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FIELD TEST SAMPLING/ANALYTICAL STRATEGIES AND IMPLEMENTATION COST ESTIMATES: COAL GASIFICATION AND FLUE GAS DESULFURIZATION

J. W. HAMERSMA, ET AL

TRW SYSTEMS GROUP
REDONDO BEACH, CALIFORNIA

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COAL GASIFICATION AND FLUE GAS DESULFURIZATION

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ABSTRACT

The report gives results of a determination of sampling and analysis implementation costs for two energy related process technologies: wet limestone scrubbing of flue gas and a Lurgi coal gasification system. Two different sampling and analytical approaches were costed which would yield the same information output. The first approach, requiring two levels of sampling and analytical effort, is called the phased sampling program. The second approach was a direct single effort to achieve the same level of information for decision-making as the phased approach. In the test cases, costed from sample acquisition through analysis, the phased sampling and analytical approach was the most cost effective.

PREFACE

This document describes the Development of Environmental Assessment Sampling and Analytical Test Strategies and Sampling and Analytical Costs prepared under Task 9 of EPA Contract Number 68-02-1412. It is the result of one of several studies funded by the Industrial Environmental Research Laboratory, Research Triangle Park (IERL-RTP) to provide background information relevant to the development of sampling and analytical strategies for environmental assessment programs. The conclusions and recommendations contained in the report do not necessarily constitute the strategies or methods which will be implemented by the Laboratory for such programs. A series of reports defining the approaches and techniques to be used on IERL-RTP projects will be issued beginning in February, 1976.

This work was conducted under the direction of Dr. R. M. Statnick, EPA Task Order Manager and administrative direction of Dr. L. Johnson, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. The Applied Chemistry Department of the Chemistry and Materials Laboratory, Applied Technology Division, TRW Systems and Energy, Redondo Beach, California was responsible for the work performed on this program. Dr. E. A. Burns, Manager, Applied Chemistry Department, was Program Manager and the Task Order Manager was Dr. J. W. Hamersma.

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1.0 SUMMARY

This section includes a detailed summary of the results of this study which is designed to stand alone as a separate document, if desired. For this reason, several Tables and Figures from the succeeding sections are included here.

1.1 BACKGROUND

To facilitate the development of a sampling and analysis strategy, the number of scenarios considered was limited to those that would best illustrate the advantages of a coherent environmental sampling and analytical strategy. Four scenarios are described in this document which stem from treating two technologies by two different approaches. It is also further assumed that the assessment would be performed only on a full-scale demonstration or commercial plant and that minimal or no information would be available from environmental tests performed on bench or pilot scale units. Thus, each case would be treated as an entire unit in which all feedstock, waste and product streams would be evaluated.

The wet limestone scrubber flue gas desulfurization (FGD) unit and the Lurgi coal gasification process were chosen as examples of two new technologies of interest to the EPA. In both cases, data are presently available and as a result, each technology provides a good data base for verifying the techniques used in this study. Finally, these examples represent the two extremes for technology of interest with the scrubber being the simplest and the coal gasifier one of the largest and most complex.

Two separate approaches have been chosen for the purposes of this report:

- The phased approach in which two sampling trips of differing aims and complexity are made to a given site, and
- The direct approach where an attempt is made to obtain samples in a single effort.

1.2 DEFINITION OF STRATEGIES

The philosophy, information benefits and cost implications of each strategy are discussed in detail in the following sections.

1.2.1 The Phased Approach

The phased approach requires two separate levels of sampling and analytical effort. The first level, which utilizes qualitative and/or semi-quantitative sampling and analysis procedures, identifies problem areas and allows the prioritization of certain streams, components and classes of materials. The second, level 2, sampling and analysis effort provides more detail on those streams identified in level 1 as being environmentally significant; level 2 will provide the information to resolve the questions or data gaps identified in level 1. This information will be used to define the control technology needs and may, in some cases, give the probable or exact cause of a given problem.

The level 1 and 2 sampling and analysis efforts are intimately linked in the overall environmental assessment effort. Level 1 and level 2 are the bases for environmental assessments; they differ only in the information output. For example, if a level 1 test showed the presence of 3-to 7-ring aromatics (PNA) and gave a positive mutagenicity test, level 2 sampling and analysis would be designed to determine the exact quantities of organics, the percentages of PNA, and the identity of as many specific PNA compounds present as possible. In addition, using the level 1 data and any available level 2 results, the sample is again tested for cytotoxicity and mutagenicity in order to confirm and expand the bioassay information. A test for carcinogenicity is also run if the results of these tests are positive. The entire data package can then be used to assess the control technology R&D needs for the stream.

Level 1 sampling and analysis has as its goal the identification of the environmental significance of a source in a qualitative and/or semi-quantitative manner. At the initiation of an environmental assessment, little is known about the specific sampling requirements of a source both practically and technically and hence, the emphasis is on survey tests. For this reason, no special procedure is employed in obtaining a quantitatively representative sample and the chemical, physical and biological testing is of a qualitative and survey nature consistent with the characteristics of the sample.

Level 2 sampling and analysis has as its goal to provide definitive data for use in the environmental assessment of a source. In order to perform this in a timely and cost effective manner, the basic questions to be answered and major problem areas must already have been defined in level 1. Consequently, level 2 sampling and analysis is characterized by obtaining representative samples, accurate stream flow rates, and by identification and quantification of specific organic and inorganic chemical classes and individual species. In this effort, biotesting in selected areas is expanded to include dose response data and also carcinogenicity testing.

The results of this effort will provide sufficient information concerning the problems delineated on level 1 in the areas of physical characteristics, organic and inorganic chemical species, and biochemical assaying such that control stream priorities and an initial estimate of process/control system regions of overlap can be established.

1.2.2 The Direct Approach

The second approach that was examined was the direct single effort approach designed to achieve the same level of information for decision making as in the phased approach. Because nothing can be assumed, the sampling and analysis effort must be planned to cover all components in all streams. Although conceptually this approach is much simpler than the phased approach, it will be shown that as the system becomes more complex, it is not nearly as cost effective as the phased approach.

A direct approach is philosophically attractive for several reasons. The primary reason is that by planning and executing a single comprehensive sampling and analysis effort, the environmental assessment can be performed in a shorter period of time and thus minimize problems with the operators of the source. In addition, this approach holds out the seldom achieved possibility that the effort can be accomplished without making a return sampling trip, and the resultant savings can be used to pay for analysis that would not have been performed had even a small amount of information been known about a stream.

The second area where the direct approach is attractive concerns sources for which considerable information is already available and sources which are similar to several other sources that have already been evaluated. In these instances prior knowledge can take the place of the level 1 effort and serve to focus the direct level 2 effort.

The overall data requirements of the direct approach are the same as for the phased approach. This requires that the same level of information required for the overall assessment be obtained directly as that which was obtained previously in two phases. Thus in the absence of definitive information to the contrary, the sampling and analysis effort must contain provisions for treating all components of all streams in a quantitative manner. This is a very difficult proposition in actual practice because of sampling and analysis "surprises" that may make even the most elaborately taken sample and most conservatively performed analysis inadequate. Thus, in many cases, specific streams will have to be resampled in order to obtain information equivalent to that proposed for the phased approach. Because the direct level 2 approach is presently being practiced by the EPA and various EPA contractors, there is considerable experience to support this contention. The required repeat effort has been demonstrated to be between 25 and 50%. An intermediate figure of 35% has been used for this study. However, since this factor is being called out separately, it can be altered readily if desired.

1.3 USE OF COST UNIT (C.U.)

In order to facilitate pricing of the manpower and analysis, it was desired to use a unit of cost larger than the dollar. For this purpose, the cost unit (c.u.) was defined to be equal to $250. In terms of site sampling manpower costs, this is approximately equal to one man-day of fully burdened labor including $70 of per diem and other general direct costs (ODC's). The primary advantage of the c.u. is that by not using dollars directly, the costing process can be implemented objectively without the accumulated biases associated with dollar costs. Furthermore, the cost unit permits ready utilization of correction factors (repeat analysis) and application of economic factors in the future. In most summary tables, however, a dollar figure is also given.

1.4 SAMPLING

Only process feed, waste and product streams were considered for this effort. The principal reasons for this are that analyses of feed streams are necessary to establish a baseline for potential contaminants and only waste and product streams will have a direct effect on the environment. Internal process streams, besides varying greatly from plant to plant, have no environmental effect except in cases of leakage where the problem becomes one mainly concerned with fugitive emissions. For this reason, a fugitive emission study was included.

1.4.1. Classification of Streams for Sampling and Costing Purposes

The basic sampling strategy has been organized around the six general types of sampling found in coal gasification or other complex technologies rather than around the analytical procedures that will be required on the collected samples. In this way, the complex and difficult task of organizing the manpower and equipment necessary for successful field sampling can be made such that meaningful units of cost can be established. In general for costing purposes, it was assumed that a separate crew would be used to take all the samples for a given category and that an accurate cost could be assigned to this task.

The method used for the determination of specific costs for sample types in this study relies on data obtained from the following four sources (vide infra):

- A survey study of presently established costs obtained from commercial organizations who routinely perform sampling tasks of this nature,
- A compilation of data resulting from TRW's involvement in projects of this nature,
- Joint discussions between project members and EPA officials concerning the applicability of these data to coal conversion processes,
- The assumptions made in formulating the cost unit figure itself.

Using the gasifier as an example, these four factors were then used to compute a total on-site time for taking the required number of samples in each of the six sampling types. This was computed as follows:

$$\text{c.u./sample} = \frac{\text{Total on-site time (in man-days)*}}{\text{number of samples}}$$

These values are shown in Table 1 and are used where applicable for both the wet limestone scrubber and the coal gasifier. The six sample types are delineated below.

- Solids and Solid Slurries - These are the coal input, bottom ash, and any aqueous stream containing more than 5-10% solids.
- Liquor Streams
  - Aqueous - Water streams containing less than 5-10% insoluble solids
  - Non-aqueous - Homogeneous streams other than water streams (usually organic).
- Gas - Streams containing no significant particulate matter. These samples include process streams, process vents, and ambient air samples.
- Flue gas containing particulate matter.
- Flue gas without particulate matter - These streams are essentially the same as the gas streams except special procedures are used to sample for acid gases and PAH compounds.
- Fugitive Dust Sampling - This includes local source sampling and plant perimeter sampling employing high volume sampler techniques.

1.4.2 Phased Approach Site Selection Criteria

The selection of sampling points in processes where phased level sampling techniques are employed relies on the concept that level 1 sampling is oriented towards obtaining survey and/or semi-quantitative results only,

* Note: one cost unit (c.u.) as defined in Section 1.3 equals one man day or $250.

TABLE 1

SUMMARY OF SITE SAMPLING COSTS

Sample Type	C.U./Site		Actual $	
	Level 1	Level 2	Level 1	Level 2
1. Solids & Slurries	0.50	1.00	125.00	250.00
2. Aqueous	0.50	0.70	125.00	175.00
3. Non-aqueous	0.67	1.00	167.00	250.00
4. Gas (Non-particulate)	0.28	0.60	70.00	150.00
5a. Flue gas (Particulate)	0.91	6.00	227.00	1500.00
5b. Flue gas (Non-particulate)	-*	1.00	-	250.00
6. Fugitive dust	0.36	0.30	90.00	75.00

*Lack of particulate must be established with a level 1 test.

whereas level 2 and direct sampling programs are intended to acquire more accurately and more definitively data necessary to perform an environmental assessment. Stream parameters such as flow rates, temperature, pressure and other physical characteristics will be obtained on both levels within the accuracy requirements of a given level of sampling. Consequently, a level 1 sample may be taken from any easily accessible port within the flow scheme of a given unit. For example, in obtaining a level 1 stack sample, the probe may be inserted in any convenient location along the duct leading to the stack and a pseudo-isokinetic sample may be taken in order to obtain qualitative data. On level 2, however, where quantitative data are required, isokinetic samples must be withdrawn from specific locations away from ducting bends and other obstructions in order to ensure a sample representative of the actual effluent.

1.4.3 Sample Site Selection

The site selection model used for the wet limestone scrubber is the spray tower system installed at Paducah, Kentucky. Seven influent and effluent sampling sites were selected involving four of the six sample types discussed in the previous section. These are tabulated in Table 2. All sites are sampled in the level 1 and direct efforts. The reduction in number of sites for level 2 sampling is discussed in Section 1.4.4 below.

TABLE 2

SUMMARY OF SAMPLE SITES
WET LIMESTONE SCRUBBER

Sample Type	Number of Sites Level 1	Number of Sites Level 2	Number of Sites Direct Level 2
1. Flue Gas (Particulate)	2	2	2
2. Miscellaneous Stack Gases	2	2	2
3. Aqueous	3	2	3
4. Reheater Fuel (Organic)	1	1	1
5. Limestone Inputs (Solids)	1	1	1

The site selection model used for the coal gasifier is the Lurgi Coal Gasification Complex proposed by the El Paso Natural Gas Company for construction in New Mexico. A generalized flow scheme for sampling purposes developed under Task 3 of this Contract (EPA 68-02-1412) was used to establish the number of sample sites in Table 3. All sites are sampled on level 1 and in the direct effort. The reduction in number of sites for level 2 sampling is discussed in Section 1.4.4 below.

TABLE 3
SUMMARY OF SAMPLE SITES
COAL GASIFIER

Sample Type	Number of Sites Level 1	Number of Sites Level 2	Number of Sites Direct Level 2
1. Solids & Slurries	6	8	8
2. Aqueous	8	6	8
3. Non-aqueous (Organic)	6	4	6
4. Gas (Non-particulate)	32	20	32
5a. Flue Gas (Particulate)	5	3	5
5b. Flue Gas (Non-particulate)	-	3	-
6. Dust (Fugitive)	11	11	11

1.4.4 Stream Prioritization for the Phased Approach

A coal gasification process is a highly complex system consisting of a wide variety of interrelated components. Level 1 sampling will show that many influent, waste and product streams are not environmentally significant. These data can serve to reduce the number of samples required on level 2 substantially. A limestone wet scrubber, on the other hand, is a very simple process as compared to a gasification system. The streams which require sampling are small in number which naturally limits the number of streams which can be assigned a low priority utilizing a phased sampling approach. Thus it is important to remember that level 1 is designed to allow allocation of resources so that level 2 can provide the desired information for an environmental assessment. Direct level 2 sampling by definition can have no stream prioritization, and thus the maximum number of sites will always be sampled in this approach.

A comprehensive stream prioritization based on the level 1 sampling and analysis effort will result in the definition of many streams of low priority. In many cases, the level 1 information will be sufficient to eliminate certain streams entirely from the level 2 effort. In some cases, limited resources may require the omission of certain low priority streams.

For the purposes of this study, it was desirable to assign conservative, but reasonable priorities to the various streams and in this manner eliminate certain streams from further consideration for the level 2 effort. In the case of the scrubber, there were so few streams that it was felt that it was not reasonable to eliminate any streams except in the trivial case of the input make-up water. However, careful examination of the gasifier streams indicated that 15-20% of the streams could reasonably be expected to be environmentally safe or of very low priority. The types and quantities of streams that were eliminated are shown in Tables 2 and 3.

1.4.5 Site Preparation Costs

Assigning a cost to this nebulous area is difficult because while the extreme cases are not rare, in most cases, these costs are low to moderate especially for the newly designed technologies being treated here. Accordingly, a reasonably low cost was assigned to site preparation with the assumption that higher costs are a special case out of the scope of this treatment.

Thus it was assumed that the erection of scaffolding and providing power would be the main site preparation cost; a further assumption was that these costs would be associated to a large extent with stack sampling as this is the most complex sampling procedure. The costs were set at $250 per stack for level 1 and $500 per stack for level 2 and direct level 2 assuming that the necessary access ports are available. In addition, preparation for the other gasifier sites which should be minimal was set at $500 for level 1, $1,000 for level 2, and $1,500 for direct level 2 corresponding roughly to 2, 4 and 6 man days, respectively.

1.5 ANALYSIS

This section summarizes the rationale used to select the analysis procedures which are used for the samples collected and describes the assumptions used to arrive at the individual unit costs.

1.5.1 Number of Samples Used for Costing

In the area of analysis, no effort was made to eliminate specific components from a given stream. All analysis reductions with the exception of the gasifier level 2 flue gas analysis are the result of the stream reductions delineated in Section 1.4. It should be noted that several sample types generate the need for two or more separate unit analysis. Thus, the ash slurry stream generates a water sample and a solids sample, and the wide boiling range organics obtained from the water and organic streams are split into $<C_6$ and $>C_6$ fractions. The flue gas particulate is collected as four samples for particulate analysis, but this is reduced to two samples for bioassay analysis. An additional trace element analysis is included on direct level 2 stack sampling for the impinger train and an additional organic analysis is added for analysis of volatile organic collected by a special tenax train. Level 2 gasifier flue gas sample analysis is postulated on the fact that no particulate was found in the gas fired boiler on level 1 analysis. Fugitive particulate samples were reduced to two samples each ($>3\mu$ and $<3\mu$) from two sets of four locations. A summary of the number of analyses is shown in Tables 4 and 5 for the gasifier and scrubber, respectively.

SUMMARY OF ANALYSIS TYPES PER OPERATIONAL CONDITION - LIMESTONE WET SCRUBBER[a)]

Sample Type	Total Samples Level 1	Total Samples Level 2	Total Samples Direct Level 2
1. Bioassay: a. Water Insoluble[b)] b. Water Soluble[b)]	10	2 4	2 8
2. Organic Analysis (per sample)	14	8	14
3. Inorganic Compound Identification	-	10	10
4. Particulate Morphology	6	6	6
5. Inorganic Element Analysis	15	15	15
6. Water Analysis	3	2	3
7. Gas Chromatographic Analysis	2	0	2

a) The number of analyses included in this table is based on the number of sites developed in Section 1.4. These numbers will be doubled if two operational conditions are sampled.

b) The distinction between water soluble and insoluble samples is made only for level 2 analysis. See Section 1.5.3.1 for details.

TABLE 5
SUMMARY OF ANALYSIS TYPES PER OPERATIONAL CONDITION - COAL GASIFIER[a)]

Analysis Type	Total Samples Level 1	Total Samples Level 2	Total Samples Direct Level 2
1. Bioassay: a. Water Insoluble[b)] b. Water Soluble[b)]	57	11 15	32 28
2. Organic Analysis	56	51	88
3. Inorganic Compound Analysis	--	28	50
4. Particulate Morphology	37	11	37
5. Coal Feed Analysis	6	8	8
6. Inorganic Element Analysis	58	47	72
7. Water Analysis	8	6	8
8. Gas Liquid Chromatography	36	27	49

a) The number of analyses included in this table is based on the number of sites developed in Section 1.4. These numbers will be doubled if two operational conditions are sampled.

b) The distinction between water soluble and insoluble samples is made only for level 2 analysis. See Section 1.5.3.1 for details.

1.5.2 Basic Analysis Scheme

The analytical schemes cited in this report are divided into 9 distinct analytical methodologies. Each of those methodologies is essentially the same for both levels of the phased approach and differ only in the level of sophistication involved.

Figure 1 illustrates a generalized flow scheme for the analytical categorization of level 1 samples. Each analysis type is assigned its own cost unit per analysis factor and a brief statement of methodology is made for each analysis type. The specific sample types to which each analytical category relate are listed beneath each group.

Figure 2 consists of a basic analysis flow scheme as applied to level 2 sampling. The diagram format is the same as that for level 1.

1.5.3 Analysis Methods and Unit Costs

The unit costs shown in Table 6 were developed using data collected from a wide variety of sources. Commercial price lists were used whenever an analysis was routine. For semi-routine analysis or very specialized analyses for which procedures are available, the appropriate authorities were consulted for their estimates of the costs. Sources included the EPA (various branches), EPA contractors (SRI, BMI, MRI, Radian), academic sources and various commercial testing laboratories. Each analysis and unit cost is briefly explained below.

1.5.3.1 Bioassay Testing

This series of tests is designed to test in a broad and general manner, the negative health effects potential of a given source stream. Level 1 bioassay includes simplified cytotoxicity and mutagenicity testing on all solid and liquid (water and organic) samples or fractions obtained. In level 2 testing, the original tests are expanded and a carcinogenicity test is added for use where appropriate. The number of samples includes all solids, liquids, and gases. In addition to the biological tests, level 1 trace element and organic tests are performed on the insoluble particulate and supernatant in order to aid in interpretation of the data. These tests are not included if the sample is entirely soluble. Level 1 and level 2 flow charts are shown separately in Figure 3.

