EPA/430/9-76/008

United States
Environmental Protection
Agency

Office of Water
Program Operations (WH-547)
Washington, D.C. 29460

July 1976
EPA-430/9-76-008

EPA

Value Engineering Workbook For Construction Grant Projects

MCD-29

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VALUE ENGINEERING WORKBOOK

FOR

CONSTRUCTION GRANT PROJECTS

MUNICIPAL CONSTRUCTION DIVISION
OFFICE OF WATER PROGRAM OPERATIONS
ENVIRONMENTAL PROTECTION AGENCY

JULY 1976

Foreword

The Federal Water Pollution Control Act Amendments of 1972 established an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water by 1983. In 1972, $18 billion was authorized by Congress to control pollution from municipal sources. Subsequent needs surveys have identified the need for additional billions of dollars. The sheer magnitude of the dollars required to construct municipal waste treatment facilities calls for cost controls to insure that Federal funds are being used effectively. Even minor percentage reductions in waste treatment facilities' costs would result in great dollar savings.

Value engineering is a cost control technique which has the proven ability to provide significant savings. Value engineering was first used in Federal Government construction projects by the Department of the Navy in 1954. Since then 14 Federal agencies involved in financing the cost of constructing facilities have incorporated value engineering programs in the design and/or construction of facilities.

EPA introduced a voluntary value engineering program in 1974. Several EPA construction grant projects have been subjected to value engineering under this program. Significant savings in capital costs and operating and maintenance costs were identified. It was concluded from these voluntary studies that value engineering was effective for cost control in wastewater projects; cost savings can be substantial; with proper management, delays will be insignificant; savings can be achieved without sacrificing project quality or reliability; and widely applicable, improved design techniques are developed.

In light of these favorable results, a policy for a mandatory value engineering program is being developed by EPA with initial emphasis on larger projects. For those projects where value engineering is not required, EPA encourages the institution of voluntary engineering studies. The costs of value engineering efforts approved by the Regional Administrator are eligible for construction grants.

The Workbook is presented in the context of the Environmental Protection Agency' construction grant program which anticipates that major grant projects will conduct value engineering studies early in Step II. This Workbook supercedes the earlier Procedural Handbook for Value Engineering which served as an interim working document while this Workbook was being prepared. The Workbook describes to municipalities and their engineering consultants and to State and Federal environmental agencies, the EPA VE program as well as the basic concepts of VE. It is however, primarily intended to serve as a working guide on the practice of value engineering for wastewater projects to those actually participating in VE studies on wastewater projects and is not intended to serve as a complete text on value engineering. For those interested in more detailed study in VE, a bibliography of recommended reading is offered.

EPA is confident that application of value engineering to the water pollution control projects will provide significant savings and will be a valuable tool in insuring better use of the resources available.

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ABSTRACT

This workbook describes procedures for applying Value Engineering (VE) techniques to wastewater treatment projects. The relationships between VE analyses and the EPA construction Grant Program are described. Information on organization of VE study plan and selection of a VE Team Coordinator is presented. Typical VE ideas and results for wastewater projects are presented.

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INTRODUCTION TO VALUE ENGINEERING

What is Value Engineering?

Value Engineering (VE) is a disciplined effort to analyze the functional requirements of a project for the purpose of achieving the essential functions at the lowest total costs (capital, operating, and maintenance) over the life of the project. Value engineering is a systematic, organized approach to obtain optimum value for each dollar spent. Through a system of investigation, using trained, multidisciplined teams, value and economy are improved by eliminating or modifying items not essential to required performance. By using creative techniques and current technical information on new materials and methods, alternative solutions are developed for specific functions. Unlike simple cost-cutting by using smaller quantities or cheaper material, VE analyzes the function of an item or method, asking such questions as:

- What is it?
- What must it to?
- What does it cost?
- What is it worth?
- What other equipment or method could be used to do the same job?
- What would the alternative cost?
- Should the alternative be used?

The heart of a VE study is the Project Workshop where the multidiscipline teams, under the guidance of the VE Team Coordinator, analyze the project for unnecessary costs. Cost reduction is accomplished without degrading essential performance, reliability, or maintainability. Through eliminating unnecessary design complexity, value engineering consistently improves reliability, maintainability and performance rather than degrading these factors. It is not an attempt to, for example, build a cheaper trickling filter but to find a way to achieve the same function as the trickling filter at a lower cost.

This workbook will describe the VE techniques that have been developed which provide a systematic approach to thoroughly investigating the above questions. Two of the key concepts underlying the VE approach are:

- Function
- Value

Function

If there is a single concept that is unique to value engineering, it is that of function. When confronted with a need to improve value, the value engineer thinks first of function. Unlike value, a highly abstract concept, a function can be precisely defined in just two words, one verb, and one noun. The purpose of reducing the function to the verb-noun form is to eliminate confusion and to clear away all but the essentials so the mind can focus on other approaches which would provide the needed function.

In the examination of functions of the components of a wastewater project, more than one function will ordinarily be identified. Those can be categorized as basic functions without which the item would have no value, and secondary functions, which support the essential functions, but which might not even be present if a different design concept had been pursued. For example, the function of the aeration basin in an activated sludge plant is basic (treat waste) while the function of a walkway leading to a platform mounted aerator (provide access) is secondary to the wastewater treatment plant. Many VE studies have completely eliminated secondary functions by providing alternative designs which achieve the basic functions. For this reason, only basic functions are considered to have value.

Value

A discussion of value is made difficult by the many meanings of the word. Values usually are measured in relation to other values. Comparisons of values often can be simplified by being expressed in the common measurement of money. Cost values can be misleading, however. For example, the embroidered logo of an "in" fashion designer increases the market price of a man's tie or a woman's scarf above what the bare article would bring. Esteem value is the difference.

Use value is that part of value attributable to the functions that a thing performs, and is the type of value with which VE is concerned. If we credit value to only basic functions, we arrive at the limit: maximum value results when essential functions are provided at minimum cost.

The walls of the building enclosing activated carbon columns in a wastewater treatment plant would have no value if the equipment could be designed to function outdoors year around. The white glazed tile on the inside walls of a vacuum filter building could have more than their apparent esteem value, through the useful functions enhance lighting, and minimize maintenance. Of course, these values must be balanced against their total costs.

The value of an item bears no relationship to the losses that would result as a consequence of its failure in service. For example, the value of the nut and bolt which is essential to holding the wing of an airplane to the fuselage is not the over $1,000,000 passenger liability that could result if the wing falls off and the plane crashes, but is instead only the lowest cost at which a nut and bolt which will hold the wing to the fuselage can be manufactured (probably a few dollars). Similarly, if the dikes of a sludge storage lagoon should burst and spill a sea of sludge onto downstream residents and industries, then those dikes did not perform their essential function, contain sludge, and they had no value. The value of adequate lagoon dikes is simply the lowest cost at which the dikes could be built and still hold safely even during the most adverse design conditions with an appropriate safety factor. The value is totally unrelated to the magnitude of the damage caused if the dikes fail.

<u>How VE Differs From Conventional Design and Design Review Practice</u>

Value engineering is not -

-- what a good designer does anyway
-- an effort to trade off essential functions to cut costs
-- merely a review to eliminate "gold-plating"
-- a method for reducing costs through degrading performance and reliability
-- in any way intended as a reflection on the competence of the designer

Often times, after the Step I selection of the cost effective approach, many key components (i.e., treatment process sizing) of the plant are accepted by the design team as given and little added effort is made to consider the costs of other alternatives. As a result, conventional design reviews often center upon assurance of adequate performance, contract technical compliance, and progress toward contract schedules, with cost given lesser rank. The thrust of VE is to give cost equal, but only equal, ranking throughout the design effort. It is not an effort to cheapen the design. It is not an effort to trade off essential functions to cut costs. Its purpose is to eliminate the costs related to non-essential functions, and to reduce to a minimum the cost to provide the essential functions. It differs from typical practice in that VE does not depend on the chance occurence of creative thinking by individual designers, but offers effective techniques and imposes mental disciplines that enable competent designers working together to channel their talents and experience in a way that achieves results ordinarily expected only from an exceptionally innovative and assertive few.

<u>Value Engineering and Cost Effectiveness Analysis</u>

Step I efforts for wastewater projects must select the most cost effective system of wastewater collection, transport, and treatment, considering total life cycle costs to design, construct, operate and maintain, the project being funded. EPA guidelines (40 CFR 35, Appendix D) for cost effectiveness analysis in Step I require that all feasible alternative waste management systems shall be identified, screened, and analyzed as to their cost effectiveness and establish certain ground rules for cost analysis (interest rates, useful life, etc.). Thus, properly conducted Step I work will select the lowest cost approach to the problem solution and establish general project concepts. However, schedules often preclude an adequate opportunity in Step I work to "fine tune" the selected project concept to minimize costs.

Experience has shown that VE can improve on even the basic concepts of many good designs. No aspect of the design is exempt from analysis by the Step II VE study. In short, there is no incompatibility between the requirement for cost effectiveness analysis in Step I, and VE in Step II for yet more economy.

Grant Eligibility of VE Studies

The cost of conducting a VE study is grant eligible upon approval by the EPA Regional Administrator. A request for the VE study should be made concurrently with the basic Step II grant application. In some cases, VE costs may be added to an existing Step II grant. Unless specific and unique justification is offered, the VE study should consider the entire design under the grant.

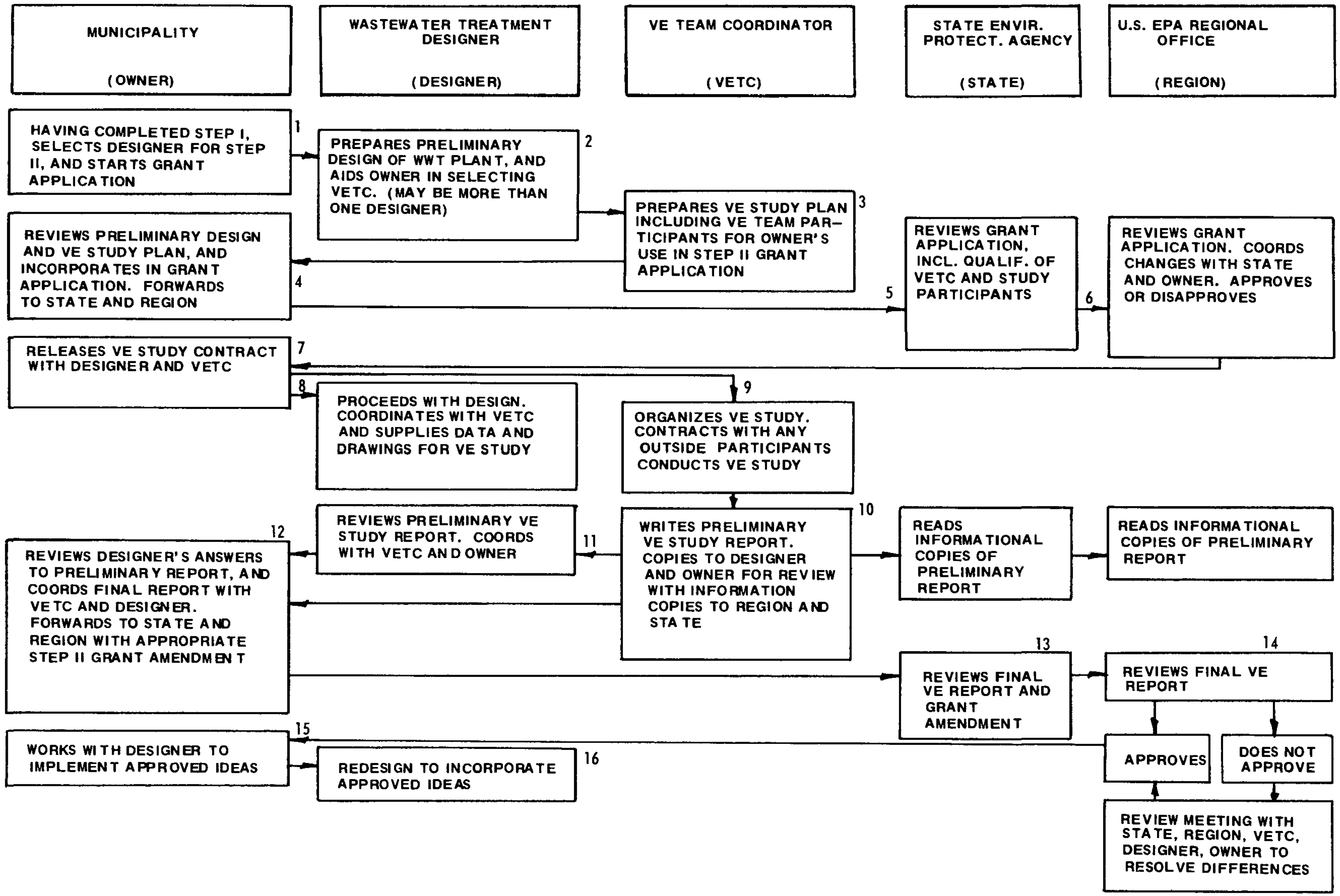
The VE Study in Relation to the EPA Construction Grant Program

The interplay between the municipality, its selected designer, the VE Team Coordinator, the State, and EPA can be best described by reference to Figure 1.

