations," Journal of Farm Economics, Vol. 45, No. 4, Nov. 1963, p. 814.

two conditions. The classes are mutually exclusive because they represent different skill level requirements for labor and discrete population sizes. An examination of the residuals after the three forms were run revealed less error within classes when using the dummy variable method.

The second method used the following functional form:

$$y = F\ (W,AW,P,U,H,C,) \tag{3.4}$$

This is estimated with the statistical equation:

$$y = B_0 + B_1W + B_2AW + B_3P + B_4U + B_5H + B_6D_1 + B_7D_2 + B_8D_3 + E \tag{3.5}$$

The prediction equation with the dummy variables is:

$$\hat{y} = b_0 + b_1W + b_2AW + b_3P + b_4U + b_5H + b_6D_1 + b_7D_2 + b_8D_3 \tag{3.6}$$

The symbol C represents the class variable in general while the symbols D_1, D_2, and D_3 represent the specific dummy variables for classes IV, III, and II, respectively. In the interpretation of this prediction equation, the dummy variables are class intercept shifters. Significance of the respective dummy variables is relative to class I which is the b_0 overall intercept. The numerical coefficients estimated for the dummy variables are to be added to the overall intercept.

The third method used the functional form:

$$y = f\ (W,AW,P,U,C) \tag{3.7}$$

The statistical equation for the method was:

$$y = B_0 + B_1W + B_2AW + B_3P + B_4U + B_6D_1 + B_7D_2 + B_8D_3 + E \quad (3.8)$$

The prediction equation is the same as equation 3.6 with the hirings variable dropped:

$$\hat{y} = b_0 + b_1W + b_2AW + b_3P + b_4U + b_6D_1 + b_7D_2 + b_8D_3 \quad (3.9)$$

The third functional relationship estimated deletes the number hired variable from the equation, but makes no other changes of the variables included in the second functional relationship. As can be noted in equation 3.9 dummy variables are included and interpreted in the same manner as in equation 3.6.

The third equation was estimated for several reasons. In the theoretical economic sense, confusion exists between measuring stocks and flows. Operator supply was defined as a stock, i.e., the sum of persons defined as operators employed at the time of the survey. Number hired, which becomes a part of the stock of operators are really a flow concept which measures addition to operator stock. Therefore, for single equation estimation, it did not seem appropriate to estimate variables reflecting both the flow and stock concepts in the same equation.

Furthermore, data for the number hired variable are difficult to obtain for estimation purposes. It would be helpful if number hired were recorded by the plants as well as separations for historical perspective and planning purposes. Finally, the correlation between population and number hired was relatively high at the .73 level. Dropping the number hired variable reduces the intercorrelation problem among the variables.

Statistical Coefficients: Supply Functions

Before discussing the results of the estimation procedures, it is appropriate to examine the intercorrelation problem. Since all the variables are included in equation 3.5 the intercorrelation coefficients for this equation are indicated in Table 3.9.

Table 3.9. Intercorrelation Coefficients for Equation 3.5

	Wages W	Alt. Wages AW	Popul. P	Unemploy. U	No. Hired H	Class IV D_1	Class III D_2	Class II D_3
W	1.000	.3295	.5164	-.1536	.3866	.6258	.2506	-.1868
AW		1.000	.2578	-.3790	.1852	.3752	-.1847	-.2070
P			1.000	-.1082	.7314	.5925	-.6937	-.2135
U				1.000	-.1752	-.1312	-.6390	.1418
H					1.000	.3357	.7726	.2219
D_1						1.000	-.2396	-.2989
D_2							1.000	-.5345
D_3								1.000

The essential feature of the intercorrelation table is that there are no high correlation coefficients. The correlation between the population variable and the number hired variable does reach a level of .73 but the other intercorrelation coefficients which range from .11 to .51 can be considered relatively low.

The model was specified as carefully as possible for predicting operators supplied and then the dummy intercept shifters were added to the regression equation. These were added because it was known that Class IV plants and Class III plants required higher skill levels and more operators than those in Class I and II plants. The correlation coefficients for the dummy variables are included in Table 3.9 along with those of the other variables. In the intercorrelation table, wages, alternative wages and population all have negative correlation with unemployment. As unemployment increases the mentioned variables decrease but the correlation levels are so low no significance needs to be attached to the sign of the relationships. The net result of the correlation coefficients presented is that large standard errors and low significance levels are not expected as a result of intercorrelation.

It should be noted that the other equations used to estimate this relationship, i.e., equations 3.3 and 3.9 have low intercorrelation coefficients similar to the results presented in Table 3.9.