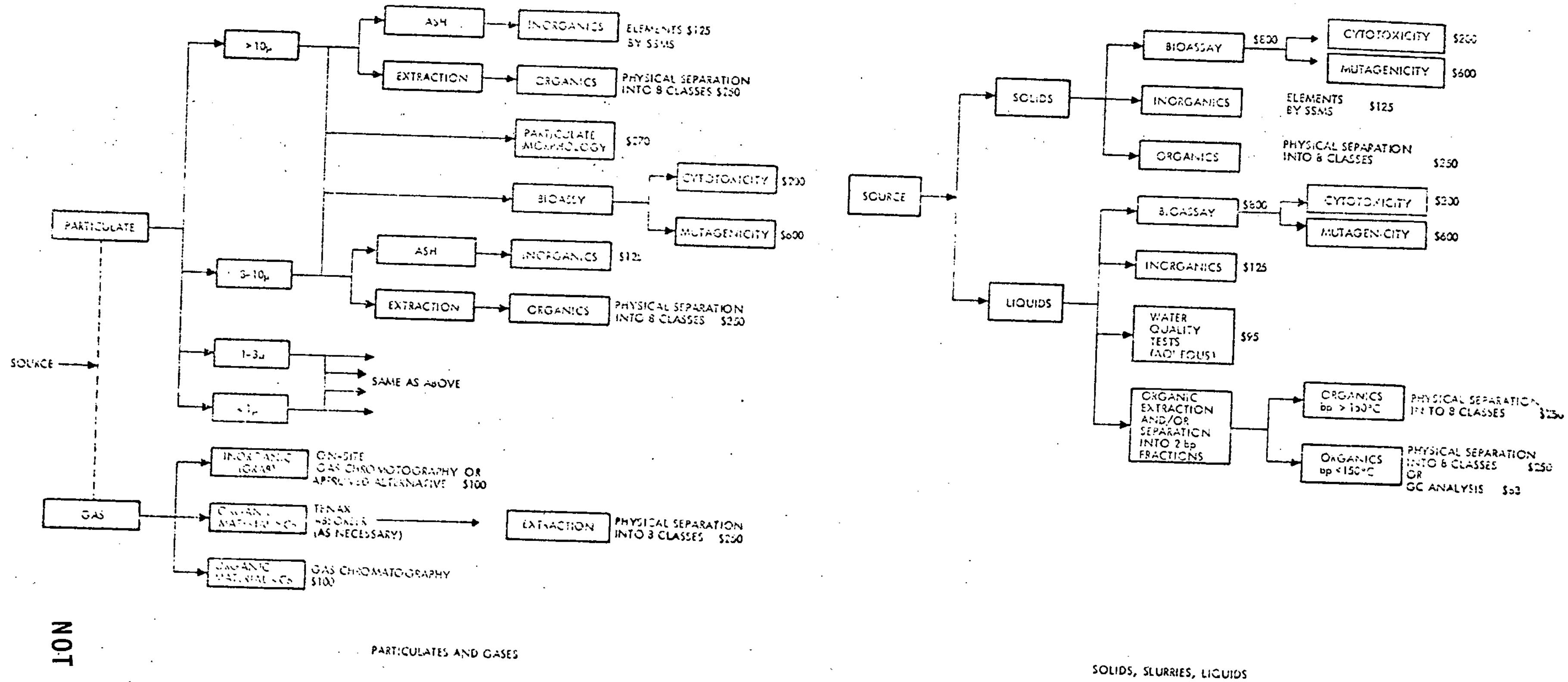


Figure 1. Basic Analytical Scheme for Level 1

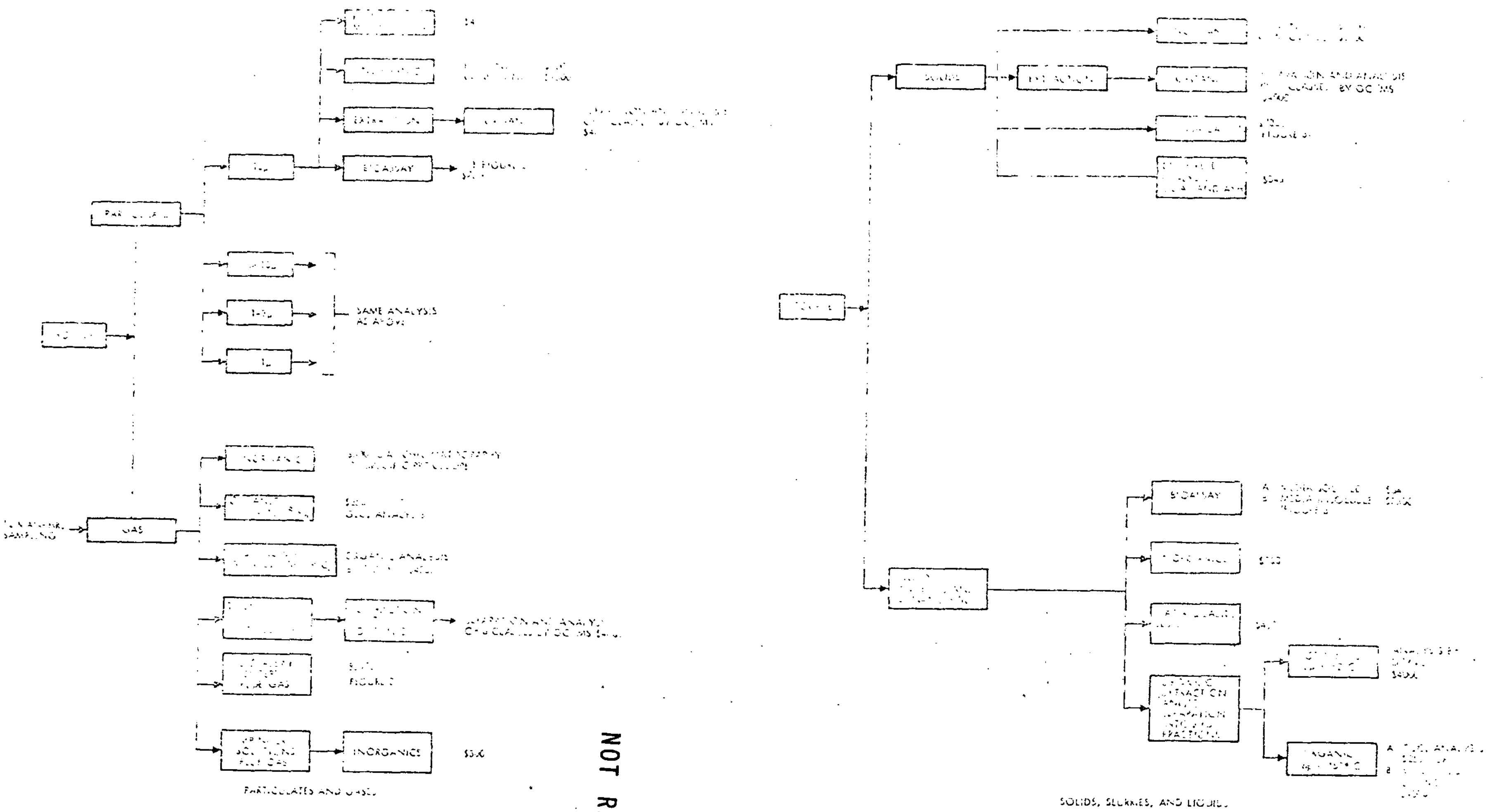


Figure 2. Basic Analytical Scheme for Level 2

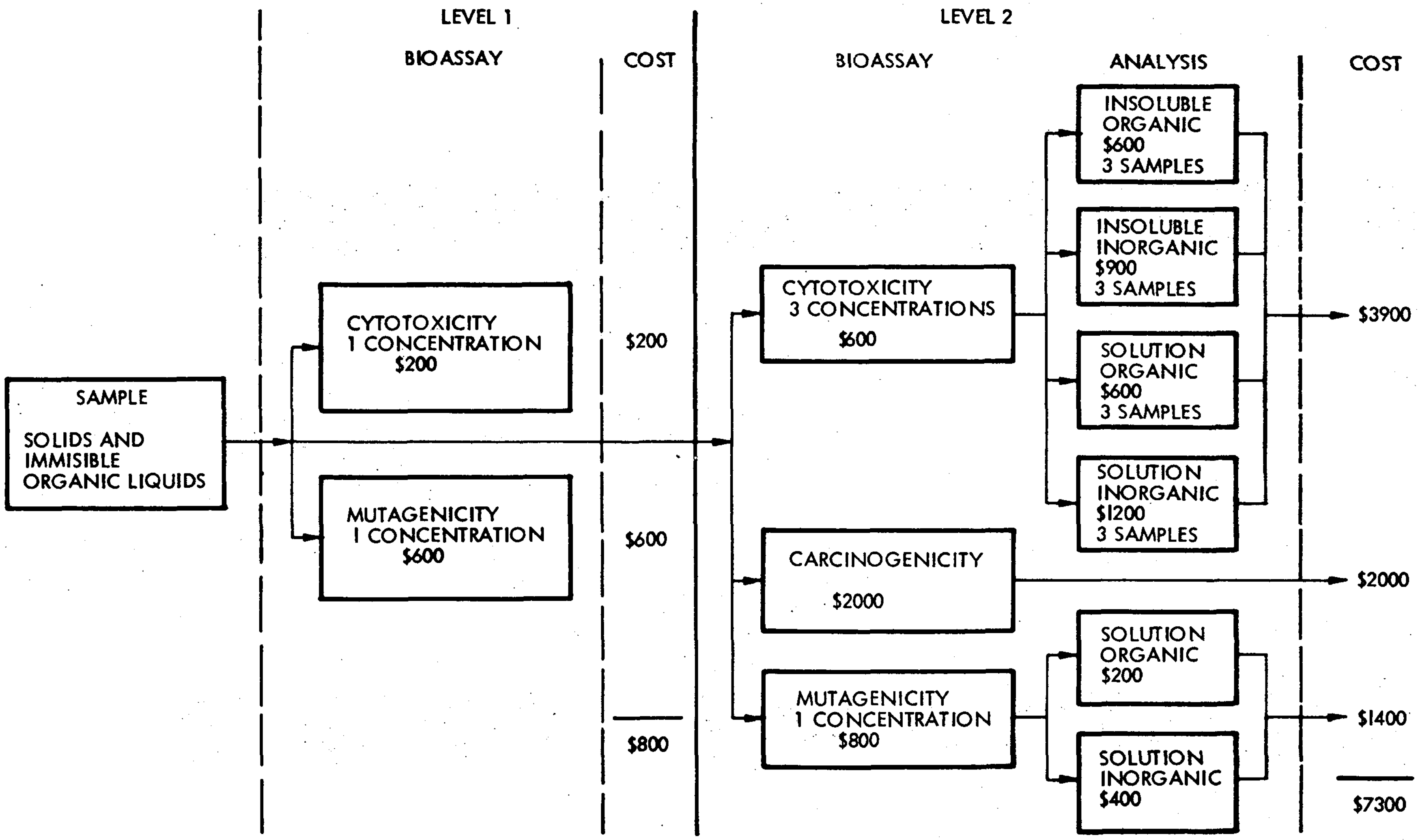


Figure 3. Bioassay Flow Chart

TABLE 6

MAJOR UNIT ANALYSIS COSTS

Analysis Category	Cost Units		Actual Cost $	
	Level 1	Level 2	Level 1	Level 2
1. Bioassay				
a. Media Soluble	3.20	13.60	800	3400
b. Media Insoluble	3.20	29.20	800	7300
2. Organic Analysis (per sample)	1.00	16.00	250	4000
3. Inorganic Compound Identification	—	6.00	—	1500
4. Particulate Morphology	1.10	1.60	270	400
5. Coal Feed Analysis	—	1.38	—	345
6. Inorganic Element Analysis	0.50	1.20	125	300
7. Water Analysis	0.38	1.80	95	450
8. Gas Chromatographic Analysis	0.25	1.00	63	250
• Acid Gases				
• C_1-C_8 Organics				
• Sulfur Compounds				

1.5.3.2 Organic Analysis (Solids and Liquids)

- Level 1 - A survey liquid chromatographic technique is used to separate the samples into 8 fractions for identification by infrared analysis of compound types. Organic samples obtained from water or organic streams are divided into a high (>150°C) and low (<150°C) boiling fraction for separate analysis and costed as two samples.
- Level 2 - The results of level 1 are used to redefine the level 1 technique so that fractions of each of the potential classes can be separated for GC/MS analysis.

1.5.3.3 Inorganic Compound Identification

Inorganic compound identification is essentially a sophisticated experimental extension of particulate morphological determinations. As such it provides information needed for level 2 characterization. At present, methodology for this type of analysis is ill-defined and costs are even more elusive. For this reason, an upper limit of 6 c.u. or $1,500 was set on the costs.

1.5.3.4 Particulate Morphology

Level 1 morphological examination of collected particulate will include microscopic examination of shape, size, distribution, surface features, and possible source. This will yield information as to general particle size distribution as well as an identification of the particulate and classification into general morphological types, as well as specific compound identification by crystalline structure. Additional information as to particulate composition will be obtained in level 2.

1.5.3.5 Coal Feed Analysis

In addition to the regular analysis on level 2, a standard set of ASTM analyses which includes sulfur forms, ultimate, proximate, and ash analyses as well as sieve (size) analysis will be performed.

1.5.3.6 Inorganic Element Analysis

Spark Source Mass Spectroscopy (SSMS) is the analytical tool costed for both the level 1 and level 2 trace element analysis.

The level 1 analysis is designed to perform as a general survey scan of all effluent streams for possible toxic or carcinogenic inorganic species. Accuracy levels of ± a factor of three were arbitrarily set for level 1 analysis and a minimum detection limit of 1 ppm for all streams tested. Level 2 accuracy was set at ± a factor 0.5 with the same detection limits. Of all the analytical techniques evaluated for level 1, SSMS was the most versatile in that all elements can be detected at the prescribed levels or lower.

1.5.3.7 Water Analysis

In addition to the normal liquid analyses, a set of approved EPA analyses is included. Level 1 analyses will be done with field equipment while level 2 analyses will be done in a commercial laboratory to achieve increased reliability and accuracy.

1.5.3.8 Gas Chromatographic Analysis

These analyses will be performed on site by a multicolumn, multidetector gas chromatograph for level 1 and wherever possible for level 2. In many cases, it will be necessary to perform the analyses on site because of the sample instability. The differences in cost between levels 1 and 2 reflect the difference in accuracy and precision of the data obtained.

1.6 COMPUTATION OF COSTS

Figure 4 shows an example of the sampling and analysis cost summary sheets used to compute the total costs for the level 1, level 2 and direct level 2 effects. The following sections explain the individual items and the methods used to compute each line.

1.6.1 Sampling Costs

The various components of the sampling effort are shown in Part I in Figure 4. The central focus of all sampling costs is the manpower necessary to perform the needed sampling tasks on-site. This number is obtained by multiplying the unit costs for each sample type listed in Table 1 by the number of sites listed in Tables 2 and 3. To this total (Item I-C-b in Figure 4) are then added other costs such as: 1) preliminary arrangements and pre-site survey, 2) trip planning and preparations, 3) correlation and reporting and 4) other direct costs.

I. TOTAL SAMPLING COSTS

A. Preliminary Arrangements and Pre-Site Survey

a. Labor

b. ODC's

B. Trip Planning and Preparations (Variable)

a. Site Preparations

b. 2.0 x Field Sampling Labor Costs

C. Field Sampling Costs (2-Man Team)

a. Travel and Miscellaneous ODC's (1000 miles)

b. Field Sampling Labor and Per Diem

D. Correlation, Reporting, Etc.

0.20 x Field Labor Costs

E. Repeat at 35% Items B, C and D (Only for Direct Level 2)

F. Total Sampling Costs

II. ANALYSIS COSTS

A. Direct Analysis Costs

B. Analysis Set-up Time, Duplicates, Etc.

0.20 x Direct Analysis Costs

C. Correlation, Reporting, Etc.

0.20 x Direct Analysis Costs

D. Repeat at 35% Items A, B, C (Only for Direct Level 2)

E. Total Analysis Costs

III. TOTAL COSTS PER PROCESS CONDITION

Figure 4. Sample Cost Computation Summary Sheet

Preliminary arrangements and pre-site survey costs (Item I-A in Figure 4) include the labor and other direct costs necessary to make the initial contacts and arrangements for the assessment as well as a pre-site survey. Since this is entirely an initial effort, there is no cost for Item A in all level 2 efforts. This labor was set at 6.0 man-days for the scrubber and 11.0 man-days for the gasifier. Other direct costs include per-diem and air fares for the pre-site survey which is based on a one-man effort for the scrubber and a two-man effort for the gasifier. Travel distances were set at 1000 miles to both units.

Trip planning and preparation (Item I-B, Figure 4) includes site preparation costs as well as the internal detailed planning and equipment assembly for the trip. Both items are highly variable and for this reason several assumptions were made concerning these costs. The site preparation costs assumptions are discussed in Section 1.4.5 Because trip planning and preparation costs are highly dependent on the general experience of the crew, the available knowledge, and/or the actual experience with a specific type of source, no attempt was made to establish these costs directly. Instead, they were set at a specific multiple of the field sampling costs so that this factor could be varied to fit a specific situation. Based on TRW experience and the assumption of no prior experience for the specified sources, this multiplier was set at 1.5 for level 1. This is reduced to 1.0 for level 2 on the assumption that the level 1 organization and experience would reduce these labor costs markedly. In the case of direct level 2 sampling, the multiplier was set at 2.0 because it is necessary to prepare for all possibilities and the need to obtain an ideal sample on a single visit requires substantial additional effort.

Correlation and reporting of the results were arbitrarily set at 20% of the field labor costs. The assumption was that this would include a basic write-up with little or no interpretation.

Field sampling ODC's (Item I-C-a) were based on a 2-man crew for the scrubber. For the gasifier, a 7-man crew was assumed for Level 1, 8 men for Level 2, and 10 men for direct Level 2. Travel was based on a 2,000-mile round trip for both examples.

1.6.2 Analysis Costs

Analysis costs were based on commercial quotes whenever possible. Estimates of non-routine analysis were based on EPA data or calculated as explained in Section 1.5.3. Whenever commercial rates were used, an additional 25% was added for handling, tabulation and interaction with the commercial laboratory. Because the analysis costs are idealized, a contingency factor of 20% (Item II-B) was added to this cost for analysis inefficiencies such as set-up time, duplicate determinations, etc. Finally, correlation and reporting of the results were arbitrarily set at 20% of the analysis costs.

1.6.3 Repeat Factor for Direct Level 2 Sampling and Analysis

As discussed in the section on strategy, Section 1.2.2, it was felt that a significant number of samples would have to be retaken and analyzed because of unforeseen circumstances. These repeats were set at 35% for both the gasifier and the scrubber. These factors are shown at Items I-E and II-D in Figure 4.

1.6.4 Replication Factor for Level 2 and Direct Level 2 Sampling and Analysis

Because a single sample of given stream, although representative of the day on which it was taken, has a high probability of not being representative of all process conditions, it is planned that a second replicate sample will be taken at all sample sites under a separate set of process conditions and preferably on a different day. This replicate factor of 2 is applied to the total of Items I and II.