With the advice of the Designer, the Owner (municipality) or Designer solicits proposals for conducting the Step II VE study (1,2), and selects a VE Team Coordinator (as described in detail later), who will provide a detailed plan for the study (3). The VE study may be conducted by the Designer provided that the VE study personnel have not been significantly involved in the Step I or II work on the project. The VE study plan is made a part of the Step II grant application (4) which is submitted to the State (5) and the EPA Regional Office (6). Upon approval, the Owner may contract directly with the VE Team Coordinator to conduct the study, and the Designer to support it (7,8,9) or the VE Team Coordinator may be a subcontractor to the Designer. The detailed study is conducted by using multidisciplined teams, each with an assigned area to study for unnecessary costs. It may prove valuable to include as the last step in the VE study prior to preparation of the preliminary VE report, an oral presentation to the Owner, Designer, State, and EPA of the study results by the VE Team Coordinator. The purpose of this presentation is to make sure that all parties understand the recommended changes and to determine concerns which the preliminary VE report should address. Such an oral presentation is essential on large projects. On smaller projects, such a presentation can be scheduled as part of the last day of the VE workshop.

Immediately following the oral presentation, the VE Team Coordinator prepares the preliminary report (10). Comments during the earlier oral presentation should not cause the deletion of a change that had been favorably evaluated by the VE teams. Action copies of the preliminary report are presented to the Owner and the Designer, with information copies to the State and Federal environmental agencies. Each recommended change will be reviewed in detail by the Designer. After the Designer has evaluated the preliminary report, a conference should be scheduled between the Owner, Designer and VE Coordinator to insure that no VE recommendations are rejected due to lack of communication between Designer and VE Team Coordinator.

FIGURE 1. STEP II VE STUDY FLOWCHART



A final report is then prepared by the Designer (11) representing the concensus of Owner and Designer as to feasibility and cost effectiveness of every recommendation of the preliminary VE report. A price tag is put on the design, construction, and operation effects of each recommended change. Reasons for rejection of recommended ideas are presented and documented. An amendment to the Step II grant application is prepared to reflect the change in design effort associated with implementing the VE changes. Copies of the final VE report (12) are distributed to the State environmental agency, to the EPA Regional Office for review and approval and to the VE Team Coordinator. By signature and distribution of the final report, the Owner indicates concurrence. If the EPA and/or State disagrees with the justification for rejection of any recommended VE change, they may call a meeting with the Owner, Designer, VE Team Coordinator, State, and EPA to resolve the differences so that approval may be granted. Having received the Regional Offices approval, the Owner works with the Designer to incorporate the approved recommended VE changes (15,16).

The VE Study Program From the Designer's Viewpoint

With a VE study now made a part of EPA's grant program, the Designer may be exposed to a previously unexperienced level of design review. A natural first reaction is one of resentment and reluctance to cooperate based on concerns that his client will be puzzled by the need to conduct added design effort, that unusual expertise or proprietary information may be exposed to competitors, that time will be wasted in responding to poorly thought out suggestions, that unjustified criticism by the Owner may result and be aired in the public media, and the project will be delayed.

Each of these concerns need to be addressed. First, the Designer should recognize that VE provides another powerful approach beyond the scope of conventional design practice to provide cost savings and that the overriding goal is to achieve savings for the Owner which will far outweigh the costs of the VE study. The Owner should seek the Designer's advice in selecting a VE Team Coordinator and teams, to avoid competitive conflicts of interest and ensure selection of a technically qualified firm. The VE effort may be contracted for either directly by the Owner, or subcontracted by the Designer as part of his contract extension. A well planned VE study should not cause any unreasonable delay in the flow of the design. Delays can be minimized by scheduling the VE effort at points in the project when other major, intermediate design reviews (by the State or by the Designers own firm) would normally occur and by involving State review personnel in the VE study so that later review times are minimized. Careful screening of the VE Team Coordinator's qualifications, experience, and past performance will insure that the VE Team Coordinator selected produces results, not just paper exercises, so that frivolous ideas will not plague the program.

Too much emphasis cannot be given to making clear that no blame will be placed or recriminations made when new ideas are found by the VE effort that result in cost savings. This attitude must prevail with all parties. A full commitment to the end result of minimum total life cycle cost for a system that meets all performance requirements is required. This goal can only be achieved by all parties working together in a harmonious and constructive atmosphere.

The VE Study Program From the Owner's Viewpoint

The Owner, if unfamiliar with the opportunity for savings made possible by VE, may see the mandatory VE study as another hurdle to progress and as an additional expense or a dilution of the available design budget. The cost of the VE study should instead be weighed against the potential savings in total life cycle cost to design, construct, operate and maintain the facility. As pointed out in a later example, the potential savings to the Owner over the life of one 3.8 mgd project were several million dollars. At the conclusion of the VE study, the Owner will participate with the VE Team Coordinator and the Designer to review the recommended VE changes, and to make the final decision as to which changes to include in the final report recommendations to State and Federal environmental protection agencies.

Availability of Training in Value Engineering Techniques

Fortunately, the concepts of VE are relatively universal and the opportunities to obtain training in their use are widespread and frequent. The engineering and business departments of several large universities conduct continuing education courses in VE in cooperation with various VE consulting firms. These sessions are typically forty (40) hours long, either a week straight through, or only mornings (or afternoons) for two weeks, to allow other activities to continue on a part-time basis.

The format of teaching is almost universal, and is termed a "VE Training Workshop", where the concepts and techniques of VE are first taught in formal classroom lectures, with training aids and examples suited to the product or industry involved. This is followed by dividing the students into small groups of mixed technical skills and experience, working together to practice the analytical and creative techniques just learned by application to a sample design problem. Periodically the groups are exposed to reinforcement of previous teaching, as well as new techniques. The sample design problem should ideally be a real one, provided by the student's firm, but may be a proven example furnished by the VE Teaching Consultant. While the latter can be more carefully controlled, an example from the students' own experience can, if well chosen, provide a spontanaeity that is a more credible learning experience. In the latter case, the VE Teaching Consultant should be expected to provide guidance beforehand in selecting projects that are neither too simple nor overwhelmingly complex.

Individuals or small groups of professionals desiring training should consider courses oriented toward construction projects such as the one week courses conducted from time to time in major cities by such groups as the American Consulting Engineers Council and the American Institute of Architects.

Reference Materials on VE

The workbook Appendix contains a list of VE reference materials which provide detailed background information on the principles and practice of VE.

VE STUDY PROCEDURES

VE Proposal to EPA

The applicant must submit the VE proposal to the State environmental regulatory agency as part of the Step II grant application for those projects where VE is to be provided. The State, upon its approval, will subsequently forward the proposal to the EPA Regional Office. Upon approval of the Regional office, the costs of the VE effort become grant eligible. The grant eligibility of the VE study cost is limited to the actual VE analysis of the project. The applicant may incorporate training as part of the proposed VE workshop. However, the intention must be so stated in the proposal, and all costs associated with such training must be computed separately. For example, the cost for a VE instructor, additional time and room space, etc., must be itemized and separately identified for training. The additional costs for training are not grant eligible. Fees for additional engineering effort required to implement an accepted VE recommendation is grant eligible when approved by the Regional office prior to the redesign.

There are five essential points that must be contained in the VE proposal; (1) the scope of the proposed VE effort; (2) the timing of the VE effort; (3) the proposed level of effort and fee; (4) the organization and qualifications of the VE team; and (5) the delineation of responsibility of the VE Team Coordinator in the resolution of differences in regard to implementation or rejection of VE recommendations.

Scope of the VE Effort

The VE effort should include analysis of all portions of the project. Should the applicant desire to restrict the scope of the VE study to only a portion of the overall grant project, he must justify the restricted scope in the proposal. Legal or regulatory requirements (such as discharge permit limitations) are not to be modified by the VE process. The time required to modify these requirements falls outside the time frame acceptable for construction projects. The extent to which the VE study reexamines work in the Step I facility plan must be a matter of judgement between all parties to the VE study (municipality, designer, State, EPA regional office). Obviously the Step I effort represents a great deal of work on cost effectiveness. Unless there is new information those conclusions should not change. Beyond the cost effectiveness portions of Step I, there is a considerable amount of collateral Step I work on environmental assessment, infiltration/inflow, and public hearings. Reopening fundamental Step I conclusions may result in a requirement to reopen the collateral Step I work. The result could be unacceptable delays with little tradeoff in benefit.

In general, therefore, the broad conclusions of the Step I work may be reviewed only under the most unusual circumstances. Even in these cases, it must be clearly shown that the potential impact of this review will not reopen major collateral Step I studies with significant impacts on project timing or the environmental assessment. While precise rules cannot be used, it is possible to define the extreme cases. For example, consider a project where the Step I study concluded that treatment and discharge using completely mixed activated sludge is the best wastewater management technique. A VE proposal for industrial reuse of the wastewater with discharge in another drainage basin would almost always not be acceptable. Conversely, a VE proposal to use step aeration in place of completely mixed activated sludge could usually be implemented without major issues in the Step I study.

When VE Should Be Done

There is a dilemma in selecting the point in design when VE should be performed. The more complete the design, the more readily will the VE teams understand the functions of the entire system and evaluate and price the basic and alternative designs accurately.

Contrarily, the cost to incorporate a VE change will increase as more and more drawings are prepared, specifications detailed, and more work must be done over. While such design costs are linear, other costs are step functions, which, having been passed, are nearly impossible to reverse. Examples are the early procurement of long lead time equipment, where at the very least, termination costs will be incurred, and early contracting for site acquisition and preparation, where a change to a space-saving system such as pure oxygen activated sludge or independent physical-chemical treatment would not be able to enjoy one of its principal advantages. Thus, it becomes necessary to strike a reasonable balance between the opposing factors of: (1) accuracy of VE results increase with increasing completeness of design, and (2) costs to implement VE changes also increase with increasing completeness of design.

The proposal must contain a detailed schedule for the VE work in relation to the design and design review. In some larger and/or complex projects, it may be desirable to schedule two VE reviews during the course of the design. The first may occur when 10-30% of the design is complete and would concentrate on basic factors such as project layout; processes used; general approach to electrical, instrumentation, controls, etc. The second review would occur when the design is complete enough (approximately 50-60% complete) that a detailed review of the electrical, mechanical, and structural designs could be made. In the many projects where only one VE review is made, this latter point is generally too late as basic changes resulting from the VE work are costly to implement. Thus, when one review is proposed, the timing must represent a reasonable balance between the ease of implementing VE ideas developed early in the project and the potential for added savings when detailed design information has been completed. EPA discourages any VE review after 80% design completion because of the costs associate with implementing changes at this late stage, the delays which could result, and the increased resistance of all parties to changes.

The proposed VE schedule must also show when the oral presentation will be made, when the preliminary VE report will be available to the Designer and when the final VE report will be completed by the Designer. Notify EPA and the State in advance of any changes in the schedule.

Level of Effort

When a number of multidiscipline teams has performed a good VE study of a number of areas of high cost, the savings in design and construction historically has far outweighed the cost of performing the study. There is often only one opportunity to make a VE savings, and that opportunity might be missed with too small an effort.

Depending on the size and complexity of the project, the VE effort may vary from one team and one study to multiple teams and/or multiple studies in order to adequately review the project. As noted above, some projects may justify two separate studies. The determination of how many teams and how many studies must be made on a case-by-case basis. For example, a large advanced waste treatment project may readily justify separate teams, each with a study area such as structures, mechanical, electrical, process, and site. If the system in question is simply an add-on to an existing plant to provide a single process, the level of effort may be relatively small and readily handled in one VE review. On the other hand, a small but highly refined system, to provide the ultimate that today's technology can achieve, would require above average effort, perhaps two reviews. If the conventional design is divided among two or more consultants, coordination and review efforts of VE would be above the norm. When a project has been divided into several, sequential steps the required VE effort is increased by the need for smaller studies, each with the same coordination, review and reporting costs. These factors illustrate the fact that the VE level of effort must be tailored to each specific project. Approval of the actual level of effort proposed lies with EPA and the State as part of the Step II grant-approval process. Obviously, the proposed level of effort must have a reasonable relationship to the potential savings which might result from the VE effort. The following example illustrates the breakdown of a VE study budget for a hypothetical project involving a relatively complex set of collection and treatment components:

VE Team

Pre-Coordination - VE Team Coordinator collects drawings and specifications; reviews, divides into projects. Finalizes arrangements with team members, arranges logistics for study.

2 man weeks

During Study

VE Team Coordinator — 1 man week

Team Members - 5 five-member teams — 25 man weeks

Travel for team members and VE Team Coordinator	$5,000
After Study - VE Team Coordinator prepares Preliminary Study Report, and coordinates with Owner and Designer. Reviews Designer's draft response.	2 man weeks

Designer

Pre-Coordination - Provides copies of drawings and specifications.	2 man weeks
During Study - Provides support to study. Answers specific inquiries about original design. Provides additional data.	1 man week
After Study - Reviews VE Team Coordinator's Preliminary Report. Investigates technical feasibility, validity of cost estimates. Prepares draft response and coordinates differences with VETC and Owner. Prepare final report.	10 man weeks
Total Labor	43 man weeks
Total Travel	$5,000

A breakdown similar to that shown above should be submitted for each project. The VE Team Coordinator's costs are relatively - but not completely - fixed regardless of plant size and complexity with the chief variable being the Team Member level of effort noted in the preceding table. VE costs are a function of both project size and complexity. As plant size increases, there is justification to search harder for economics - perhaps using more than one team for each major sub-system - even in the simplest of projects. Addition of teams results in a step increase in costs. As the plant complexity increases (i.e., more sub-systems), the number of justifiable teams for a given plant capacity increases.

