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Environmental Engineering

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January 4, 1983

Mr. Harold D. Lester
U.S. Environmental Protection Agency
Office of Analysis and Evaluation
401 M Street, S.W. (WH-586)
Washington, D.C. 20460

Subject: Final Report for EPA Contract No. 68-01-6404,
Work Assignment No. 12

Dear Chip:

Enclosed are five copies of the final report for the above-referenced contract and Work Assignment. The report is entitled "Review of Two NPDES Permit Assistance Manuals." As we discussed on the telephone last week, we will not do the case study until after you have reviewed this report.

If you have any questions concerning the report, please give me a call.

Sincerely,

Jean L. Williams

Jean L. Williams
Project Manager

JLW/bl

cc: Negotiator
Patent Advisor
Library
Project File - 105.04 Wa 12

PRA

EPA 0795

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Final Report for EPA Contract No. 68-01-6404,
Work Assignment No. 12

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is currently in the process of preparing "second-round" NPDES permits. These include both BAT permits for which effluent guidelines have been proposed or promulgated, and BEJ (Best Engineering Judgement) permits for point sources that have no applicable national effluent guidelines. The wastewater treatment technology on which the BEJ permit is based must be shown by the permit writer to be economically achievable for the facility receiving the permit. To do this, the permit writer must first calculate the cost of the appropriate wastewater treatment technology and then determine if it is economically achievable.

Other offices within EPA have prepared two analytical manuals which are intended as guidance to those state and regional office staff who are preparing "second-round" NPDES permits. These manuals are:

- A Standard Procedure of Cost Analysis of Pollution Control Operations; and
- Protocol for Determining Economic Achievability for NPDES Permits.

This report summarizes the results of a review by Pope-Reid Associates, Inc. (PRA) of these two manuals. The review was based on a two-fold approach that both evaluated the documents individually and assessed the feasibility of using the documents in conjunction with each other. Each of the manuals was reviewed with respect to:

- the soundness of the methodology;
- the type(s) of information and data needed;
- the assumptions employed; and
- ease of use.

The manuals were also reviewed in terms of their compatibility with each other. The format of this report reflects this two-fold approach. The two sections which follow the recommendations present the results of PRA's review of the Cost Analysis Manual and the Economic Achievability Protocol. The next section discusses the use of the two manuals together. Following it is a reference section and an appendix which contains a description of the preparation of an annotated bibliography.

RECOMMENDATIONS

This section contains a summary of PRA's recommendations regarding the Cost Analysis Manual and the Economic Achievability Protocol. The recommenations are described in more detail in the next three sections of the report.

Cost Analysis Manual

1. Some of the values/costs of factors (e.g., labor, land, laboratory, and waste disposal costs) have changed since the Manual was written in 1977. These factors should be reviewed and updated to reflect more current values if necessary.

2. The Cost Analysis Manual seems to be better suited to calculate capital and O & M costs for chemical processing facilities in general. It should be revised to reflect cost estimating for wastewater treatment systems. This will include deleting those sections which are not applicable to wastewater treatment facilities and orienting the focus of the Manual to the needs of BEJ permit writers.

3. The section on estimating costs to retrofit a facility should be expanded.

4. New examples should be provided which reflect cost estimates for wastewater treatment facilities.

5. Information on a given topic in the present Cost Estimating Manual is scattered throughout the two volumes. The format of the Manual should be revised so that step-by-step calculations are shown for each relevant cost estimating methodology.

6. The bibliography/reference sections should be updated, expanded, and changed in format to an annotated bibliography.

Economic Achievability Protocol

Firm Level Analysis

1. EPA's policy on economic achievability should be clearly defined in the Protocol.

2. Procedures should be added to evaluate the effect of BEJ investments and costs on the profitability of a firm.

3. Prodedures should be added to evaluate the effects of BEJ investments and costs on competition with substitute products and products produced in other countries.

4. Procedures should be adapted or supplemented to provide insight on sources of capital available to a firm.

5. The assumption used in several of the tests (which assumes that BEJ costs would be paid for from current assets, earnings, or cash flow) should be reconsidered. This assumption may be more conservative than necessary.

6. Each test should incorporate data for three to five years. Clear guidelines should be provided for evaluating historical trend data.

7. Each test should be adapted to consider the differential effects on small firms. This is one of the most critical problems with this analysis.

8. Clear explanations should be provided for each test. Explanations should include definitions of all relevant terms, statements of purpose for each test, critical values to indicate whether a firm passes or fails a test, and step-by-step procedures for locating data and performing calculations.

9. Data items such as interest rates and investment tax credits should be specified as variables to be supplied by the permit writer. Clear instructions for selecting the correct data should be provided.

10. Errors in the explanations and sample calculations (identified in the description of each test) should be corrected.

11. The fixed charge coverage ratio and Beaver's ratio should be modified or replaced. These tests do not provide adequate insight into the ability of a firm to meet its long-term obligations.

12. Beaver's ratio should not be relied on as a predictor of bankruptcy. If bankruptcy prediction is an integral part of the economic achievability analysis, a more effective procedure should be chosen.

13. The market value analysis should be eliminated from the methodology.

Plant Level Analysis

1. Additional guidance should be given to the permit writer for purposes of determining the appropriate SIC code for a plant when the plant belongs to more than one SIC.

2. The Protocol should be modified to address circumstances in which part of a plant's wastewater is regulated by effluent limitations guidelines and the remaining wastewater is to be controlled by a BEJ permit.

3. Consideration of BCT cost-effectiveness criteria should be included in the Protocol to facilitate estimating costs for plants that also discharge conventional pollutants.

4. The three plant level tests rely on financial data from the most recent fiscal year of a plant. The tests should be applied for the three most recent fiscal years.

5. More guidance should be given when the three tests do not provide definite conclusions concerning the economic achievability of BEJ technology.

6. The utility of the Gross Margin and Revenues tests should be reconsidered to determine if they provide additional information about the economic achievability of BEJ technology.

7. The Protocol should be revised to identify a source of the interest rate (or discount factor). The interest rate is needed to calculate the total annual costs of a BEJ technology.

REVIEW OF COST ANALYSIS MANUAL

Introduction

This section contains the results of PRA's review of A Standard Procedure for Cost Analysis of Pollution Control Operations. In reviewing this document, PRA concentrated on evaluating the following:

- the timeliness of the engineering assumptions used;
- the soundness of the cost estimating methodology;
- the ease with which the Manual can be used by permit writers;
- the flexibility and accuracy of the Manual when applied to a variety of plant situations; and
- the compatibility of the Manual with the Economic Achievability Protocol.

Summary of the Cost Analysis Manual

The document A Standard Procedure for Cost Analysis of Pollution Control Operations presents a standardized procedure for preparing engineering cost estimates and economic evaluations of chemical processing facilities. This would include pollution control operations, although the Cost Estimating Manual is much more generalized in scope. The procedure is applicable to projects in various economic sectors (i.e., private, regulated, and public). The Manual presents a recommended format, termed the specification, which is used to organize the information for the economic evaluation into three segments: the descriptive segment, the cost analysis segment, and the reliability assessment. The Manual also contains guidelines to aid in the selection of financial and operating factors and to establish the level of detail required.

The descriptive segment contains brief descriptions of five items: facility description; capacity rating; abstract of the scope of the project; performance specification; and stage of development.

The cost analysis segment is made up of the three elements -- the specified parameters, the cost estimate, and the feasibility evaluation. The specified parameters include:

- the interest (discount) rate;
- the facility life and depreciation period;
- the construction time;
- a reference unit for process costs;
- a cost index; and
- an inflation rate.

The cost estimate includes capital investment, annual expenses, and profit and cash flow. The following methods are presented for determining capital investment at the study or preliminary estimate level: Lang, Chilton, Guthrie, ICARUS, and Unit Process. The cost data and any expected revenues are used to calculate several measures of merit which represent the criteria for assessing economic feasibility. The Manual discusses the following measures of merit:

- return on investment (ROI);
- internal rate of return (IROR);
- payout time;
- equivalent annual cost; and
- unit costs.

The third segment of the Manual describes methods for assessing the reliability of the measures of merit.

The bulk of the Cost Analysis Manual consists of 11 appendices that provide detailed background material and two comprehensive examples. The appendix subjects are:

- Capital Investment Estimation;
- Annual Expense Estimate;
- The Cash Flow Concept;
- Discrete and Continuous Interest Factors;
- Measures of Merit;
- Cost Indices and Inflation Factors;
- Rates of Return and Interest Rates;
- Methods of Reliability Assessment;
- Sensitivity Analysis;
- Example I -- Cost Analysis of Flue Gas Desulfurization (FGD) Retrofit Facility; and
- Example II -- Cost Analysis of Chlorolysis Plant.