1.7 RESULTS AND CONCLUSIONS

The results of the cost computations are shown in Table 7 and Figure 5 for the wet limestone scrubber and coal gasifier. These totals include sampling and resulting analysis repeats of 35% for both direct level 2 efforts and a replication factor of two in order to obtain samples for two process conditions for all level 2 efforts. Although the scrubber and gasifier differ markedly in size, complexity, basic technology and cost of assessment, the following conclusions are evident:

- The phased approach was found to be more cost effective in all aspects than the direct approach for both technologies. For the

TABLE 7

SAMPLING AND ANALYSIS
COST SUMMARY ($)

	Limestone Wet Scrubber			Coal Gasifier		
Strategy	Sampling	Analysis	Total	Sampling	Analysis	Total
Level 1	5,100	21,575	26,675	28,425	109,925	138,350
Level 2	18,850	254,450	273,300	53,950	1,149,100	1,203,050
Phased Total	23,950	276,025	299,975	82,375	1,259,025	1,341,400
Direct Level 2	41,450	548,150	589,600	194,370	2,937,400	3,131,770

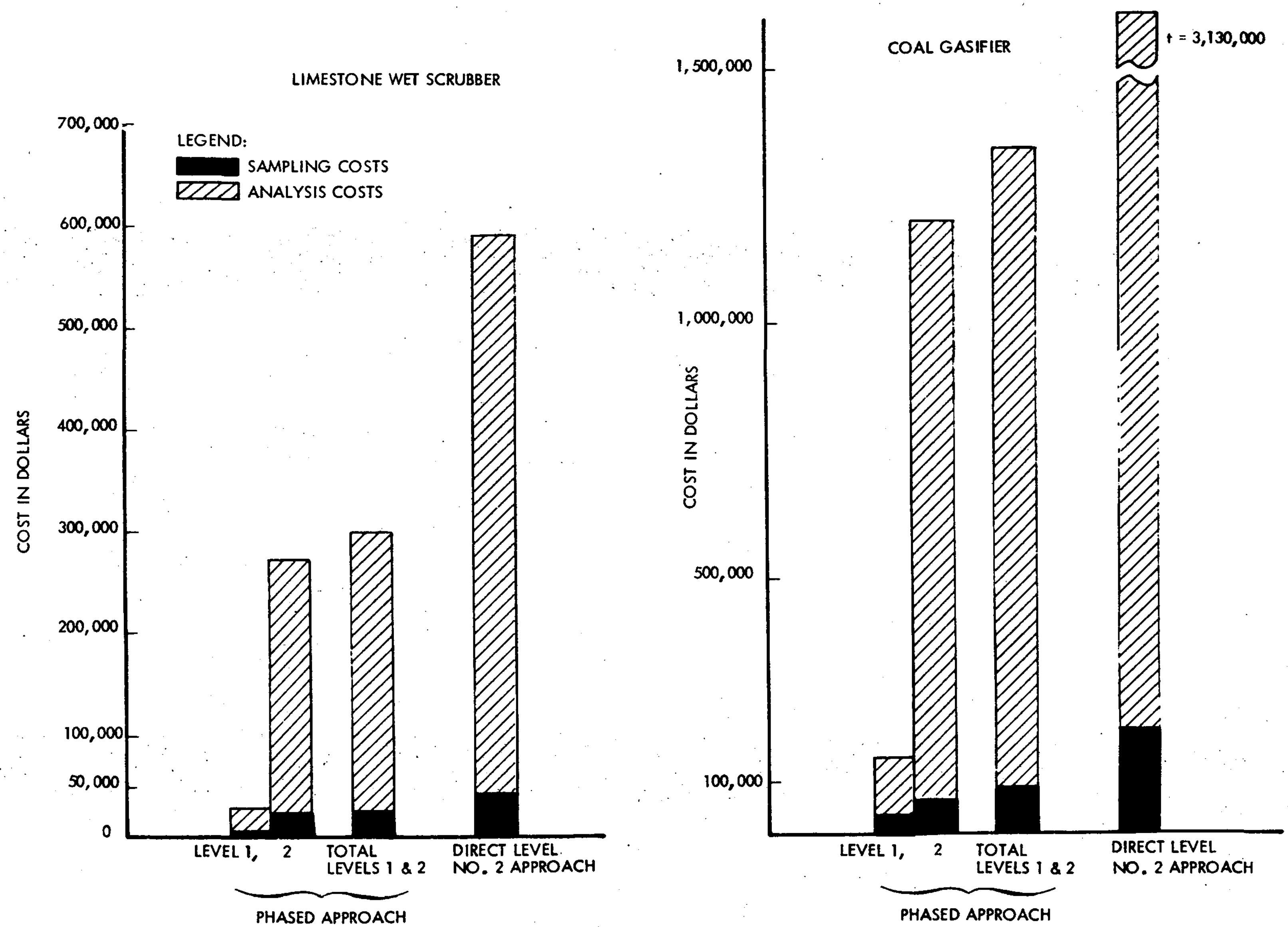


Figure 5. Summary of Sampling and Analysis Costs

gasifier, this amounted to a factor of 2.3; for the wet limestone scrubber, direct costs were higher by a factor of 2.0.

- The advantages of the phased sampling and analysis approach were found to be approximately proportional to the complexity of the process being sampled. Thus, while the phased approach resulted in a 58% reduction in costs over the direct approach in the gasifier, the corresponding savings for the wet limestone scrubber were 49%.

- Within the phased approach, the level 1 sampling and analysis is only 8-10% of the total cost of the phased effort. Thus, many qualitative judgments including whether or not a full-scale endeavor is necessary can be decided before a commitment is made to initiate a detailed final (level 2) assessment.

- The following were found to be cost sensitive items:

  1. Flue gas (particulate matter) sampling has a significantly higher unit cost on both levels 1 and 2 than another type of sampling.
  2. In level 1, bioassay testing constitutes the major analyses costs. In both the phased and direct level 2 effort, bioassay testing and organic analysis costs followed by inorganic compound identification are the major cost sensitive items.

- Sampling, although very important, consists of about 10% of the total effort.

2.0 CONCLUSIONS

1. Two approaches, a phase two stage and a single direct effort, were used to provide all necessary inputs for an environmental assessment and were applied to a wet limestone scrubber and a coal gasification complex. In the phased approach, the required information is obtained in two distinct phases with differing objectives and technical sophistication while in the direct approach, the same result is obtained in a single comprehensive effort.

2. The phased approach was found to be more cost effective in all aspects than the direct approach for both technologies even though the scrubber and coal gasifier differ markedly in size, complexity, basic technology, and total cost of sampling and analysis. For the gasifier, this amounted to a factor of 2.3 for the wet limestone scrubber, direct costs were higher by a factor of 2.0.

3. The advantages of the phased sampling and analysis approach were found to be approximately proportional to the complexity of the process being sampled. Thus, while the phased approach resulted in a 58% reduction in costs over the direct approach for the gasifier, the corresponding savings for the wet limestone scrubber were 49%.

4. Within the phased approach, the initial (level 1) sampling and analysis is only 8 - 10% of the total cost of the phased effort. Thus, many qualitative judgments including whether or not a full scale endeavor is necessary can be decided before a commitment is made to initiate a detailed final (level 2) assessment.

5. The following were found to be cost sensitive items:

- Flue gas (particulate) sampling has a significantly higher unit cost on both levels 1 and 2 than another type of sampling.
- In level 1, bioassay testing constitutes the major analyses costs. In both the phased and direct level 2 effort, bioassay testing and organic analysis costs followed by inorganic compound identification are the major cost sensitive items.

6. Sampling, although very important, consists of about 10% of the total effort.

3.0 RECOMMENDATIONS

1. This study should be continued in order to refine the philosophy, assumptions and costing data used in this report, as well as to evaluate EPA and EPA contractor's comments generated by this document.

2. Additional studies should evaluate the generality of this approach by application of the methodology to other technologies.

3. Cost effective implementation of the above should include the development of a computer program that will eliminate the intensive manual labor involved in the calculation of costs and cost summaries such that cost implications of additional scenarios based on differing assumptions can be investigated in detail.

4.0 INTRODUCTION (References 1, 2, 3)

The development of this set of environmental sampling and analytical test strategies and test strategy costs has been prepared for the Process Measurement Branch of the Industrial Environmental Research Laboratory, Environmental Protection Agency, Research Triangle Park, North Carolina, in partial fulfillment of Task 9 of Contract No. 68-02-1412.

The current energy shortage and the emphasis on the use of energy with minimal environmental impact will result in the development of large scale new industries for coal conversion, stack gas cleaning, oil shale processing and greatly increased coal cleaning facilities. These new technologies will, by nature of both their size and numbers, have considerable positive or negative impact on the environment. In addition, it is becoming of increasing importance to assess the impact of existing industries on the environment. For these reasons, the EPA is currently developing methodologies to assess both the technical and economic requirements for this effort.

The strategy for the preparation of this report was to examine two test methodologies and to apply them in a detailed manner to two energy related technologies in order to ascertain the results of the various assumptions involved. The wet limestone scrubber flue gas desulfurization and the Lurgi gasification processes were chosen because they are both examples of technologies in which substantial effort to identify potential pollutants has already been performed and thus provide a good data base for this study. In addition, the wet scrubber unit is probably the simplest case that will be of interest and the Lurgi process is both an example of a synthetic energy technology and representative of a very complex plant.

For the purposes of this report, only feedstocks, inputs to control devices and all waste and product streams were considered. The sampling and analysis of internal or interconnecting process streams was not considered because this would increase the complexity of an environmental assessment by an order of magnitude while providing only a small additional amount of information.

The environmental impact of these streams is mostly in the form of fugitive emissions which is treated as a separate subject in the case of the gasifier. If control technology is found to be necessary, these process streams will have to be investigated as necessary to solve the problem.

Analysis of the feedstocks and inputs to control devices is necessary in order to establish baseline data to help in evaluating effluent streams which are discharged directly into the environment. Fugitive emissions have not been included for the wet limestone scrubber as this would necessitate a complete assessment of the entire power plant complex. In the case of the Lurgi gasifier, a simple effort has been included so that a firm decision can be made whether or not a separate fugitive emission program should be initiated.

In the interest of simplicity, two sampling and analytical approaches designed to give the same level of information for decision making were chosen. The first approach, called the phased approach, requires two separate levels of sampling and analytical effort. The first level, utilizing qualitative and semi-quantitative sampling and analysis procedures, identifies sampling and analysis problem areas and allows the prioritization of streams, components and/or classes of materials in the overall assessment. The second level sampling and analysis effort after having been focused by level 1, will be designed to give the desired information. This information will then be used to define the control technology needs and may in some cases yield probable causes or even isolate the problem.

The second approach that was examined is the direct single effort strategy which is designed to achieve the same level of information for decision making as in the phased approach. Because nothing can be assumed, the sampling and analysis effort must be planned to cover all components in all streams. Although conceptually this approach is much simpler than the phased approach, it will be shown that it is not nearly as cost effective as the phased approach.

The strategy, site selection, analysis methods and their corresponding costs are explained in the following sections along with a summary of the results.

5.0 PROGRAM RESULTS

This section provides a detailed description of the results of the program activities. The section is organized to provide a technical summary of the findings of this effort, the strategy and underlying philosophy of environmental testing, general costing considerations and assumptions, sampling considerations regarding the factors affecting site selection, methodology and unit costs, analysis procedures and analysis unit costs, and finally, a summary of sampling and analysis costs.

5.1 STRATEGY

The general considerations and assumptions that were used in developing both the phased and direct sampling and analysis stratégies are developed in the following sections.

5.1.1 General Considerations (References 3, 4, 5)

To facilitate the development of a sampling and analysis strategy, the number of scenarios considered was limited to those that would best illustrate the advantages of a coherent environmental sampling and analytical strategy. Consequently, two technologies were treated according to two different approaches for a total of four cases. It was also further assumed that the assessment would be performed only on a full-scale demonstration or commercial plant and that minimal or no information would be available from environmental tests performed on bench or pilot scale units. Thus, each case would be treated as an entire unit in which all feedstock and effluent streams would be evaluated.

The wet limestone scrubber flue gas desulfurization (FGD) unit and the Lurgi coal gasification process were chosen as examples of new technologies of interest to the EPA for environmental control and synthetic fuel production, respectively. In both cases, substantial effort has already been performed in the area of environmental assessment, and as a result, each provides a good data base for verifying the techniques used in this study. Finally, these examples represent the two extremes for technology of interest with the scrubber being the simplest and the coal gasifier one of the largest and most complex.

Internal process streams were not treated directly. Although single unit technologies like a wet limestone FGD scrubber, for example, have a minimum of in-process streams, a large coal gasification complex covering several square miles has hundreds of interconnecting streams that have only an indirect effect on the environment either by affecting the output of units producing effluents or by inadvertent leakage. In the former case, these streams may be investigated if control technology must be developed, but this data is not necessary in order to make an executive decision on the environmental impact of a given effluent stream.

Leakage from internal process streams results in a fugitive emission problem. For this reason, an atmospheric sampling effort is included in order to determine whether or not these emissions present a problem and to identify some problem areas for further study rather than to provide a complete fugitive emission analysis profile of the plant. A fugitive emission study for the limestone scrubber was not included because this would necessitate a complete environmental assessment of the power plant complex which is outside the scope of this task.

Two separate approaches have been chosen for the purposes of this report:

- The phased approach in which two sampling trips of differing aims and complexity are made to a given site, and
- The direct approach where an attempt is made to obtain any necessary replicate samples in a single effort.

The philosophy, information benefits and cost implications of each approach are discussed in detail in the following sections.

5.1.2 The Phased Approach (References 6, 7)

The phased approach requires two separate levels of sampling and analytical effort. The first level, utilizing qualitative and/or semi-quantitative sampling and analysis procedures, identifies problem areas and allows for prioritization of streams, components and classes of materials. The second, level 2, sampling and analysis effort, after having been focused by level 1, will be designed to provide information that will produce quantitative emission data concerning specific compounds identified in level 1. This information will be used to define the control technology needs and may, in some cases, give the probable or exact cause of a given problem.

5.1.2.1 Strategy of the Phased Approach

The basic philosophy of this approach recognizes the intuitive feeling on the part of sampling and analysis personnel that it is impossible to prepare for every conceivable condition on the first sampling and analysis effort. Thus, unknown conditions and components of streams will result in unreliable information and data gaps that will require a significant percentage of the analyses to be repeated with a refocused objective. In other cases, the sample size or sampling procedure may not be adequate to quantitate components that are actually found in a stream. If elaborate "state-of-the-art" sampling and analysis methods were employed, this would involve considerable additional expenses as a result of this "real-time" learning process. A second possibility is that many streams or even the entire installation may not be emitting hazardous substances in quantities of environmental significance. If this fact could be determined by a simplified set of sampling and analysis techniques, the resultant savings in both time and funds could then be used for further testing in other areas where there is greater need. A third possibility is that budgetary limitations may require prioritizing a series of installations so that the available funds can be used in assessing those installations most in need of control technology. Again, a simplified sampling and analysis methodology would be an advantage to EPA's environmental assessment effort. Thus, a phased approach offers potential benefits in terms of cost savings and increased information that is obtained for a given level of effort.

The level 1 and 2 sampling and analysis efforts are intimately linked in the overall environmental assessment effort. Level 1 focuses the sampling and analysis effort in level 2 with the resultant quantitative identification of specific species. For example, if a level 1 test showed the presence of 3-to 7-ring aromatics (PNA) and gave a positive mutagenicity test, level 2 sampling and analysis would be designed to determine the exact quantities of organic constituents, the percentage of PNA, and the identity of as many specific PNA compounds present as possible. In addition, using the level 1 data and any available level 2 results, the sample is again tested for cytotoxicity and mutagenicity in order to confirm and expand the bioassay information. A test for carcinogenicity is also run if the results of the mutagenicity test are positive. The entire data package can then be used to assess the control technology R&D needs for the stream.

A detailed explanation of level 1 and level 2 analysis along with their expected outputs is given in the following sections.

5.1.2.2 Definition of Level 1 Sampling and Analysis

Level 1 sampling and analysis has as its goal the identification of the pollution potential of a source in a qualitative and/or semi-quantitative manner. At the initiation of an environmental assessment, little is known about the specific sampling requirements of a source both practically and technically and hence, the emphasis is on survey tests. For this reason, no special procedure is employed in obtaining a representative sample and the chemical, physical and biological testing is of a qualitative and survey nature consistent with the characteristics of the sample.

On this level, the sampling and analysis is designed to show within broad general limits the presence or absence, the approximate concentrations, and the emission rate of inorganic elements, inorganic anions and selected fractions of organic compounds. Physical testing mainly concerns the particulate matter and includes size distribution as well as microscopic examination in order to determine gross physical characteristics of the material. Bioassay is designed to determine the cytotoxicity and mutagenicity of a sample within broad limits.

The results of this phase are then used to establish priorities for additional testing among a series of sources. Within a given source, streams can be prioritized according to pollution potential. Finally, within a given stream, component priorities can be established.

Level 1 serves a crucial role in that it provides environmental information and permits certain questions to be answered. However, level 1 is not designed to stand alone as an environmental assessment effort and its most important function is to focus future sampling and analysis programs on specific streams and components for the level 2 effort. By delineating specific sampling, analysis and decision making problem areas, the level 1 effort will establish the methodology of the level 2 effort in such a way that answers can be provided to questions formulated by the level 1 effort.

5.1.2.3 Definition of Level 2 Sampling and Analysis

Level 2 sampling and analysis has as its goal to provide definitive data that will complete the environmental assessment of a source. In order to perform this in a timely and cost effective manner, the basic data to be obtained and major problem areas must already have been defined in level 1. Consequently, level 2 sampling and analysis is characterized by obtaining representative samples, accurate stream flow rates, and by identification and quantification of specific organic and inorganic chemical classes and individual species. In this effort, biotesting in selected areas is expanded to include dose response data and also carcinogenicity testing.

The results of this phase will provide more detailed information concerning the classes of chemicals delineated by level 1 in the areas of physical characteristics, organic and inorganic chemical species, and biochemical assaying such that control stream priorities and an initial estimate of process/control system regions of overlap can be established.

5.1.3 <u>The Direct Approach</u>

The second scenario that was examined was the direct single effort designed to achieve the same level of information for decision making as in the phased approach. Because nothing can be assumed, the sampling and analysis effort must be planned to cover all components in all streams. Although conceptually this methodology is much simpler than the phased approach, it will be shown that as the system becomes more complex, it is not nearly as cost effective as the phased approach.

5.1.3.1 Philosophy of the Direct Approach

A direct approach is philosophically attractive for several reasons. The primary reason is that by planning and executing a single comprehensive sampling and analysis effort, the environmental assessment can be performed in a shorter period of time and thus minimize problems with the operators of the source who may not be exactly cooperative. In addition, this approach holds out the seldom achieved possibility that the effort can be accomplished without making a return sampling trip and the resultant savings can be used to pay for analysis that would not have been performed had even a small amount of information been known about a stream.

5.1.3.2 Data Requirements of the Direct Approach

The overall data requirements of the direct approach are the same as for the phased approach. This requires that the same level of information required for the overall assessment be obtained directly that was obtained previously in two phases. Thus in the absence of definitive information to the contrary, the sampling and analysis effort must contain provisions for treating all components of all streams in a quantitative manner. This is a very difficult proposition in actual practice because of sampling and analysis "surprises" that may make even the most elaborately taken sample and most conservatively performed analysis inadequate. Thus, in many cases, specific streams will have to be resampled in order to obtain information equivalent to that proposed for the phased approach. Because the direct level 2 approach is presently being practiced by the EPA and various EPA contractors, there is considerable experience to support this contention. The required repeat effort has been shown to be between 25 and 50%. An intermediate figure of 35% has been used for this study. However, this factor is being called out separately and can be easily altered if desired.

5.2 GENERAL COSTING CONSIDERATIONS, ASSUMPTIONS AND COMPUTATIONS

This section delineates the assumptions used in the development of costs in Sections 5.2.3 and 5.2.4 and the method of computation of total sampling and total analysis costs in Section 5.2.2. An example of sampling and analysis cost computation summary sheets is shown in Figure 6.

5.2.1 Use of the Cost Unit (C.U.)

In order to facilitate pricing of the manpower and analysis, it was desired to use a unit of cost larger than the dollar. For this purpose, the cost unit (c.u.) was defined to be equal to $250. In terms of site manpower costs, this is approximately equal to one man-day of fully burdened labor including $70 of per diem and other general direct costs (ODC's). The primary advantage of the c.u. is that by not using dollars directly, the costing process can be implemented objectively without the accumulated biases associated with dollar costs. Furthermore, the cost unit permits ready utilization of correction factors (repeat analysis) and application of economic factors in the future. In most summary tables, however, a dollar figure is also given.

5.2.2 Computation of Total Sampling Costs

Figure 6 provides a listing of the elements of cost required to estimate the environmental assessment sampling and analysis cost for each process condition. Preliminary arrangements and pre-site survey costs (Item I-A in Figure 6) include the labor and other direct costs necessary to make the initial contacts and arrangements for the assessment as well as a pre-site survey. As this is entirely an initial effort, there is no cost for this item in all level 2 efforts. The labor was set at 6.0 man-days for the scrubber and 11.0 man-days for the gasifier. (The preliminary arrangements and pre-site survey costs in a variety of cases should average about 8.5 man-days). Other direct costs include per-diem and air fares for the pre-site survey which is based on a one-man effort for the scrubber and a two-man effort for the gasifier. Travel distances were set at 1000 miles for both units.