Although it is difficult to generalize on the appropriate level of VE effort, the following represents the maximum effort envisioned as reasonable by EPA, unless the project is unusually complex:

Grant Eligible Project Costs	Maximum VE Effort
$ 5,000,000	10 man weeks
50,000,000	50 man weeks
100,000,000	100 man weeks

Selecting the VE Team Coordinator and Participants

The first step of conducting a VE study is the selection of the VE Team Coordinator and the teams that will participate. The VE team can be made up of members of the design firm (provided the designer certifies that the team members have not been significantly involved in any part of the proposed project design or Step I study except for VE analysis) or the VE effort can be subcontracted to or contracted directly with an outside firm. The objectivity of the VE Team Coordinator and participants is essential to the success of the VE effort. The Owner must assure the relative independence of the VE Team and the VE Study Proposal must discuss the means by which this assurance will be achieved. If this assurance is lacking, then another approach must be adopted. When an outside firm is used, the VE Team Coordinator should be selected with the advice of the Owner's design firm, but should perform the VE study independently. In cases where the VE effort is a separate contract, the selection of the VE Team Coordinator should be in accordance with EPA regulations for the procurement of architectual or engineering services (subsection 35.936-35.939, Federal Register, December 17, 1975).

In selecting the VE Team Coordinator who will lead the VE study, and, those who will participate as team members, several attributes should be considered. First is qualifications of the VETC in both theoretical knowledge and practical experience in the use of the techniques of value engineering. He should have the first hand knowledge and experience to guide and overcome the various negative responses that can arise during a VE study. Practical experience relating to directing the study, and preparing an implementation plan to effectively incorporate the recommendations of the VE study teams is desirable. Second, and equally important, is technical and managerial competence of Team members. They should be highly qualified in the disciplines they represent. The creativity of the teams will be proportional to the competence of their members, and to judicious selection of the mix of those disciplines. Selection of a VE Team Coordinator should also consider these factors: (a) the individual's record of recent accomplishments by the use of VE techniques in construction, preferably of wastewater treatment projects, and (b) that the proposed study coordinator is particularly well qualified in VE related to construction oriented projects, and in managing such a study. The participants proposed for the study should have current design, construction, procurement, operation or administrative experience suited to the analysis of the subject design.

A record of past accomplishments on wastewater projects will become available in EPA Regional Offices as the VE study program progresses. In the interim, similar records from the GSA's Public Building Service (PBS) VE Program and from the Corps of Engineers, may be considered.

A typical VE team has five members and is composed of members who bring interdisciplinary skills to the project. For a treatment plant, a typical team composition might be an electrical engineer, a mechanical engineer, a civil/structural engineer, a sanitary engineer, and a cost estimator. However, some projects may require other disciplines. The interdisciplinary composition of the Step II VE team is vital to the VE concept. It is also vital that the VE team members be completely isolated from their normal duties during the Project Workshop. The team members must be experienced professionals in their own field. It may be desirable to designate a leader for each team, preferably one with some VE experience, if the bulk of the team members have limited VE experience. It is acceptable that persons other than design engineers may constitute a part of the total study group. The Public Works Administrator, Sanitation District Director, City Auditor, Purchasing Division Manager, Treatment Plant Superintendent, and others from similar positions, or their designated subordinates often can contribute to a value study by providing a fresh viewpoint that "doesn't know that it can't be done". When such administrative persons share the responsibility for recommending value enhancing changes, the probability of adoption of the idea is often improved. The VE team coordinator should not be a member of any one VE study team except when only one team is conducting the VE study. The attendance at actual VE sessions should be limited primarily to working members of the teams. VE sessions, particularly those sessions involving idea generation, weighing and analysis, will work best if the number of non-participating observers is held to a minimum.

Final approval of the VE team qualifications is at the discretion of the Regional Office. In reviewing the proposal, the Regional Office will consider the size and complexity of the project. The Regional Office may use the following definitions to designate an acceptable level of capabilities for a given project.

Level 1: The VETC and all teams members have completed a 40 hour VE training workshop and have experience on at least two other VE studies of construction projects.

Level 2: All team members have completed a 40 hour VE training workshop and 50% of the team members (including the VETC) have experience on at least two other VE studies of construction projects.

Level 3: Fifty percent of the team members have completed a 40 hour VE training workshop and the VETC has experience on at least two other VE studies of construction projects.

Level 4: 4a - The VETC has completed a 40 hour VE training workshop and has experience on at least two other VE studies of construction projects.

4b - The VETC has completed a 40 hour VE training workshop and has experience on at least one other VE study of a construction project.

4c - The VETC has completed a 40 hour VE training workshop.

VE training workshops are conducted by organizations such as the General Services Administration, the American Institute of Architects, the American Consulting Engineer Council, or an accredited university. The Society of American Value Engineers conducts a certification program but does not distinguish between construction project or non-construction project experience.

VE Fee

The applicant should submit a detailed fee schedule for conducting the VE analysis. The fee schedule should list the man-hour requirements for the recommended level of effort. Man-hour unit costs, overhead costs, and profit should be given. A sample form (EPA Form 5700-41) is shown in Figure 2.

Conducting the VE Study

The heart of the VE study is the VE Project Workshop where the VE study teams analyze the project. However, both pre- and post-workshop efforts are important.

Pre-Project Workshop Preparation - The success of a VE Project Workshop is greatly dependent on proper preparation. Certain information and documents should be furnished by the Designer to be distributed to the team members by the VE Team Coordinator before the Project Workshop. This will prepare the study teams for their particular area of study, and help the teams determine what reference material to bring. The Owner, Designer, and VE Team Coordinator should meet to agree upon the extent and format of materials to be used in the Project Workshop. This may impact the Designer's priorities in the early phase of design. Copies of drawings, detailed cost data, specifications, reports, and pertinent regulations are required in sufficient numbers to permit team members to investigate various areas simultaneously. The availability of these materials at the start of the Project Workshop is critical in light of the coordination required to assemble the VE teams. Documents needed by each team include:

Drawings: One complete set of team's area of study. If the total number of drawings in the entire set is relatively small, it may be desirable to have one complete set of drawings per team. If it is decided that each team will have a copy of drawings pertinent to only their particular study area, then it is highly desirable to have one or more complete reference sets for use by all teams. If final design drawings are not yet available, design sketches showing the layouts of all equipment and structures, piping, valves, etc. should be provided. These drawings need not be on final plan sheets, but should be readable and reasonably to scale. They are the type of sketches an engineer would hand to a good designer or draftsman for incorporation into the final plans.

Background Report: This report should summarize the history of the project; the highlights of the project reports and other applicable documents such as discharge standards, soils reports and pilot study data; flow diagrams and mass balances; process calculations; process and instrumentation drawings; site and plot plans; design criteria; hydrologic and weather data which might influence design; a listing of applicable local codes; regulations and permit criteria from local planning groups; and names and phone numbers of members of the design firm and owner where

COST OR PRICE SUMMARY FORMAT FOR SUBAGREEMENTS UNDER U.S. EPA GRANTS *(See accompanying instructions before completing this form)*	*Form Approved OMB No. 158-R0144*

PART I - GENERAL

1. GRANTEE Municipal Utility District, Riverville, Calif.	2. GRANT NUMBER C-10-2000
3. NAME OF CONTRACTOR OR SUBCONTRACTOR ACE Consulting Engineers	4. DATE OF PROPOSAL July 10, 1976
5. ADDRESS OF CONTRACTOR OR SUBCONTRACTOR *(Include ZIP code)* 100 Main Street Newton, California	6. TYPE OF SERVICE TO BE FURNISHED Value Engineering Study

PART II - COST SUMMARY

7. DIRECT LABOR *(Specify labor categories)*	ESTIMATED HOURS	HOURLY RATE	ESTIMATED COST	TOTALS
VE Team Coordinator	400	$ 15.00	$ 6,000	
VE Team Participants from ACE Consulting Engineers (13)	520	12.00	6,240	
DIRECT LABOR TOTAL:				$ 12,240
8. INDIRECT COSTS *(Specify indirect cost pools)*	RATE	× BASE =	ESTIMATED COST	
Overhead	96%	$ 12,240	$ 11,750	
INDIRECT COSTS TOTAL.				$ 11,750
9. OTHER DIRECT COSTS				
a. TRAVEL			ESTIMATED COST	
(1) TRANSPORTATION (See Support Data for Details)			$ 920	
(2) PER DIEM 70 man days @ $35			$ 2,450	
TRAVEL SUBTOTAL			$ 3,370	
b. EQUIPMENT, MATERIALS, SUPPLIES *(Specify categories)*	QTY	COST	ESTIMATED COST	
Printing		$ 1,200	$ 1,200	
EQUIPMENT SUBTOTAL:				
c. SUBCONTRACTS			ESTIMATED COST	
12 VE Team Participants (See Support Data for Details)			$ 9,800	
SUBCONTRACTS SUBTOTAL			$ 9,800	
d. OTHER *(Specify categories)*			ESTIMATED COST	
			$	
OTHER SUBTOTAL			$ 14,370	
e. OTHER DIRECT COSTS TOTAL:				$ 14,370
10. TOTAL ESTIMATED COST				$ 38,360
11. PROFIT				$ 2,685
12. TOTAL PRICE				$ 41,045

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FIGURE 2

additional information and clarification can be obtained. The entire information package should be discussed and agreed on by the Designer and the VE Team Coordinator. The package should be assembled by the Designer and provided to the VE Team Coordinator in the agreed on number of copies prior to the first VE session. At the first VE session, the Designer should present the background report and answer questions from the VE team.

- Detailed Cost Data: The cost data should be as complete and as detailed as practicable.

- Copies of the specifications, design criteria, regulations, and report. If relatively complete specifications are not yet available at the time of the VE study, outline specifications should be provided. These should be written by the Designer who should also list the design philosophy, discuss alternatives that were considered by the designer; tell whose equipment was selected and whose would be accepted as substitution; give loading rates, flows, power requirements; discuss standby capacity and reliability and describe how the process will be controlled. The written specifications should be supplemented by at least a process and instrumentation diagram for the system showing important details not yet incorporated in the plans.

- Copies of design calculations

Sufficient guidance on any constraints of the VE study's scope should be provided. It should be clear as to what the VE study will be allowed to consider regarding process changes. For instance, the following series represents an escalating severity of constraints:

- You must retain the requirements for an effluent BOD of 30 mg/l
- You must use the activated sludge process
- You must use the oxygen activated sludge process
- You must use the oxygen activated sludge process with covered tanks
- You must use the oxygen activated sludge process with this loading, configuration, temperature, redundancy ....

If any such constraints are proposed, they should be clearly justified.

Following collection of the available data, the VE Team Coordinator should analyze and validate the original cost estimate prior to the initiation of the workshop. The importance of this step cannot be overemphasized because it will establish the basis (i.e., unit costs, quantities, etc.) of the original estimate, it will serve as the basis of comparison for other alternatives generated in the workshop, and it insures that all costs are determined in a consistent manner. There are several approaches to validation of the original cost estimate. The VE Team Coordinator and the Designer may agree to use throughout the VE study, the same cost estimator who prepared the Designer's original cost estimates. This approach in essence accepts the original estimates as valid. A potential weakness in this approach is that if the original estimates are seriously in error, the absolute value of all other estimates will also no doubt be in error. The VE Team Coordinator may have another cost specialist available or may retain such a specialist as a consultant for the VE study. In this case, it is desirable to obtain the detailed cost estimates (unit quantities and unit prices) from the Designer. The VE cost specialist can then evaluate the unit prices used by the Designer and readily determine any differences from unit costs he considers accurate for the project locale. If such differences occur, the Designer and the VE Team Coordinator must agree on a common basis for cost estimates so that all alternatives are priced consistently.

Worksheet 1 can be used in evaluating the original cost estimate and in determining the areas of differences. (Note: Blank worksheets in reproducible form may be found in the Appendix. Where appropriate, example completed forms are presented in the text.) Worksheet 2 can be used for summarizing the results. An example of Worksheet 2 is shown for an example project. In this case, the VE coordinator was in reasonably close agreement with the estimate developed by the Designer.

The VE Study Job Plan - It is the purpose of VE to provide a systematic approach that is efficient and less susceptible to oversight. The framework of that approach is termed the VE Job Plan. The VE job plan consists of six phases of activity which constitute the bulk of the VE study. They are:

- The Information Phase
- The Speculative or Creative Phase
- The Evaluation or Analytical Phase
- The Investigation Phase
- The Recommendation Phase
- The Follow-Up and Implementation Phase

The following sections discuss each of these phases in detail and present specific examples.

Information Phase - The purpose of this phase is to collect all facts, opinions, and data that are pertinent to the design being considered. Typical are these:

What are the essential functions
Field experience in other locales with the system
Reliability records
Equipment availability - lead times
Performance versus cost, size, etc.
Need for further development
Materials and alternates
Ease of operation, need for training
Necessary ancillary equipment
Energy and consumable materials demands
Space requirements
Safety to operators
Safety, annoyance to neighbors

COST VALIDATION

PROJECT COST SUMMARY

ITEM	ORIGINAL ESTIMATE	NEW ESTIMATE
Sitework	2,813,000	2,367,500
Structures	10,853,000	12,024,100
Major Equipment	10,497,000	10,000,000
Piping	5,755,000	5,280,000
Electrical	6,183,000	6,087,700
Heating, Ventilating, Air conditioning	2,477,000	2,230,000
Miscellaneous Equipment	647,000	646,600
Other:		
Plumbing	440,000	369,000
Potable Water Bldg.	250,000	200,000
SUBTOTAL	39,915,000	39,204,900
Contingencies	3,992,000	1,960,200
TOTAL	43,907,000	41,165,100

Discipline must be exercised here to insure that time is taken to collect facts and to check them out, rather than relying on unfounded opinion. Ask "What are the assumptions here - which may be masquerading as knowledge"? List the assumptions, and review them one by one. Discipline must also be exercised not to begin suggestion of alternatives until the information collection phase has been completed.