Table 3.10. Regression Coefficients from Supply Equations in Indiana, 1969

Equation		Operator Wage (W)	Alternative Wage (AW)	Population (P)	Unemployment (U)	Hirings (H)	Class IV (D_1)	Class III (D_2)	Class II (D_3)	R^2
3.2	b_i	.0059 b/	.0046 b/	.0166 b/	.2038	.3385 b/	---	---	---	.59
	S_{b_i}	(.00098)	(.0023)	(.0068)	(.1503)	(.2246)	---	---	---	
3.5	b_i	.0021 a/	.0031	.0079	.2187 a/	.4858 b/	5.128 b/	1.918 b/	.1603	.67
	S_{b_i}	(.0014)	(.0021)	(.0069)	(.1364)	(.2098)	(1.3151)	(.8306)	(.6783)	
3.8	b_i	.0023 a/	.0029	.0189 b/	.1746	---	4.6374 b/	1.9121	.0235	.65
	S_{b_i}	(.0014)	(.0022)	(.0051)	(.1379)	---	(1.325)	(.8482)	(.6900)	

a/ Indicates the decision to reject the null hypothesis that, at the .05 level the amount of variation in operator supply accounted for by the variable is not different from zero, on the basis of F tables.

b/ Indicates the decision to reject the null hypothesis that, at the .01 level the amount of variation in operator supply accounted for by the variable is not different from zero, on the basis of F tables.

The R^2 value reflects the "goodness of fit" of the respective equations to the data. It ranges from .59 to .67 for the estimating equations described in Table 3.10. The amount of variance explained by the variables included in equation 3.5 exceeds the variance explained in equation 3.2 by 8 per cent. When the number hired variable is dropped from equation 3.5, as in equation 3.8, the R^2 value is lowered by two per cent.

Table 3.10 compares the results of the three estimating equations. Levels of significance for each regression coefficient are determined by comparing the coefficient obtained to zero by means of the F distribution. In the case of the dummy variables for class the coefficient shown when significant, is statistically different from the Class I intercept. The dummy variables shift the supply function relative to the first class; they do not change the slope of the estimating equation.

Interpretation of Regression Coefficients

Wage

In Table 3.10 the regression coefficients are indicated for each variable in conjunction with their level of significance. The sign of the wage variable was positive as had been anticipated from *a priori* economic reasoning. The coefficient for the wage variable in equation 3.2 was highly significant at the 1 per cent level of the F test. In equation 3.5 and 3.8 it was significant at the 5 per cent level of the F test. In equation 3.8, for example, this coefficient indicates as wages are increased by one dollar per month the quantity of men supplied to the wastewater treatment industry per plant would increase .0023. Therefore to increase the operator supply by one man for a given plant it would be necessary to raise the wage rate by $434.50 per month, all other things equal.

Although the supply function is interpreted above on a per plant basis, for broad planning purposes if it were known that the state as a whole would need more operators than the number supplied with current wages, then wages could be raised in the industry relative to the other variables.

For example, if there were 250 plants in Indiana and wages were increased by 10 per cent or about $50 per month, then the number of operators supplied should increase by 25 men. Since 76 new secondary plants are expected to be built before 1972 in Indiana, it may be possible to obtain 25 of these 76 operators by increasing wages in the industry above present relationships by $50, ceteris paribus.

It is important to remember that the model is a relative wage model. Elasticities tend to be lower when using cross sectional data and the chance exists that the true slope has not been identified. There are no lags built into the model between salary readings and operator response readings because time is held constant by the cross sectional method. The linear regression analysis makes strong assumptions in order to fit the regression line to the data. It is incorrect to interpret the results as suggesting exactly how the operator will perform down to the last decimal point. It is clear, however, that given the data studied and the method of analysis used, the wage variable appears to have reasonable potential as a policy tool.

Alternative Wages

Regression coefficients for the alternative wages variable range from a low of .0029 in equation 3.8 to a high of .0046 in equation 3.2. The positive sign held by this coefficient in all three equations was the opposite of that expected. It was presumed that higher wages in alternative occupations would decrease the number of operators available to the wastewater treatment plants rather than increase them as suggested by these positive coefficients. However, the impact of this economically incorrect sign is mitigated by the failure of the coefficients to be significantly different from zero at the 5 per cent level of confidence in two of the three equations examined.[3/] It appears little reliability can be placed in this coefficient for making projections of labor supply functions.

One possible explanation for the positive sign on the alternative wage regression coefficient might be the entry of the wage data for this coefficient. Since alternative wages were obtained on a county basis, when counties had both large and small waste treatment plants located within the county the same alternative wage was included for both scales of plant. This would tend to reduce differences which might have been more clearly apparent if disaggregate data would have been available to alternative wages in the specific local of the plant, i.e., small town or large city, could have been used in the analysis rather than the more aggregate county data.

3/ This situation is not unusual since other studies have found it difficult to quantify significantly the importance of the alternative wage variable in labor supply functions. For example, see Schuh, G.E., "An Econometric Investigation of the Market for Hired Labor in Agriculture," Journal of Farm Economics, Vol. 44, May 1962, pp. 307-321.