Capital Cost Estimates

Capital cost estimates will differ in the data and other resources required to prepare them; in the experience/knowledge required of the analyst; and in the accuracy of the results obtained. The Cost Analysis Manual discusses five different cost estimating methodologies, which vary in terms of the accuracy that can be obtained. In general, estimates which are the most accurate also require the most data. The five methodologies discussed in the manual, from the least to the most complex, are:

- order-of-magnitude/ratio estimate;
- study (or factored) estimate;
- preliminary/budget authorization estimate;
- definitive/project control estimate; and
- detailed/firm contractor's estimate.

The first three are also called "conceptual estimates" and are the most suitable to use in preparing BEJ permit cost estimates. Of these three, the study estimate will probably be most likely to provide the information required by writers of BEJ permits.

Study estimates can be either "factored" or "unit process" estimates. Four methods of developing factored estimates are discussed in the Manual--those of Lang, Chilton, Guthrie, and ICARUS. In the Lang method (Table 1), the sum of the delivered costs of the major pieces of plant equipment is multiplied by a single factor to obtain the plant capital cost. The factor used depends only on whether the plant processes primarily solids or fluids. In the Chilton method (Table 2), an installation factor is applied to the sum of the delivered prices of major plant equipment and then additional factors are used to obtain the costs of auxiliaries. A common variant, not discussed in the Manual, is to apply separate installation factors to the purchase cost of each piece of major equipment, sum these installed costs, and then apply additional factors for the costs of auxiliaries. Guthrie's method (Table 3) increases the complexity and accuracy of this variant by applying individual factors for materials and labor for installation and auxiliaries to the purchased price of each piece of major equipment and then summing these costs. The ICARUS method (Table 4) is a simplification of the Guthrie method.

Table 1. Lang Method

Use Equation: $I_F = (\Sigma E)(L)$

Where: I_F = total plant cost (total module cost; fixed capital investment for equipment, buildings, site development);

ΣE = Sum of major plant items (MPIs), ΣE delivered[(a)]; and

L = Lang factor.

1. Total plant cost
2. Interest during construction, if applicable, and capitalized
3. Modification of the facilities and start-up costs, if capitalized

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4. Total depreciable investment
5. Land
6. Working capital

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7. Total capital investment

(a) Same as FOB job site

Table 2. Chilton Method

(Factored costs of sum of major plant items (MPIs), $\leq E$, delivered)

Item	Factor	Operating On	Cost of Item
1. Sum of major plant items (MPIs), $\leq E$, delivered[a]	--	--	
2. Installed, erected equipment cost		#1	
3. Piping (includes insulation)		#2	
4. Instrumentation		#2	
5. Buildings and site development		#2	
6. Auxiliaries (electric, steam, etc.)		#2	
7. Other		#2	
8. Total physical cost (Direct cost), DC (sum of 2 through 7)			
9. Indirect cost (20 to 50% of DC, avg 34%), IC			
10. Total bare module cost, BMC			
11. Contingency (10 to 50% of BMC; avg 15%)			
12. Contractor's fee (about 3% of BMC)			
13. Total plant cost (Total module cost), I_F			
14. Interest during construction, if applicable, and capitalized			
15. Modification of the facilities and start-up costs, if capitalized			
16. Total depreciable investment			
17. Land			
18. Working capital			
19. Total capital investment			

(a) Same as FOB job site

Table 3. Guthrie Method

Sum of each MPI[(a)] (this includes adjuncts, such as solids handling facilities, site development, industrial buildings, off-site facilities)

1.	MPIs, purchased[(a)], $\leq E$
2.	Direct (field) material, m
3.	Direct (field) labor, L
4.	Sum of direct costs, (Total physical cost) DC, for each MPI and adjunct
5.	Indirect cost (20 to 50% of DC, ave 34%), IC
6.	Total bare module cost, BMC
7.	Contingency (10 to 50% of BMC; avg 15%)
8.	Contractor's fee (about 3% of BMC)
9.	Total plant cost (Total module cost), I_F
10.	Interest during construction, if applicable, and capitalized
11.	Modification of the facilities and start-up costs, if capitalized
12.	Total depreciable investment
13.	Land
14.	Working capital
15.	Total capital investment

(a) Major plant items (MPIs)

Table 4. ICARUS Method

1.	Sum of installed costs for MPIs - includes indirect costs associated with each item
2.	Total of special items (solids handling facilities, site development, industrial buildings, off-site facilities)
3.	Base plant cost (Total bare module cost), BMC
4.	Contingency (10 to 50% of BMC; avg 15%)
5.	Contractor's fee (about 3% of BMC)
6.	Retrofit increment (if applicable)
7.	Total plant cost, I_F
8.	Interest during construction, if applicable, and capitalized
9.	Modification of the facilities and start-up costs, if capitalalized
10.	Total depreciable investment
11.	Land
12.	Working capital
13.	Total capital investment

The Manual considers the Lang method, which is the simplest of the three, to be the least reliable and useful only for checking the results calculated by one of the other three methods. In fact, the basis of the Lang method has been questioned in the recent literature[4]. The Chilton method, the more complex Guthrie method, and the ICARUS method are all recommended by the Manual and enjoy wide acceptance. However, the sources of data that can be used with the Guthrie and ICARUS methods are limited, consisting chiefly of Guthrie's own works and the EPA report prepared by ICARUS[2]. There are many recent sources of data for the Chilton method[8,9].

Another method of preparing study estimates of capital costs is discussed in Appendix A of the Manual. This is the Unit Process method (Table 5), which is also satisfactory and enjoys wide acceptance. The Manual is in error, however, in stating that "At present this method seems applicable only to liquid waste treatment where the facilities are analogous to large sewage treatment plants." A modification of the Unit Process method involving installed costs has been used for chemical plant equipment by Dryden and Furlow[6] and to some extent by Peters and Timmerhaus[11], Perry[10], and others, although the most typical applications have been to large sewage treatment plants[3,5]. In this modification, the costs of piping and other auxiliaries are estimated by factors applied to the sum of the installed equipment costs as in the Chilton method.

The Chilton and Unit Process methods are the most suitable to calculate the capital cost for BEJ permits. These methods are relatively simple and the data needed are readily available. The Manual should be revised to emphasize these two methods, explain the differences between them, and recommend sources of data for each by means of an annotated bibliography. The information on these two methods should be consolidated. Other methods should be deemphasized or deleted.

In addition to the plant capital cost, there are additional capital requirements which must be addressed, including land, funds required during construction and startup, and working capital. The discussion in the Manual is adequate but should be consolidated and in some cases updated.

Table 5. Unit Process Method

(Sum of unit process modules)

Process Module Identification	Total Cost
1. Process module No. I -	
2. Process module No. II -	
3. Process module No. III -	
4. Process module No. IV -	
5. Process module No. V -	
6. Process module No. VI -	
7. Total plant cost, I_F	
8. Interest during construction, if applicable, and capitalized	
9. Modification of the facilities and start-up costs, if capitalized	
10. Total depreciable investment	
11. Land	
12. Working capital	
13. Total capital investment	

Many facilities will need to add on or retrofit water pollution control systems to the basic plant in order to comply with their BEJ permit requirements. Retrofitting a plant with pollution control equipment often costs more than installing the same equipment in a new plant or expansion. Process modifications and structural modifications which may have been otherwise unnecessary, space constraints, utility expansions, and lost production account for a large portion of this difference. The Cost Analysis Manual contains only a brief discussion of this topic. The discussion and recommendations summarized in the Manual were developed from the retrofit of flue gas desulfurization units on coal-fired utility boilers. The viability of extending the flue gas desulfurization retrofit factors to the situations facing a writer of BEJ permits is questionable. The Manual should therefore include more information on retrofit and process modification cost/factors. A section discussing these topics, with a more extensive listing of cost factors (based perhaps on case studies of wastewater treatment system installation), would be useful to the permit writer.

Annual Expense Estimates

The Manual summarizes two methods for estimating annual expenses:

- adaptation of actual costs; and
- factored expense estimates.

The first method requires records of actual costs of similar or identical operations and an understanding of the rationale which was used to allocate indirect costs (e.g., labor additives, plant overhead, general expenses, etc.) This method should be deleted because probability of the two preceeding conditions being fulfilled is minimal.

The second method, factored expense estimation, should be used by permit writers to calculate annual expenses. A very good discussion of the items to be included in the annual expense estimate is included in the Manual. This discussion should be modified as shown in Table 6 to make it a more useful tool in the permit writing process.

Table 6. Recommended Modifications to the Annual Expense Estimate Methodology

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Raw Materials	General sources of cost data (i.e., suppliers, marketing people, published prices); freight charges and by-products are mentioned	Expand; include a table to be used as a guide for checking freight charges
Operating Labor	Summarizes three methods for estimating operating needs: • prepare a schedule of jobs and functions/ develop labor requirement from time segment data in Haines[7]; • use Wessel's[12] equation which is based on process type, process steps, and capacity; and • use information from similar operations. A table of the 1977 average hourly earnings of chemical workers in 10 states	A source other than Haines that addresses wastewater treatment system work and time segments should be included; Wessel's equation is based on labor requirements in the chemical process industry and should be deleted; the table of average hourly earnings should be updated from 1977 to the present; listing of sources of labor information should be included (i.e., plant union contracts, Bureau of Labor Statistics, etc.)