For projects involving expansion or upgrading of an existing plant, a visit to the existing plant is recommended as part of the information gathering phase. A presentation of the process fundamentals, problems and applications by the VE Team Coordinator is an excellent technique to get the information session underway and for educating non-process members in what they are studying. Maintenance and operation of components, space requirements, safety, clearances, utilities, weights and other features can be discussed. Other team members who may be familiar with all or specialized requirements of the equipment can also discuss them. During this introductory discussion, it will also be helpful for the Team Coordinator to review VE methods to be used, approximately how much time is to be allotted to each event, etc. The briefing is helpful even when all team members are familiar with VE methods and have worked together previously. The basic questions to be answered in this phase are: what is the system, what does it do, what does it cost? In order to do this, the project is first broken down into sub-systems and their functions. The "verb-noun" concept discussed earlier is used to define the functions. The functions are then classified as "basic" or "secondary" as discussed earlier. In the case of the overall wastewater treatment facility, the functions can be placed into two classes: (1) basic- a sub-system which treats wastes; (2) secondary- sub-systems which do not treat wastes. Worksheet 3 provides a form for tabulating the results of the functional analysis.

The cost of each sub-system is also tabulated and compared to its "worth". Worth is an indication of the value of performing a specific function. Extreme accuracy in estimating the worth is not critical since it is merely used to determine areas of high potential savings and not to determine a specific design alternative. Sub-systems performing only secondary functions have no worth because they are not directly related to the basic function of the plant to treat waste. An example would be access roads to a treatment plant. Although roads may be required, roads don't provide treatment. Thus, they are a good place to look for savings without affecting the basic function. The worth of the primary sub-system is determined by estimating the cost of the simplest and most functional alternative to achieve the same function. The cost of this alternative is the worth of the sub-system. The alternatives considered in determining worth may be developed by asking the basic questions "what else will perform the essential function" and "what will that cost". Approximate costs are determined for the alternatives to determine the worth. For example, accomplishments of the basic function of a pencil, make marks, can be accomplished by a bare piece of lead costing two cents. Therefore, the worth of making marks is two cents. A metal holder for the lead would have a secondary function, contain lead, and would have no worth. The cost-worth ratio for a $2 mechanical pencil then becomes 100:1. A ratio this high certainly indicates that savings could be realized while still meeting the basic function. High values of the "cost-worth" ratio suggest large potential cost savings, in which case the sub-system is selected for additional analysis. Also, the cost-worth evaluation will indicate those areas where effort should stop because of diminishing returns.

An example (using Worksheet 3) for an entire wastewater treatment plant is shown. An example of worth calculation may be offered by the design of a stormwater retention basin with a volume of 10 million gallons. The basic function may be defined as "retain water". The design under review includes a covered concrete basin with an estimated cost of $2,700,000. The worth of this basin is the lowest initial cost way to retain 10 million gallons of water which would be an unlined, earthen basin. Such a basin has an estimated cost of $70,000. Thus, the cost to worth ratio is $2,700,000/ $70,000 or about 38:1. Such an extremely high ratio would certainly lead to pursuit of alternates. Perhaps the earthen basin used to determine worth would not meet all the criteria, but it might lead to selection of a steel tank with a cost of $538,000.

To further refine the identification of those sub-systems and components of a treatment plant offering the most potential for cost savings, each sub-system is divided into its main components wherever possible. In a manner similar to that used in determining the worth of each sub-system, the worth of each component is determined by estimating the cost of the simplest and most functional alternative to the component. A team evaluating, for example, the structural sub-system would perform a similar, but more detailed analysis (as shown in the second example using Worksheet 3) where the basic function of the sub-system is defined as shown. The basic function of the sub-system differs from the basic function of the total system. In the example, the basic function of the underground structure sub-system is "transmit load" while the total system basic function was "treat waste". When the total system was broken down into the sub-system, items such as reinforcing steel which are not directly related to "treat waste" then have worth. The sum of the worth of all the components and/or sub-systems then provides a model plant which provides an indication of the reasonableness of the original cost of each sub-system.

This "cost model" is then used to select areas for further study - i.e., those areas having the greatest difference between the "model" and "actual" costs. Worksheet 4 may be used to present the cost model. An example is presented for an activated sludge plant. In this case, the cost of each sub-system was divided by the design capacity of the plant and the costs then expressed as dollars per gallon per day of capacity. The model indicated that the areas with the most potential for savings were: process (secondary and tertiary), plant layout (because of its major effect on interface costs), waste transport, pumping, piping, and electrical distribution. These selected areas would then be subjected to detailed evaluation in the Project Workshop.

Speculative or Creative Phase - The desired output of this phase is completely free interplay of ideas, to create an extensive list of alternative

Worksheet 3 - Example

ITEM:	Underground Structure
BASIC FUNCTION:	Transmit Load

FUNCTIONAL ANALYSIS

FUNCTIONAL ANALYSIS

ITEM	FUNCTION Verb	FUNCTION Noun	FUNCTION Kind *	COST	WORTH	COMMENTS
Concrete	Transmit	Load	B	160,000	120,000	
Formwork	Shapes	Concrete	S	250,000	0	
Reinforcement	Transmit	Load	B	285,000	90,000	
Excavation	Prepare	Site	S	100,000	0	
Damp Proofing	Protect	Eqpt.	S	5,000	0	
TOTAL				800,000	210,000	

* B = Basic
S = Secondary

ITEM:	Total Plant
BASIC FUNCTION:	Treat Waste

FUNCTIONAL ANALYSIS

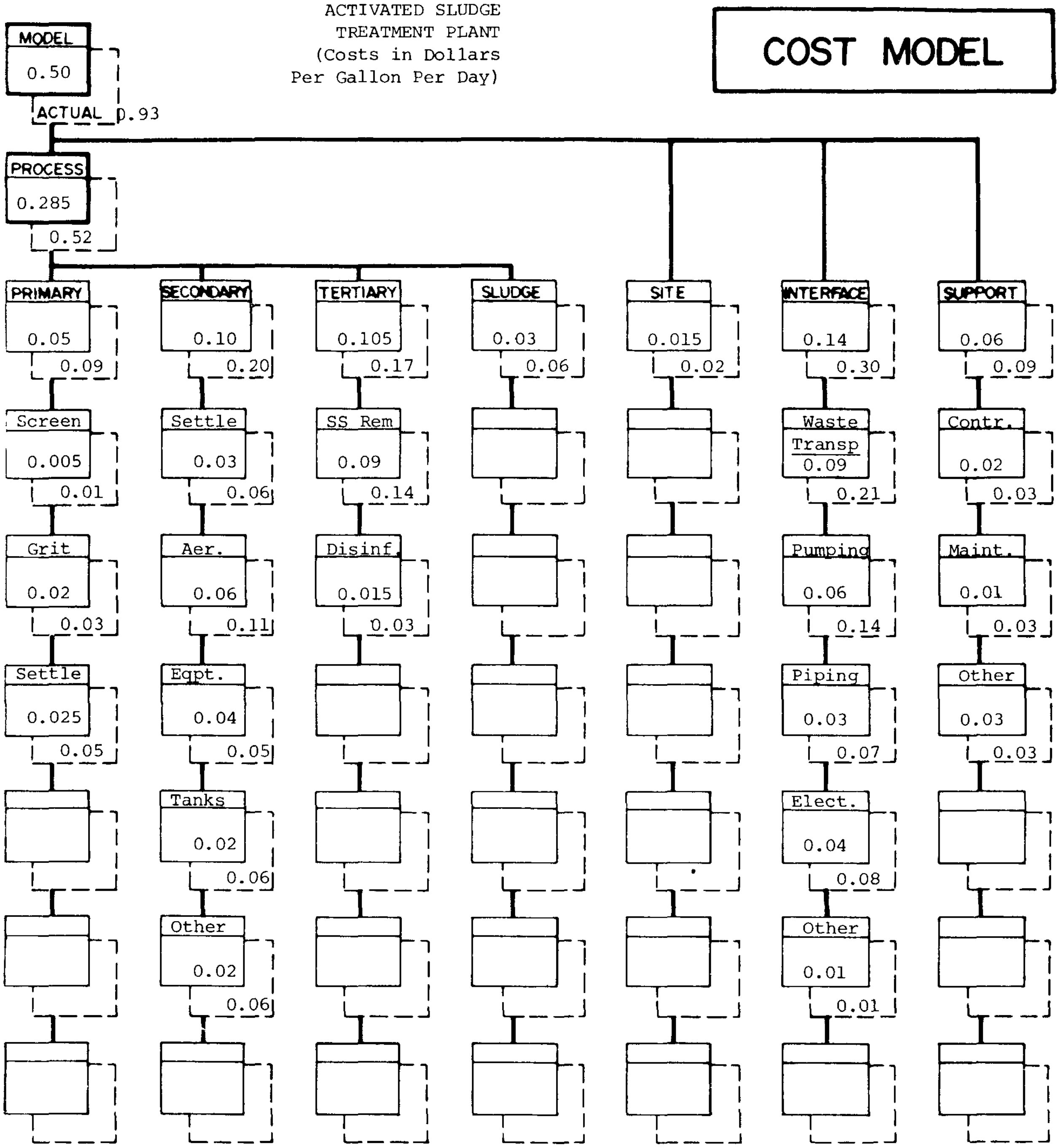
FUNCTIONAL ANALYSIS

ITEM	FUNCTION			COST	WORTH	COMMENTS
	Verb	Noun	Kind *			
Sitework	Provides	Access	S	90,000	0	
Primary Treatment	Treat	Waste	B			
Secondary Treatment	Treat	Waste	B	2,070,000	900,000	
Tertiary Treatment	Treat	Waste	B			
Interface	Connect	Systems	S	1,305,000	0	Pumping, Piping, Electrical, etc.
Operational Support	Provide	Support	S	360,000	0	Garage, lab, office, etc.
Sludge Disposal	Handles	Sludge	S	275,000	0	
TOTAL				4,100,000	900,000	

* B = Basic
S = Secondary

ACTIVATED SLUDGE
TREATMENT PLANT
(Costs in Dollars
Per Gallon Per Day)

COST MODEL



ways to perform the essential function found during information gathering. The key to results is to delay any critical judgement or comments until after all the ideas have been generated. There will be a strong tendency to discuss some ideas or to argue about their relative merits when they are suggested. Such evaluation will suppress creative thinking. VE texts offer a list of thought provoking questions to get a slowstarting creative session under way such as:

What is the input?
What is the output?
What should go in between?
Could this be done automatically?
Is all of the known information available to me?
What emotions or attitudes am I dealing with?
Are specifications tight or loose?
Could this be done somewhere else?
What would happen if this weren't done at all?
Could this be done mechanically? Electrically? By hand?
Could you twist present structures to improve them?
What other fields have this kind of problem?
How much of this is a result of custom? Tradition? Opinion?
What else could this be made to do?
How could this be done piecemeal?
How else could the basic function be accomplished?
Where is our greatest economic effort expended?
Why hasn't anyone done this before?
How would postponement of this objective affect the project?
Can better use be made of existing facilities?
Are the "ground rules" real or imaginary?
What can be combined?
What should be divided?
Why are the present limits adopted?
How can this be made more compact?
What other layout might be better?
Can it be made safer?
What other materials would do this job?
If all specifications could be forgotten, how else could the basic function be accomplished?
Could these means be made to meet specifications?

The more ideas, the better. Care is taken to avoid evaluation of suggestions; rather, members are encouraged to generate and share their ideas regardless of how "far out" they might appear. Negative comments on any idea are to be avoided during this phase. Creativity is inhibited by simultaneous evaluation. During the Speculative Phase, every idea raised should be recorded immediately, against the possibility it might be forgotten. Every idea has the potential of value as illustrated by the following example. A group of aerodynamicists, using the wing area, power and weight of a bee, demonstrated analytically that the bee could not fly. The bee, howevever, wasn't aware of this, so he just flew anyhow. The aerodynamicists erred by limiting their analysis to fixed-wing theory. The bee used ornithopter theory. It worked. Moral: Sometimes the expert specialist limits himself by what he knows so surely. Keep an open mind. There is no such thing as a foolish speculation.

Worksheet 5 may be used for listing the ideas as they are generated. An example of ideas generated by a team working on a wastewater pumping station and outfall portion of a project is shown to illustrate the concept.