Population

The regression coefficient for population is significant at the 1% level in equations 3.8 and 3.2. In equation 3.5 it does not appear to be significant but the number hired variable could be influencing this result since it is relatively closely correlated with population. In all three equations the sign of the coefficient is positive as was expected from the economic logic of the relationship. Population data are entered in units of 1,000 people which means in equation 3.8, for every 1,000 increase in population, operators supplied increase by .0189. For about a 50,000 increase in population one more operator is supplied. With Indiana population in 1968 of about 5,000,000, a 1 per cent increase in population would supply one additional man to the wastewater treatment industry, *ceteris paribus*.

Other research supports the significance of the relationship between population and occupational employment found in this study.[4/] The magnitude of the coefficient, .0189 in equation 3.8 is smaller per 1,000 than might be expected. It may be because of discrepancies between total population and the population serviced by the wastewater treatment plants or it may be due to the industrial loadings which are included in the population design equivalents for

---

4/ Fishman, L., *et. al.*, *Methodology for Projection of Occupational Trends in the Denver Standard Metropolitan Statistical Area*, Univ. of Colorado, Boulder, Colorado, pp. 7-8, March, 1966.

which the plants are constructed.

Unemployment

Analysis indicated the unemployment variable to be non-significant at the 1 per cent or 5 per cent levels in equations 3.2 and 3.8. However, equation 3.5 did show the unemployment coefficient significant at the 5 per cent level. The sign of the coefficients in all three equations is positive which is consistent with economic theory. Economic logic indicates increases in unemployment in the county of plant location should result in an increase in the number of operators available for employment in wastewater treatment plants. This interpretation assumes the skill level of the available men qualifies them as operators.

In equation 3.8 the regression coefficient means that as unemployment increases by one per cent, .174 more operators become available per plant. Since the coefficient is not significant at the F levels used for the other variables, care should be used in the interpretation. In projection the preference is to use the variable instead of assuming its influence on operator supply to be zero. At the state level of planning if the average unemployment increased one per cent the operator response might be about 40 more men for waste treatment plants.

Number Hired

The regression coefficient associated with the number hired variable is highly significant in both equation 3.2 and 3.5 at the 1 per cent level of significance. The sign of the coefficient is positive which indicates that as the number of men hired increases the supply of operators increases. The statistical analysis raises some question about the appropriate interpretation of the number hired variable. The variable is closely correlated with population (see Table 3.9). In equation 3.5 the significance of the population regression coefficient appears to be reduced due to the influence of the number hired variable. In equation 3.8 which drops the number hired variable to correct the intercorrelation problem the significance of the population regression coefficient is enhanced, but at the expense of a lower explanation of the variance as R^2 drops from .67 to .65. In examining this loss of explanatory value by means of the F distribution it is apparent that the amount of explanation provided by the number hired variable was significant at the 5 per cent level.[5/]

The statistical problem of interpretation is further compounded by the theoretical stock and flow relationship. The number of men hired is a flow concept that is included

---

5/ This test compares the value of F to the change in mean square regression divided by the residual variance from equation 3.5.

in a regression analysis where all the other variables reflect stock situations. In this cross sectional study which is an instantaneous picture at one point in time, the interpretation of the number hired flow variable is not clear. It is possible to develop a system of equations to reflect manpower flows, but that has not been done in this case.

Considering the statistical trade-off possible and the theoretical problems associated with the number hired variable, it appears equation 3.8 may be the more appropriate functional relationship of the supply function to use for projection purposes.

Class

The class coefficients are to be regarded as intercept shifters. In equation 3.8 the coefficients for classes III and IV are shown to be significantly different from class I which is structured to appear as the overall b_0 equation intercept. Class II does not appear to be significantly different from class I. The interpretation is that in classes III and IV operator quality is significantly different from class I. The slopes within each class are assumed to be the same.

Summary

On the basis of the foregoing discussion, equation 3.8 was chosen to use for projection purposes. The R^2 of equation 3.8 is slightly lower than equation 3.5 but the reduction in intercorrelation and the improvement in economic logic achieved through the use of equation 3.8 seemed more important than the loss in explanation power. Furthermore, from a practical point of view data for population are more readily available than data for number hired. Equation 3.2 was not used because of persistent errors in the residuals when plants were not identified by class.

Projecting Operator Supply

A manpower projection, much like careful forward planning, is capable of identifying potential occupational imbalance which can then be used as the basis for designing programs to correct the imbalance. The projection method is described in detail and requires a minimum level of information in the hope that the method can be used on State and Regional levels by personnel responsible for manpower, educational, and water resources planning.