Table 6. Recommended Modification to the Annual Expense Estimate Methodology (continued)

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Direct Supervision	Recommends that this be estimated at 10 to 25 percent of operating labor	This should be examined in more detail and direction should be given to aid the permit writer in choosing the appropriate percentage
Maintenance Labor and Materials	Recommends that this be estimated at 4 to 10 percent of the total plant cost (35 to 50 percent for rotating equipment)	Modify this section to address wastewater treatment systems
Operating Supplies	Recommends that this be estimated at 6 percent of the operating labor or 15 percent of maintenance costs; special supplies should be added in separately	Examine this section in more detail to determine which factor is more reasonable in the particular situations faced by permit writers; provide writer with narrative to explain estimate development; include a list of sources of operating supply costs
Labor Additives	Recommends that fringes (vacations, disability pay, pension funds, unemployment taxes, social security, etc.) be estimated at 25 to 50 percent of the direct labor cost	Expand this section to explain the estimation process in more detail; update factor; include sources of this information (i.e., union contracts)

Table 6. Recommended Modifications to the Annual Expense Estimate Methodology (continued)

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Utilities	Provides a short description of how utility costs are generally handled; includes a table of typical utility and fuel costs	Edit the narrative so it pertains only to the situations that permit writers might face; utility and fuel costs change with time and vary from region to region, so the table should be updated to the present and expanded to include regional trends; sources of utility information should be included
Effluent Treatment and Disposal	Provides a short description of how waste disposal costs are generally handled; 1976 costs of sludge ponding in clay-lined and Hypalon-lined ponds; 1976 costs for treatment and disposal	This section should be expanded and updated to address the current waste disposal practices and costs (conventional and hazardous wastes); sources which may be used to obtain waste treatment and disposal cost information should be included
Preparation for Shipping	Short description of the cost to prepare a product for shipping	This should be deleted because it is not applicable to wastewater treatment systems

Table 6. Recommended Modifications to the Annual Expense Estimate Methodology (continued)

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Plant Overhead	Description of costs that fall under the general heading of plant overhead (i.e., plant management, personnel, plant protection, store rooms, roads, sewers, etc.); recommends that this cost be estimated as 50 to 100 percent of operating and maintenance, or a percentage of operating labor plus a percentage of maintenance, or a proportion of both labor (45 to 50 percent) and investment (1 to 5 percent)	This should be examined in more detail (with respect to wastewater treatment systems) and direction should be given to aid the permit writer in choosing the method and percentages which are appropriate for the particular case
Control Laboratory	Summarizes two methods for determining control laboratory costs: • estimate the number of analysts and multiply this by $40,000 to $50,000 per year per person; and • take 10 to 20 percent of the operating labor cost	Update and expand this section so that it applies to wastewater treatment systems (e.g., small companies may contract this work out)

Table 6. Recommended Modifications to the Annual Expense Estimate Methodology (continued)

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Technical and Engineering	Recommends that these costs be estimated in the same manner as control laboratory cost ($40,000 to $50,000 per year per person)	Update and expand this section so that it applies to wastewater treatment systems; these costs are a function of equipment type size, and system complexity, etc.
Insurance and Taxes	Recommends these items be estimated at 1 and 2 percent of the fixed capital investment, respectively	May want to include regional variations in taxes and differences in insurance due to type of facility (e.g new types of insurance required for plants generating, handling, or treating hazardous wastes)
Royalties	Short description of what royalties are	List some examples of wastewater treatment equipment and/or systems that have royalties associated with them and provide guidelines for estimating typical royalty charges

Table 6. Recommended Modifications to the Annual Expense Estimate Methodology (continued)

Element of Annual Operating Expense Estimate	Information Present in the Manual	Recommended Modifications to the Manual
Depreciation	Describes the estimation of depreciation by three methods: • straight line method; • sum of digits (accelerated); and • double declining balance (accelerated). Also mentions that for pollution abatement equipment, special rules may sometimes apply	Modify this section so it addresses only depreciation of wastewater treatment systems; expand to clarify the differences between tax depreciation and financial depreciation; include examples of equipment lifetimes for tax and financial depreciation calculations; update and expand based on information in IRS regulations

Data Sources

Equipment vendors, raw material suppliers, and utilities can be invaluable sources of information in the development of both capital and annual cost estimates. The Manual states this but does not provide any insight into how to locate quickly the vendor of a specific type of equipment or raw material. Nor does it describe what questions should be asked of the vendor.

The Manual should include a list of sources of vendor information (i.e., periodicals, buyers' guides, etc.). It should also include a checklist of questions to be asked and points to be remembered when dealing with vendors. Examples of these are:

1. Ask for a detailed description of the piece of equipment for which the estimate is being obtained.
2. Ask if the cost estimate includes such factors as taxes, shipping, etc.
3. If possible, obtain a cost estimate from two or more independent vendors.

Annotated Bibliography

The reference sections in the Manual should be updated and the format revised to make the Manual more useful to permit writers. The reference lists should be updated from 1977 to the present. In addition, a program should be instituted to periodically provide updated reference listings to permit writers. The following sources of cost information should be added to the references.

- Construction Cost Manuals
  - -- Innovative and Alternative Technology Assessment Manual (EPA-430/9-78-009)
  - -- Richardson (subscription service)
  - -- Dodge (subscription service)
  - -- Means
- Vendor Information
  - -- Pollution Equipment News
  - -- CEE Buyer's Guide

- Chemical Costs
  -- Chemical Marketing Reporter
- Cost/Index Information
  -- Engineering News Record and Construction Cost Index
  -- Engineering News Record and Building Cost Index
  -- Marshall & Swift Equipment Cost Index
  -- Chemical Engineering Plant Cost Index
  -- GNP Implicit Price Deflator, U.S. Bureau of Labor Statistics
  -- Consumer Price Index, U.S. Bureau of Labor Statistics
  -- 5 MGD Treatment Plant Cost Index, for a trickling filter, U.S. EPA
  -- 50 MGD Treatment Plant Cost Index, for activated sludge, U.S. EPA
  -- Complete Urban Sewer System Index

The format of the reference sections should be revised by annotating each reference and listing the annotated references by topic area. This could probably best be done by preparing an annotated bibliography. It would include the author and title of a work on a given subject area and a short abstract summarizing the contents of the work. The methodology for preparing an annotated bibliography is described in the appendix.

Because such a wide variety of information exists for water pollution control equipment, a literature search and annotated bibliography are useful tools for collecting and summarizing water pollution control equipment cost and design information. An annotated bibliography would be useful to permit writers because it would provide them with a concise listing of references that may be used to quickly answer questions that may arise during the permit development process. In addition, the cost estimate for major equipment items should be verified with vendors and/or the literature. An annotated bibliography would facilitate using the literature to verify cost estimates.

The annotated bibliography should be structured so that the references are listed by topic area to enable the user to find appropriate references more easily. Examples of annotated bibliography topics that may be of interest to permit writers are:

- wastewater treatment design and operating parameters;
- capital investment estimation;
- annual expense estimation;
- methods for determining the economic feasibility of systems; and

- retrofit problems and how they impact cost estimates.

Following is an example of a recommended format for the reference sections.

CAPITAL INVESTMENT ESTIMATION

(1) Culp, R.L., Wesner, G.M., and Culp, G.L. Handbook of Advanced Wastewater Treatment. 2nd edition. Van Nostrand Reinhold Company, New York, New York. 1978. 632 pp.

Fully describes the practical engineering design and operation of advanced wastewater treatment plants. The chapter on estimating costs presents cost curves for both conventional and advanced processes; shows how to use cost indices to adjust these costs to any time frame; and provides the means for adjusting labor, material and other costs which are subject to local variations.

(2) Guthrie, K.M. Process Plant Estimating, Evaluation and Control. Craftsman Book Company of America, Solana Beach, California. 1974. 606 pp.

A complex but comprehensive technique is presented to quickly assemble capital cost estimates, prepare economic feasibility studies, establish resource control during construction, and maintain economic stability over the productive life of capital projects. Summarizes labor, material and equipment costs for every type of refinery and fluid-phase chemical process plant. Some of these process modules are suitable for pollution control.

REVIEW OF ECONOMIC ACHIEVABILITY PROTOCOL

Introduction

Not only will permit writers need an engineering cost manual to estimate the costs of BEJ technology, but they will also need a manual that will aid them in determining the economic achievability of the costs of proposed BEJ technology. Although such a manual has not yet been written, a methodology that estimates the economic achievability of BEJ technology has been proposed. This methodology is entitled Protocol for Determining Economic Achievability for NPDES Permits. The results of PRA's evaluation of the Protocol are presented in this section, which contains four parts. The first is a brief summary of the Protocol. The second and third sections review and discuss two major sets of economic achievability tests: firm level tests and plant level tests. The fourth section discusses problems with the Protocol.