A good method for developing ideas is termed functional analysis. A tool for this method is the "ladder of abstraction", where each rung represents either more specific or more abstract objects or functions. The series Treat Waste, Protect Stream, Enhance Environment, Protect Life, illustrates this concept, where each following item includes the previous, but is more encompassing. In the investigation of functions, the question, "Why verb-noun" leads upward to a function more abstract than before, while the question, "How verb-noun" leads downward to a more specific function. The classic example from VE teaching is the pencil, whose function is to "make marks". The increasingly abstract series, write words, transmit thoughts, communicate ideas, change attitudes, answers the repeated "Why?", while "How?" leads from make marks to smear graphite. If the first answer to a pencil's function had been write words, the "How" would force the answer, make marks. Write words is only one of the answers to, "Why make marks?" Others are to sketch pictures, to mark sawcut. At each rung of the ladder, other functions can be conceived. Another reason to write words might be simply to take notes, and that to aid memory. Other ways to make marks are a paint brush, a spray can, a typewriter. Thoughts are transmitted and ideas communicated by television, cinema, radio and speeches. Notes can be taken by tape recorder or camera. The reader can visualize not merely a ladder, but a whole matrix of more and less abstract functions at each level, with many answers to "How?" and "Why?" at each level. Persistently questioning "what else will do that?" fills out the breadth of the matrix. Pursuing the "How" and "Why" questions, a VE study team can increase the probability of drawing out an innovative insight that will free them from routine design answers.

An outgrowth of this matrix of abstraction is termed FAST diagramming, from Function Analysis System Technique. The purpose is not to produce a diagram per se but only to serve as another tool to stimulate thinking. Convention is for the path of abstraction to run horizontally, with why? answers at the left, and how? at the right (see Worksheet 6). An additional dimension is added by searching for support logic, for example, inquiring into the time relationships of functions, "When is verb-noun performed?" and when that function is performed, what else must be happening concurrently, or just before or after. Other questions ask whether the manner of performing a function causes some other, dependent, function to come into existence. These concurrent requirements are plotted vertically in relation to the other function. Since team understanding of the relationships of functions can vary so much during the course of analysis, it is useful to write each function on a separate card, to allow easy changes of the matrix. The team begins by listing the basic function of the item (i.e., decrease BOD in example Worksheet 6). By then listing specific (or less abstract) ways of achieving the basic function (moving from the question of "why"

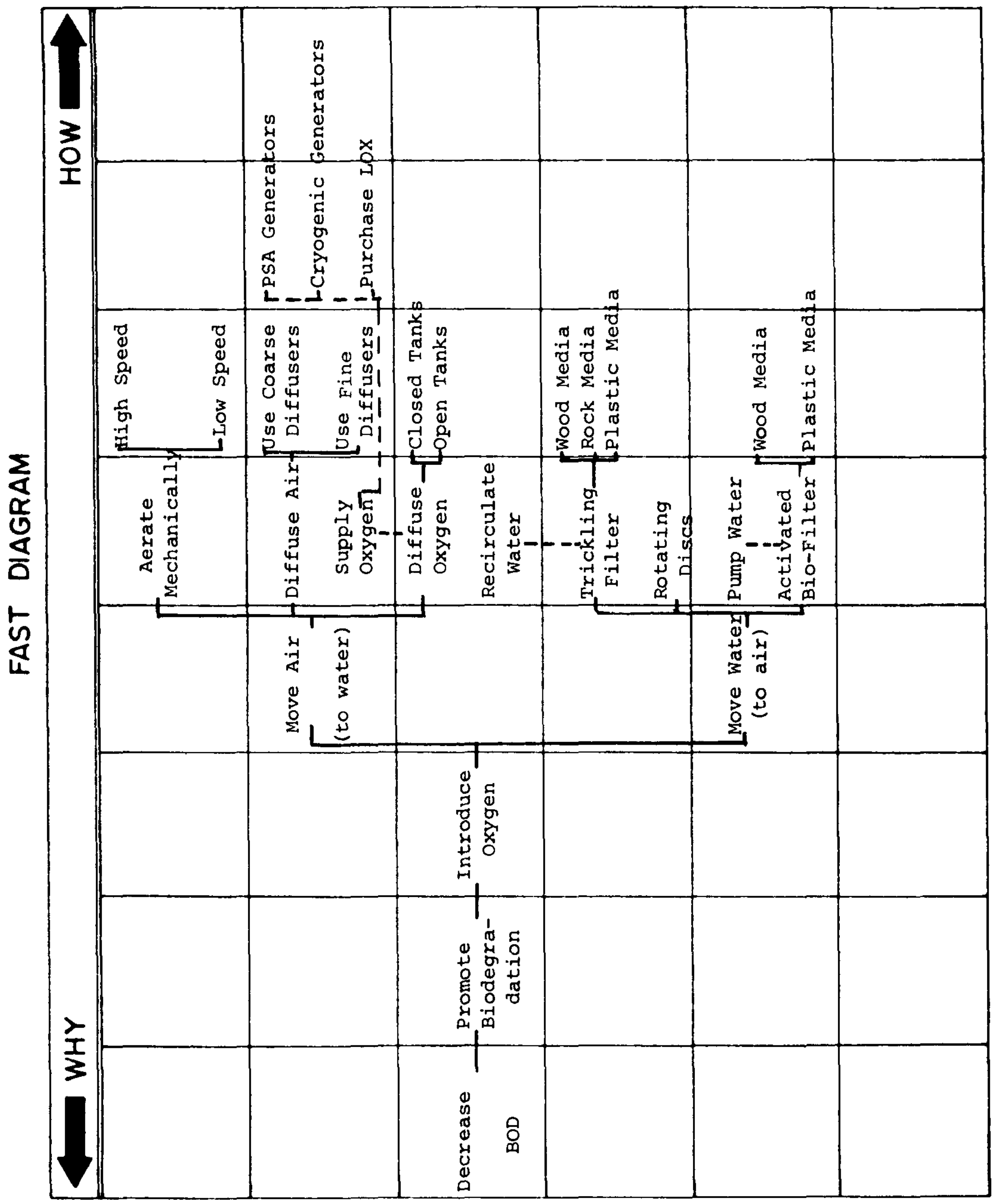
LIST ALL IDEAS -
EVALUATE LATER

SPECULATIVE PHASE	
ITEM:	Pump Station
BASIC FUNCTION:	Transport Waste

Combine pumps	Reduce initial pump sizes
Use one pump	
Modify piping	
Change hydraulic gradient	
Relocate pump station	
Change pump type	
Use higher speed pumps	
Use submersible pumps	
Combine influent lines	
Change pipe material	
Use reciprocating pumps	
Use frequency variation	
Use hydraulic coupling	
Use eddy current coupling	
Use common speed pumps	
Reduce pipe friction	
Use factory assembled station	
Change valving	
Eliminate valves	
Reduce fittings	
Relocate discharge line	

FAST DIAGRAM

ITEM: SECONDARY PROCESS



to the question of "how"), the team may generate many ideas and a wide variety of ideas. For example, one of the ways of reducing BOD is the introduction of oxygen. In moving toward the less abstract question of "how", ideas such as aerate mechanically, inject pure oxygen, etc., are generated.

The Evaluation or Analytical Phase - During the speculative or creative phase, all critical comment and judgement was suspended, in order not to inhibit the flow of ideas, no matter how wild. With that behind, the team now considers the feasibility of each of those ideas, but looking positively for a way that each could be made to work, rather than critically for an excuse for rejection. The faults of each idea must be identified, of course, but for the sake of fault elimination, possibly by combining two or more ideas in a way to correct the faults of each. Preliminary rough cost estimates may be needed to help narrow down the field as well as evaluation of technical strong and weak points, and unusual requirements such as special labor skills to build or operate, higher or lower than normal material costs to operate, space economies, etc.

The ideas generated in the speculative phase should be screened by criteria such as:

Are the performance requirements met?
Does the alternative meet the quality requirements?
Are the reliability requirements met?
Are the original reliability requirements unreasonably high?
Will the system accept the alternative without excessive redesign in other areas?
Is there an improvement, or at least no loss, in the maintainability of the system?

For each of the ideas selected, the workshop team identifies potential advantages and disadvantages. The relative merits are then discussed by the team and a numerical rating assigned to each idea (see Worksheet 7 using same pumping station project as in Worksheet 6). During this phase, it will be seen that the VE job plan is not a pat one-two-three routine, but that it is normal to return to earlier phases, as for example here, to gather new information that had not been anticipated, or to save ideas that would be rejected for some shortcoming by combining them creatively. Finally, with these data in hand, the best ideas are selected for further investigation.

The Investigation Phase - In this phase, the most feasible alternatives are investigated more completely. All specifications (performance, reliability, etc.) must be met. Use of standard materials, parts, and equipment should be maximized. Implementation costs (both labor and other costs) to redesign, and possibly to discard, remove or modify existing facilities must be carefully evaluated. Collateral advantages to the Owner may be found, in byproduct values (i.e., recyclable compost) and social benefits. Equal depth of investigation should be followed for all alternatives, rather than simply for the one seen as best, in order that review agencies can confirm these data if desired. All of the data developed in

IDEA EVALUATION

ITEM:	Pump Station
BASIC FUNCTION:	Transport Wastes

IDEA	ADVANTAGES	DISADVANTAGES	IDEA RATING*
Use screw-lift pumps	Initial Cost Operating Cost	Less Flexible Future Replacement Redesign Building	5
Relocate Pump Station	Operating Cost	Initial Cost	2
Relocate Lines	Maintenance Less Initial Cost	Redesign	9
Constant Speed Pumps	Initial Cost	Shorter Life Operating Efficiency	4
Common Trench for Lines	Initial Cost	Redesign	8
Factory Assembled Pump Station	Initial Cost	Operation Availability Redesign Aesthetics	3
Submersible Pumps	Initial Cost	Maintenance Code Requirements Redesign	1
Change Pump Controls	Initial Cost	Redesign	6
Reduce Initial Pump Size	Initial Cost O & M Savings	Redesign	10

* 10 = MOST DESIRABLE, 1 = LEAST DESIRABLE

this investigation should be documented and retained, to support any proposals.

Worksheet 1 can be used for capital cost calculations. The evaluation of alternatives also includes comparison of annual Operation, Maintenance, Replacement (OMR) costs. These costs are coupled with the annual capital costs to determine the total life cycle costs (see Worksheet 8 again using the pump station example). Also, refer to Appendix D for the EPA Cost-Effectiveness Guidelines on interest rates, useful life, etc. Obtaining accurate cost estimates for several alternative approaches may be difficult in the short time available during the project workshop. For this reason, it may be desirable in some cases to temporarily adjourn the project workshop after the speculative phase for 1-2 weeks to permit the VE Team Coordinator to conduct the cost estimating work. Even with inclusion of a cost specialist in the project workshop it may be necessary to telephone manufacturers and suppliers for capital costs and other users of the equipment for operation and maintenance costs. EPA and State offices may be a source of cost data from recent grant projects. Published papers and reports are often a useful source of cost data. Where there is some uncertainity associated with costs for a given alternative, a sensitivity analysis can be made by assuming what appears to be a mid-range value and then determining the effect of the high and low range of possibilities. The VE team must carefully document the method of estimating and sources of costs as later disagreements on the practicality of a recommended change may well hinge upon this factor.

Factors other than costs - such as improved performance, reliability, aesthetics, and flexibility - also influence the desirability or acceptability of the alternatives. Such factors are assigned a weight from 1 to 10, with higher values for greater importance. Each alternative is then evaluated against each factor and subjectively rated - 1 for poor, 2 for fair, 3 for good, and 4 for excellent. The rating is multiplied by the factor's weighted value and totals arrived at for each alternative. Based on these totals, the alternatives are then ranked (see Worksheet 9) by the relative attractiveness of each alternative.

The Recommendation Phase - Since the VE Team Coordinator will be either an outside consultant or an uninvolved member of the design firm or the Owner's design group, he will not be in a position to decide to implement any of the ideas favored by the VE study teams, and so a proposal must be made to the decision makers. This consists of an oral presentation to all parties involved, as described earlier (see Figure 1 and related text) followed by a written report in more detail. The total report of the VE study should be broken down into separate sections for each idea to be considered. Each section should start with a one-page summary of old way vs. new way, and the life cycle cost savings to be realized. Succeeding pages should include sketches and cost analyses of the old and new, and all of the data described in "Investigation Phase", presented in a manner to answer the questions that can logically be expected from decision makers who may favor the status quo.

The recommended alternates should be described as concisely as possible with the cost benefits summarized. Rationale should be presented for each

LIFE CYCLE COSTS

ITEM: Pump Station

INITIAL COSTS (in $1,000)	ORIGINAL	ALT. 1	ALT. 2	ALT. 3
Base Cost	840	648	648	648
Interface Costs	965	965	863	863
(a)				
(b)				
Other Initial Costs				
(a)				
(b)				
TOTAL INITIAL COST	1,805	1,613	1,511	1,511
REPLACEMENT COSTS				
Year 12 **@** 10 **% Amount** (Add 4th Pump)		388	388	388
Present Worth of Future Replacement Cost		124	124	124
Year ___ @ ___ % Amount				
Present Worth of Future Replacement Cost				
Year ___ @ ___ % Amount				
Present Worth of Future Replacement Cost				
ANNUAL COSTS				
Amortized Initial Cost @ 6 1/8**%** * 20 **Year**	157	141	132	132
Capital Recovery of the Present Worth of the Replacement Cost				
(a) Year 12		13	13	13
(b) Year				
(c) Year				
Annual Costs				
(a) Maintenance				
(b) Operations				
(c) Maintenance plus Operation	192	154	154	119
TOTAL ANNUAL COSTS	349	308	299	264
Annual Difference	-	41	50	85
PRESENT WORTH OF ANNUAL DIFFERENCE		470	573	975

*Source = Water Resources Council
Federal Register

Worksheet 8
Example

LIFE CYCLE COSTS

ITEM: Pump Station

INITIAL COSTS	ORIGINAL	ALT. 1	ALT. 2	ALT. 3
Base Cost	840	648	648	648
Interface Costs (a)	965	965	863	863
(b)				
Other Initial Costs (a)				
(b)				
TOTAL INITIAL COST	1805	1613	1511	1511
REPLACEMENT COSTS				
Year 12 @ 6 1/8 % Amount (Add 4th Pump)		388	388	388
Present Worth of Future Replacement Cost		190	190	190
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
SALVAGE VALUE**				
Year 20 @ 6 1/8 % Amount ____	0	258	258	258
Present Worth of Future Replacement Cost		81	81	81
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
ANNUAL COSTS				
Amortized Initial Cost @ 6 1/8 % *20 Year ____	157	141	132	132
Capital Recovery of the Present Worth of the Replacement Cost				
(a) Year 12		17	17	17
(b) Year				
(c) Year				
Annual Costs				
(a) Maintenance				
(b) Operations				
(c) Maintenance Plus Operations	192	154	154	119
TOTAL ANNUAL COSTS	349	312	303	268
Annual Salvage Value Credit (Amortized)				
(a)	0	7	7	7
(b)				
NET ANNUAL COSTS	349	305	296	261
Annual Difference	-	44	53	88
PRESENT WORTH OF ANNUAL DIFFERENCE		499	602	999

*Source = Water Resources Council, Federal Register
**Assumed straight line depreciation to zero over 20 year life.