To illustrate the method, operator supply for the State of Indiana is projected for 1972. In addition, projections are developed for two economic regions of the state to illustrate application of the model at the regional level. The economic regions selected included one or more significant metropolitan areas and follow previously designated economic regions.[6] They are contiguous and relatively compact regions capable of being identified by the major cities in the

---

6/ Footnote 13, p. 34.

region. The two regions chosen were regions 9 and 11, Richmond and Columbus, respectively.[7/] These economic regions are quite appropriate for the labor projection method used in this study.

Projection of Independent Variables to 1972

The first step after the prediction equation has been estimated with 1969 data is to extend the component variables forward to 1972. A summary of the average annual percentage change in the dependent variables extrapolated to 1972 is presented in Table 3.11. The source of the average annual percentage change and the reasons it was selected are discussed in the following sections.

Table 3.11. Average Annual Per Cent Change in Mean Values of Dependent Variables Expected Between 1969 and 1972

	Dependent Variable			
Location	Wages (W)	Alternative Wages (AW)	Population (P)	Unemployment[a/] (U)
Indiana	+ 4.0%	+ 4.0%	+ 1.5%	4.1%
Region 9	4.6	4.6	.95	2.9
Region 11	4.4	4.4	2.9	4.1

a/ This is the percent used in 1972 not the ave. annual per cent change.

7/ These include the following counties in Region 9: Fayette, Franklin, Rush, Union and Wayne. Region 11 includes: Bartholomew, Brown, Decatur, Jackson and Jennings.

The rates of increase in the alternative wage variable for the State and each region were obtained from secondary data sources.[8] They are based on the increases that have occurred in manufacturing wages during the period 1965 to 1969. For region 9 and 11 the anticipated increase in alternative wage rates are an annual average of 4.6 per cent and 4.4 per cent respectively. For the State of Indiana an increase at the annual average rate of 4 per cent is assumed for the period from 1969 to 1972.

To estimate the change expected in the operator wage rate from 1969 to 1972 two approaches were possible with the data available. The first approach would utilize a historical comparison of salary changes between the period 1960 and 1969 as the basis for straight line future extrapolation.[9] Data that were available for this approach indicated an increase of salary at an annual average rate of 4.7 per cent per year. The second approach would be to consider operator salary increases to follow the same rate of growth as the alternative wage rates would at the same location. The latter approach was followed since it seemed more reasonable to expect the operator wage rates to follow the pattern of wage changes in the local area rather than to be independently

---

8/ Indiana Manpower Trends, Indiana Employment Security Division, July 1967 and August 1968.

9/ Salary Survey in Municipal Treatment Plants in Indiana - 1960, Journal Water Pollution Federation, Washington 16, D.C., pp. 734-736, July 1961.

determined.

The rates of increase in population between 1969 and 1972 are derived from secondary data sources.[10/] The rates are straight line projections based upon the changes in population which have occurred in Indiana, Region 9, and Region 11 between 1960 and 1968. For the State of Indiana it is estimated that population will increase at an average annual rate of 1.5 per cent.[11/] For Regions 9 and 11 the increase expected between 1969 and 1972 is an annual average of .95 per cent and 1.7 per cent respectively.

Independent estimates of population growth from 1970 to 1975 for the regions of interest verify the lower rate in Region 9 in comparison to Region 11.[12/]

Unemployment in both regions was determined for 1967 and 1968 by comparing the number of men unemployed with the size of the total work force. An average of these two years was used as a basis for county unemployment rates in the regression analysis. In Region 11 unemployment was 4.1 per

---

10/ Release P2, Bureau of Vital Statistics, Indianapolis, Indiana, 1968.

11/ Heller, M.W., Indiana Manpower Trends to 1975, Indiana Employment Security Division, January, 1967, p. 6.

12/ This source suggested Region 9 population would increase at an average annual rate of .5 per cent while the increase in Region 11 would be at a rate of 1.72 per cent. For further detail see:
Indiana Population Projections 1965-1985, Vol. 1. Total for the State, Economic Regions and Counties, Research Report No. 3, Graduate School of Business, Indiana University, Prepared by Bureau of Business Research pages throughout the book.

cent in 1967 and 3.1 per cent in 1968. In Region 9 unemployment was 2.9 per cent in 1967 and 3.5 per cent in 1968.

A simple average of these two years did not seem to be appropriate as the basis for projecting 1972 unemployment rates because of the insight gained from other sources. Total employment for Region 11 has been projected to grow 6.5 per cent between 1967-75.[13/] In the same region population was expected to grow 13.6 per cent in the same period of time. For this reason the higher 1967 unemployment rate, 4.1 per cent is chosen for 1972. Total employment in Region 9 has been projected to grow 11.1 per cent in the 1967-75 period.[14/] Population was projected to grow 7.6 per cent during the same period. Using a similar line of reasoning the lower 1967 rate of 2.9 per cent was selected for the 1972 estimate in Region 9.

For the State of Indiana no change in unemployment level is projected. The 1969 level was set at 4 per cent and the 1972 estimate was 4 per cent.