I. TOTAL SAMPLING COSTS

A. Preliminary Arrangements and Pre-Site Survey

a. Labor

b. ODC's

B. Trip Planning and Preparations (Variable)

a. Site Preparations

b. N* x Field Sampling Labor Costs

C. Field Sampling Costs

a. Travel and Miscellaneous ODC's (2000 mi. round trip)

b. Field Sampling Labor and Per Diem

D. Correlation, Reporting, Etc.

0.20 x Field Labor Costs

E. Repeat at 35% Items B, C and D (Use only for Direct Level 2)

F. Total Sampling Costs/Process Conditions

II. ANALYSIS COSTS

A. Direct Analysis Costs

B. Analysis Set-up Time, Duplicates, Etc.

0.20 x Direct Analysis Costs

C. Correlation, Reporting, Etc.

0.20 x Direct Analysis Costs

D. Repeat at 35% Items A, B, C (Use only for Direct Level 2)

E. Total Analysis Costs

III. TOTAL COSTS - PROCESS CONDITION NUMBER 1

*N = 1.5 for level 1
= 1.0 for level 2
= 2.0 for direct level 2

Figure 6. Sample Cost Summary Sheet

Trip planning and preparation (Item I-B, Figure 6) includes site preparation costs as well as the detailed planning and equipment assembly and testing for the sampling effort. Both items are highly variable and for this reason several assumptions were made concerning these costs. The site preparation costs assumptions are discussed both in Section 5.3.7 and Appendix C and will not be discussed further here. Because trip planning and preparation costs are highly dependent on the general experience of the crew, the available process knowledge, and/or the actual experience with a specific type of source, no attempt was made to establish these costs directly. Instead, they were set at a specific multiple of the field sampling costs with the idea that this factor could be varied to fit a specific situation. Based on TRW experience and the assumption of no prior experience for the specified sources, this multiplier was set at 1.5 of the field sampling labor for level 1 (Item I-C-b, Figure 6). This is reduced to 1.0 times the field sampling labor for level 2 on the assumption that the level 1 organization and experience would reduce these labor costs markedly. In the case of direct level 2 sampling, the multiplier was set at 2.0 because it is necessary to prepare for all possibilities and the need to obtain an ideal sample in a single visit requires substantial additional effort.

Correlation and reporting of the results were arbitrarily set at 20% of the field labor costs. The assumption was that this would include a basic write-up with little or no interpretation.

Field sampling (Item I-C-a) ODC's were based on a 2-man crew for the scrubber. For the gasifier, a 7-man crew was assumed for Level 1, 8 men for level 2 and 10 men for direct level 2. Travel was based on a 2,000 mile round trip for both examples. The central focus of all sampling costs is the manpower necessary to perform the needed sampling tasks on-site. This is Item I-C-b in Figure 6. The cost requirements to acquire a sample of a given type are given in Table 8. The derivation of these costs is discussed in detail in Section 5.3.8.

TABLE 8

SUMMARY OF SITE SAMPLING COSTS

Sample Type	C.U./Sample		Actual $	
	Level 1	Level 2	Level 1	Level 2
1. Solids & Slurries	0.50	1.00	125.00	250.00
2. Aqueous	0.50	0.70	125.00	175.00
3. Non-aqueous	0.67	1.00	167.00	250.00
4. Gas (Non-particulate)	0.28	0.60	70.00	150.00
5a. Flue Gas (Particulate)	0.91	6.00	227.00	1500.00
5b. Flue Gas (Non-partic.)	- *	1.00	-	250.00
6. Fugitive Dust	0.36	0.30	90.00	75.00

* Lack of particulate matter must be established with a Level 1 test.

5.2.3 <u>Computation of Total Analysis Costs</u> (References 8, 9, 10, 11 and 12)

Analysis costs were based on commericial quotes whenever possible. Estimates of non-routine analysis were based on EPA data or calculated as explained in Section 5.4.3. Whenever commercial rates were used, an additional 25% was added for handling, tabulation and interaction with the commercial laboratory. Because the analysis costs are idealized, a contingency factor of 20% (Item II-B Figure 6) was added to this cost for analysis inefficiencies such as set-up time, duplicate determinations, etc. Finally, correlation and reporting of the results were arbitrarily set at 20% of the analysis costs. A summary of the analysis costs used in this study by sample type for both level 1 and level 2 is presented in Table 9.

TABLE 9

MAJOR UNIT ANALYSIS COSTS

Analysis Category	Cost Units		Actual Cost $	
	Level 1	Level 2	Level 1	Level 2
1. Bioassay				
a. Media Soluble	3.20	13.60	800	3400
b. Media Insoluble	3.20	29.20	800	7300
2. Organic Analysis (per sample)	1.00	16.00	250	4000
3. Inorganic Compound Identification	—	6.00	—	1500
4. Particulate Morphology	1.10	1.60	270	400
5. Coal Feed Analysis	—	1.38	—	345
6. Inorganic Element Analysis	0.50	1.20	125	300
7. Water Analysis	0.38	1.80	95	450
8. Gas Chromatographic Analysis	0.25	1.00	63	250
• Acid Gases				
• C_1-C_8 Organics				
• Sulfur Compounds				

5.2.4 Repeat Factor for Direct Level 2 Sampling and Analysis

As discussed in the section on strategy, Section 5.1.3, it was felt that a significant number of samples would have to be retaken and analyzed because of unforeseen circumstances. These repeats were set at 35% for both the gasifier and the scrubber. These factors are shown as Items I-E and II-D in Tables 24 and 33 in Sections 5.5 and 5.6.

5.2.5 Replication Factor for Level 2 and Direct Level 2 Sampling and Analysis

Because a single sample of given stream, although representative of the day on which it was taken, has a high probability of not being representative of all process conditions, it is planned that a second replicate sample will be taken at all sites under a separate set of process conditions and preferably on a different day. This replicate factor of 2 is applied to the totals of Sections I and II.

5.3 SAMPLING

This section describes the rationale that has gone into the sample site selection, sampling methodology and sampling unit costs for the wet limestone scrubber flue gas desulfurization process and the Lurgi coal gasification process.

5.3.1 Types of Streams to be Sampled

As stated in the introduction and strategy sections, only process feed, product and waste streams are being considered for this effort. The principal reasons for this are that analysis of feed streams is necessary to establish a baseline for potential contaminants and only product and waste streams will have a direct effect on the environment. Internal process streams, besides varying greatly from plant to plant, have no environmental effect except in cases of leakage where the problem becomes one mainly concerned with fugitive emissions. For this reason, a fugitive emission study is included.

5.3.2 Classification of Streams for Sampling and Costing Purposes (References 4, 13 through 21).

The basic sampling strategy has been organized around the six general types of sampling found in coal gasification or other complex technologies rather than around the analytical procedures that will be required to collect the samples. In this way, the complex and difficult task of organizing the manpower and equipment necessary for successful field sampling can be made such that meaningful units of cost can be established. In general, for costing purposes, it was assumed that a separate crew would be used to take all the samples for a given category and that an accurate cost could be assigned to this task. The total cost was then divided by the number of samples to obtain the unit costs. This value is shown in Table 13 in Section 5.3.8 and is used where applicable for both the wet limestone scrubber and coal gasifier. The six sample types are delineated below while the costing is explained in Sections 5.3.7 and 5.3.8.

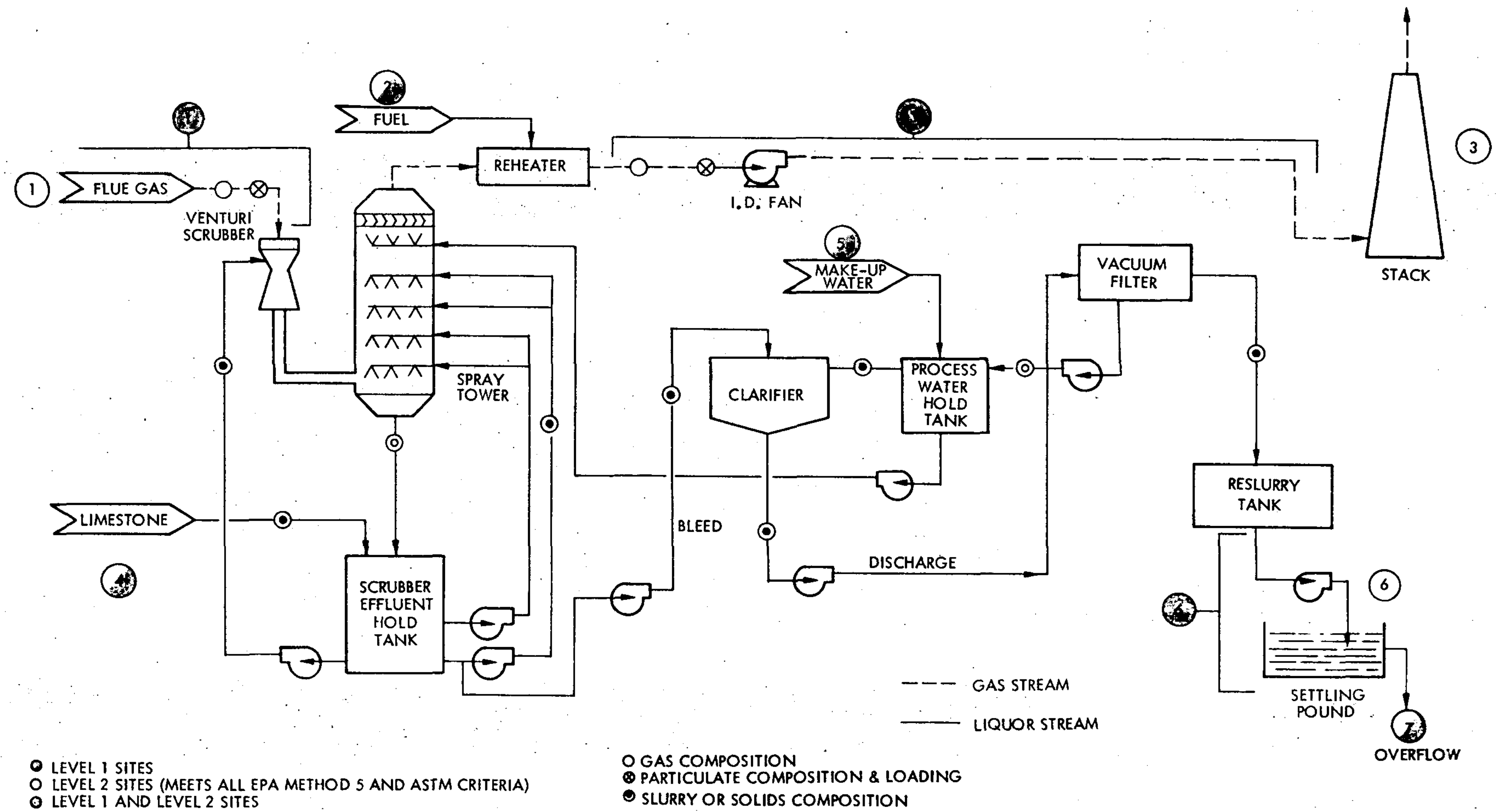
- Solids and Solid Slurries - These are the coal input, bottom ash, and any aqueous stream containing more than 5-10% solids.

- Liquor Streams
  - Aqueous - Water streams containing less than 5-10% insoluble solids.
  - Non-aqueous - Homogeneous streams other than water streams.
- Gas Streams containing no significant particulate matter. These samples include process streams, process vents, and ambient air samples.
- Flue gas containing particulate matter .
- Flue gas without particulate matter - These streams are essentially the same as the gas streams except special procedures are used to sample for acid gases and PAH compounds.
- Fugitive Dust Sampling - This includes local source sampling and plant perimeter sampling employing high volume sampler techniques.

5.3.3 Selection of Sampling Locations for the Phased Approach

The selection of sampling points in processes where phased sampling techniques are employed relies on the concept that level 1 sampling is oriented towards obtaining survey and/or semi-quantitative results only, whereas level 2 sampling is intended to acquire more accurate data necessary to complete the environmental assessment. Stream parameters such as flow rates, temperature, pressure and other physical characteristics will be obtained on both levels within the accuracy requirements of a given level of sampling. Consequently, a level 1 sample may be taken from any easily accessible port within the flow scheme of a given unit. For example, in obtaining a level 1 stack sample, the probe may be inserted in any convenient location along the duct leading to the stack and a psuedo-isokinetic sample may be taken in order to obtain qualitative data. On level 2, however, where quantitative data are required, isokinetic samples must be withdrawn from specific locations away from ducting bends and other obstructions in order to ensure a sample representative of the actual effluent.

The sampling site alternatives for the phased sampling approach are shown diagramatically for the wet limestone scrubber in Figure 7. Similar consideration will apply to any solids two phase stream. In the case of homogenous streams such as aqueous (non-slurry), non-aqueous



* THE POWER PLANT IS NOT INCLUDED FOR THE PURPOSES OF THIS REPORT.

Figure 7. Typical Process Flow Diagram For Limestone Venturi Spray Tower System

(organic), and gas (without particulate) streams, level 1 and level 2 sampling sites and techniques could be quite similar.

5.3.4 Sample Site Selection - Wet Limestone Scrubber (Ref. 22)

The model used for a limestone wet scrubber is illustrated in Figure 7 by the spray tower system installed at Paducah, Kentucky. The seven indicated sampling sites involve four of the six sample types discussed in the previous section. These sites along with their respective flow diagram identification numbers are listed individually below:

- Solids and Slurries - Process limestone and settling pond inputs, flow chart number 4 and 6.
- Aqueous samples - Process make-up water and settling pond overflow, flow chart numbers 5 and 7.
- Non-aqueous sample - Reheater fuel, number 2.
- Flue gas (particulate) samples - Flow chart numbers 1 and 3

5.3.5 Sample Site Selection - Coal Gasifier (Refs. 4, 14, 23)

The Lurgi Coal Gasification Complex proposed by the El Paso Natural Gas Company for New Mexico was chosen as a model for the coal gasifier. Considerable planning for both sampling and analysis has been performed under Task 3 of this contract (EPA 68-02-1412). A generalized flow scheme developed for this task is shown in Figure 8. This figure shows an interrelationship between the various process units and sampling sites. This diagram has been simplified for quick reference use into the single block diagram in Figure 9 which shows input and output streams only. The water system is shown separately in Figure 10. The various sampling locations are shown superimposed on a model of the El Paso Plant in Figure 11.

In the coal gasification complex, with the exception of the stacks and the solids and slurry streams, there is generally little or no difference between the physical location of the sampling site for level 1 and level 2. (However, sampling techniques will be different for levels 1 and 2). This is due to the fact that the predominant number of streams are homogeneous throughout the length of their respective transfer systems; and since most samples are of the grab or composite type on both levels 1 and 2, the site of sample withdrawal need not change.

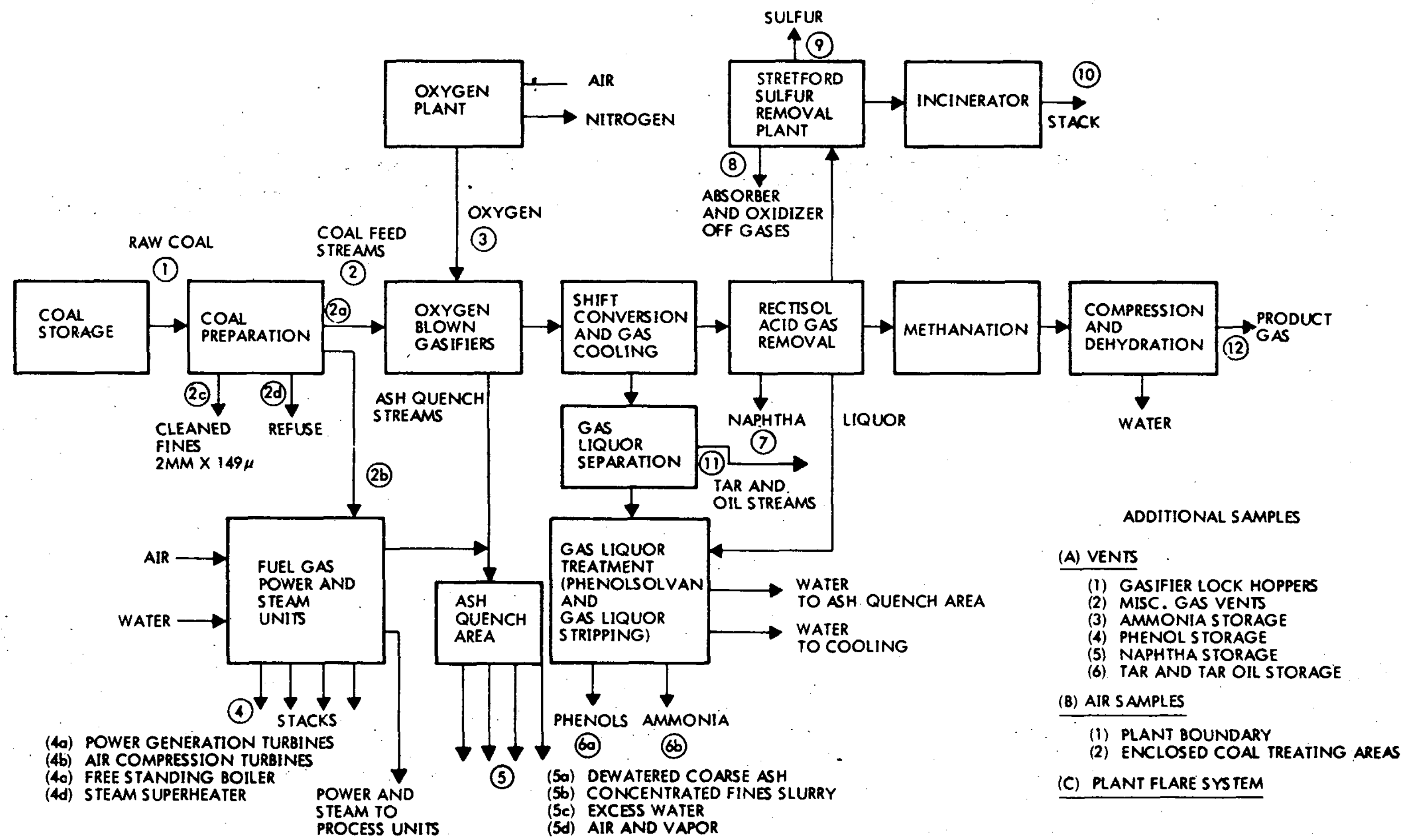


Figure 8. Sampling Diagram for a Lurgi Gasification Process Excluding Water System