ALTERNATIVE EVALUATION

ITEM: Pump Station

	FACTORS *										
	CAPITAL COST	O & M COST	REDESIGN	IMPLEMENTATION TIME	PERFORMANCE	RELIABILITY	SAFETY			TOTAL	RANK
FACTOR WEIGHT 10 = MAXIMUM ▶	8	8	3	5	10	10	9				
	2	2	4	4	3	2	4				
Initial Design	16	16	12	20	30	20	36			150	4
	4	3	2	4	3	2	4				
Relocate Line	32	24	6	20	30	20	36			168	2
Reduce Initial	4	4	2	3	4	4	4				
Pump Size	32	32	6	15	40	40	36			201	1
Change Pump	3	2	2	3	3	3	4				
Speed Controls	24	16	6	15	30	30	36			157	3
Change Pumps	1	3	1	3	3	3	4				
to Screw Lift	8	24	3	15	30	30	36			146	5
Use Constant	2	2	2	3	2	2	4				
Speed Pumps	16	16	6	15	20	20	36			129	6

*** EXCELLENT = 4, GOOD = 3, FAIR = 2, POOR = 1**

of the proposed changes. Worksheet 10 provides a form for such a presentation using the earlier pump station example. Whenever appropriate, drawings which graphically present the recommendations should accompany the narrative. Any thoughts that the workshop team has on implementation of the recommended changes should be incorporated in the recommendation for consideration in preparation of the VE report.

At the conclusion of the VE workshop, each of the teams' workbooks are compiled into a single volume, the VE Job Plan Workbook.

Follow-Up or Implementation Phase - The VE study will have no value if its recommendations are never implemented, or are delayed until only a few are feasible. Thus, expeditous completion of Steps 11 and 12 in Figure 1 is important. Pride of authorship will make the Designer less than enthusiastic about suggested changes. Having selected the Designer, and having been a part of the Step I study, the Owner's staff has a similar pride of authorship. To a lesser degree, the State and Federal environmental protection agencies identify with the logic paths that led to the existing design. To a greater or lesser degree, there are many who would interpret VE recommendations for change as a criticism of either their design efforts, or of their concurrence with the design as it developed. The VE Team Coordinator is biased toward change. Having been assigned to develop better ideas, he must expect client dissatisfaction if none result. By the nature of roles, the Team Coordinator is the constant force for change. For that reason, the VE study program gives to the Coordinator the task of pulling together the best of the study suggestions, presenting them in an objective manner, and following up to insure that the Designer has fully understood every advantage of the recommended changes.

Certain negative reactions may be expressed during this phase, and a carefully conducted and well-documented VE study is essential to answering these objections. It is the VE Team Coordinator's responsibility to see that the VE study recommendations are fully considered. The astute VE Coordinator will include on his study teams, members from the Owner's staff, the Designer's staff (within the limitations discussed), and State agency and EPA regional offices. By helping to develop the VE study recommendations, they will understand the changes, and have the background to objectively support the VE recommendations.

The VE Report

The Oral Presentation - As the last step of the Project Workshop, the VE Team Coordinator makes an oral presentation. This presentation includes all recommendations of the VE Teams. The response from those attending the presentation will enable any concerns expressed to be addressed in the written, preliminary report.

Preliminary Report - This report is prepared by the VE Team Coordinator from the information contained in the VE Job Plan Workbook. The VE Job Plan Workbook, calculations, and other detailed data must be included in an appendix.

V.E. RECOMMENDATION

ITEM: Pump Station

PROPOSED CHANGE:

1. Relocate the pipelines. This provides a savings in initial cost.

2. Reduce the initial pumping capacity by using 3 pumps, 24 mgd each, and add one 24 mgd pump at 12 years rather than using 3 pumps at 33.6, 38.5, and 39.5 mgd capacity. This provides a saving in initial and total costs.

3. Achieve motor speed adjustment through frequency change instead of with liquid rheostat control. This will enable use of squirrel cage motors instead of wound rotor motors. The change will improve energy and maintenance costs.

COST SUMMARY	
INITIAL - ORIGINAL	$1,805,300
INITIAL - PROPOSED	1,511,400
INITIAL SAVINGS	293,900 (16%)
TOTAL ANNUAL COSTS - ORIGINAL	377,000
TOTAL ANNUAL COSTS - PROPOSED	287,000
ANNUAL SAVINGS	90,000 (24%)
PRESENT WORTH - ANNUAL SAVINGS	880,000

The report should include:

- Overall project description, including project estimated construction cost
- Present design, showing cost and drawings
- Proposed design, showing cost and sketches
- Estimated implementation costs
- Implementation procedures, timing, and problems, if any
- Instant contract savings
- Operations, maintenance, and replacement cost savings
- Total life-cycle costs

This method of expressing cost savings should be presented in both present-worth amounts and in annual savings amounts, in accordance with EPA cost effectiveness analysis guidelines. In addition, the savings should be presented as percent of system and percent of entire construction costs or total annual costs.

Distribution of the preliminary report by the VE Team Coordinator shall include at least the following:

	No. of Copies	
Designer	2	Action Copies
Owner	2	
State Pollution Control Agency	2	Information Copies
EPA, Regional Office	3	

Preliminary Report Review - The Designer and the Owner shall review the preliminary VE study report. It is their responsibility to accept or reject the proposals of the report. The report copies for EPA and the State agency are information copies. After the Designer has evaluated the preliminary report, a conference should be considered between the Owner, Designer and VE Coordinator to insure that no VE recommendations are rejected due to lack of communication between Designer and VE Team Coordinator, and that the Owner has an opportunity to hear both sides of any differences of opinion.

Final VE Report - The Designer prepares a final VE study report describing those VE recommendations accepted and those rejected. He responds to all recommendations contained in the preliminary report.

For those recommendations accepted, an implementation plan, schedule, and costs are shown. In addition, the resultant savings are presented in present worth amount and in amortized form, including the following:

a. Initial cost savings
b. Operating, maintenance and replacement cost savings
c. Implementation costs
d. Improvements in reliability, maintenance, or operation

For those recommendations rejected by the Designer and/or Owner, justification for rejection shall be included in the report. Rejection may be based on cost effectiveness, reliability, project delay, unusual operating and maintenance problems, and other factors that may be critical to the treatment process or to the environmental assessment.

The Designer shall include in this report his redesign fee associated with the accepted recommended changes and an appropriate request for a Step II grant amendment. Two copies of the final VE study report shall be sent by the Designer to the EPA Regional Office with agreed upon numbers of copies being sent to the State Pollution Control Agency for review and approval. If the EPA and/or State disagrees with the justification for rejection of any recommended VE change, they may call a meeting with the Owner, Designer, VE Team Coordinator, State and EPA to resolve the differences so that approval may be granted.

TYPICAL VE IDEAS AND RESULTS FOR WASTEWATER PROJECTS

It is the purpose of this section to describe some ideas generated in past VE efforts on wastewater projects to illustrate the nature of ideas generated in the speculative phase. These illustrative ideas (presented below in the general technical areas of site, electrical/energy, structural, and process) are followed by specific ideas and results from actual workshops.

Site

Consolidate structures
Relocate structures
Replace grass with ground cover or gravel
Reduce roads, walks
Change paving type
Reroute pipes
Shorten utilities runs
Do landscaping with in-house staff
Reduce fencing
Use plant effluent for irrigation
Relocate site
Modify on-site parking
Change plant layout
Purchase more land
Change hydraulic profile

Electrical/Energy

Use methane for fuel
Recycle waste heat
Use solar energy
Use independent power source for backup rather than on-site generator
Use intermediate weight conduit
Use plastic conduit with concrete envelope
Use direct burial cable
Use precast manholes
Space manholes further apart
Use multiplexing control systems
Reduce lighting levels
Change lighting fixture type
Relocate load centers
Use aluminum instead of copper
Use switches and fuses rather than circuit breakers
Modify heating and cooling ducts
Modify insulation

Change fuel source

Structural

Combine buildings
Use multi-story buildings
Use pre-engineered or pre-fabricated buildings
Minimize building area by use of outdoor equipment
Revise interior finishes
Use precast structural system
Change wall siding material
Change roofing material
Use high strength concrete, steel
Use lightweight concrete
Use steel tanks
Use post-tensioned concrete
Vary wall and slab thickness
Use gunite construction
Simplify formwork
Use metal stairs
Use common wall construction
Reduce reinforcing steel in concrete
Relocate or omit water stops
Replace precast covers with metal decks
Optimize tank dimensions
Use tension rings
Eliminate windows
Consolidate doors
Revise door types
Use drywall
Change framing materials

Process

Use flow equalization to reduce peak loads
Change pump type
Use multiple, stepped constant speed pumps rather than variable speed
Change unit process
Combine unit processes
Use existing structures for different function
Use gravity flow rather than pumping
Change pipe material
Combine pumps
Change hydraulic gradient
Use open channels rather than pipe
Use factory assembled pump stations
Reduce number of valves
Use common trench construction
Change valve type
Change aerator type
Implement water conservation program
Realign sewer routes

Plainville, Connecticut Workshop - This section summarizes a VE workshop which was conducted on the Plainville plant when the design was 15% complete. The treatment plant studied was an existing secondary treatment plant with present flow of 1.7 million gallons per day (MGD) to be expanded to a 3.8 MGD capacity to include tertiary treatment facilities to meet the following treatment levels:

				Final Effluent	
Parameter (mg/l)	Design Inf.	Primary Eff.	Secondary Eff.	W/Filtration	W/Filtration & Chemicals
BOD	180	126	10	5	2
Suspended Solids	200	80	20	10	1
Ammonia Nitrogen	33	33	2	2	2
Phosphorus as P	20	20	15	14	2
UOD	371	290	24	17	12

The project construction costs previous to the VE Workshop was estimated to be $7,550,000, increased by engineering fees of $750,000 totalling $8,300,000. Prior to the VE, the recommended project included the following elements (see Figure 3):

a. New pretreatment facilities for coarse screening, grit removal, comminution and flow monitoring equipment.
b. Primary clarification - two additional primary settling tanks to operate in conjunction with the existing units.
c. New sewage pumping facilities to lift the settled sewage to the subsequent treatment units.
d. Flow equalization capacity achieved by utilization of the existing trickling filter basins and existing sewage pump station.
e. Multi-stage rotating biological disc system designed to remove 94% of the ultimate oxygen demand (UOD) present in the raw sewage influent.
f. Chemical treatment utilizing suitable coagulants in conjunction with final clarification to achieve 90% removal of the phosphorus present in the raw sewage and to insure consistent effluent quality for acceptable operation of the subsequent filtration facilities.
g. Multi-media filtration followed by disinfection and post-aeration of the final effluent to obtain 99% suspended solids removal and an effluent free of pathogenic organisms with a minimum dissolved oxygen concentration of 7.0 mg/l at point of discharge.
h. Sludge handling facilities to include utilization of the existing anaerobic digesters for primary sludge; additional heated aerobic digestion for the secondary and tertiary sludges, two vacuum filters for sludge dewatering and two new dump trucks for hauling of the dewatered sludge to the Town landfill for final disposal.