The average annual per cent change indicated for each variable in Table 3.11 is utilized to estimate the level of these variables in 1972. The results of this estimation are presented in Table 3.12 with a comparison to the mean value of the variables in 1969. The 1972 estimates are entered

---

13/ Heller, M.W., Indiana Regional Employment Projections, 1967-1975, pp. 4-5. May 1970.

14/ *Ibid*.

Table 3.12. Mean Value of Dependent Variables in 1969 and Estimated Value in 1972

Variable and Class	Indiana 1969	Indiana 1972	Region 9 1969	Region 9 1972	Region 11 1969	Region 11 1972
Wage (dollars per month)						
I	$179	$200	$179	$204	$179	$203
II	443	496	443	504	443	501
III	608	681	608	692	608	688
IV	959	1074	959	1091	959	1086
Alternative Wages (dollars per month)						
I	$551	$617	$523	$592	$518	$583
II	532	596	523	592	518	583
III	551	617	523	592	518	583
IV	665	745	523	592	518	583
Population (number)						
I	1055	1097	1259	1272	1019	1065
II	3326	3457	3590	3684	3492	3647
III	12,057	12,535	19,211	19,715	13,408	14,001
IV	110,958	115,358	47,924	49,182	23,957	25,016
Unemployment (per cent)						
I	3.5%	3.5%	3.2%	2.9%	3.6%	4.1%
II	3.8	3.8	3.2	2.9	3.6	4.1
III	3.3	3.3	3.2	2.9	3.6	4.1
IV	2.9	2.9	3.2	2.9	3.6	4.1

into the structural equation to obtain a projection of the level of the dependent variable (number of operators) in 1972. The results of this estimation are described below.

Projection of Quantity of Operators Supplied

Table 3.13 compares the results of the prediction equation using 1969 and projected 1972 values for the four dependent variables. The total supply of men increases by 3.2 operators between 1969 and 1972 in Region 9 and by 4.0 men in Region 11. In both Regions the greater increase is shown in the smaller plants, i.e., Class I and II plants. In Region 9 the Class III and IV plants increase by only .3 and .5 men respectively. A similar pattern occurs in Region 11. Additional plants which will be operational by 1972 are included in the projection. The actual number of men involved will exceed the number indicated in both Class I and II because these two classes hire many part time workers and the increase indicated refers to full time man equivalents. In spite of different employment, wage, and population growth rates in the two regions the projected pattern of increases in the quantity of operators supplied appears to be quite similar.

Table 3.14 presents the results of the projection of operator supply for 1972. The total expected increase in number of operators supplied will be 116.8 full time man equivalents between 1969 and 1972. The projected number of operators supplied by class for 1972 indicates at the state

Table 3.13. Number of Plant Operators Supplied in 1969 and Projected for 1972 in Region 9 and 11

	Region 9			Region 11		
	1969[a/]	1972[b/]	Increase	1969[a/]	1972[b/]	Increase
Class I	.6	1.8	1.2	.8	2.1	1.3
Class II	4.4	5.6	1.2	4.7	6.4	1.7
Class III	3.4	3.7	.3	3.4	3.8	.4
Class IV	7.4	7.9	.5	7.0	7.6	.6
Total	15.8	19.0	3.2	15.9	19.9	4.0

a/ Mean estimate from supply equation 3.8.

b/ Projection for 1972 based on equation 3.8.

Table 3.14. Number of Indiana Plant Operators Supplied in 1969 and Projected for 1972

Class	1969[a/]	1972[b/]	Increase
I	18.0	66.9	48.9
II	111.6	151	39.4
III	149.5	166	16.5
IV	183.4	195.4	12.0
Total	462.5	579.3	116.8

a/ Mean estimate from supply equation 3.8.

b. Projection for 1972 based on equation 3.8.

level the same trend evident at the regional level. Class I and II plants show the largest increases in operator supply. In Class I plants an increase in quantity supplied of 49 men is projected. Part of this increase is the result of wage and population increases but the greater share of the increase is due to the 64 additional locations in Indiana which are expected to have treatment facilities by 1972. In contrast, Class II plants are expected to have only 4 additional locations by 1972 but Table 3.14 shows an additional 39.4 operators will be supplied which reflects primarily increases in the independent variables. Note many of the men in the Class I and II plants will be on a part time basis which means that even larger numbers of men are actually involved in the additional supply.

It is important to recognize that no claim is made that the levels of the variable projected to 1972 in this study are the "correct" extrapolation of present data. They seem to be reasonable estimates that are internally consistent as a group and comparable with other external sources of information. The key point they are meant to illustrate is how to project the supply function for labor in 1972. If other levels of the projected variables seem more appropriate, they can be utilized with the estimating equation to obtain alternative projections of the labor supply function. Often other techniques are used for projection of the independent variables to future years, such as, exponential smoothing, which may yield different estimates of the level of the variables than the straight line method of projection utilized here. Once the structural equation of supply is estimated these alternative methods of estimating changes in the independent variables for any time period in the future, not just 1972, can be used in conjunction with the structural equation to estimate the dependent variable.