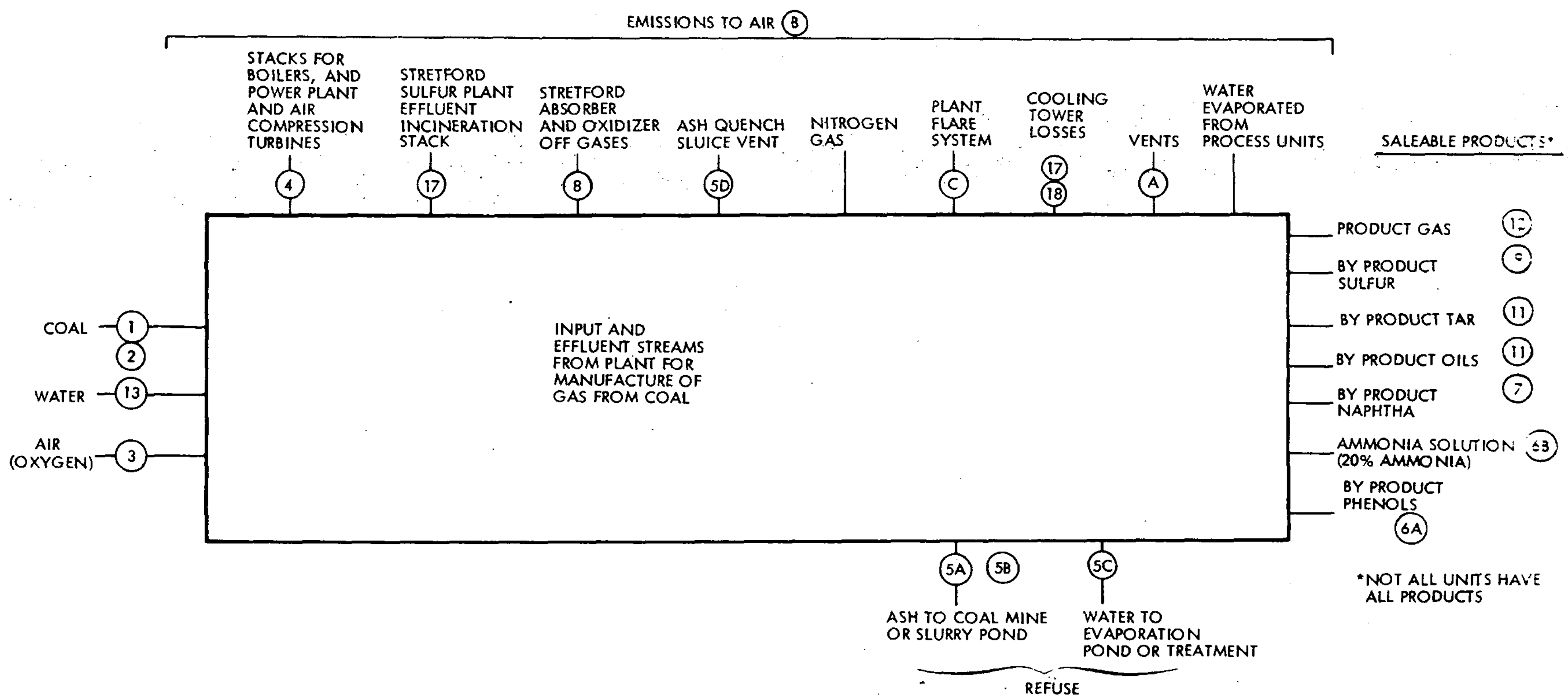


Figure 9. Gasification Plant Effluent Flow Diagram

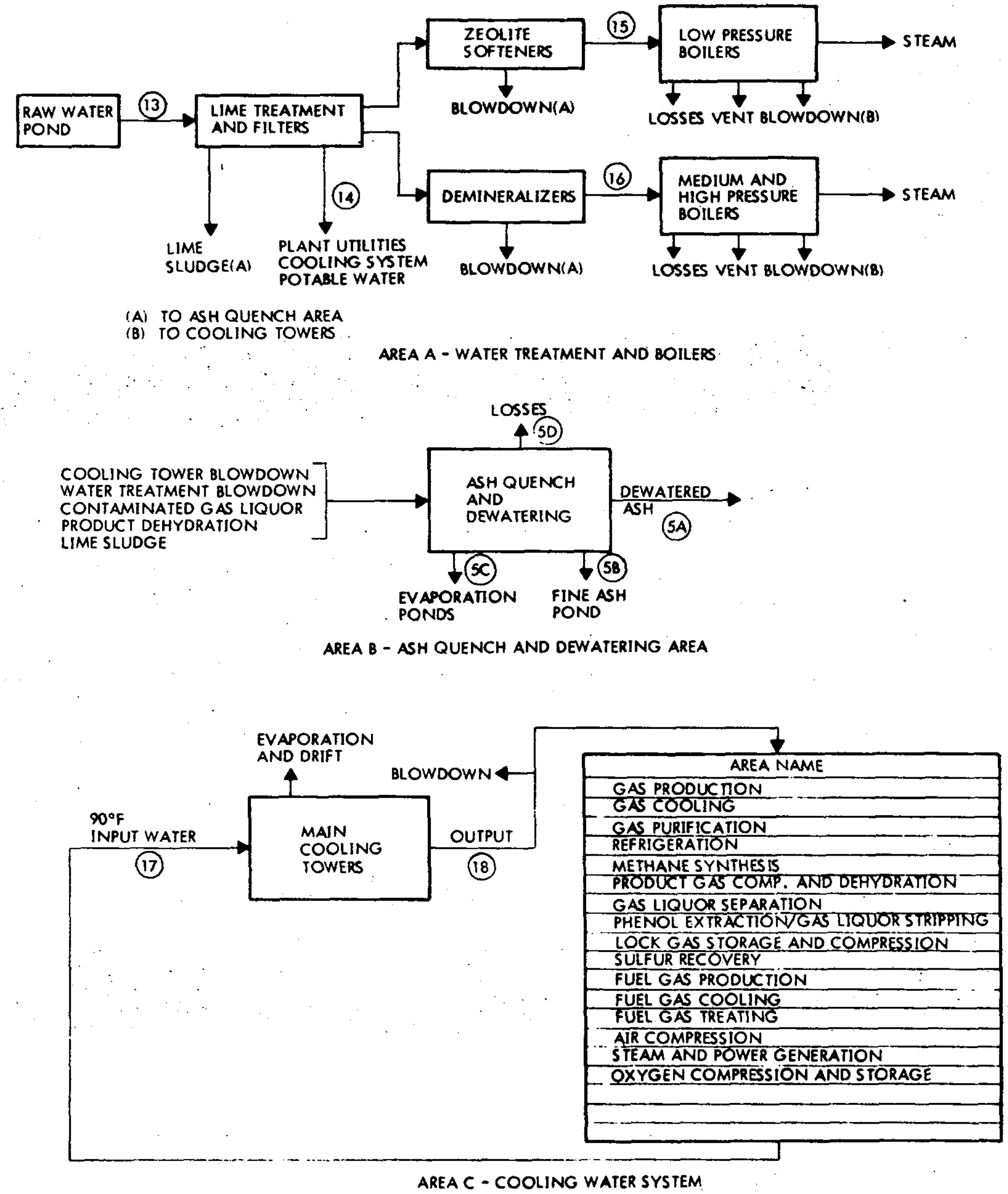


Figure 10. Water Sampling Points for a Lurgi Coal Gasification Complex (With Cooling Towers)

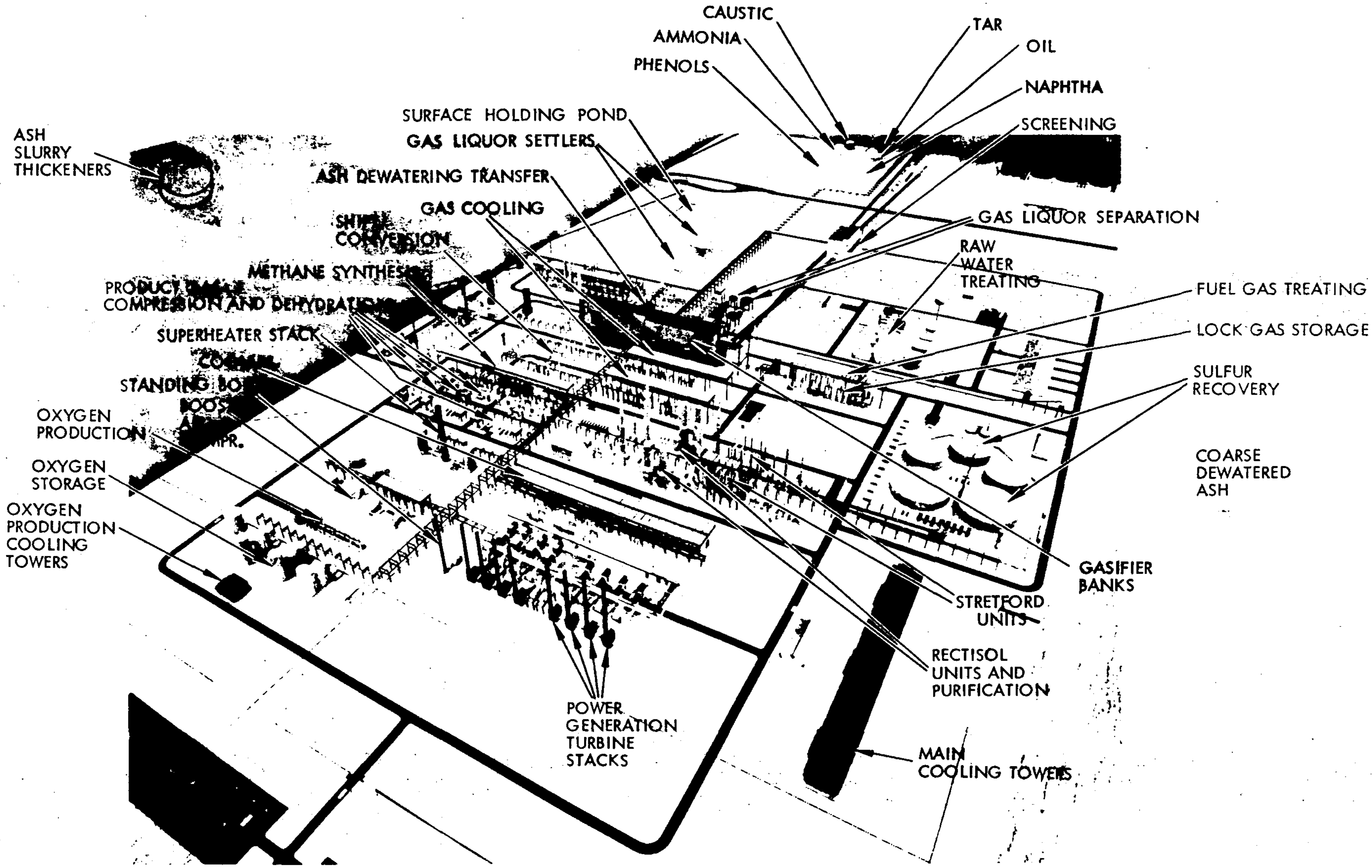


Figure 11. Model of El Paso Lurgi Coal Gasification Complex (Total Area - 1.5 sq. mi).

The streams assigned to each sampling category are listed below:

1. Solid and slurry stream. These include the feed coal, ash residue slurries and sulfur byproduct streams and correspond to stream numbers 1, 2a, 2b, 2c, 2d, 5a, 5b and 9 in Figures 8 and 9.

2. Aqueous streams. These are represented in Figures 9 and 10 by numbers 5c, 6b and 13 through 18. These include various water inputs, byproduct ammonia, waste water from the ash quenching area as well as the inputs and outputs to the cooling towers.

3. Non-aqueous (organic) streams. These are byproduct phenol, naphtha, and tar streams. These are indicated by numbers 6a, 7, and 11 in Figure 8. These streams are also transported via piping systems and samples are taken from in-line taps.

4. Gas (no particulate matter) streams. Sampling locations for gas streams are more diverse than those for any other group. They include:

    - product gas (12)
    - oxidizer and absorber off gases (8)
    - oxygen stream (3)
    - ambient samples (B)*
    - vents (A)*
    - flare systems (C)*

5. Flue gas samples are represented in Figures 8 and 9 by numbers 4a, 4b, 4c, 4d and 10. In the model considered for this study, there are fourteen stacks grouped in accordance with the following configuration:

    - four power generation turbine stacks (4a)
    - four air compression turbine stacks (4b)
    - one free-standing boiler stack (4c)
    - four steam superheater stacks (4d)
    - one Stretford unit tail gas incinerator stack.

    From each group of four, one representative stack is sampled in level 1. The free standing boiler and incinerator stack are both sampled. The flue gas samples will be taken with the modified SASS multicyclone system.

*See Figure 8 for location of additional samples

6. Fugitive dust samples are taken around the plant boundary and around the coal storage piles using high volume samplers. Sampler positioning is the same on both levels 1 and 2.

5.3.6 Stream Prioritization for the Phased Approach

A coal gasification process is a highly complex system consisting of a wide variety of interrelated components. Level 1 sampling will show that many influent and waste streams are not environmentally significant. These data will serve to reduce the number of samples required on level 2 substantially. A limestone wet scrubber, on the other hand, is a very simple process as compared to a gasification system. The streams which require sampling are small in number which naturally limits the number of streams which can be assigned a low priority utilizing a phased sampling approach. Also, it is important to remember that level 1 is designed to allow allocation of resources so that level 2 can provide the desired information for an environmental assessment. Direct level 2 sampling by definition can have no stream prioritization, and thus the maximum number of sites will always be sampled in this approach.

A stream prioritization based on the level 1 sampling and analysis effort will result in many streams of low priority. In many cases, the level 1 information will be sufficient to eliminate certain streams entirely from the level 2 effort. In some cases, limited resources may require the omission of certain low priority streams.

For the purpose of this study, it was desirable to assign conservative, but reasonable priorities to the various streams and in this manner eliminate certain streams from further consideration for the level 2 effort. In the case of the scrubber, there were so few streams that it was felt that it was not reasonable to eliminate any streams except in the trivial case of the input make-up water. However, careful examination of the gasifier streams indicated that 15-20% of the streams could reasonably be expected to be of very low priority. The types and quantities of streams that were eliminated are discussed below.

It is anticipated that in a coal gasifier, coal and ash sampling and fugitive dust sampling will show little or no reduction in the number of sampling sites between level 1 and level 2. The lack of coal and ash sampling site reduction stems from: 1) the high probability the ash will be significantly toxic, 2) the small number of streams available, and 3) the inconsistent nature of the streams in question. In the sampling of fugitive dust, the reduction of sampling positions would be unilateral rejection of the requirement for that type of sampling. The prioritization to be effected as a result of level 1 is for samples, not sampling sites. Data provided within the framework of a phased level sampling approach may in certain instances indicate the need to increase rather than decrease the sampling requirements on level 2.

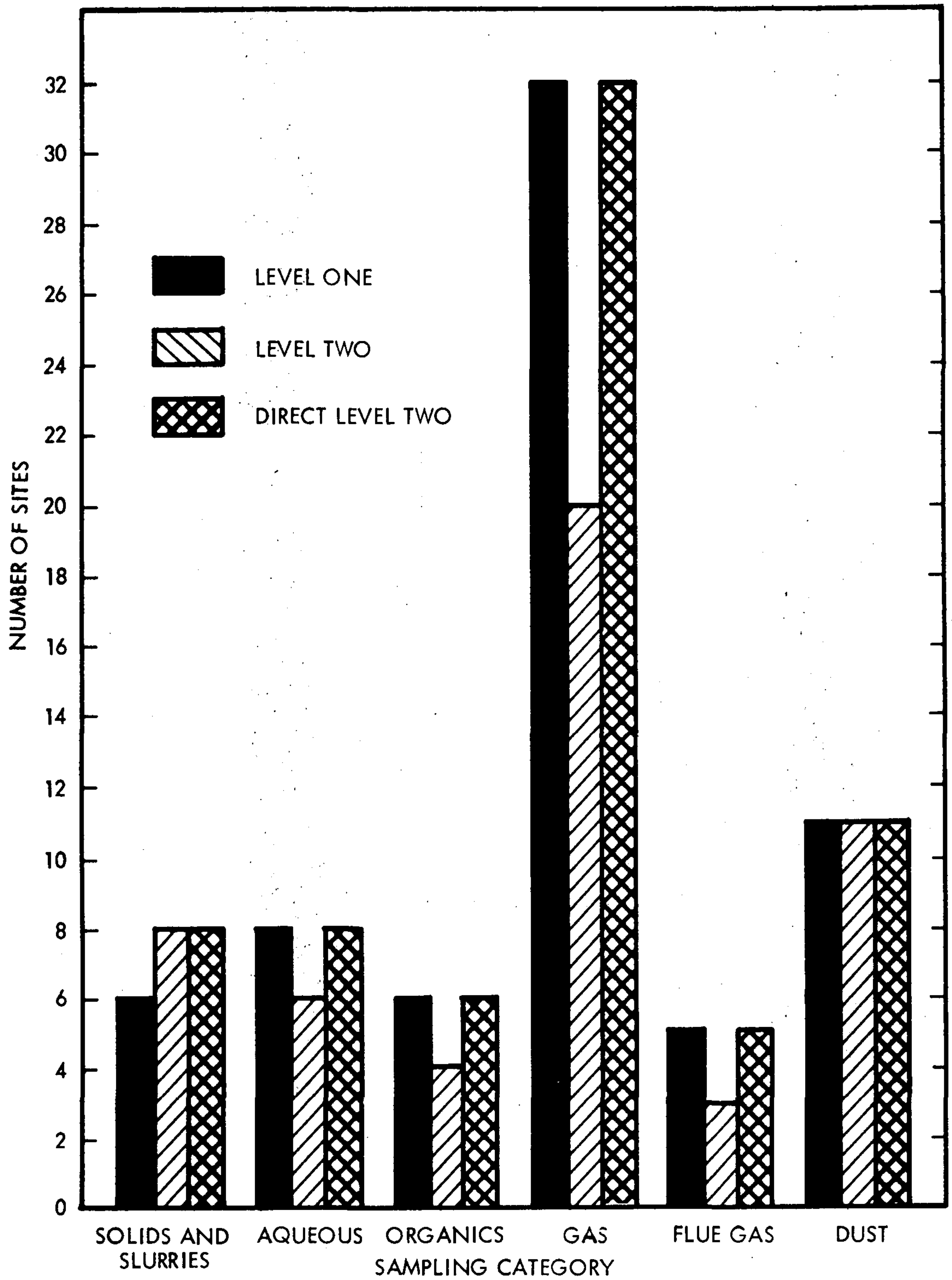
Water, flue gas, organics and gas samples could all show significant sampling point reduction for the level 2 effort. The following items represent the anticipated data obtained as the result of level 1 sampling:

- Various treated water streams will be found to be environmantally acceptable.
- Many blowdown vents, release valves and gas streams will exist at safe waste stream levels.
- Gas fired boiler and incinerator stacks are expected to yield a minimum of particulate and acid gas and, consequently, many of these stacks may be eliminated from a second level sampling effort.
- Process controls for liquid organic streams will generally prove to be effective, thus reducing the number of level 2 samples.

The results of this site reduction comparing the number of level 1, level 2 and direct level 2 sampling sites are shown graphically in Figure 12 for the coal gasifier and in tabular form in Tables 10 and 11 for both the coal gasifier and the scrubber.

5.3.7 Site Preparation Costs (Refs. 2,5)

Site preparation costs are an item that is very hard to define because of the extreme variation from site to site. In many cases, special valves or ports may have to be installed at considerable cost. However, special preparations most often involve: 1) scaffolding that must be erected in order to acquire the sample, 2) providing auxiliary power to operate the sampling



* THIS BAR GRAPH REPRESENTS SITE OF ENVIRONMENTAL INTEREST ONLY AND DOES NOT REFLECT REPLICATE SAMPLES OR ESTIMATED RESAMPLING EFFORT IN THE DIRECT LEVELS.

Figure 12. Summary of Sampling Sites - Coal Gasifier

TABLE 10

SUMMARY OF SAMPLE SITES
COAL GASIFIER

Sample Type	Number of Sites Level 1	Number of Sites Level 2	Number of Sites Direct Level 2
1. Solids and Slurries	6	8	8
2. Aqueous	8	6	8
3. Non-aqueous (Organic)	6	4	6
4. Gas (Non-particulate)	32	20	32
5a. Flue Gas (Particulate)	5	3	5
5b. Flue Gas (non-particulate)	-	3	-
6 Dust (Fugitive)	11	11	11

TABLE 11

SUMMARY OF SAMPLE SITES
WET LIMESTONE SCRUBBER

Sample Type	Number of Sites Level 1	Number of Sites Level 2	Number of Sites Direct Level 2
1. Flue Gas (Particulate)	2	2	2
2. Miscellaneous Stack Gases	2	2	2
3. Aqueous	3	2	3
4. Reheater Fuel (Organic)	1	1	1
5. Limestone Input (Solids)	1	1	1

hardware,or 3) installation of sampling ports (especially for level 2 particulate matter samples). These preparations may or may not be provided by the plant maintenance crews. Other minor preparations may be the providing of special tools, safety equipment, or the overhaul of a valve or part to make it more serviceable. In more extreme cases, equipment, pipes, or electrical wiring may have to be installed for safety or sampling reasons.

Assigning a cost to this nebulous area is difficult because while the extreme cases are not rare, in most cases, these costs are low to moderate especially for the newly designed technologies being treated here. The newly designed technologies will probably have sampling ports for criteria pollutants. However, environmental assessment is to identify new pollutants or new streams which need specifications; consequently,it is not probable that all sampling facilities will be covered. Accordingly, a reasonably low cost was assigned to site preparation with the assumption that higher costs are not applicable to the processes studied in this treatment. Thus,it was assumed that the erection of scaffolding and providing power would be the main site preparation cost; a further assumption was that these costs would be associated to a large extent with stack sampling, since this is the most complex sampling procedure. The costs were set at $250 per stack for level 2 assuming that the necessary access ports are available. In addition, preparation for the other gasifier sites which should be minimal was set at $500 for level 1, $1,000 for level 2, and $1,500 for direct level 2, corresponding roughly to 2, 4 and 6 man days, respectively. These costs are summarized in Table 12. A more detailed explanation of the more general case is given in Appendix C.