In addition to the basic treatment elements, a new administration

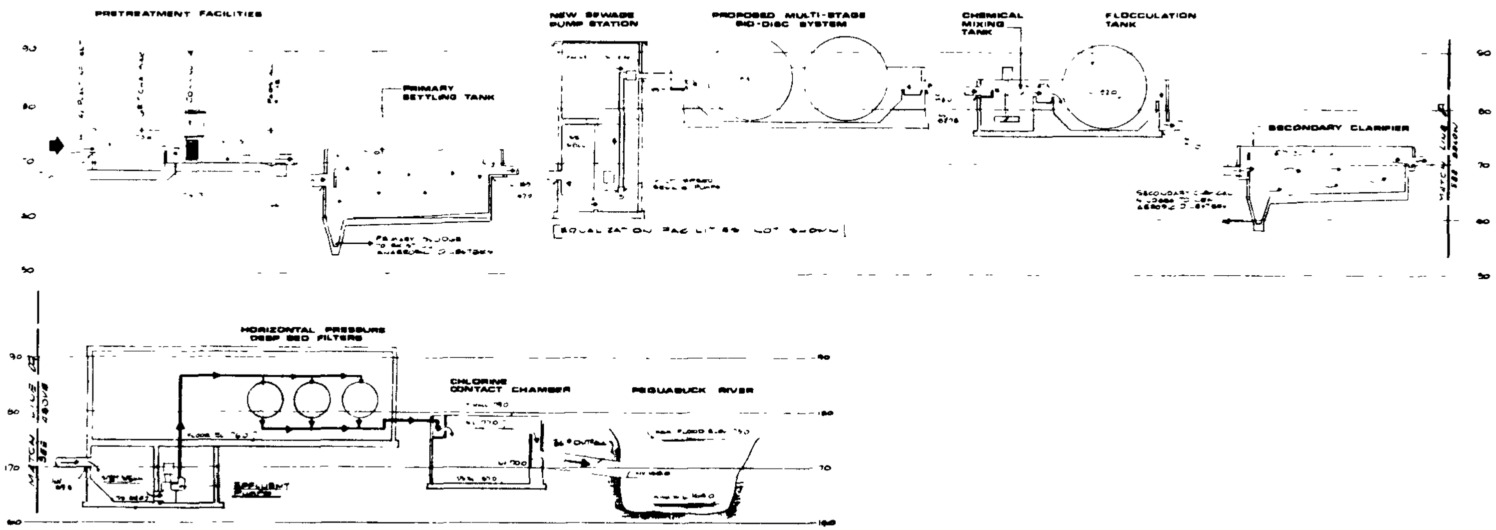


FIGURE 3

Plainville, Connecticut Process Before VE Workshop building was proposed to be erected to include room for administrative offices, laboratory facilities, maintenance shops and storage space for trucks and other related vehicles and equipment. Also proposed for the first stage of construction was greater capacity in the main interceptor entering the treatment plant.

After gaining the approval of the Town, the State Department of Environmental Protection (DEP), and EPA, the design firm retained a separate firm to conduct a VE Workshop. Five workshop teams were organized. Consisting of about five members each, the teams (Site, Energy, Process, Buildings, and Underground Structures) were composed of engineers, architects, landscape architects, a chemist, value engineering specialists, three key members of the Town of Plainville, and a member of the State DEP.

The following summarizes the major recommendations of each team:

Site - Consolidate several proposed separate structures into one building. This single structure would include the bio-discs, tertiary facilities, new pump station, new aerobic and existing anaerobic digesters, and administration building. This would substantially reduce the cost of interface piping, the item which had the highest cost-to-worth ratio.

Energy - Use heat pumps for heating and cooling using the plant effluent as a source of heat energy; use programmed electrical demand limiters on motors to allow cycling, reducing demand charges; use solar heating for space heating and domestic hot water.

Process - Use existing trickling filters instead of converting them to flow equalization basins; convert existing secondary clarifiers (which do not work hydraulically) to chlorine contact chambers; retain existing sludge beds instead of abandoning them; eliminate septic waste holding tank; eliminate 4 Bio Contactors through continued use of trickling filters; substitute conventional flocculation equipment for 2 Bio Contactors; eliminate diffusers and compressors in discarded equalization basins; use screw pumps with no building structure instead of centrifugal multi-speed pumps; use gravity in place of pressure filters; eliminate 3 pumps and standby generator by designing for gravity flow. Figure 4 shows the revised process.

Buildings - Reduce the building area required from 40,200 sq.ft. to 17,800 sq.ft. by use of outdoor-rated equipment, elimination of pretreatment building, elimination of pump station building, and consolidation of buildings.

Underground Structures - Consolidate structures to save excavation, backfill, pumping, and dewatering during construction, use of common walls and revise configuration of tank construction to produce significant savings (approximately 35% of the concrete walls and flow channels were eliminated), use high strength reinforcing as well as substitution of wood baffle walls where water tightness is not a consideration.

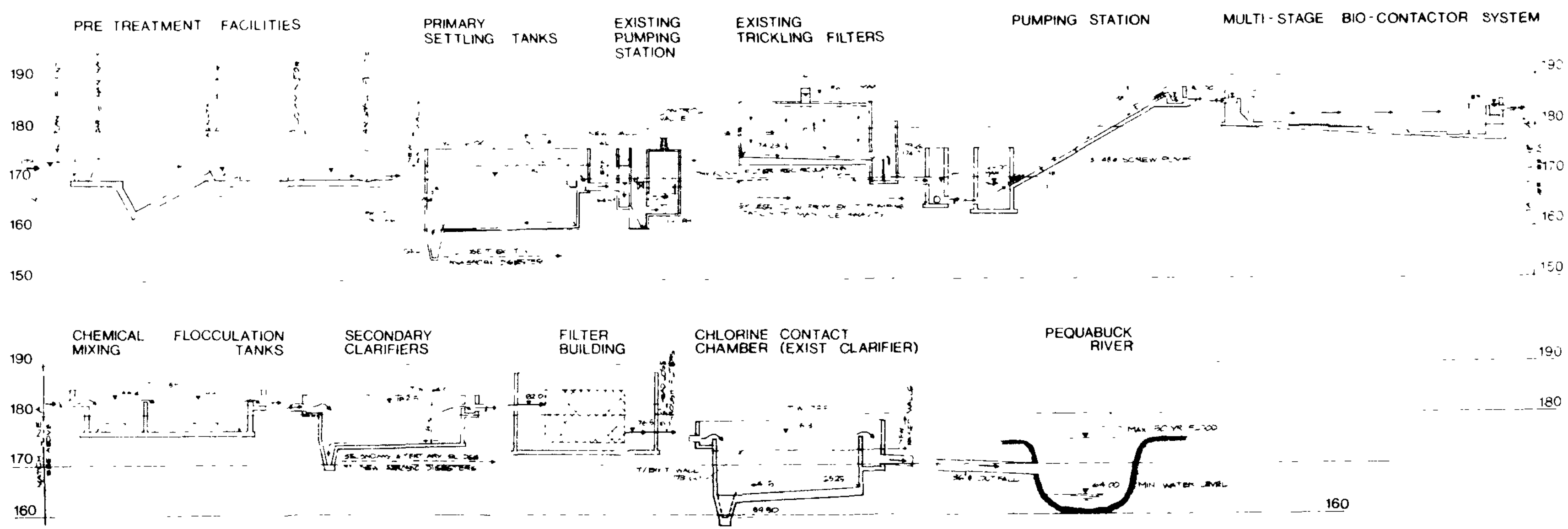


FIGURE 4

Plainville, Connecticut Process After VE Workshop

The following summarizes the cost savings by teams:

Team		First Cost Savings	Annual OMR Cost Savings	
(1)	Site	$ 316,600	$ 38,400	
(2)	a. Energy-Mechanical	155,600	22,500	
	b. Energy-Electrical	73,400	89,900	
(3)	Process	209,000	28,000	
(4)	Buildings	322,300	33,800	
(5)	Underground Structures	362,000	-	
	TOTALS	$1,438,900(100%)	$212,600	(100%)

Base Cost Pre-Workshop	7,550,000	533,000	
Workshop Savings	1,438,900(100%)	212,600	(100%)
Savings (New Budget)	1,151,120(80%)	-	
New Budget Design to Cost Model	$6,398,880	$320,400	

The significance of the above savings can be demonstrated when related to first cost, financing, administration, and accumulated maintenance, operation and replacement (OMR) costs during the life of the project. The 30 year Life Cycle Cost (Total Savings) is $9,000,000 (first cost savings of $1,151,120 with assoicated interest and annual OMR savings of $212,600). The local government will be recipients of the major portion, or $6,600,000 of the $9,000,000 overall savings, the major portion of which occurs in the form of OMR Savings. Converting the above savings to a present worth value may be summarized as follows:

	Present Worth, Savings	
	Total	Local Portion
First Savings	$1,151,120	$ 287,780(25% of total)
OMR Savings ($212,600/yr., 7% interest, 30 years)	2,636,240	2,636,240(100% of total)
TOTAL	$3,787,360	$2,924,020(77% of total)

These savings are those projected by the VE study but implementation of the recommended changes was still pending at the time of preparation of this workbook. The cost of the VE study was about $50,000.

Ocean County Sewerage Authority Workshop - This workshop was conducted on a regional wastewater treatment facility with treatment units designed for a peak hydraulic capacity of 41.2 mgd. Unfortunately, the VE study was made after the design was completed. As a result, the scope of the VE effort was limited and excluded any review of the treatment process or any proposals which would delay the original schedule. In spite of these restrictive circumstances, changes resulting in initial savings of about $700,000 were actually implemented.

The treatment plant consisted of the following processes:

- influent pump
- aerated grit removal
- primary clarification
- activated sludge aeration basin
- secondary clarification
- anaerobic sludge digestion and centrifugation
- chlorination
- ocean outfall

The cost of the project was estimated by the design consultant as $43,907,000. Four areas were investigated in the VE study: Piping and pumping; structural; sludge handling facility; electrical. The following paragraphs summarize the major proposals of the VE teams.

Pumping and Piping

Relocate pipelines (influent line, outfall, storm drain)and resize influent pumps from 3 ea. at 33.6, 38.5, 39.5 MGD to three 24 MGD pumps initially and add one(1) 24 MGD no sooner than twelve years. Adjust motor speed through frequency change instead of with liquid rheostat control enabling use of squirrel cage motors in lieu of wound rotor motors. Use unlined ductile iron pipe in lieu of glass lined ductile iron pipe for grit and septic sludge lines. Use schedule 80 PVC for potable water. Use no Hub CI soil pipe for sanitary lines. Reduce the number of lawn sprinkler heads.

Structural

Retain digester wall heat by using insulation, reduce wall and mat thickness using tension rings and eliminate parapet. For primary and scondary clarifiers: reduce wall thickness, reduce reinforcing steel, reduce slab thickness.

Sludge Handling Facility

Reduce the weight of the roof section by using metal decks, rigid insulation, achieve roof pitch by tapering the insulation or sloping the structural steel and use cantilevered beams where possible. For the exterior wall, use utility brick and reduce the thickness of backup blocks. Eliminate parapet and limestone coping in favor of a gravel stop.

Electrical

Use fiber conduit in concrete rather than rigid steel conduit for power and control ducts. Use intermediate weight conduit rather than heavy weight conduit. Reduce minimum conduit size from 3/4-inch to 1/2-inch. Reduce lighting levels. Use less expensive lighting fixtures. Eliminate two manholes. Use lead acid batteries in place of nickel cadmium.

The cost savings as estimated by the VE teams were:

	First Cost Savings	Annual Savings
Pumping and piping	500,000	90,800
Structural	790,000	-
Sludge handling	220,600	-
Electrical	500,000	126,000
	2,010,600	216,800

The teams felt that if the VE effort had been carried out earlier, there were added areas that could have been considered. For example, the electrical team felt that evaluation of obtaining peaking power from solar energy (especially since solar energy peaks correspond to the plant peak power demand) and reduction of energy costs through process changes were two specific areas in this category. This study underscores the need for proper timing of the VE study.

A detailed evaluation of the VE recommendations by the design engineer and the State and Federal regulatory agencies lead to the adoption of items which had the following savings and associated redesign costs:

	Savings, Capital OMR	VE and Redesign Costs
Pumping and piping	108,000	3,640
Structural	110,640	10,760
Sludge Handling	275,000	17,360
Electrical	203,400	22,200
	697,040	53,960
Cost of VE study	-	54,750
Cost of Review by Designer	-	17,400

Some of the ideas suggested by the VE teams were rejected based upon a common agreement by the Designer, Owner, State Agency and EPA because of potential delays in the project schedule as well as other valid reasons.