Several issues could be raised about the scope of the review of the Protocol. These include:

- whether EPA has an explicit policy defining "economic achievability";
- whether EPA has decided to have permit writers implement this policy in BEJ permits; and
- whether EPA intends to provide permit writers with a step-by-step manual to use in implementing this policy.

PRA's review has not addressed these issues. We have concentrated our efforts on the changes in the Protocol that would be required to make it useful as a manual for permit writers to use in implementing EPA's policy on economic achievability.

Summary of the Economic Achievability Protocol

The objective of the Protocol is "to assist permit writers in determining the effect of installing pollution control technologies on the financial condition of the firms and plants." The approach that was chosen to meet this objective had to have three characteristics. The first characteristic was that the approach had to define economic achievability. The Protocol defines economic achievability at

the firm level and the plant level as the ability to "afford to purchase and operate treatment equipment." The second characteristic was that the approach had to recognize the limitations on availability of firm-level and plant-level financial data. The third characteristic was to "recognize the limited resources available to each writer." These three characteristics were molded into the Protocol by establishing two different sets of tests: firm level tests and plant level tests.

The firm level tests consist of seven tests. Five of them are related to financial statement analysis. Financial statement analysis uses data from balance sheets and income statements to calculate financial ratios. The financial ratios are used to analyze the ability to raise the necessary capital to buy and install BEJ technology. These ratios are: the current ratio, the quick ratio, the fixed charge coverage ratio, Beaver's ratio, and the debt-equity ratio. The remaining two firm level tests are related to stock market value analysis. They are used to measure the effect of pollution control costs on stock price and to examine trends in the market value of the stock.

The plant level tests, which according to the Protocol are intended for use only when a firm contests the results of the firm level analysis, emphasize the relationship of a plant's earnings before taxes to its annual cost of BEJ technology. Three plant level tests are suggested: the earnings test, the gross margin test, and the revenue test.

The Protocol was prepared for an EPA workshop which was held in August 1982. The document consists of copies of slides that were exhibited at the workshop. As such, it is not in a format that lends itself to fully informed review and criticism. PRA did not have the benefit of the discussions and explanations by the workshop moderator and participants in our review of the Protocol, but we tried to be sensitive to this problem.

The Protocol was not written to be used directly by a permit writer. It is obvious that a substantial writing effort will be needed to transform the Protocol into a manual which is useable by a permit writer. In the evaluation, PRA addressed the methodology and content of the Protocol rather than its format and presentation.

Firm Level Analysis

Introduction

The firm level analysis is designed to provide a rigorous methodology for estimating economic achievability using publicly available data. The procedure combines financial statement analysis and market value analysis to evaluate the ability of a company to afford a proposed investment in BEJ technology.

The financial statement analysis evaluates the historical performance of a firm by calculating three types of financial ratios:

- liquidity ratios (current ratio and quick ratio), which measure the ability of a firm to meet its short-term financial obligations;
- solvency ratios (fixed charge coverage ratio and Beaver's ratio) which measure the ability of a firm to meet long-term financial obligations; and
- leverage ratio (debt-equity), which indicates the extent to which a firm's financial resources have been provided through borrowing.

The Protocol states that the five firm level tests require three types of data:

- the four-digit SIC code;
- financial statements for a firm from Moody's Industrial Manual; and
- industry averages for selected ratios from Annual Statement Studies by Robert Morris Associates.

The market value analysis attempts to predict the future financial performance of a firm by evaluating the effect of investment in BEJ technology on the market value of its common stock. The two tests in the market value analysis evaluate the ratio of market value to book value. The tests measure:

- market to book ratios for the three preceding years (without measuring the effect of pollution control investment); and
- market to book ratio for the most recent year, adjusted to reflect the effects of the investment in BEJ technology.

The Protocol does not specify the sources for data on market and book values.

The rest of this section presents the individual tests and problems with their use in the Protocol.

Current Ratio

The current ratio is a commonly-used indicator of the ability of a firm to meet its short-term obligations. The ratio, which compares current assets to current liabilities, indicates the extent to which short-term obligations are covered by cash and near-cash assets. The Protocol defines the current ratio as:

$$CR = \frac{CA}{CL}$$

where: CR = current ratio;
CA = current assets;
CL = current liabilities.

The Protocol does not clearly define the components to be included (or excluded) in current assets or current liabilities. Other references indicate that current assets include cash, marketable securities, accounts receivable, and inventories. Current liabilities include accounts payable, short-term notes payable, the current portion of long-term debt, the current portion of lease obligations, and accrued taxes.

The Protocol also does not explain where to find the values to be used in the test calculations. The values for current assets and current liabilities are taken from the Comparative Consolidated Balance Sheet in Moody's Industrial Manual.

The current ratio test consists of two parts. First, the current ratio is calculated without the cost of the BEJ technology. Then the ratio is recalculated with the capital cost of the BEJ technology subtracted from current assets. The second part of the test could be expressed as:

$$CR = \frac{CA-CI}{CL}$$

where: CR = current ratio;
CA = current assets;
CI = capital cost of BEJ technology;
CL = current liabilities.

For all of the ratio tests, the capital cost is adjusted to reflect the investment tax credit, which is assumed to be 15%. The investment tax credit should be entered by the permit writer to assure that the calculations reflect current tax law. Data sources and instructions should be provided to assure that the correct value is used.

The intended use of the current ratio without the cost of pollution controls is unclear. The example in the Protocol presents this ratio for each of the three previous years. This information is clearly useful for indicating the trend in liquidity position over time. However, no guidance is offered on how to incorporate this information into the economic achievability analysis and decision-making process.

The Protocol presents two "critical values" for evaluating the current ratio with the cost of pollution controls. The first is a traditional rule-of-thumb for credit analysis which suggests a minimum current ratio of 2.0. This ratio would assure that the firm could cover its obligations even if the value of current assets, particularly inventories, was substantially reduced in the event of a forced liquidation. The second is the "average" current ratio for the industry. In actual practice current ratios differ from industry to industry. Upper quartile, median, and lower quartile values for current ratios in each four-digit SIC category are available in Annual Statement Studies by Robert Morris Associates, Inc.

The Protocol presents both the traditional "2.0" rule of thumb and the industry average as "critical values" for the current ratio. Neither value is explicitly designated as the pass/fail point for this test.

The definition of these critical values produces two potential shortcomings in the use of the current ratio in the Protocol. First, the test result may be ambiguous if the current ratio for a firm falls between the industry average and 2.0. Second, if the industry average (actually the median) is used as the pass/fail point for this test, half of the firms in the SIC category would be expected to fail the test.

These problems could easily be corrected by specifying a single critical value to indicate if a firm passes the current ratio test. EPA may also wish to consider a different industry reference point such as the lower quartile to indicate passing or failing this test.

Although the presentation in the Protocol causes the problems described above, the current ratio appears to be a useful indicator of the ability of a firm to meet its short-term obligations.

Quick Ratio

The quick ratio, which is closely related to the current ratio, is also a common indicator of ability to meet short-term obligations. The quick ratio compares quick assets (current assets minus inventories) with current liabilities. The Protocol defines the quick ratio as:

$$QR = \frac{CA-I}{CL}$$

where: QR = quick ratio;
CA = current assets;
I = inventories;
CL = current liabilities.

The numerator includes all current assets except inventories. These current assets are owned by the firm or legally obligated to it. The firm can reasonably expect to convert these assets to cash at their book value. Inventories, on the other hand, might have to be sold below book value in case of liquidation. Current liabilities are defined exactly as they are for the current ratio.

The Protocol does not explain how to obtain the values to be used in the test calculations. The values for current assets, inventories, and current liabilities are all available from the Comparative Consolidated Balance Sheet in Moody's Industrial Manual.

The quick ratio test includes two parts. First, the quick ratio is calculated without the cost of the BEJ technology. Then the quick ratio is recalculated with the capital cost of BEJ technology subtracted from quick assets. The second test can be expressed as:

$$QR = \frac{CA-I-CI}{CL}$$

where: QR = quick ratio;
CA = current assets;
I = inventories;
CI = capital cost of BEJ technology;
CL = current liabilities.

As with the current ratio, the intended use of the quick ratio without the cost of pollution control is unclear. The Protocol presents this ratio for the three previous years in the example calculations, but does not explain how to incorporate this useful information into the evaluation of economic achievability.

The Protocol presents two "critical values" for the quick ratio with the cost of pollution controls. The first is a rule-of-thumb for credit analysis which suggests a minimum quick ratio of 1.0. This ratio would assure that the firm could cover all of its current obligations with cash and near-assets. That is, all current obligations could be met without liquidating inventories.