TABLE 12

SITE PREPARATION COSTS[a]

	No. Stacks	Cost	Other Costs	Total Cost
		GASIFIER		
Level 1	5	5.0 c.u.	2 c.u.	7.0 c.u.
Level 2	3	6.0 c.u.	4 c.u.	10.0 c.u.
Direct Level 2	5	1.0 c.u.	6 c.u.	16.0 c.u.
		LIMESTONE SCRUBBER		
Level 1	2	2.0 c.u.	-	2.0 c.u.
Level 2	2	4.0 c.u.	-	4.0 c.u.
Direct Level 2	2	4.0 c.u.	-	4.0 c.u.

[a]The design drawing indicates the presence of sampling ports which meet EPA published criteria.

5.3.8 Sampling Methods and Unit Costs (Refs. 4, 13-21)

As previously stated, all components to be sampled have been grouped into six distinct categories. These six categories, along with the cost unit figure established for each type on levels 1 and 2, are listed below in Table 13. These costs include average on-site labor for equipment breakout, assembly, sampling, disassembly and clean-up. Generally speaking, the differences in cost between levels 1 and 2 stem from the greater degree of sophistication required in acquisition of a level 2 sample. As stated earlier, the requirements for obtaining a sample for quantitative analysis are much more rigid than those for obtaining a sample for qualitative analyses. Summary diagrams for sampling are shown in Figures 13 and 14.

TABLE 13

SUMMARY OF SITE SAMPLING COSTS

Sample Type	c.u./sample		Actual $	
	Level 1	Level 2	Level 1	Level 2
1. Solids & Slurries	0.50	1.00	125.00	250.00
2. Aqueous	0.50	0.70	125.00	175.00
3. Non-aqueous	0.67	1.00	167.00	250.00
4. Gas (Non-particulate)	0.28	0.60	70.00	150.00
5a. Flue gas (Particulate)	0.91	6.00	227.00	1500.00
5b Flue gas (Non-particulate)	-*	1.00	-	250.00
6. Fugitive dust	0.36	0.30	90.00	75.00

* Lack of particulate matter must be established with a level 1 test.

The method used for the determination of specific costs for sample types in this study relies on data obtained from the following four sources:

- A survey study of presently established costs obtained from commercial organizations who routinely perform sampling tasks of this nature,
- A compilation of data resulting from TRW's involvement in projects of this nature,
- Joint discussions between project members and EPA officials concerning the applicability of these data to coal conversion processes,
- The assumptions made in formulating the cost unit figure itself.

Using the gasifier as an example, these four factors were then used to compute a total on-site time for taking the required number of samples in each of the six sampling categories. This was computed as follows:

$$\text{c.u./sample} = \frac{\text{Total on-site time (in man-days)*}}{\text{number of samples}}$$

*See Section 5.2. One man-day equals one c.u. equals $250.

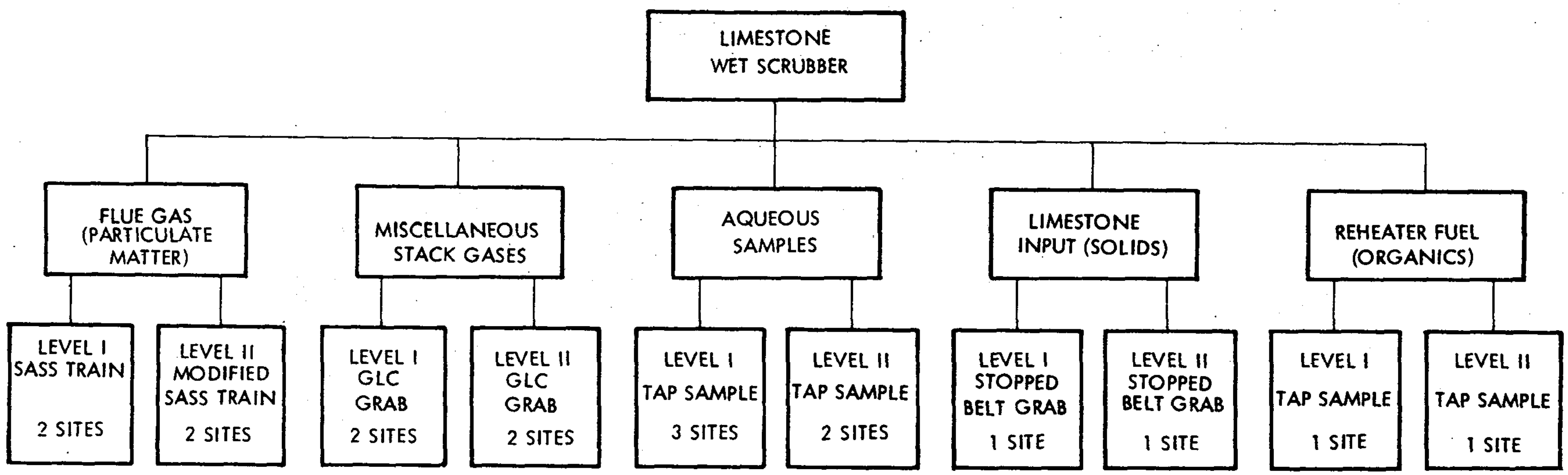


Figure 13. Wet Limestone Scrubber - Sampling Site Summary Chart

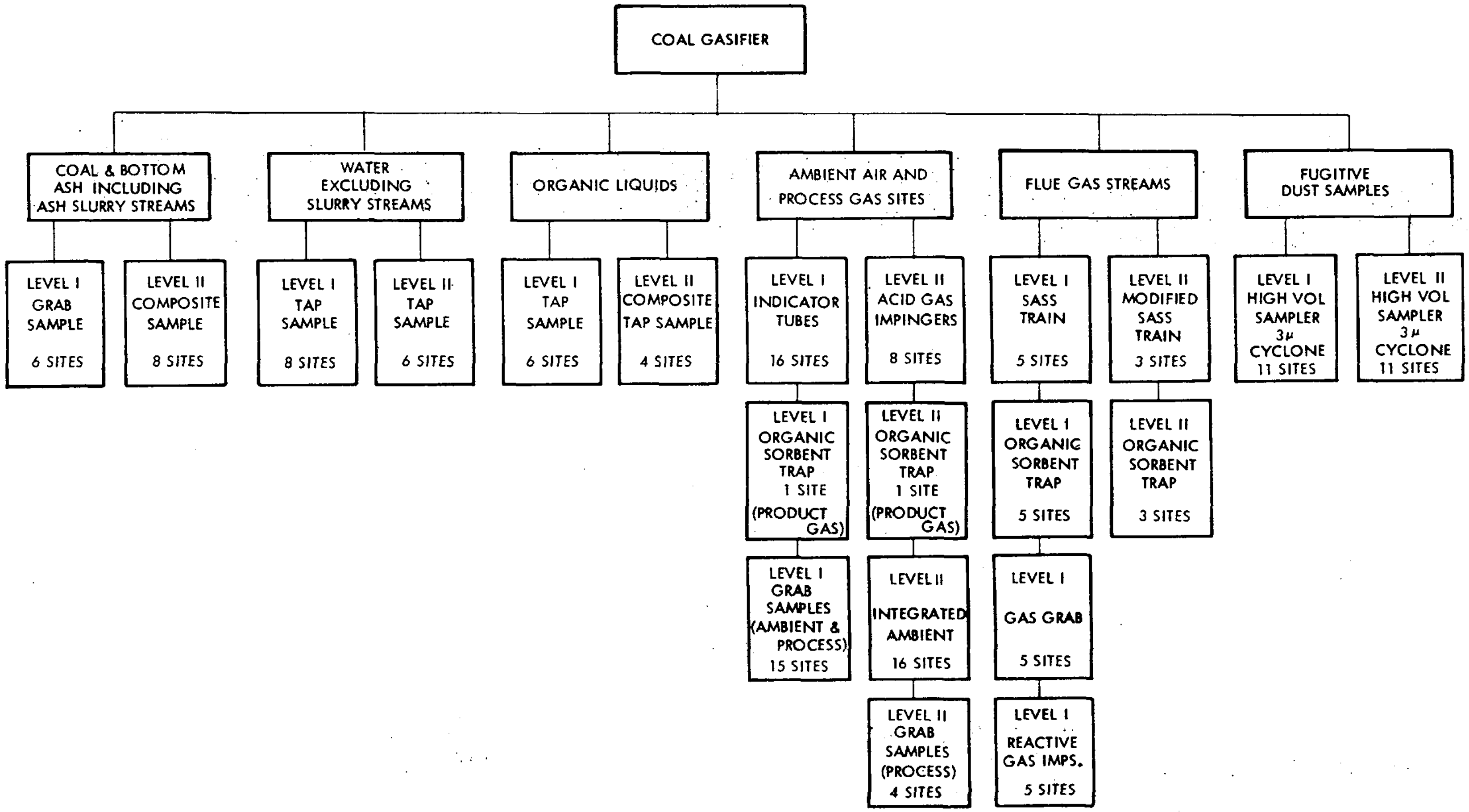


Figure 14. Coal Gasifier - Sampling Site Summary Chart

These average sampling costs were tabulated in Table 13 and used as general costs applicable to other units. Special costs required to implement the procedure by a certain site are defined as site preparation costs. This computation can be illustrated for the solids and solids slurry category. In this case level 1 sample acquisition for coal and ash consists simply of taking a grab sample from any point along a stopped conveyor belt. Equipment identification, travel to sampling point, establishing stopped belt conditions, sample acquisition and travel to the next point, etc. for 6 sampling points were estimated to be a 3 man-days, or

$$\frac{\text{3 man-days*}}{\text{6 samples}} = 0.5 \text{ c.u./sample}$$

which is approximately 4 hours per sample. In level 2 coal and ash sampl acquisition, greater care is exercised in obtaining a representative samp by taking composite samples. The added cost incurred as a result of this increased complexity raises the coal and ash cost to one cost unit per sample on level 2; or, 8 hours are needed to obtain one sample.

Level 1 sample acquisition for water involves essentially the same level of time effort as coal and ash in that it involves the assembly out of the sampling equipment, travel to the sampling point, and sample acquisition. Obviously, taking a tap sample is not so time consuming as taking a stopped belt sample; however, there are a greater number of water samples to be taken and more care must be exercised in the sampling technique. In level 2 water sampling, the sampling technique is more complex insofar as a representative sample must be obtained for quantitative analysis, thus requiring composites of certain streams, refrigeration, etc. The time interval required for the level 2 water sampling of 6 streams is 4.2 man days. Hence:

$$\frac{\text{4.2 man-days}}{\text{6 samples}} = 0.7 \text{ c.u./sample}$$

Therefore, a time period of approximately 5.6 hours is needed to obtain one level 2 water sample.

Obtaining a level 1 organics tap sample is slightly more difficult than obtaining a level 1 water tap sample due to the greater diversity in available tap locations and the various stream conditions which must be accounted for, such as heat, viscosity, pressure, etc. Assuming 6 organics streams, the total projected time figure for level 1 organics sampling is 4 man days; therefore, 4/6 = 0.67 c.u./sample or about 5.4 hours per sample. Level 2 organics are even more complex in that specific stream characteristics must be taken into consideration in order to obtain a representative sample. Heated systems require cooling apparatus on the sampling equipment; three-phase systems require a representative sample of each phase. Streams in which heavy particulate exists should be sampled isokinetically. Many organic streams are hazardous to the sampler and special precautions must be taken for safety reasons. Considering the reduced number of streams on level 2 and the above factors added into the cost, the time figure for level 2 sample acquisition becomes 4 man days, which calculates out to one cost unit per sample or 8 hours per sample.

The gas sample category in level 1 contains the largest number of samples and the gas sampling task requires the largest period of time for completion. Level 1 gas sampling consists primarily of gaseous grab samples for on-site GC analysis. This task involves obtaining ambient samples, vent samples, pipeline samples, duct samples and possibly flare samples. Thirty-two locations have been decided upon and a duration time of 9 man-days has been assumed; hence:

$$\frac{\text{9 man-days}}{\text{32 samples}} = \text{0.28 c.u./sample}$$

or 2.2 hours per sample.

The gas sampling category on level 2 also contains the largest number of samples and requires the greatest time for completion. Increased complexity on level 2 is represented by a more extensive use of integrated and composite samples and the increasingly difficult accessibility of sampling locations. A total of 20 samples has been identified and the proposed completion time is 24 man-days.

$$\frac{\text{12 man-days}}{\text{20 samples}} = \text{0.60 c.u./sample} = \text{4.8 hours/sample}$$

Flue gas sample acquisition is the most complex group of the six. The instrumentation is complex, the equipment is cumbersome, problems are frequently encountered, and the actual sample acquisition is time-consuming. Level 1 flue sampling differs from level 2 flue sampling in that the sample withdrawal point is not critical and isokinetic sampling conditions are not necessary in order to obtain qualitative data. For the sampling of five flue stacks on level 1, a total of 4.6 man days has been assumed, thus establishing a c.u./sample figure of 0.91. The time required for obtaining one flue gas sample would therefore be approximately 7 hours. On level 2 where isokinetic conditions and replicate samples are required and sample port selection becomes specific, the cost unit per sample rises from 0.91 to 6.00 to allow for the added complications. This substantial increase is based on the fact that a two-man crew is required to operate the equipment and takes three days to obtain three replicate samples to be composited for analysis.

A special case for the flue gas sampling exists where no significant particulate is found in level 1 sampling and analysis. This case by definition can only be assigned to level 2. This modification includes sampling for PAH compounds with a Tenax trap, acid gas impingers, and gas samples for gas chromatographic analysis. The cost assigned to this task was 1 man-day or 1.00 c.u. These costs were applied to the level 2 sampling of the gasifier stacks to reflect the assumption that level 1 sampling and analysis would show the absence of significant particulate from the gas fired boilers.

Fugitive dust samples are taken with high volume particulate samplers containing in-line cyclone attachments. The principal time involvement in ambient particulate sample acquisition concerns sampler positioning and post sampling sample transfer. The actual sampling time may last from 24 to 48 hours depending on particulate densities; however, during run times the samplers may be left unattended.

Eleven positions for fugitive samples* have been identified on both levels 1 and 2. This is the only sampling category wherein the unit costs per sample are greater on level 1 than on level 2. Level 2 sampling is expected to require less time than level 1 sampling for the following two reasons:

*Comprising eight upwind-downwind samples (including plant parameter and coal storage area) and three other locations within closed buildings.

- Areas for sample positioning will have been identified.
- Electrical outlet locations will have been established resulting in fewer wiring problems on level 2 than on level 1.

Level 1 fugitive dust sampling is expected to require a total of four man-days for eleven sampling sites, thus establishing a cost unit per sample figure of 0.36. Level 2 fugitive dust sampling for the same number of sites will require approximately 3.3 man-days resulting in a 0.30 c.u./sample figure.

All cost unit per sample figures derived from the above study are directly applicable to the limestone wet scrubber model. Due to the relative simplicity of a limestone wet scrubber system, the number of streams available for sampling is small. Consequently, in addition to the previously mentioned six sampling categories, specific streams may be identified. The two specifically identified streams for a limestone wet scrubber not included in the sample type breakdown for a gasifier are:

1) Reheater fuel input stream; this is essentially an organic tap sample.

2) Limestone input; this is essentially a stopped belt solids sample.

For specific costing information relative to the sampling of a limestone wet scrubber, refer to Table 13.

5.4 ANALYSIS

This section describes rationale used to select the analysis procedures which are used for the samples collected and describes the assumptions used to arrive at the individual unit costs.

5.4.1 Number of Samples Used for Costing Assumptions (References 4, 5, 6, 14, 24)

In the area of analysis, no effort was made to eliminate specific components from a given stream. All analysis reductions with the exception of level 2 flue gas analysis established for the level 2 analysis effort are the result of the stream reductions delineated in Section 5.3. It should be noted that several sample types generate two or more samples for separate unit analysis. Thus, the ash slurry stream generates a water sample and a solids sample, and the wide boiling range organics obtained from the water and organic streams are split into separate high boiling ($>C_6$) and low boiling samples ($<C_6$) for organic analysis. The flue gas particulate is collected as four samples for particulate analysis, but this is reduced to two samples for chemical and bioassay analysis in level 1. An additional trace element analysis is included on direct level 2 stack sampling for the impinger train and an additional organic analysis is added for analysis of volatile organic collected by a special tenax train. Level 2 gasifier flue gas sample analysis is postulated on the fact that no particulate was found in the gas fired boiler on level 1 analysis. Fugitive particulate samples were reduced to two samples each ($>3\mu$ and $<3\mu$) from two sets of four locations. A summary of the number of gasifier analyses is shown in Table 14.

5.4.2 Basic Analysis Scheme

The analytical procedures cited in this report are divided into 9 distinct categories. Each of these categories is essentially the same at both levels of the phased approach and differs only in the level of sophistication involved.

Figure 15 illustrates a generalized flow scheme for the analytical categorization of level 1 samples. Each analyses type is assigned its own cost unit per analysis factor and a brief statement of methodology is made for each analysis type.

TABLE 14. SUMMARY OF ANALYSIS
TYPES PER OPERATIONAL CONDITION -
COAL GASIFIER[a)]

Analysis Type	Coal and Ash			Water			Organic		
	Level 1	Level 2	Direct Level 2	Level 1	Level 2	Direct Level 2	Level 1	Level 2	Direct Level 2
1) Bioassay: a. Water Insoluble[b)]	6	3	6	8	0	0	6	4	6
b. Water Soluble[b)]		0			6	8		0	0
2) Organic Analysis	0	3	3	16	12	16	12	8	12
3) Inorganic Compound Analysis	-	3	3	-	0	0	-	0	0
4) Particulate Morphology	0	0	0	0	0	0	0	0	0
5) Coal Feed Analysis	6	8	8	0	0	0	0	0	0
6) Inorganic Element Analysis	6	8	8	8	6	8	6	4	6
7) Water Analysis	0	0	0	8	6	8	0	0	0
8) Gas Liquid Chromatography	0	0	0	0	0	0	12	4	12

[a] The number of analyses included in this table is based on the number of sites developed in Section 5.3. These numbers will be doubled if two operational conditions are sampled.

[b] The distinction between water soluble and insoluble samples is made only for level 2 analysis. See Section 5.4.2 for details.

TABLE 14. SUMMARY OF ANALYSIS TYPES PER OPERATIONAL CONDITION - COAL GASIFIER [a] (Cont'd)

Analysis Type	Gas			Flue			Dust			Totals		
	Level 1	Level 2	Direct Level 2	Level 1	Level 2	Direct Level 2	Level 1	Level 2	Direct Level 2	Level 1	Level 2	Direct Level 2
1) Bioassay: a. Water Insoluble[b]	0	0	0	15	0	20	22	4[c]	8[c]	57	11	32
b. Water Soluble[b]		6	12		3	0		0	0		15	28
2) Organic Analysis	1	3	10	5	3	25	22	22	22	56	51	88
3) Inorganic Compound Analysis	-	0	0	-	3	25	-	22	22	-	28	50
4) Particulate Matter Morphology	0	0	0	15	0	15	22	11	22	37	11	37
5) Coal Feed Analysis	0	0	0	0	0	0	0	0	0	6	8	8
6) Inorganic Element Analysis	1	1	3	15	6	25	22	22	22	58	47	72
7) Water Analysis	0	0	0	0	0	0	0	0	0	8	6	8
8) Gas Liquid Chromatography	24	20	32	0	3	5	0	0	0	36	27	49

c) Samples were combined for more detailed testing.

Figure 16 consists of a basic analysis flow scheme as applied to level 2 sampling. The diagram format is the same as that for level 1.

5.4.3 Analysis Procedures and Unit Costs (References 8, 9, 10, 11, 25)

The unit costs shown in Table 15 were developed using data collected from a wide variety of sources. Commercial price lists were used whenever an analysis was routine. For semi-routine analysis or very specialized analyses for which procedures are available, the appropriate authorities were consulted for their estimates of the costs. Sources included the EPA (various branches), EPA contractors (SRI, BMI, MRI, Radian), academic sources and various commercial testing laboratories. Each analysis and unit cost is briefly explained below.