With the estimate of labor supply in 1972 available, planning personnel can compare it to the estimate of the number of operators that will be required for plants that will be operating in 1972. Information is available about the class of plants expected to be operating in 1972 and about pollution control priority construction plans which permits the estimation of operator needs. When this comparison is made, if the estimate of number of operators proposed is not identical to the anticipated needs, correction of the situation can be initiated through the adjustment of variables, such as, wages which are subject to managerial control.

CHAPTER IV

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

The summary section of the final chapter restates the problem and highlights the main features of the review of literature and economic theory. The data used and the method of analysis are described including a projection of the expected regional and state plant operator supply for 1972. This summary is followed by the conclusions from the research results for both projection methodology and pollution control. The conclusions indicate policy directions and implications. Improvements in the study and areas for further research are suggested in the final section of this chapter.

Summary

The problem examined in this study was to analyze the supply of Indiana wastewater treatment plant operators. The approach to the problem involved both estimation of the supply function for 1969 and estimation of the quantity of operators expected to be supplied in 1972. This would indicate what level of supply would occur in 1972 if no steps were taken through manpower management or changes in training programs to adjust supply to prospective demand for operators.

The review of literature revealed the following three techniques for projecting manpower supply: 1) input-output analysis, 2) economic activity analysis, 3) and employer forecasts. Several studies found employer forecasts to be inadequate while other studies suggested disaggregated data were unavailable for use in the input-output analysis. Economic activity analysis was found to suffer from very large, overly sensitive swings in projected labor outcomes with only small percentage changes in activity. Multiple regression analysis using significant causal variables to formulate supply functions with explanatory power independent of employer forecasts appeared to offer a feasible alternative to those suggested in the literature.

Economic theory was used to formulate a manpower supply and demand model in the wastewater treatment plant context. Operator supply was postulated to be a function of wages, alternative wages, population, unemployment and number hired plus additional class of plant intercept shifters. Operator demand was postulated to be a function of factors such as wages, design capacity per plant, plant age, plant capital, the technology used and working conditions as reflected in turnover rates.

A single equation least squares multiple regression analysis was conducted to fit a supply function to cross sectional plant data for 1969. The functional form of the equations estimated was linear. Standard F tests were used to examine the significance of the parameters generated for operator supply. The prediction equation chosen for projection and policy implications was one of three which were analyzed to investigate the effect of different restrictions on the regression results.

Data were drawn for operator supply analysis from a wage and employment survey of the wastewater treatment industry conducted in November of 1969, and from secondary data sources. The high response from the mail survey, resulted in a sample of 129 plants out of the 245 plants in the State providing data for analysis. The primary use of the survey was to provide data about the wages of plant operators. The mean value of operator wages in Class II, III, and IV plants were $479, $464, and $538 monthly, respectively. Operator wages were apparently lower than manufacturing wages in the same communities. The data for the three other variables, i.e., alternative wages, population, and unemployment, were obtained from secondary sources.

The following functional relationship was selected to provide the basis for developing projections of 1972 labor supply:

Operator supply = .0023 Wages + .0029 Alternative Wages
+ .0189 Population + .174 Unemployment
+ the class shifting dummy variables.

This equation had an R^2 of .65. The regression coefficient for population was significant at the 1 per cent level; the coefficient for wages was significant at the 5 per cent level.

The coefficients for alternative wages and unemployment variables were not significant at either the 1 per cent or 5 per cent levels.

This estimating equation was selected over alternative equations for projection purposes because of more consistent economic logic and greater availability of the data required for estimation. Intercept shifters were included to avoid errors in the predictions for the smaller Class I and II plants which are important in Indiana. Alternative wages and unemployment were left in the equation during the projection phase to avoid the assumption of zero influence and reflect their theoretical importance for the supply of manpower.

A projection of operator supply in 1972 was made for economic regions 9 and 11 and for the state as a whole. The projection results for the two regions and the state had quite similar patterns showing some increase in supply as a result of increased wages and population. The increase in number of operators supplied was greater in the smaller Class I and II plants than in the larger Class III and IV plants. For the State of Indiana an increase of 48.9 full time man equivalents were projected at Class I plants while an increase of only 12.0 men was projected for Class IV plants between 1969 and 1972. This was partly because of new facilities being developed in some locations between 1960 and 1972. The projection of total operator supply made at the state level indicated by 1972 that 116.8 additional operators would be supplied. Class I and II were expected to contribute 88 of the additional men out of the total 116.8. The coefficients identified by the regression analysis for the prediction equation make it possible to see how the change in each variable affects operators supplied in the various plant classifications in Indiana.