The second is the "average" quick ratio for the industry. The Protocol indicates incorrectly that industry averages are available from Robert Morris Associates. However, quick ratio is not included in Morris and cannot be calculated from the information given. (Morris does include industry averages for total current assets, inventories and current assets. However, a correct industry average would be an average of quick ratios for individual firms, not a single calculation using industry averages for each component of the test.) The effect of this shortcoming is to provide only a single critical value, the rule-of-thumb value of 1.0.

Despite the problems cited above, the quick ratio is a useful indicator of the ability of a firm to meet short-term obligations. The quick ratio complements the current ratio by indicating liquidity problems which could be masked by large but hard-to-liquidate inventories.

Fixed Charge Coverage Ratio

The fixed charge coverage ratio measures the ability of a firm to cover fixed financial obligations from operating earnings. The ratio indicates the extent to which earnings can decline without causing the firm to have trouble meeting interest and other fixed charge obligations. The Protocol defines this ratio as:

$$FCCR = \frac{CEBFC}{FC}$$

where: FCCR = fixed charge coverage ratio;
CEBFC = cash earnings before fixed charges;
FC = fixed charges.

The Protocol does not clearly explain the components of cash earnings before fixed charges or fixed charges. However, they can be inferred from the example given in the text. Cash earnings before fixed charges can be expressed as:

$$CEBFC = NPBT+FC+D$$

where: CEBFC = cash earnings before fixed charges;
NPBT = net profit before taxes;
FC = fixed charges;
D = depreciation.

Fixed charges can be expressed as:

$$FC = IE+OFP+CPLTD$$

where: FC = fixed charges;
IE = interest expense;
OFP = other fixed payments;
CPLTD = current portion of long-term debt.

The information required to compute the value of these components can be calculated with some difficulty from the Comparative Consolidated Income Statement in Moody's Industrial Manual. However, this calculation would require a clear explanation because both numerator and denominator require calculations involving several lines in the Moody's Income Statement. (For example, calculation of the numerator would involve ten different lines in Moody's.)

The example in the Protocol simplifies the calculation by referring to a sample income statement presumably provided by the firm being analyzed. Use of this statement does not agree with the statement of data needs at the beginning of the firm level analysis section of the Protocol.

The test calculates the fixed charge coverage ratio with the capital cost of BEJ technology subtracted from the numerator. That is:

$$FCCR = \frac{CEBFC-CI}{FC}$$

where: FCCR = fixed charge coverage ratio;
CEBFC = cash earnings before fixed charges;
CI = capital cost of BEJ technology;
FC = fixed charges.

The Protocol specifies that the capital cost should be calculated assuming that it will be financed with proportions of debt equal to the current debt ratio for the whole firm. This assumption requires the analyst to calculate the debt ratio for the firm, the portion of the BEJ technology cost financed with debt, and the interest and principal payments. Step-by-step instructions would probably be required to assure that this test could be completed without error.

In addition, the calculations require two items of data which the Protocol does not explain how to obtain. First, interest charged on new debt is not available from any of the data sources and would probably have to be supplied by the permit writer or the firm. A specific source or basis should be designated to avoid ambiguity. Second, annual operating and maintenance (O&M) expenditures would probably be supplied by the permit writer using cost engineering data.

The completed fixed charge coverage ratio calculation is compared with the critical values listed in the Protocol. A ratio greater than 2.0 indicates solvency, a ratio less than 1.5 indicates insolvency, and a ratio between 1.5 and 2.0 indicates questionable solvency. The Protocol does not explain the basis for these designations.

The fixed charge coverage ratio provides useful information on the impact of capital investment for BEJ technology on the ability of a firm to meet its fixed charge obligations. However, the test procedure is poorly explained and complicated to perform. This procedure should be clarified and simplified or an alternative test should be provided.

Beaver's Ratio

Beaver's ratio measures the extent to which a firm can cover its total liabilities with current earnings. The Protocol states that Beaver's ratio has been identified as the "single best predictor of bankruptcy." The ratio is presented as:

$$BR = \frac{IGCF}{CL+LTD}$$

where: BR = Beaver's ratio;
IGCF = internally generated cash flow;
CL = current liabilities;
LTD = long-term debt.

The Protocol does not clearly explain what is included in the components of the ratio. The reader can infer from Worksheet 4a that the "internally generated cash flow" equals net income after taxes plus depreciation. Current liabilities are defined as in the current ratio.

The definition of long-term debt in the Protocol is unclear. The example in Worksheet 4a uses long-term liabilities in the calculation of Beaver's ratio. The value for long-term liabilities, which is taken from the sample balance sheet, includes long-term debt, deferred income taxes, minority interest, and other accrued liabilities. (The difference between long-term liabilities and long-term debt in the example calculation exceeds $19,000,000.) The inconsistency between the definition of Beaver's ratio and the calculation must be corrected to eliminate potential confusion.

The data required for calculating the ratio are available from the Comparative Consolidated Balance Sheet in Moody's Industrial Manual and from the sample balance sheet. The sample balance sheet follows the examples from Moody's but is not referenced in the Protocol.

Values for net income after taxes, depreciation, and current liabilities are taken directly from Moody's. The value for long-term liabilities in the example calculation is taken from the sample balance sheet. (The value for long-term liabilities can also be calculated by adding four lines in the Moody's balance sheet.)

The Beaver's ratio test calculates the ratio with the numerator and denominator adjusted to incorporate the effects of the proposed investment in BEJ technology. The test assumes that the investment would be financed with proportions of debt equal to the debt ratio of the firm. This assumption requires the user to calculate the debt ratio for the firm, the portion of the BEJ technology investment financed with debt, and interest and principal payments.

The test calculation requires data for interest charged on new debt and annual O&M expenditures as described in the section on the fixed charge coverage ratio. In addition, the calculation includes values for marginal income tax rate and depreciation rates. These are assumed to be constants in the Protocol, but probably should be entered by the user to assure that they reflect current tax law.

The completed Beaver's ratio calculation is compared with critical values provided in the Protocol. A ratio greater than 0.2 indicates solvency, a ratio less than 0.15 indicates insolvency and a ratio between 0.15 and 0.2 indicates questionable solvency. The Protocol does not explain the basis for these critical values.

The Protocol states that a study has identified the ratio as the single best predictor of bankruptcy. The study in question was William H. Beaver's "Financial Ratios as Predictors of Failure" published in 1967.(1) Beaver's work emphasized empirical analysis of bankrupt and non-bankrupt firms. Beaver's approach, which relied on single ratios as predictors of bankruptcy, has not been widely accepted. The literature since Beaver's pioneering work has emphasized techniques for combining the insights from a variety of financial ratios.

Some researchers have questioned the usefulness of the various ratios for predicting business failures. While several approaches have been used to classify firms as bankrupt or non-bankrupt after the fact, none has been demonstrated as a successful predictor of future business failures.

Beaver's ratio appears to have been included in the Protocol primarily for its usefulness in predicting bankruptcy. Because of the problems described above, however, the use of Beaver's ratio should be reconsidered. If predicting bankruptcy is an important part of the economic achievability evaluation, a substantially different approach may be required.

Debt-Equity Ratio

The debt-equity ratio measures the extent to which the capital resources of a firm are financed through debt. The ratio which compares debt to stockholders' equity is presented as:

$$DER = \frac{LTL}{TSE}$$

where: DER = debt-equity ratio;
LTL = long-term liabilities;
TSE = total stockholders' equity.

The Protocol does not explain what is included in the long-term liabilities or total stockholders'equity. Long-term liabilities are defined, as in Beaver's ratio, to include long-term debt, deferred income taxes, minority interest, and other accrued liabilities. Total stockholders' equity includes common stock at par, additional paid-in capital, preferred stock, and retained earnings.

The example calculation presented in Worksheet 5 uses data taken from the sample balance sheet for both components of the ratio. Both items could be taken from the Comparative Consolidated Balance Sheet in Moody's Industrial Manual. Long-term liabilities would have to be calculated by adding four separate lines in Moody's. Total stockholders' equity could be taken directly from Moody's. The net effect would be a calculation which would be no more complicated than the example calculation.

The debt-equity ratio test calculates the ratio without including the effect of the proposed investment in BEJ technology. This approach is based on the assumption that the investment would be financed using a proportion of debt equal to the debt ratio of the firm. However, this requires two additional assumptions. First, all of the debt will be funded as a long-term liability. Second, all of the non-debt portion of the investment must be from some form of additional capital contribution from stockholders (such as sale of additional stock). If any of the investment is financed from existing assets the stockholders' equity (the denominator) will not increase proportionately.

This approach may not be consistent with the other tests, because it makes the non-conservative assumption that the firm will choose to finance the non-debt portion of the capital investment through sale of stock. The opposite assumption, that the non-debt portion of the capital investment would be financed out of current assets, would be more consistent. This could be accomplished by revising the test to incorporate the effect of the proposed investment on the ratio, as the Protocol does for all of the previous tests.

The Protocol states that no general target exists for this ratio but that industry averages and historic ratios are important comparative indicators. The example calculation in Worksheet 5 presents values for upper quartile, median, and lower quartile in the industry. This approach causes two problems. First, the lack of target ratios assures that for at least some firms the results of this test would be indeterminate.