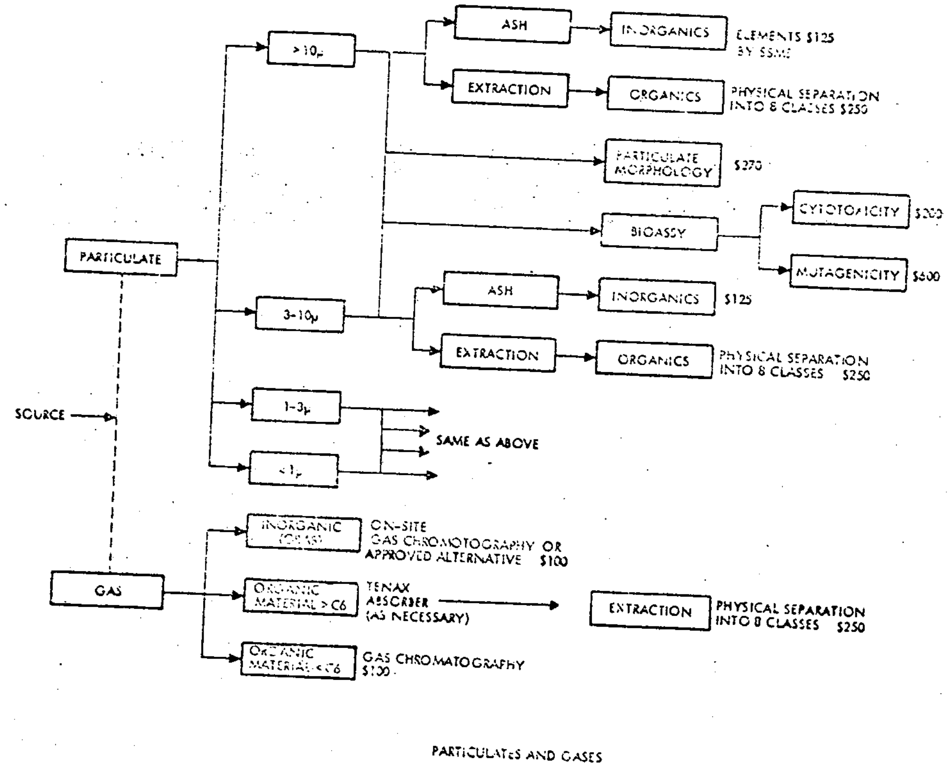
5.4.3.1 Bioassay Testing (References 5, 26-32)

This series of tests is designed to test in a broad and general manner, the health effects of a given source sample. The approach and costs shown in Figure 17 were developed by the EPA's Experimental Biology Laboratory. Level 1 bioassay includes simplified cytotoxicity and mutagenicity testing on all solid and liquid (water and organic) samples or fractions obtained. In Level 2 testing, the original tests are expanded and a carcinogenicity test is added for use where appropriate. The number of samples includes all solids, liquids, and gases. In addition to the biological tests, level 1 costed trace element and organic tests are performed on the insoluble particulate and supernatant in order to aid in interpretation of the data. These tests are not included if the sample is entirely soluble.

5.4.3.2 Organic Analysis (Solids and Liquids) (References 5, 6, 33-43)

- Level 1 - A survey liquid chromatographic technique is used to separate the samples into 8 fractions for identification by infrared analysis of compound types. Organic samples obtained from water or organic streams are divided into a high (>150°C) and low (<150°C) boiling fraction for separate analysis and are costed as two samples.

- Level 2 - The results of level 1 are used to redefine the level 2 technique. The level 2 organic analysis includes HPLC separation of the organic mixture and GC/MS analysis of eight of the resultant HPLC fractions. The cost is 2 c.u. per run and



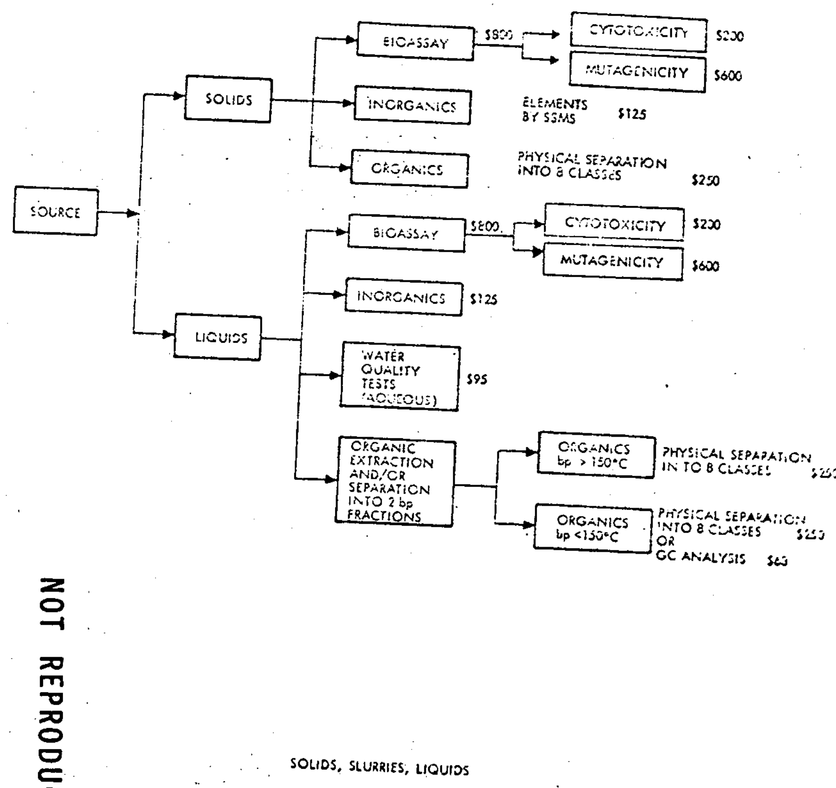


Figure 15. Basic Analytical Schemes for Level 1

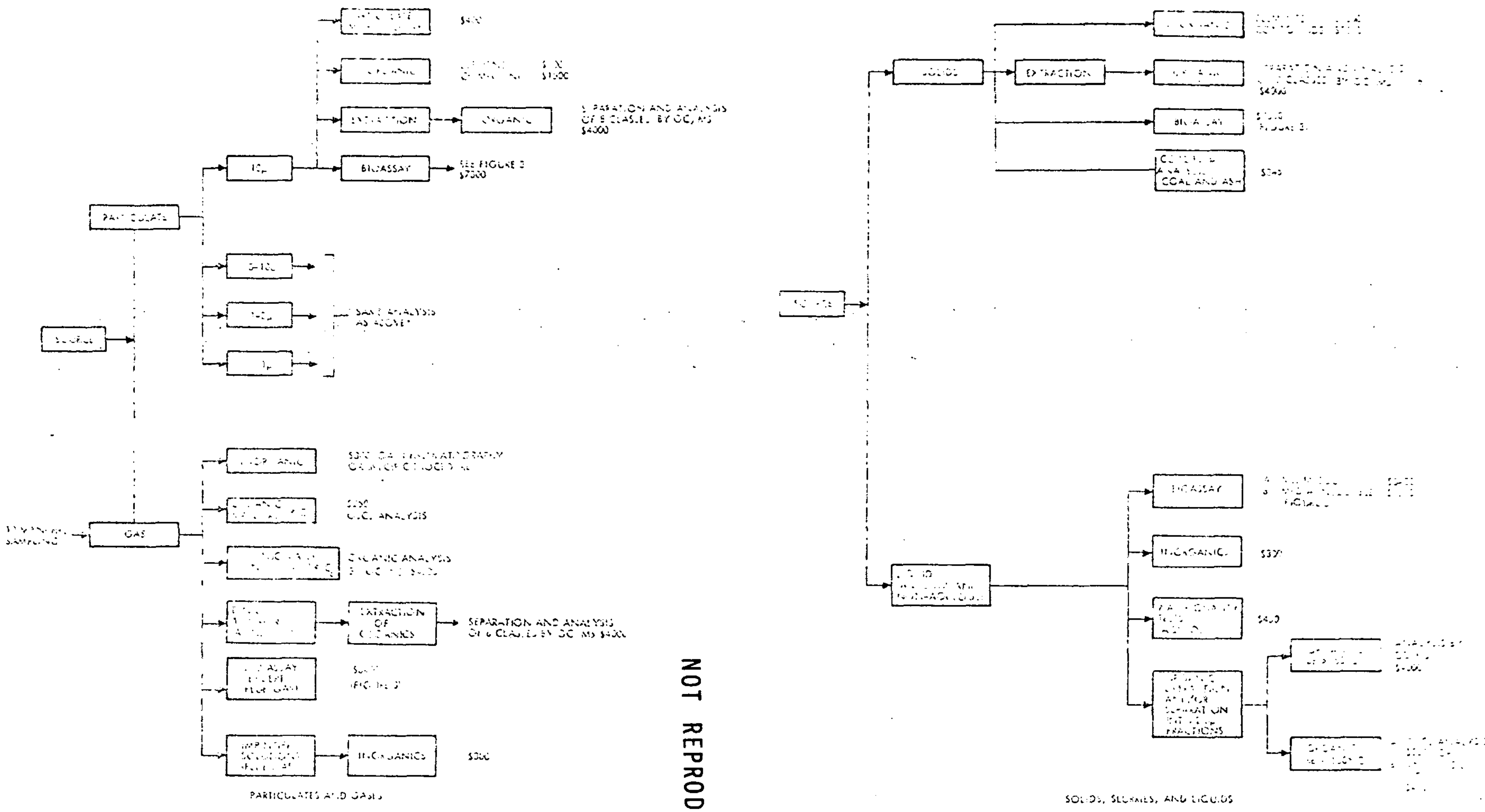


Figure 16. Basic Analytical Schemes for Level 2

TABLE 15

MAJOR UNIT ANALYSIS COSTS

Analysis Category	Cost Units		Actual Cost $	
	Level 1	Level 2	Level 1	Level 2
1. Bioassay				
a. Media Soluble	3.20	13.60	800	3400
b. Media Insoluble	3.20	29.20	800	7300
2. Organic Analysis (per sample)	1.00	16.00	250	4000
3. Inorganic Compound Identification	—	6.00	—	1500
4. Particulate Morphology	1.10	1.60	270	400
5. Coal Feed Analysis	—	1.38	—	345
6. Inorganic Element Analysis	0.50	1.20	125	300
7. Water Analysis	0.38	1.80	95	450
8. Gas Chromatographic Analysis	0.25	1.00	63	250
• Acid Gases				
• C_1-C_8 Organics				
• Sulfur Compounds				

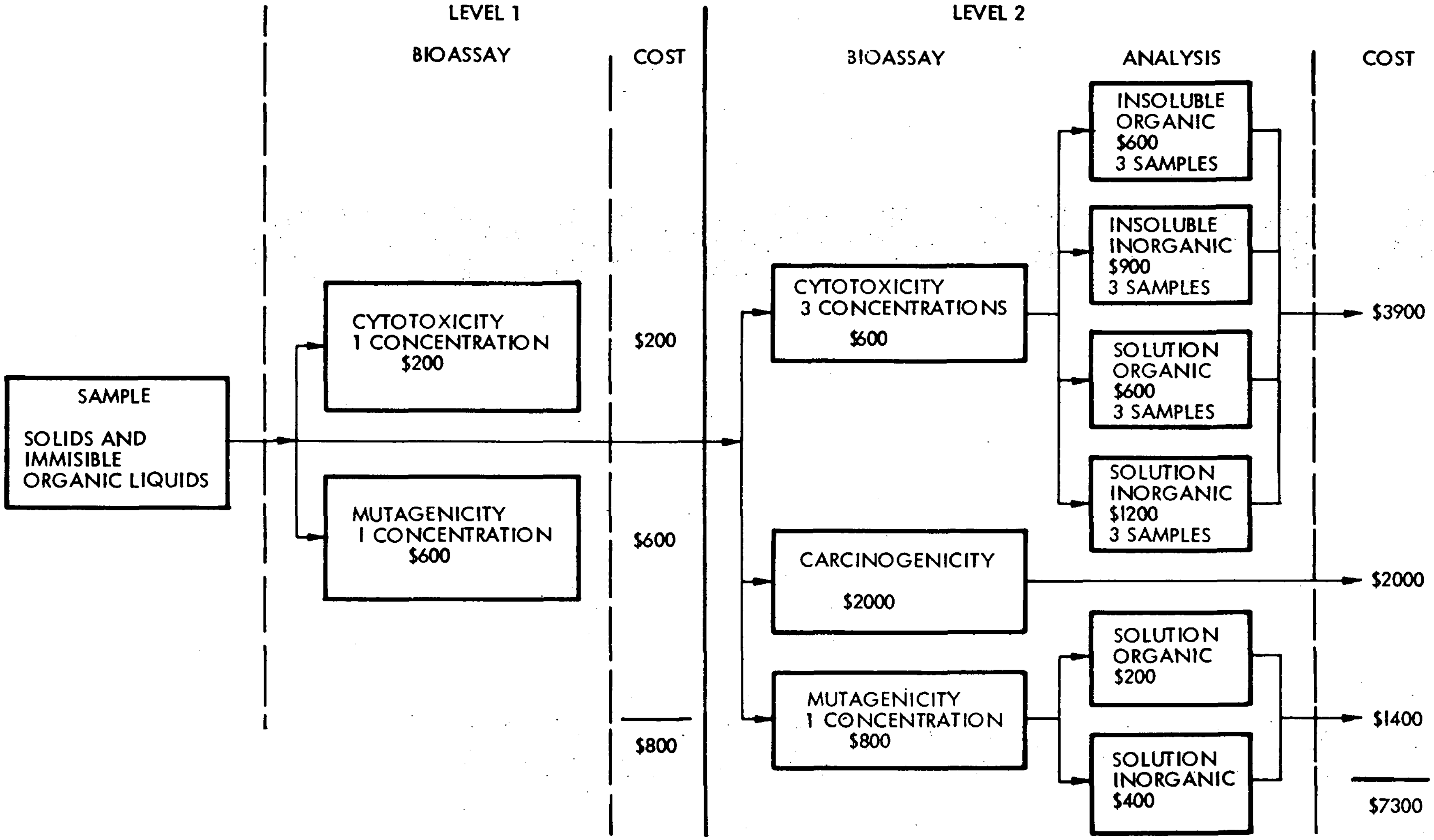


Figure 17. Bioassay Flow Chart

it is assumed that 8 runs per sample will be needed for a total cost of 16.0 c.u.

5.4.3.3 Inorganic Compound Identification (References 44,45)

Inorganic compound identification is essentially a sophisticated experimental extension of particulate morphological determinations. As such it provides information needed for level 2 characterization. At present, methodology for this type of analysis is ill-defined and costs are even more elusive. For this reason, an upper limit of 6 c.u. or $1,500 was set on the costs. A proposed analysis scheme is shown in Figure 18.

5.4.3.4 Particulate Morphology (References 6, 46-48)

Level 1 morphological examinations of collected particulate will include microscopic examination of shape, size, distribution, surface features, and possible source. The method used includes a polarized light microscope for particles >0.5μ and over, and scanning electron microscopy (SEM) for < 0.5μ particles. The usage of these two techniques will yield information as to general particle size distribution as well as classification into general morphological types, and specific compound identification by crystalline structure. This analysis is approximately $275.00/sample. Additional information on particulate composition will be obtained in level 2. This additional information is obtained at an additional cost of $125.00/sample by performing a SEM-EDX or X-ray microprobe analysis to determine semi-quantitatively the elemental concentration of specific particulate.

5.4.3.5 Coal Feed Analysis (References 45, 48, 49)

In addition to the regular analysis, this is a standard set of ASTM analyses for level 2 which includes sulfur forms, ultimate, proximate, and ash analysis as well as sieve (size) analysis.

5.4.3.6 Inorganic Element Analysis (References 5, 8, 45, 50, 51, 52)

Spark Source Mass Spectroscopy (SSMS) is the analytical tool costed for both the level 1 and level 2 trace element analysis. This technique was chosen after comparison with Neutron Activation Analysis (NAA), X-Ray

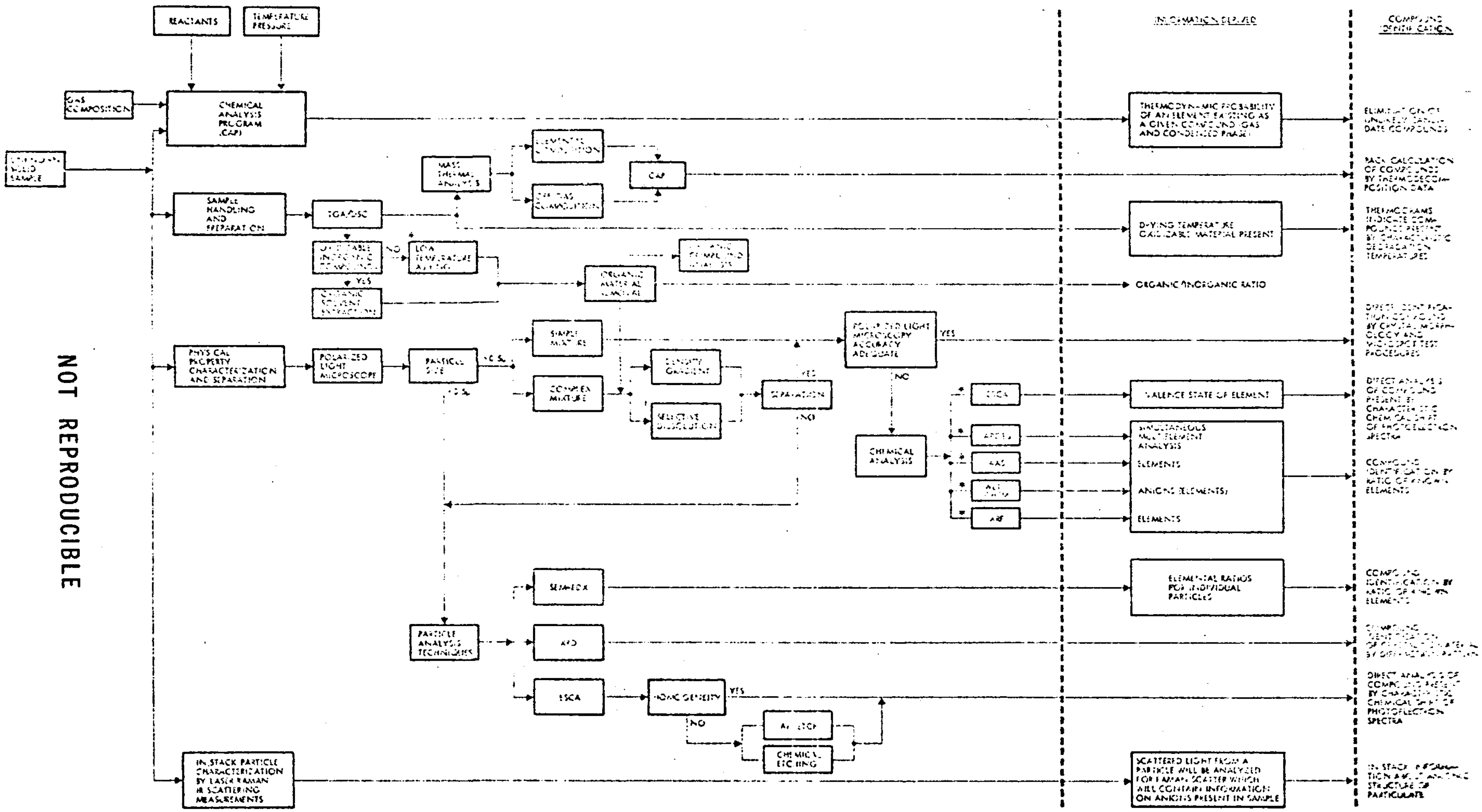


Figure 18. Inorganic Compound Characterization Scheme

Fluorescence (XRF), Optical Emission Spectroscopy (OES), and Atomic Absorption Spectroscopy (AAS) for accuracy, precision, versatility, cost and detection limits.

A level 1 analysis is designed to perform as a general survey scan of all effluent streams for possible toxic or carcinogenic inorganic species. In this type of scheme, the most important parameters for an analytical technique are detection limits, multi-element capability, speed and cost. Of lesser importance for level 1 are accuracy and precision. Level 2 analyses are designed to generate more accurate analytical data for specific species found present during level 1 testing. Accuracy levels of ± a factor of three were arbitrarily set for level 1 analysis and a minimum detection limit of 1 ppm for all streams tested. Level 2 accuracy was set at ± a factor of 0.5 with the same detection limits. Of all the analytical techniques evaluated for level 1, SSMS was the most versatile in that all elements can be detected at the prescribed levels or lower. The major difficulty associated with this type of analysis is that organic matrices, especially the oils and tars from the gasifier complex, must be removed prior to analysis. Appropriate sample preparation techniques were evaluated and are included in the various analysis costs.