Conclusions

The statistical results of the regression analysis suggest that it is possible to predict operators supplied using wages, population, alternative wages and unemployment when suitable intercept shifts for size of plant and quality of manpower, are included in the estimating equation.

The identification of wages and population as significant explanatory variables for operator supply may have been the most important contribution of the study. A complaint often expressed among those attempting labor projections, is the lack of relevant and reliable data which can be used for meaningful policy decisions. Since data must often be disaggregated by age, race, skill, region, locality and labor market, some of these demands for data are difficult and costly to meet. This study suggested the large set of factors known to affect labor supply might be reduced to a small set for which data are known to be available.

In Indiana new plant construction for wastewater treatment appeared to be concentrated in the smaller towns. This trend emphasized the need, as facilities are constructed, for more operators in the rural towns and villages. Results of the study also indicated that increases in operators salaries had occurred from 1960 to 1969, yet it appears that salaries still were not directly competitive with wages in alternative possible employment.

The study concludes that higher wages offered within the wastewater treatment industry, other things being equal, can attract more manpower in the industry. By carefully analyzing salary schedules within the economic setting of each plant the supply function indicates the impact on operator numbers that results from wage changes. For example, it is shown that for an increase of $50 per month in salary scale (about a 10 per cent increase) at all treatment plants in Indiana, the number of operators supplied would increase by about 25 men in the state. These values are statistically valid within known limits and appear to be reasonable. If pollution abatement goals are not being met because operators are not available for the plants then one possible solution would be to increase the wage rates to attract more operators.

Another approach to the operator supply problem where capital can be substituted for labor, involves building more capital intensive plant operations to reduce the number of operators required. This may require more highly skilled operators to man the new plants.

The operator survey revealed that many plants are managed on a part time basis. Often, time must be spent at the plants for building and grounds maintenance which may not require certified operators or skilled pay levels.

The operator needs might be reduced through regional pollution control management. It was apparent in the mapping, recording and projecting necessary for the analysis of operator supply, that many of the plants of similar size and class were located geographically close together. Is it possible that one man could monitor several small automated treatment facilities in closely grouped small towns? An example might be combining the management of plants in Brookston, Monticello, Chalmers, and Delphi. Such a man could be paid well, trained well and employed full time in the supervision of the plants.

Anothet trend relevant to all water resource areas is the change in environmental attitudes held by the general public. Note that 68 new plants are expected to be constructed before 1972 in Indiana. This construction along with the improvement of present plants which has taken place creates better working conditions in a job with new higher status. The neat modern surroundings, often with odor control are more conducive to hiring and keeping capable manpower. Municipal treatment plant operation has become more of a service which affects the quality of local water resources. This quality, with the new awareness figures prominently in local recreational and esthetic goals. Changes in job status and environmental attitudes should improve the supply of operators available for wastewater treatment.

Limitations

The conclusions of this study must be considered subject to the limitations that constrain the broad general applicability of the results. Persons well acquainted with the wastewater treatment industry may question the practical predicative accuracy per plant of the statistical tools. It is simply assumed that all factors which affect labor supply will continue to change in the same manner in the future as they have in the past. It is true that the relationships established by the regression analysis will gradually lose their accuracy for predictive purposes. However, the knowledge of the most important explanatory factors which affect the supply of wastewater treatment plant operators gained in this study can permit others to analyze these factors with new data to reestablish coefficient values for future time periods. If it can be shown that the explanatory variables listed are capable of meaningful forecasts of operator supply then the needed records would be willingly provided.

Policy Implications

The major contribution of this study is expansion in the scope of managerial alternatives for the labor input available to the wastewater treatment industry. It is no longer necessary to rely solely upon training more men as the solution to operator shortages. This research clearly indicates several management alternatives are available to solve this problem. First, increased operator wages can attract more operators to wastewater treatment plants, ceterus paribus. The increase in wages necessary to attract a specific number of men into the industry can be derived from the supply function estimated in this study. Second, the increase in population expected in the State for which new treatment facilities are being constructed will increase the number of operators available to work in wastewater treatment plants, ceterus paribus. Third, regional management of several small plants by one operator may reduce manpower needs. Fourth, the substitution of capital for labor by construction of more highly automated plants can reduce the number of operators required. Fifth, expansion of the employment information available to potentially interested workers in the State can influence the number of men supplied for this work. Sixth, the strong interest in environment quality exhibited in the society today should increase the number of men interested in wastewater treatment. Seventh, it is possible to design training programs to increase the skills of present operators or train new operators. This is an important management alternative, but it is listed last here to emphasize that it is only one of several alternative solutions to the wastewater treatment operator supply problem. Further information on this management alternative can be found in a recent study by J.P. Lisack.1/

Future Research

Future research could involve multiple equation models, such as, the one developed in Appendix B. These models could include distributed lags to more closely approximate the quantity supplied and wage relationship if time series data were available to use for estimation of the coefficients. Application of models, such as these, to several different occupations might isolate certain key variables that are most important in explaining the observed relationship. If these variables were similar for different occupations it would be possible to generalize to suggest the appropriate data for analysis in occupations that had not been examined individually.