Second, the ratio used in Robert Morris Associates' Annual Statement Studies is not the same as the ratio used in the Protocol. The nearest ratio in Morris is the debt-worth ratio which is defined as:

$$\frac{D}{W} = \frac{TL}{TNW}$$

where: D = debt;
W = worth;
TL = total liabilities;
TNW = tangible net worth.

This ratio is different from the debt-equity ratio in two respects. First, the numerator includes current liabilities. Second, Morris does not clearly define tangible net worth. Thus the denominator may differ from the denominator used in the Protocol. With these problems, this test offers no clear guidelines for interpreting the results.

The debt-equity ratio is a useful indicator of the extent to which the capital of the company has been obtained through borrowing. This ratio may provide insight concerning the ability of a firm to raise capital through additional borrowing. However, the test presented in the Protocol is not defined with sufficient clarity to be used in evaluating the economic achievability of potential investments in BEJ technology.

Market Value Analysis

Market value analysis is intended to provide an estimate of the future financial performance of a firm. This analysis examines trends in market value of the firm's stock and measures the effect of pollution control costs on stock price. Several major problems limit the usefulness of this test.

The Protocol assumes that stock market value equals the net present value of the expected future cash flows of a firm. This assumption may agree with theory but be infeasible in use. It should be reconsidered to assure its appropriateness and usefulness in this context.

The procedure requires the user to calculate the net present value of the proposed investment in BEJ technology. However, the procedure is unclear and the sources for several types of data have not been provided.

The example calculations for net present value in Worksheet 6 include several items which are not explained. The rate of growth in operating cost is based on cost engineering assumptions which are not stated. The user must know these assumptions to generate the appropriate value. The definitions and values for company beta, risk-free rate, and credits for product recovery are not explained. The user must be provided with a source for these data to perform the analysis.

The net present value of the investment in BEJ technology is used to calculate an adjusted stock price. The procedure calculates the effect of the investment on stock price if the cost is spread over all outstanding shares. Data are required for the high and low values of the stock and the number of outstanding shares. The Protocol needs to be revised to indicate the source of these data and the specific dates from which they should be taken. Without explicit directions, many valid results are possible because of the daily fluctuations in market price.

The market value analysis involves two tests. The first compares the market value to book value of the stock without adjustment for the investment in BEJ technology. As with the procedure for adjusting stock prices, sources and specifications for market and book values have not been provided. In addition, no guidelines are presented for interpreting the results. This test is intended to show the historic trend of market to book ratio.

The second test calculates the market to book value after the market value has been adjusted to incorporate the effects of the investment in BEJ technology. No specific guidelines for interpreting the results of this test have been provided. The Protocol does state that a firm will not go bankrupt as long as the market value remains above zero after the effects of the pollution control investment have been incorporated. No justification is provided for this statement. In addition, it offers little insight for interpreting the ratios for non-bankrupt firms.

The market value analysis is designed to increase the predictive power of the economic achievability methodology. However, the problems described above would prevent the user from developing exact and unambiguous results. In addition, the variability of market prices suggests that the predictive capabilities offered by this analysis are questionable. This test should probably be deleted from the Protocol and one or more alternative tests should be substituted for it.

Plant Level Analysis

Introduction

According to the Protocol, if a firm contests the firm level analysis, plant level analysis is performed. The plant level analysis consists of three tests: the earnings before taxes test, the gross margin test, and the revenues test. All of the tests attempt to estimate a plant's earnings before taxes and compare them to the annual cost of BEJ technology. If the estimated earnings before taxes exceed the annual cost of BEJ technology, the technology is considered to be economically achievable.

Given this definition of economic achievability at the plant level, there are two implicit assumptions that must be true if the plant level analysis is to generate realistic results. The first is that a plant will not be able to pass forward any of its increased pollution control costs. The validity of this assumption will vary from industry to industry and will partly depend on the cost of the BEJ pollution control technology that the competitors of the plant will be required to install. In a very competitive industry, a plant will presumably be able to pass forward few of its increased costs. The opposite will be true of a plant in a less competitive industry, unless the competitors are issued permits that require less costly BEJ technology.

The second assumption is that a plant would be willing to expend a significant portion, if not all, of its earnings before taxes on BEJ pollution control, perhaps reducing the profitability of the plant to near zero. This is an unlikely option to be exercised.

Although the above two assumptions tend to have a balancing effect on each other, their net effect is unknown. It is recommended that EPA reconsider the plant level analysis because of the possibly biased results to which these assumptions could lead.

The following sections of the report describe each of the three tests, analyze some of the shortcomings of the tests, and discuss the data requirements for performing the plant level tests.

Earnings Before Taxes Test

The earnings before taxes (EBT) test compares the annual cost of additional pollution control expenditures due to the BEJ permit with a plant's earnings before taxes. If EBT exceed the annual costs of pollution expenditures the technology is deemed economically achievable; if EBT are less, the technology is not economically achievable. If EBT are equal to additional BEJ annual costs, no concrete decision can be made.

Earnings before taxes are defined by the Protocol as the following:

$$EBT = PR - COGS - CO$$

where: EBT = earnings before taxes;
PR = plant revenues;
COGS = cost of goods sold;
CO = corporate overhead.

Additional BEJ annual costs are defined as the following:

$$AC = ACC + OM$$

where: AC = annual costs of BEJ technology;
ACC = annualized capital cost = capital cost x capital recovery factor;
OM = annual operating and maintenance costs.

The EBT test thus is defined as the following:

$$(PR - COGS - CO) - (ACC + OM) \overset{?}{<=>} 0$$

In practice, the test is limited by the problem of the allocation of overhead to a specific plant. As indicated in the Protocol, corporate overhead is not usually allocated to individual plants and biases in corporate overhead would be difficult to detect. Although this is usually a function of size, this may not always be the case. For a one-plant company, the distinction between plant overhead, which is included in cost of goods sold, and corporate overhead may not be easy to delineate.

Gross Margin Test

Gross margin (GM) is the difference between revenues and cost of goods sold. The term is applicable at the plant level as well as the firm level. This test compares the annual cost of BEJ technology as a percentage of gross margin to the industry's earnings before taxes expressed as a percentage of the industry's gross margin. (Industry is defined as the four-digit SIC code of a plant.) The test looks like the following:

$$\frac{AC}{GM_p} \lessgtr \left(\frac{EBT}{GM}\right)_I$$

where: AC = annual costs of BEJ technology;
GM_p = gross margin of the plant;
$\left(\frac{EBT}{GM}\right)_I$ = the ratio of earnings before taxes to gross margin for the industry.

When AC/GM_p is less than $(EBT/GM)_I$, the BEJ technology is considered to be economically achievable. If not, the test is inconclusive and plant closure analysis is necessary. The source of $(EBT/GM)_I$ is Annual Statement Studies published by Robert Morris Associates, Inc.

It is unclear what additional information is given by the GM test when the EBT for a plant are known. This test gives some indication of financial conditions of a plant vis-a-vis that of a typical plant in the industry. It does not, however, lead the permit writer to any additional information concerning the economic achievability of installing BEJ technology.

If the Protocol were revised such that this test was performed only when the EBT test could not be performed, it could serve as an adequate substitute for estimating EBT. Multiplying the plant's GM by the industry's EBT/GM gives a good estimate if one assumes that the EBT/GM of the plant is equal or nearly equal to the EBT/GM of the industry. Thus, if the above assumption is true the following is true:

(1) Plant EBT = Industry (EBT/GM) X Plant GM

Then:

$$(2)\quad \frac{\text{Plant EBT}}{\text{Plant GM}} = \text{Industry (EBT/GM)}$$

Note that equation (2) is very similar to the GM test inequality. The major difference is that the EBT of the plant occurs on the left side of the equation instead of the annual cost of BEJ technology for the plant.

When the test is viewed in this manner, it is identical to the EBT test, except that the annual cost of BEJ technology is compared to an estimate of the plant's EBT instead of actual EBT; however, the test relies on the assumption that the EBT/GM for the plant is equal to the EBT/GM for the industry.

A major disadvantage of this test is that it assumes that the balance sheet of a single plant is typical of the industry. It can be shown that a plant which has higher EBT than typical plants of the same size can have a lower EBT/GM than the industry EBT/GM. Therefore, if economic achievability is defined as the plant being able to cover the annual cost of BEJ technology from its EBT, this test may lead to the wrong conclusion. The true utility of EBT/GM is that it is an indication of how much corporate overhead is "eating into" the plant's EBT. This is shown by the following:

$$\frac{EBT}{GM} = \frac{R - COGS - CO}{R - COGS} = 1 - \frac{CO}{R - COGS}$$

where: R = plant revenues;
COGS = cost of goods sold;
CO = corporate overhead;
EBT = earnings before taxes;
GM = gross margin.