APPENDIX A

WORKSHEETS

COST WORKSHEET

Item	Units	No. Units	ORIGINAL ESTIMATE		NEW ESTIMATE	
			Cost/Unit	Total	Cost/Unit	Total

COST VALIDATION

PROJECT COST SUMMARY

ITEM	ORIGINAL ESTIMATE	UPDATED ESTIMATE
Sitework		
Structures		
Major Equipment		
Piping		
Electrical		
Heating, Ventilating, Air conditioning		
Miscellaneous Equipment		
Other:		
______________		
______________		
______________		
______________		
SUBTOTAL		
Contingencies		
TOTAL		

Worksheet 3

ITEM:	
BASIC FUNCTION:	

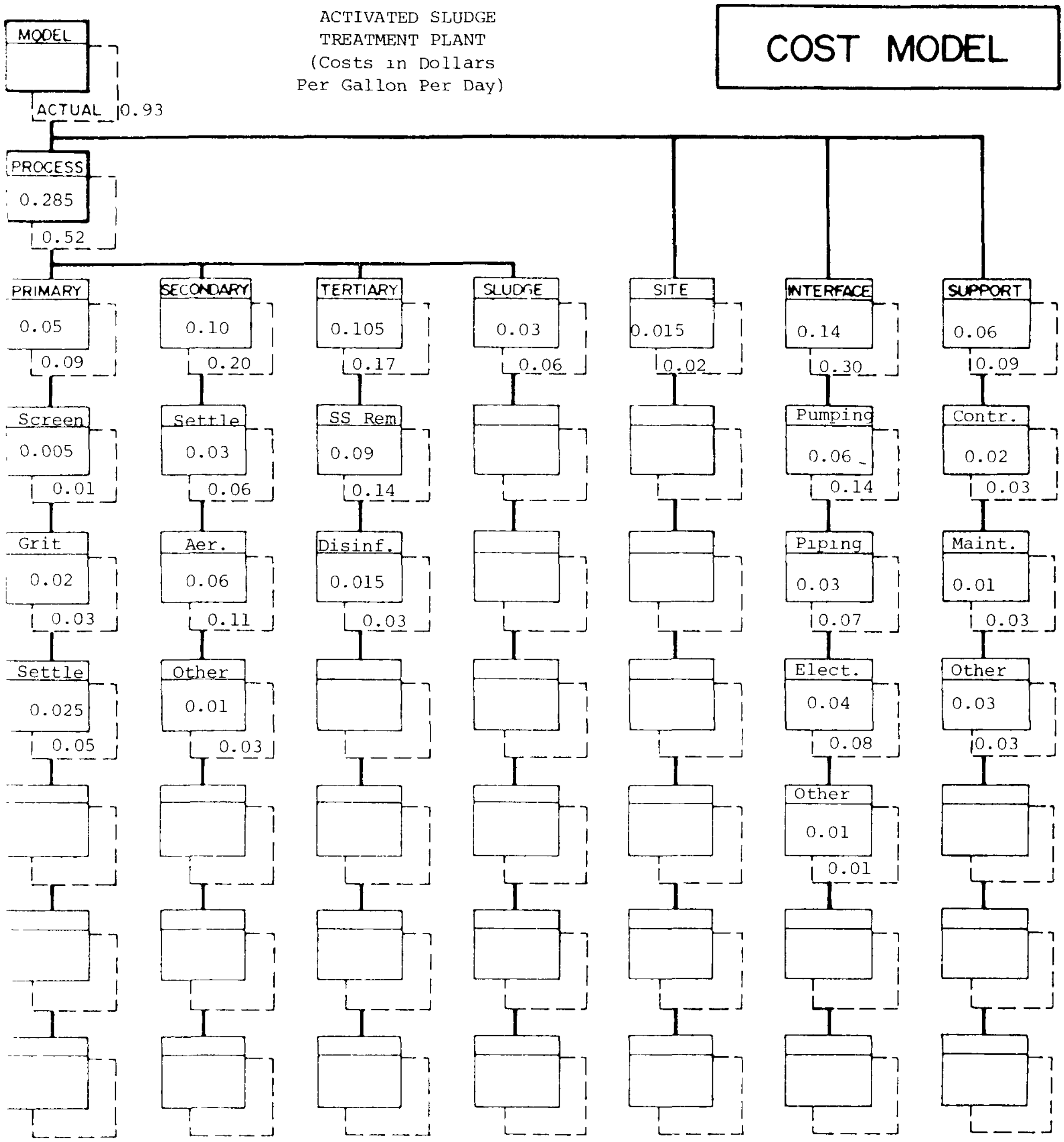
FUNCTIONAL ANALYSIS

FUNCTIONAL ANALYSIS

ITEM	FUNCTION			COST	WORTH	COMMENTS
	Verb	Noun	Kind *			

* B = Basic
S = Secondary

Worksheet 4 - Example



LIST ALL IDEAS –
EVALUATE LATER

SPECULATIVE PHASE

ITEM:	
BASIC FUNCTION:	

FAST DIAGRAM

ITEM:

FAST DIAGRAM

HOW

WHY

IDEA EVALUATION

ITEM:	
BASIC FUNCTION:	

IDEA	ADVANTAGES	DISADVANTAGES	IDEA RATING *

* 10 = MOST DESIRABLE, 1 = LEAST DESIRABLE

LIFE CYCLE COSTS

ITEM:

INITIAL COSTS	ORIGINAL	ALT. 1	ALT. 2	ALT 3
Base Cost				
Interface Costs (a)				
(b)				
Other Initial Costs (a)				
(b)				
TOTAL INITIAL COST				
REPLACEMENT COSTS				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
SALVAGE VALUE				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
Year ____ @ ____ % Amount ____				
Present Worth of Future Replacement Cost				
ANNUAL COSTS				
Amortized Initial Cost @ ____ % ____ Year ____				
Capital Recovery of the Present Worth of the Replacement Cost				
(a) Year				
(b) Year				
(c) Year				
Annual Costs				
(a) Maintenance				
(b) Operations				
(c)				
TOTAL ANNUAL COSTS				
Annual Salvage Value Credit (Amortized)				
(a)				
(b)				
NET ANNUAL COSTS				
Annual Difference				
PRESENT WORTH OF ANNUAL DIFFERENCE				

ALTERNATIVE EVALUATION

ITEM:	

	FACTORS *									
	CAPITAL COST	O & M COST	REDESIGN	IMPLEMENTATION TIME	PERFORMANCE	RELIABILITY	SAFETY			TOTAL	RANK
FACTOR WEIGHT 10 = MAXIMUM ▶											

* EXCELLENT = 4, GOOD = 3, FAIR = 2, POOR = 1

V.E. RECOMMENDATION

ITEM:	

PROPOSED CHANGE:

COST SUMMARY	
INITIAL - ORIGINAL	
INITIAL - PROPOSED	
INITIAL SAVINGS	
TOTAL ANNUAL COSTS - ORIGINAL	
TOTAL ANNUAL COSTS - PROPOSED	
ANNUAL SAVINGS	
PRESENT WORTH - ANNUAL SAVINGS	

APPENDIX B

BIBLIOGRAPHY

BIBLIOGRAPHY

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APPENDIX C

GLOSSARY OF VE TERMS

Glossary of VE Terms

<u>Value Engineering (VE)</u>

A specialized cost control technique which is based on a systematic and creative approach to identify unnecessarily high cost in a project in order to arrive at a cost saving without sacrificing the reliability or efficiency of a project.

<u>VE Team Coordinator</u>

A person who is qualified to direct and conduct a VE study on a waste treatment project. The VE team coordinator must have sufficient VE background to meet the qualifications specified by the Environmental Protection Agency.

<u>VE Study or VE Workshop</u>

A project study or review session where the objective is to review an actual project to propose cost saving alternatives to the designer. The workshop is performed by a VE team or teams chaired by a VE team coordinator. Each team session may take 40 hours or less depending on the size and the complexity of the project. Sometimes, a review session may be divided into 2 or 3 sub-sessions of 8 to 24 hours each.

<u>VE Training Workshop</u>

A workshop where the major objective is to provide at least 40 hours of academic training in VE methodology with application of the methodology to example or actual projects.

<u>Life Cycle Costs</u>

Ownership costs for the functional life of the project. It includes cost for design, construction, operation, maintenance and replacement.

<u>Implementation Cost</u>

Costs incurred for implementing the VE recommended changes. This normally includes costs for reviewing the VE change proposal, final report writing and project redesign (if required).

<u>Cost Effectiveness</u>

The economy and effectiveness of performing a required function in terms of life cycle cost.

APPENDIX D

EPA COST-EFFECTIVENESS ANALYSIS

GUIDELINES

COST-EFFECTIVENESS ANALYSIS GUIDELINES

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—GRANTS

PART 35—STATE AND LOCAL ASSISTANCE

Appendix A—Cost-Effectiveness Analysis

On July 3, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing guidelines on cost-effectiveness analysis pursuant to section 212(2)(c) of the Federal Water Pollution Act Amendments of 1972 (the Act) to be published as appendix A to 40 CFR part 35.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. No changes were made in the guidelines as earlier proposed. All written comments are on file with the agency.

Effective date.—These regulations shall become effective October 10, 1973.

Dated September 4, 1973.

JOHN QUARLES,
Acting Administrator.

APPENDIX A

COST EFFECTIVENESS ANALYSIS GUIDELINES

a. *Purpose.*—These guidelines provide a basic methodology for determining the most cost-effective waste treatment management system or the most cost-effective component part of any waste treatment management system.

b. *Authority.*—The guidelines contained herein are provided pursuant to section 212 (2)(C) of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

c. *Applicability.*—These guidelines apply to the development of plans for and the selection of component parts of a waste treatment management system for which a Federal grant is awarded under 40 CFR, Part 35.

d. *Definitions.*—Definitions of terms used in these guidelines are as follows:

(1) *Waste treatment management system.*—A system used to restore the integrity of the Nation's waters. Waste treatment management system is used synonymously with "treatment works" as defined in 40 CFR, Part 35.905–15.

(2) *Cost-effectiveness analysis.*—An analysis performed to determine which waste treatment management system or component part thereof will result in the minimum total resources costs over time to meet the Federal, State or local requirements.

(3) *Planning period.*—The period over which a waste treatment management system is evaluated for cost-effectiveness. The planning period commences with the initial operation of the system.

(4) *Service life.*—The period of time during which a component of a waste treatment management system will be capable of performing a function.

(5) *Useful life.*—The period of time during which a component of a waste treatment management system will be required to perform a function which is necessary to the system's operation.

e. *Identification, selection and screening of alternatives*—(1) *Identification of alternatives.*—All feasible alternative waste management systems shall be initially identified. These alternatives should include systems discharging to receiving waters, systems using land or subsurface disposal techniques, and systems employing the reuse of wastewater. In identifying alternatives, the possibility of staged development of the system shall be considered.

(2) *Screening of alternatives.*—The identified alternatives shall be systematically screened to define those capable of meeting the applicable Federal, State, and local criteria.

(3) *Selection of alternatives.*—The screened alternatives shall be initially analyzed to determine which systems have cost-effective potential and which should be fully evaluated according to the cost-effectiveness analysis procedures established in these guidelines.

(4) *Extent of effort.*—The extent of effort and the level of sophistication used in the cost-effectiveness analysis should reflect the size and importance of the project.

f. *Cost-Effective analysis procedures*—(1) *Method of Analysis.*—The resources costs shall be evaluated through the use of opportunity costs. For those resources that can be expressed in monetary terms, the interest (discount) rate established in section (f)(5) will be used. Monetary costs shall be calculated in terms of present worth values or equivalent annual values over the planning period as defined in section (f)(2). Nonmonetary factors (e.g., social and environmental) shall be accounted for descriptively in the analysis in order to determine their significance and impact.

The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse nonmonetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal.

(2) *Planning period*.—The planning period for the cost-effectiveness analysis shall be 20 years.

(3) *Elements of cost*.—The costs to be considered shall include the total values of the resources attributable to the waste treatment management system or to one of its component parts. To determine these values, all monies necessary for capital construction costs and operation and maintenance costs shall be identified.

Capital construction costs used in a cost-effectiveness analysis shall include all contractors' costs of construction including overhead and profit; costs of land, relocation, and right-of-way and easement acquisition; design engineering, field exploration, and engineering services during construction; administrative and legal services including costs of bond sales; startup costs such as operator training; and interest during construction. Contingency allowances consistent with the level of complexity and detail of the cost estimates shall be included.

Annual costs for operation and maintenance (including routine replacement of equipment and equipment parts) shall be included in the cost-effectiveness analysis. These costs shall be adequate to ensure effective and dependable operation during the planning period for the system. Annual costs shall be divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater collected and treated.

(4) *Prices*.—The various components of cost shall be calculated on the basis of market prices prevailing at the time of the cost-effectiveness analysis. Inflation of wages and prices shall not be considered in the analysis. The implied assumption is that all prices involved will tend to change over time by approximately the same percentage. Thus, the results of the cost effectiveness analysis will not be affected by changes in the general level of prices.

Exceptions to the foregoing can be made if their is justification for expecting significant changes in the relative prices of certain items during the planning period. If such cases are identified, the expected change in these prices should be made to reflect their future relative deviation from the general price level.

(5) *Interest (discount) rate*.—A rate of 7 percent per year will be used for the cost-effectiveness analysis until the promulgation of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources." After promulgation of the above regulation, the rate established for water resource projects shall be used for the cost-effectiveness analysis.

(6) *Interest during construction*.—In cases where capital expenditures can be expected to be fairly uniform during the construction period, interest during construction may be calculated as $I \times \frac{1}{2} P \times C$ where:

I = the interest (discount) rate in Section f(5).
P = the construction period in years.
C = the total capital expenditures.

In cases when expenditures will not be uniform, or when the construction period will be greater than three years, interest during construction shall be calculated on a year-by-year basis.

(7) *Service life*.—The service life of treatment works for a cost-effectiveness analysis shall be as follows:

Land	Permanent
Structures (includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)	30–50 years
Process equipment (includes major process equipment such as clarifier mechanism, vacuum filters, etc.; steel process tankage and chemical storage facilities; electrical generating facilities on standby service only).	15–30 years
Auxiliary equipment (includes instruments and control facilities; sewage pumps and electric motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators, etc.; electrical generating facilities on regular service).	10–15 years

Other service life periods will be acceptable when sufficient justification can be provided.

Where a system or a component is for interim service and the anticipated useful life is less than the service life, the useful life shall be substituted for the service life of the facility in the analysis.

(8) *Salvage value*.—Land for treatment works, including land used as part of the treatment process or for ultimate disposal of residues, shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. Right-of-way easements shall be considered to have a salvage value not greater than the prevailing market value at the time of the analysis.

Structures will be assumed to have a salvage value if there is a use for such structures at the end of the planning period. In this case, salvage value shall be estimated using straightline depreciation during the service life of the treatment works.

For phased additions of process equipment and auxiliary equipment, salvage value at the end of the planning period may be estimated under the same conditions and on the same basis as described above for structures.

When the anticipated useful life of a facility is less than 20 years (for analysis of interim facilities), salvage value can be claimed for equipment where it can be clearly demonstrated that a specific market or reuse opportunity will exist.

[FR Doc.73-19104 Filed 9-7-73;8:45 am]

☆U.S. GOVERNMENT PRINTING OFFICE: 1980-0-677-094/1133