It would be interesting to explore in depth the relationship between alternative wages and the quantity of men supplied. Why is it difficult to obtain the correct sign or significance for the regression when economic theory suggests such a clear relationship? Studies in other occupations of this problem could be particularly helpful in the attempt to quantify this relationship.

An interesting experiment with profound policy management

1/ Lisack, G.P., Manpower Requirements for Pollution Control and Water Resources in Indiana, Manpower Report 69-1, 24 February 1969. Purdue University.

significance would involve testing the idea of full time regional wastewater treatment plant operators serving several communities which were located close to each other. This experiment could test whether it was more efficient to employ one man full time to supervise a few plants with the additional cost of traveling from one plant to another or whether a part time man employed in each town would provide more efficient service.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

Bloom, G.F., and Northrup, H.R., Economics of Labor Relations. Homewood: Richard D. Irwin, Inc., 1961.

Cartter, A.M., and Marshall, R.F., Labor Economics: Wages, Employment, and Trade Unionism. Homewood: Richard D. Irwin, Inc., 1967.

Fein, R., The Doctor Shortage: An Economic Diagnosis. Washington: The Brookings Institution, 1967.

Fleisher, B.M., Labor Economics: Theory and Evidence. Englewood Cliffs: Prentice-Hall, Inc., 1970.

Kaufman, J.J., Farr, G.N., and Shearer, J.C., The Development and Utilization of Human Resources. University Park: The Pennsylvania State University Institute for Research on Human Resources, 1967.

Maki, D.R., A Forecasting Model of Manpower Requirements in the Health Occupations. Ames: Industrial Relations Center, 1967.

Whybark, C.D., Forecasting Pilot and Mechanic Requirements and Pilot Supply for Civil Aviation. Palo Alto: Graduate School of Business Stanford University, 1967.

Articles, Reports and Documents

Cohen, S. "The Supply Curve of Labor Re-examined," Industrial and Labor Relations Review, Vol. 13 (October, 1959), 64-71.

Eddleman, B.R. "Estimating the Effects of Resource Development Programs on Regional Employment," American Journal of Agricultural Economics, Vol. 51, No. 5 (December, 1969), 1434-1441.

Fishman, L., Roberts, W.E., Franks, C.M., and McCormick, W.W. Methodology for Projection of Occupational Trends in the Denver Standard Metropolitan Statistical Area. A Report Prepared by the Bureau of Economic Research. Boulder: University of Colorado, 1966.

Gisser, M. "Needed Adjustments in the Supply of Farm Labor," Journal of Farm Economics, Vol. 49, No. 4 (November, 1967), 806-815.

_________. "Schooling and the Farm Problem," Econometrica, Vol. 33 (July, 1965), 582-592.

Hansen, W.L. "Labor Force and Occupational Projections," Proceedings of Third Annual Meeting, Industrial Relations Research Association (December, 1965), 10-20.

Kneese, A.V. "Economics of Pollution Control," A Report for Water Resources and Economic Development in the South, Atlanta: Agricultural Policy Institute, North Carolina State University, (August, 1965), 97-107.

Lisacks, J.P. Manpower Requirements for Pollution Control and Water Resources in Indiana and a Related Pollution Control Technology Curriculum. A Report Prepared by the Office of Manpower Studies, School of Technology, Purdue University. 1969.

Phelps, E.H. "Money-Wage Dynamics and Labor-Market Equilibrium," Journal of Political Economy, Vol. 76 (July/August, 1968), 678-711.

Roesenthall, N. "Projections of Manpower Supply in a Specific Occupation," Monthly Labor Review, Vol. 89, No. 11 (November, 1966), 1262-1266.

Schuh, G.E. "An Econometric Investigation of the Market for Hired Labor in Agriculture," Journal of Farm Economics, Vol. 44 (May, 1962), 307-321.

Stein, B., and Leung, C. Local Manpower Data Programs: An Analysis. A Report Prepared for the Office of Manpower Policy, Evaluation and Research, U.S. Department of Labor, August, 1966.

Swerdloff, S. "Manpower Projections: Some Conceptual Problems and Research Needs," Monthly Labor Review, Vol. 89, No. 2 (February, 1966), 138-142.

Tyrchniewics, E.G., and Schuh, G.E. "Regional Supply of Hired Labor to Agriculture," Journal of Farm Economics, Vol. 48 (August, 1966), 537-556.

"Manpower and Training Needs in Water Pollution Control," Report of the Department of Interior Federal Water Pollution Control Administration to the Congress of the United States. Document No. 49, 90th Congress, 1st Sess., August 2, 1967.