Another disadvantage is that the plant may be unwilling or unable to provide GM data, and without GM data this test cannot be performed.

Revenue Test

The revenue test compares the annual cost to a plant for BEJ technology (expressed as a percentage of revenues) to the industry average of earnings before taxes (expressed as an average of revenues). The comparison is the following:

$$\frac{AC}{R_P} \lessgtr \left(\frac{EBT}{R}\right)_I$$

where: AC = annual cost of BEJ technology;
R_P = plant revenues;
$\left(\frac{EBT}{R}\right)_I$ = the industry average of earnings before taxes divided by revenues.

As with the GM test, this test could be used to estimate plant revenues when actual plant revenues are unknown. However, the usefulness of this test when actual plant revenues are known is unclear.

It can be shown that a plant that has a higher EBT than typical plants of the same size can also have a lower EBT/R than the industry EBT/R. Thus if plant economic achievability is defined as the plant being able to cover the annual cost of BEJ technology from its EBT, this test may lead to the wrong conclusion. The actual utility of this test is that it is a measure of the costs-to-revenues ratio for a plant. This is shown by the following:

$$\frac{EBT}{R} = \frac{R - COGS - CO}{R}$$

where: R = plant revenues;
COGS = cost of goods sold;
CO = corporate overhead;
EBT = earnings before taxes.

Data Requirements and Sources

Table 7 illustrates the data requirements for each of the three tests. A major advantage of the plant level analysis is that the data requirements are minimal.

The source of plant financial data is the company. These data may be the most difficult to obtain. EPA should consider whether there is any legal obligation on the part of the company to provide these data. The definition of what is included in the financial data will probably vary from firm to firm. The Protocol should include precise definitions of these terms and how to manipulate the data if the firm keeps its books on a different basis. These definitions should be consistent with those used in Annual Statement Studies.

The capital and annual costs of the treatment technology are calculated by the permit writer using the methodology given in the engineering cost analysis manual. The Protocol is vague about the calculation of the interest rate for the capital recovery factor; more explanation of the derivation of the interest rate is needed.

Industry ratios for the GM and revenue tests can be calculated from Annual Statement Studies. These averages are not directly given, and the Protocol should include an explanation of how to calculate them.

Table 7. Data Needs for the Plant Level Analysis

Data	Tests			Source of Data
	EBT	GM	Rev.	
Financial Data				
Plant Revenue	X	X	X	Company
Cost of Goods Sold	X	X		Company
Corporate Overhead	X			Company
BEJ Technology Costs				
Capital Cost	X	X	X	Permit Writer/Cost Manual
Capital Recovery Factor				
- Life of Equipment	X	X	X	Permit Writer/Cost Manual
- Interest Rate	X	X	X	?
Annual O & M	X	X	X	Permit Writer/Cost Manual
Industry Ratios				
EBT/GM		X		Annual Statement Studies
EBT/R			X	Annual Statement Studies
Plant SIC Code		X	X	Plant or Dun & Bradstreet

The plant SIC code should be available from the plant. If it is not, Dun & Bradstreet lists SIC codes for many plants.

Analysis of the Economic Achievability Tests

Introduction

In analyzing the Protocol PRA identified several problem areas where changes or revisions should be made. These problem areas are discussed below. They are divided into three different types: problems common to both the firm level and plant level analyses, problems related to the firm level analysis only, and problems related to the plant level analysis only.

Common Problems

Policy on Economic Achievability. The policy of EPA on "economic achievability" is not clearly defined in the Protocol. A proposed BEJ technology is considered to be economically achievable if a firm or plant "can afford to purchase and operate" the required treatment equipment. This phrase could encompass a wide range of interpretations ranging from limits on reduced profitability to limits on plant closure.

The exact intent of the above definition cannot be inferred from the Protocol. Although the methodology includes measures of ability to raise capital, potential for bankruptcy, and other considerations, no consistent policy is evident.

Time Frame. Several procedural problems limit the usefulness of the Protocol. First, most of the tests provide a one-year view of a plant or firm. A few tests require data on three-year trends. However, the methodology does not provide clear guidelines for interpreting these tests. As a result, the pass/fail tests all span a single-year increment. Because of this emphasis on short-term time frames, the methodology provides little insight into long-term historical performance of a plant or firm.

The market value analysis provides very little insight into future performance of a firm. The Protocol provides no indication of the effect that business cycles may have on the performance of a firm. As a result, permit writers will be forced to write permits to cover a long time period based on a very short-term perspective.

Although not explicitly stated, it is implied that the three plant level tests should be performed using financial data for the most recent fiscal year of a plant. Because swings in the economy directly affect the financial performance of a plant, it would be better to perform these tests for the latest three years, or some type of averages for the latest three years. We believe this would produce a clearer picture of the ability of a plant to afford the BEJ technology.

SIC Code Definition. The GM test and the revenue test in the plant level analysis and the current, quick, and debt-equity ratios in the firm level analysis all require the permit writer to compare financial data to industry averages for firms or plants in the same SIC code. No direction is given when a plant or firm belongs to more than one SIC. This problem could be solved by using the primary SIC of a plant as a basis for determining the SIC to which it should be compared. However, it is likely that for large integrated shops, the production activity of the primary SIC may not be the major wastewater-producing activity. For example, an electroplating captive operation may be the major contributor of toxic pollutants, yet the primary SIC code for the plant may be that for automobile production. The permit writer must then decide whether the proper SIC code (for purposes of the plant tests) is SIC 3471 (Electroplating) or 3711 (Motor Vehicles and Passenger Car Bodies).

This problem is potentially more serious at the firm level. A large diversified firm may have plants in many different SIC codes. The financial situation of a diversified firm may be determined primarily by activities unrelated to the SIC code of the individual plant being evaluated for a permit. As a result, comparison of financial data for the firm with industry averages for the SIC group of a plant may produce misleading results.

Interest Rate and Investment Tax Credit. In some instances, the Protocol does not provide the data which the permit writers will need to perform the tests. Two examples are the interest rate and investment tax credit.

Some of the firm-level tests use investment tax credits in the calculation of the ratios, but no data source is provided for the permit writer. The amount of the investment tax credit that can be taken in any one year is a function of the current Federal tax law. To minimize use of a permit writer's time, the Protocol should

explain how to calculate the investment tax credit. Basic information that is needed is the type of investment (building, land, rolling stock, etc.) and the amount of tax credit that Federal law allows for each type of investment.

To calculate the total annual costs of a BEJ technology, the capital costs, annual O&M costs, and the appropriate interest rate must be known. Capital costs and annual O&M costs can be calculated directly by using the engineering cost manual; however, the interest rate will vary among both firms and industries. The Protocol provides no guidance as to the appropriate interest rate or the specific total annual cost calculation when the interest rate, capital costs, and annual O&M costs are known.

Presentation. The Protocol was intended as a workshop guidebook. Accordingly, it includes only a brief explanation and an example for each test. The level of detail presented is not sufficient to permit effective use of the Protocol.

The procedures for gathering the appropriate data from Moody's and Morris are not clearly explained. In a few instances, the examples are actually calculated using data from an alternate source.

Several of the test procedures include errors which would prevent a permit writer from calculating the results correctly. These problems are described in detail for each test in the preceding sections.

Several of the critical values for the firm level analysis do not indicate clearly whether a proposed BEJ technology would pass the test. Critical values are not provided for some of the tests. As a result, these tests can be expected to be inconclusive in many instances. In addition, the plant level analysis does not contain guidance for those situations where the tests give conflicting results. The example in the Protocol that exhibits the use of the tests in tandem show that the technology is economically achievable under all three tests. The plant level analysis should be expanded to address conflicting results.

The firm level analysis does include a table indicating how to interpret the tests in case they present conflicting results. However, the table should be explained and more detail should be provided.

Firm Level Problems

Firm Size. Several of the tests may actually measure firm size, rather than the impact of the BEJ investment or annual costs on the firm. The BEJ investment or annual costs are likely to be a larger percentage of a small firm's assets, earnings, or cash flow than those of a larger firm. As a result, a small firm is more likely to fail the tests.

For example, the impact of BEJ costs for one plant of a 50-plant company may be negligible when compared to the company's financial base. For a single-plant firm the impact, as measured by the Protocol, is much larger because the relative amount of BEJ investment or annual costs is a much larger portion of the company's financial base. If one assumes that the results of the financial tests should be the same for plants with identical production technology and financial costs, then the size of the firm should be irrelevant. The tests recommended in the Protocol obscure this distinction. One anomalous result is that a financially weak plant in a multi-plant firm may receive a more stringent BEJ permit than a prosperous plant in a smaller firm. This appears to be contrary to the Protocol's intent.

The use of financial ratios may mask the differential effects which pollution control investments may have on small firms. For example, small firms may face difficulties in raising capital that are not predicted by the ratio tests.

The data required to conduct these tests for small firms may not be available in Moody's for two reasons. First, firms are included in Moody's for a fee, and companies that do not sell common stock in substantial volume or issue bonds are not likely to be listed. Second, closely held firms will not be listed. Alternate data sources should be specified for these firms.

Scope of the Methodology. The firm level analysis includes financial statement analysis as an indicator of historical performance and market value analysis as a predictor of future performance. However, several relevant issues are not addressed.

First, the methodology compares the financial performance of a firm with that of other firms in the same industry. Firms may also face substantial competition from industries which supply substitute products and from firms in other countries which may not bear the same pollution control costs. These factors affect the ability of

a firm to pass costs forward. The Protocol does not address these important economic considerations.

Second, the financial statement analysis emphasizes liquidity, solvency, and leverage. All of these relate to the ability of a firm to borrow the necessary capital. The methodology does not evaluate sources of capital, which may be much more limited for some firms and industries than for others. In addition, the methodology does not evaluate the effect of the BEJ requirements on the profitability of a firm. The adverse effect on the profitability of a healthy firm may be substantial without causing the firm to fail any of the ratio tests.

Third, the firm level analysis primarily measures the effects of capital expenditures on the firm. The effects of operation and maintenance costs, which can exceed annualized capital costs, are generally ignored. The firm level analysis should be revised to consider the financial effects of operation and maintenance costs.

Fourth, the tests all rely on an unlikely assumption. For all of the tests except the debt-equity ratio, the methodology assumes that the investment for at least the non-debt portion of the capital investment would be financed from current assets, current cash flow, or current earnings. This assumption may not be justified.

Finally, several of the tests involve a comparison with the median value for the industry. As a result, half of the firms in each industry can be expected to fail each of these tests. A comparison with the lower quartile value for the industry may be more appropriate.

Plant Level Problems

Revenues. All of the tests in the plant level analysis rely on data for the revenues of a plant. In an integrated corporation, a plant may serve as a "cost" center and may not generate revenues. One example is an ore mine that feeds an ore smelter which also belongs to the company. The mine incurs costs but no revenues. The smelter generates revenues that can be allocated collectively, but not individually, to both the smelter and the mine. Another example is a sub-assembly plant that produces assembled parts for the main assembly plant. The corporation may assign a transfer price to the ore or assembled parts, but this price may not reflect the market price (if one exists) because of tax considerations.

Corporate Overhead. The Protocol recognizes that allocations of corporate overhead to specific plants may be difficult to estimate and biases in corporate overhead difficult to detect. (Corporate overhead is a data requirement only for the EBT test.) This may be a problem for both large and small corporations alike. A one-plant company may not be able to distinguish between plant overhead (which is included in cost of goods sold) and corporate overhead.

Value of GM and Revenue Tests. The Protocol fails to discuss the role of the GM and revenue tests. It states that the GM and revenue tests are "designed to provide a measure of economic achievability equivalent to the earnings test." In light of this statement, it would seem that these two tests are redundant. As stated earlier, these tests provide no information that is not already provided by the EBT test. All three tests attempt to relate the annual costs of BEJ technology to the plant's earnings before taxes, yet the EBT test provides the best measure because it relies exclusively on plant data, while the other two tests rely on industry data as a proxy for plant data. Both the GM and revenue tests should be reconsidered in terms of their validity and utility.

Partial Regulation. An integrated plant may have part of its wastewater generation already regulated by national BAT guidelines, but the rest of its wastewater generation may not have BAT guidelines. A current example of such a situation is an aluminum refinery plant that also has a coil coating operation. No BAT guidelines have been promulgated for aluminum refining, yet BAT guidelines are already in place for coil coating on aluminum. Provisions need to be made in the Protocol to deal with such circumstances.

INTERFACING OF THE MANUALS

The Cost Analysis Manual and the Economic Achievability Protocol cannot be used in conjunction with each other by a permit writer unless major modifications are made to the two documents. In addition, the information contained in the two manuals is not set forth in a manner that would facilitate use of the manuals by a permit writer. A step-by-step presentation of the methodologies in both manuals would do much to improve their utility, either for use separately or in conjunction with one another.

There is some overlap between the information in the Cost Analysis Manual and the Protocol, in that the Manual addresses some aspects of the economic feasibility of a technology. If the Protocol is to be used in conjunction with the Manual, this overlap should be eliminated. This can be done by deleting the following sections from the Cost Analysis Manual.

- Volume I
  - Cost Estimate -- Net Profit and Cash Flow (pp. 12, 27, 33, and 37); and
  - Feasibility Evaluation (pp. 14-16, 27, 28, 33, 37, and 38).
- Volume II
  - The Cash Flow Concept (Appendix C);
  - Discrete and Continuous Interest Factors (Appendix D);
  - Measures of Merit (Appendix E); and
  - Rates of Return and Interest Rates (Appendix G).

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APPENDIX

PREPARATION OF AN ANNOTATED BIBLIOGRAPHY

Introduction

In the text of this report, PRA has recommended that the reference sections of the Cost Analysis Manual be updated and changed to an annotated bibliography format. The purpose of this appendix is to provide information on abstracts and indexes that deal with water pollution control and an indication of the level of effort required to revise the reference sections in the Manual by preparing an annotated bibliography.

There are two ways to prepare an annotated bilbiography, either by means of a manual search of the literature or by doing a computer-based literature search. The procedures for compiling and annotating a bibliography are described in the following sections.

Literature Search

The first step in a literature search is to compile a list of key words which is relevant to the subject matter. Some of the computerized data bases have a thesaurus for selecting the key words used in their data base. Once a list of key words has been compiled, the searcher begins examining pertinent journals, abstracts, indexes, and/or computerized data bases for information using the key words. Each citation stored in a computerized data base has a list of descriptors or identifiers that describe the contents of the publication and an abstract of the publication. During the search the computer scans either the list of descriptors or the title and the abstract for the key words or phrases. The latter type of search, scanning the title and abstract for key words, is called free text. If the key words or phrases which are input to the computer appear in either the descriptors or free text, the citation is printed. Citations are printed offline at computer centers, so depending on the location of the searcher, a few days' time should be allowed for mail delivery of the printout. Each printed citation includes the following information: author, title, source of the article (i.e., journal, conference, etc.), and the abstract. However, it should be noted that the Pollution Abstracts data base does not contain abstracts for articles dated earlier than 1978.

The following abstracts and indexes are recommended sources for obtaining information on water pollution control equipment. For those abstracts and indexes available in computerized form, the name of the computerized data base is listed.

- APPLIED SCIENCE AND TECHNOLOGY INDEX

  Indexes 218 English-language periodicals in an alphabetical subject index only. Orientation is toward trade literature. Issued monthly.

- CHEMICAL ABSTRACTS

  Computerized data base -- Chemical Abstracts Condensates

  Covers the whole field of chemistry and chemical engineering. Over 9000 journal articles, dissertations, patents, technical reports, conference proceedings, and books are covered. Signed abstracts. Issued weekly.

- ENGINEERING INDEX

  Computerized data base -- Compendex

  Major abstract publication for engineering literature. Covers journal articles, publications of engineering societies, conference proceedings, and selected government reports in civil, electrical, environmental, industrial, and mechanical engineering. Published monthly.

- GOVERNMENT REPORTS ANNOUNCEMENTS AND INDEX

  Computerized data base -- NTIS

  Covers reports of government-sponsored research and reprints of articles resulting from government research in engineering, biology, physical sciences, and life sciences.

- POLLUTION ABSTRACTS

  Computerized data base -- Pollution Abstracts

  Covers journal articles, books, government reports, and conference proceedings in air pollution, marine pollution, freshwater pollution, sewage/wastewater treatment, solid wastes, land pollution, pesticides/chemical contaminants, noise pollution, radiation, and environmental action.

- SELECTED WATER RESOURCES ABSTRACTS

  Covers books, journals articles, reports, and conference proceedings on water quality management including wastewater treatment processes.

- WATER POLLUTION ABSTRACTS

  Covers books, journals, proceedings, reports, and foreign literature in the areas of conservation of water resources, analysis and examination of water and waste sewage, trade wastewaters and the effects of pollution. Published monthly.

- U.S. GOVERNMENT PUBLICATIONS: MONTHLY CATALOG

  A current bibliography of publications issued by all branches of the government. Arranged by issuing body.

After those abstracts which relate to the subject matter have been identified, the journal articles, books, reports, and conference proceedings which the abstracts summarize should be obtained for review.

Obtaining and Annotating Publications

A copy of as many of the publications as possible should be obtained for review. Many of the journal articles can be photocopied from the serials collection of a local university. Also, through Interlibrary Loan (ILL), books and government and consultants' reports can be borrowed from any library within the United States. Each publication should be reviewed and discrepancies in the literature should be noted. When there are discrepancies in the literature, the annotated bibliography should recommend which reference to use. Also, if a publication would be especially useful, it should be recommended in the annotated bibliography.

An annotated bibliography can be prepared either by using the abstract found in the indexes, printed abstracts, or computer printout, or an abstract can be written after reviewing the publication.