A more accurate and correspondingly more expensive SSMS procedure is costed as a level 2 and direct level 2 analysis. The more accurate (±50%) analysis is achieved using more sophisticated instrumentation and comparing analytical values with standards prepared to approximate the sample composition.

Although only SSMS was costed for level 2 analyses, ancilliary techniques might also be used for specific elements, the usage of which would depend on the completion and evaluation of level 1 analysis as to elements present and approximate levels of concentration.

5.4.3.7 Water Analysis (References 28, 29, 53-59)

In addition to the normal liquid analyses, an entire set of approved EPA analyses is included. The tests and the costs for analysis by commercial laboratory are tabulated in Appendix B.

- Level 1 analyses are costed via estimated labor necessary to perform these analyses with portable Hach kits which are used to allow flexibility in the field and reduced cost.
- Level 2 analyses are to be done in a commercial laboratory to achieve increased reliability and accuracy.

5.4.3.8 Gas Chromatographic Analysis (References 60-70)

These analyses will be performed on site by a multicolumn, multi-detector gas chromatograph for level 1 and wherever possible for level 2. In many cases, it will be necessary to perform the analyses on site because of the sample instability. The differences in cost between levels 1 and 2 reflect the difference in accuracy and precision of the data obtained.

5.5 TOTAL SAMPLING AND ANALYSIS COSTS - WET LIMESTONE SCRUBBER

The unit costs, number of sampling sites, and number of analyses established for the wet limestone scrubber described in Section 5.3 and 5.4 have been used to compute itemized and total sampling costs for this unit. The results of these calculations are tabulated in Tables 16-24.

5.5.1 Computation of Repeat and Replicate Sample Costs

It has been assumed for the purposes of this report that a 35% repeat rate will be necessary because of the nature of direct level 2 sampling. No specific assumptions have been made as to where the major portion of these repeats will occur and thus, this added cost is taken as a direct percent of the sampling and analysis costs and added to the total.

In addition to the above costs, it may be necessary to sample two or three process conditions in order to obtain adequate information for an environmental assessment of the entire complex. By definition, two distinct level 2 or direct level 2 efforts will have to occur at different times. Two process conditions were assumed for this report. Thus, the total level 2 (direct or phased) costs were multiplied by a factor of two to provide for this second effort. This increment is shown as Item IV in all summary tables.

5.5.2 Computation of Sampling Costs

The method of computing sampling costs has been explained in Section 5.2. Tables 16, 17, and 18 show an itemized computation for level 1, level 2 and direct level 2 field sampling costs based on the number of samples and unit costs derived in Section 5.3. These totals are tabulated in Tables 22, 23 and 24 as Item I-C-b. To this is added an additional cost of 1.5, 1.0 and 2.0 times the basic cost for trip planning and preparations for level 1, level 2 and direct level 2 sampling, respectively. Additional itemized costs are added as necessary for travel, ODC's, site preparation, a pre-site survey and reporting. Finally, the total sampling costs are computed.

TABLE 16

SUMMARY OF LEVEL 1 FIELD SAMPLING COSTS[a)]

LIMESTONE WET SCRUBBER

Site Type	No. of Site(s)	c.u./ Site	Total c.u.	Actual %
1. Flue Gas (Particulate)	2	0.91	1.82	58.3
2. Water Quality	3	0.50	1.00	32.1
3. Limestone	1	0.10	0.10	3.2
4. Reheater Fuel	1	0.20	0.20	6.4
	7	-	3.12	100.0

a) Labor and per diem costs to obtain one set of samples for each sampling site.

TABLE 17

SUMMARY OF LEVEL 2 FIELD SAMPLING COSTS[a)]

LIMESTONE WET SCRUBBER

Site Type	No. of Site(s)	c.u./ Site	Total c.u.	Actual %
1. Flue Gas (Particulate)	2	6.0	12.0	90.9
2. Misc. Stack Gases	2	0.1	0.2	1.5
3. Aqueous	2	0.3	0.6	4.6
4. Reheater Fuel	1	0.2	0.2	1.5
5. Limestone Input	1	0.2	0.2	1.5
	8	-	13.2	100.0

a) Labor and per diem costs to obtain one set of samples for each sampling site.

TABLE 18

SUMMARY OF DIRECT LEVEL 2 FIELD SAMPLING COSTS[a]

LIMESTONE WET SCRUBBERS

Site Type	No. of Site(s)	c.u./ Site	Total c.u.	Actual %
1. Flue Gas (Particulate)	2	6.0	12.0	88.9
2. Misc. Stack Gases	2	0.1	0.2	1.5
3. Aqueous	3	0.3	0.9	6.6
4. Reheater Fuel	1	0.2	0.2	1.5
5. Limestone Input	1	0.2	0.2	1.5
	9	---	13.5	100.0

[a]Labor and per diem costs to obtain one set of samples for each sampling site.

5.5.3 Computation of Analysis Costs

The method of computing analysis costs has been explained in Section 5.2. The basic unit costs used to compute the total cost were derived in Section 5.4 which assumes 100% efficiency. To this is added an additional cost of 20% for set-up time, duplicates, etc. and another 20% for correlation and reporting. In addition, another 35% was added to the total of the above for repeat samples taken on direct level 2. Only the basic analysis costs will be discussed in this section with the aggregate costs being shown in Summary Tables 19, 20, and 21.

Tables 19, 20 and 21 show an itemized computation for level 1, level 2, and direct level 2 sampling costs based on the number of samples and unit costs derived in Section 5.4. Note that on all levels, bioassay and organics analysis are the cost sensitive items and inorganic compound analysis is the third most important item for both level 2 analyses. Thus, an all cost benefit analysis should concentrate on these items.

TABLE 19

BASIC LEVEL 1 ANALYSIS COSTS[a)]
LIMESTONE WET SCRUBBER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay	10	3.20	32.0	51.9
2. Organic Analysis (per sample)	14	1.00	14.0	22.7
3. Inorganic Compound Identification	--	--	--	--
4. Particulate Morphology	6	1.10	6.6	10.7
5. Coal Feed	--	--	--	--
6. Inorganic Element Analysis	15	0.50	7.5	12.1
7. Water Analysis	3	0.38	1.1	1.8
8. Gas Chromatographic Analysis	2	0.25	0.5	0.8
9. Miscellaneous Costs	--	--	--	--
	50	-	61.7	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 22, 23, and 24.

TABLE 20

BASIC LEVEL 2 ANALYSIS COSTS[a)]
LIMESTONE WET SCRUBBER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay				
a. Soluble	2	11.20	22.4	6.2
b. Insoluble	4	29.20	116.8	32.6
2. Organic Analysis (per sample)	8	16.00	128.0	35.7
3. Inorganic Compound Identification	10	6.00	60.0	16.7
4. Particulate Morphology	6	1.60	9.6	2.7
5. Inorganic Element Analysis	15	1.20	18.0	5.0
6. Water Analysis	2	1.80	3.6	1.0
7. Gas Chromatographic Analysis	0	--	--	--
8. Miscellaneous Costs	1	.30	.3	.1
	48	-	358.7	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 22, 23, and 24.

TABLE 21

BASIC LEVEL 2 ANALYSIS COSTS - DIRECT SAMPLING[a)]
LIMESTONE WET SCRUBBER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay				
a. Soluble	2	13.60	27.2	4.7
b. Insoluble	8	29.20	233.6	40.2
2. Organic Analysis (per sample)	14	16.00	224.0	38.6
3. Inorganic Compound Identification	10	6.00	60.0	10.3
4. Particulate Morphology	6	1.60	9.6	1.7
5. Coal Feed	--	--	--	--
6. Inorganic Element Analysis	15	1.20	18.0	3.1
7. Water Analysis	3	1.80	5.4	0.9
8. Gas Chromatographic Analysis	2	1.00	2.0	0.4
9. Miscellaneous Costs	1	0.30	.3	0.1
	61	-	580.1	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 22, 23 and 24.

TABLE 22

LIMESTONE WET SCRUBBER SAMPLING AND ANALYSIS COSTS

LEVEL 1

I. TOTAL SAMPLING COSTS		
A. Preliminary Arrangements and Pre-site Survey		
1. Labor	6.0 c.u.	
2. ODC's	1.0 c.u.	
	7.0 c.u.	$1,750
B. Trip Planning and Preparations (Variable)		
1. Site Preparations	1.0 c.u.	
2. 1.5 x Field Sampling Labor Costs	4.7 c.u.	
	5.7 c.u.	$1,425
C. Field Sampling Costs (2-Man Team)		
1. Travel and Miscellaneous ODC's (1000 Miles)	4.0 c.u.	
2. Field Sampling Labor and Per Diem	3.1 c.u.	
	7.1 c.u.	$1,775
D. Correlation, Reporting, Etc		
0.20 x Field Labor Costs	0.6 c.u.	$ 150
E. Total Sampling Costs	20.4 c.u.	$5,100
II. ANALYSIS COSTS		
A. Direct Analysis Costs	61.7 c.u.	$15,425
B. Analysis Set-up Time, Duplicates, Etc.		
0.20 x Direct Analysis Costs	12.3 c.u.	$3,075
C. Correlation, Reporting, Etc.		
0.20 x Direct Analysis Costs	12.3 c.u.	$3,075
D. Total Analysis Costs	86.3 c.u.	$21,575
III. TOTAL SAMPLING AND ANALYSIS COSTS	106.7 c.u.	$26,675
	834 hrs. @ $32/hr.	

TABLE 23

LIMESTONE SCRUBBER SAMPLING AND ANALYSIS COSTS

LEVEL 2

I. TOTAL SAMPLING COSTS		
A. Preliminary Arrangements and Pre-Site Survey		
1. Labor (Included in Level 1)	0.0 c.u.	
2. ODC's	0.0 c.u.	
B. Trip Planning and Preparations (Variable)		
1. Site Preparations	2.2 c.u.	
2. 1.0 x Field Sampling Labor Costs	13.2 c.u.	
	15.4 c.u.	$3,850
C. Field Sampling Costs (2-Man Team)		
1. Travel and Miscellaneous ODC's (1000 Miles)	6.5 c.u.	
2. Field Sampling Labor and Per Diem	13.2 c.u.	
	19.7 c.u.	$4,925
D. Correlation, Reporting, Etc.		
0.20 x Field Labor Costs	2.6 c.u.	$ 650
E. Total Sampling Cost	37.7 c.u.	$9,425
II. ANALYSIS COSTS		
A. Direct Analysis Costs	363.5 c.u.	$90,875
B. Analysis Set-up Time, Duplicates, Etc.		
0.20 x Direct Analysis Costs	72.7 c.u.	$18,175
C. Correlation, Reporting, Etc.		
0.20 x Direct Analysis Costs	72.7 c.u.	$18,175
D. Total Analysis Costs	508.9 c.u.	$127,225
III. TOTAL COST-PROCESS CONDITION NUMBER 1	546.6 c.u.	$136,650
IV. TOTAL COST-PROCESS CONDITION NUMBER 2	546.6 c.u.	$136,650
V. GRAND TOTAL LEVEL 2 COSTS	1093.2 c.u.	$273,300
	8540 hrs. @ $32/hr.	

TABLE 24

LIMESTONE SCRUBBER SAMPLING AND ANALYSIS COSTS

DIRECT LEVEL 2

I. TOTAL SAMPLING COSTS		
A. Preliminary Arrangements and Pre-Site Survey		
1. Labor	6.0 c.u.	
2. ODC's	1.0 c.u.	
	7.0 c.u.	$ 1,750
B. Trip Planning and Preparations (Variable)		
1. Site Preparations	2.0 c.u.	
2. 2.0 x Field Sampling Labor Costs	27.0 c.u.	
	29.0 c.u.	$ 7,250
C. Field Sampling Costs (2-Man Team)		
1. Travel and Miscellaneous ODC's (1000 Miles)	6.5 c.u.	
2. Field Sampling Labor and Per Diem	13.5 c.u.	
	20.0 c.u.	$ 5,000
D. Correlation, Reporting, Etc.		
0.20 x Field Labor Costs	4.0 c.u.	$ 1,000
E. Repeat at 35% Items B, C and D	22.9 c.u.	$ 5,725
F. Total Sampling Costs	82.9 c.u.	$ 20,725
II. ANALYSIS COSTS		
A. Direct Analysis Costs	580.1 c.u.	$145,025
B. Analysis Set-up Time, Duplicates, Etc.		
0.20 x Direct Analysis Costs	116.0 c.u.	$ 29,005
C. Correlation, Reporting, Etc.		
0.20 x Direct Analysis Costs	116.0 c.u.	$ 29,005
D. Repeat at 35% Items A, B, C	284.2 c.u.	$ 71,050
E. Total Analysis Costs	1096.4 c.u.	$274,075
III. TOTAL COST - PROCESS CONDITION NUMBER 1	1179.3 c.u.	$294,825
IV. TOTAL COST - PROCESS CONDITION NUMBER 2	1179.3 c.u.	$294,825
V. GRAND TOTAL - DIRECT LEVEL 2 COST	2358.6 c.u.	$589,650
	18,426 hrs. @ $32/hr.	

5.6 TOTAL SAMPLING AND ANALYSIS COSTS - COAL GASIFIER

The unit costs, number of sampling sites, and number of analyses established for the Lurgi coal gasifier described in Sections 5.3 and 5.4 have been used to compute itemized and total sampling costs for this unit. The results of these calculations are tabulated in Tables 25-33.

5.6.1 Computation of Repeat and Replicate Sample Costs

It has been assumed for the purposes of this report that a 35% repeat rate will be necessary because of the nature of direct level 2 sampling. No specific assumptions have been made as to where the major portion of these repeats will occur and thus, this added cost is taken as a direct percent of the sampling and analysis costs and added into the total.

In addition to the above costs, it may be necessary to sample two or three process conditions in order to obtain adequate information for an environmental assessment of the entire complex. By definition, two distinct level 2 or direct level 2 efforts will have to occur at different times. Two process conditions were assumed for this report. Thus, the total level 2 (direct or phased) costs were multiplied by a factor of two to provide for this second effort. This increment is shown as Item IV in all summary tables.

5.6.2 Computation of Sampling Costs

The method of computing sampling costs has been explained in Section 5.2. The basic unit cost used is the field labor necessary to sample a specific site. Tables 25, 26 and 27 show an itemized computation for level 1, level 2 and direct level 2 field sampling costs based on the number of samples and unit costs derived in Section 5.3. These totals are tabulated in Tables 31, 32 and 33 as Item I-C-b. To this is added the additional cost of 1.5, 1.0 and 2.0 times this basic cost for trip planning and preparations for level 1, level 2 and direct level 2 sampling, respectively. Additional itemized costs are added as necessary for travel, ODC's, site preparation, a pre-site survey and reporting. Finally, the total sampling costs including repeats and replications are computed. Note that the costs are relatively evenly

Table 25

BASIC LEVEL 1 FIELD SAMPLING COSTS[a)]

COAL GASIFIER

Site Type	No. of Sites	c.u./ Site	Total c.u.	Actual %
1. Solids and Slurries	6	0.50	3.0	10.2
2. Aqueous	8	0.50	4.0	13.6
3. Non-Aqueous (Organics)	6	0.67	4.0	13.6
4. Gas (No Particulate)	32	0.28	9.0	30.5
5. Flue Gas (Particulate)	5	0.91	4.6	18.6
6. Dust (Fugitive)	11	0.36	4.0	13.5
	68	-	28.6	100.0

a) Field labor and per diem costs to obtain one set of samples for each sampling site.

TABLE 26

BASIC LEVEL 2 FIELD SAMPLING COSTS[a)]

COAL GASIFIER

Site Type	No. of Sites	c.u./ Site	Total c.u.	Actual %
1. Solids and Slurries	8	1.00	8.0	23.2
2. Aqueous	6	0.70	4.2	12.2
3. Non-Aqueous (Organics)	4	1.00	4.0	11.6
4. Gas (No Particulate)	20	0.60	12.0	34.8
5. Flue Gas (No Particulate)	3	1.00	3.0	8.7
6. Dust (Fugitive)	11	0.30	3.3	9.5
	52		34.5	100.0

a) Field labor and per diem costs to obtain one set of samples for each sampling site.

TABLE 27

BASIC DIRECT LEVEL 2 FIELD SAMPLING COSTS[a)]
COAL GASIFIER

Site Type	No. of Sites	c.u./ Site	Total c.u.	Actual %
1. Solids and Slurries	8	1.00	8.0	11.1
2. Aqueous	8	0.70	5.6	7.8
3. Non-Aqueous (Organics)	6	1.00	6.0	8.3
4. Gas (No Particulate)	32	0.60	19.2	26.6
5. Flue Gas (Particulate)	5	6.00	30.0	41.6
6. Dust (Fugitive)	11	0.30	3.3	4.6
	70	-	72.1	100.0

a) Field labor and per diem costs to obtain one set of samples for each sampling site.

distributed. The gas samples incur a larger cost due to the large number of samples that are being taken. The disproportionate cost in the flue gas sampling between levels originates from the fact that for level 2,only samples for organic analysis are being taken because in this case, level 1 analysis would have shown no particulate in this gas fired boiler. Direct level 2 costs are postulated on particulate being present.

5.6.3 Computation of Analysis Costs

The method of computing analysis costs has been explained in Section 5.2. The basic unit costs used in Tables 28, 29 and 30 were derived in Section 5.4 and are the most efficient analysis. To this is added an additional cost of 20% for set-up time, duplicates, etc. and another 20% for correlation and reporting. In addition, another 35% was added to the total of the above for analysis of samples taken from resampled streams in the direct level 2 effort. Only the basic analysis costs will be discussed in this section with the aggregate costs being shown in Summary Tables 31, 32, and 33.

Tables 31, 32 and 33 show an itemized computation for level 1, level 2 and direct level 2 sampling costs based on the number of samples and unit costs derived in Section 5.4. Note that on all levels, bioassay and organics analysis are the cost sensitive items and inorganic compound analysis is the third most important item for both level 2 analyses. Thus, all cost benefit analysis should concentrate on these items.

TABLE 28

BASIC LEVEL 1 ANALYSIS COSTS[a)]
COAL GASIFIER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay	57	3.20	182.4	58.0
2. Organic Analysis (per sample)	42	1.00	42.0	13.4
3. Inorganic Compound Identification	40	--		
4. Particulate Morphology	37	1.10	40.7	13.0
5. Coal Feed	--	--	--	--
6. Inorganic Element Analysis	58	0.50	29.0	9.2
7. Water Analysis	8	0.38	3.0	1.0
8. Gas Chromatographic Analysis	44	0.25	11.0	3.5
9. Miscellaneous Costs	30	0.20	6.0	1.9
	316	-	314.1	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 31, 32, and 33.

TABLE 29

BASIC LEVEL 2 ANALYSIS COSTS[a)]
COAL GASIFIER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay				
a. Soluble	15	13.60	204.0	12.5
b. Insoluble	11	29.20	321.2	19.6
2. Organic Analysis (per sample)	51	16.00	816.0	49.7
3. Inorganic Compound Identification	26	6.00	156.0	9.5
4. Particulate Morphology	23	1.60	36.8	2.2
5. Coal Feed	8	1.38	11.0	0.7
6. Inorganic Element Analysis	47	1.20	56.4	3.4
7. Water Analysis	6	1.80	10.8	0.7
8. Gas Chromatographic Analysis	27	1.00	27.0	1.6
9. Miscellaneous Costs	8	.30	2.4	0.1
	222	-	1641.6	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 31, 32 and 33.

TABLE 30

BASIC LEVEL 2 ANALYSIS COSTS, DIRECT SAMPLING[a)]
COAL GASIFIER

Sample Type	No. of Samples	c.u./ Sample	Total c.u.	Actual %
1. Bioassay				
a. Soluble	29	13.60	394.4	10.7
b. Insoluble	28	29.20	817.6	26.9
2. Organic Analysis (per sample)	88	16.00	1408.0	46.3
3. Inorganic Compound Identification	45	6.00	270.0	8.9
4. Particulate Morphology	42	1.60	67.2	2.2
5. Coal Feed	8	1.38	11.0	0.4
6. Inorganic Element Analysis	72	1.20	86.4	2.8
7. Water Analysis	8	1.80	14.4	0.5
8. Gas Chromatographic Analysis	37	1.00	37.0	1.2
9. Miscellaneous Cost	8	.30	2.4	0.1
	365	-	3108.4	100.0

a) These costs are based on one set of analysis per site delineated in Tables 8, 9 and 10. Reporting and replicates are listed in Tables 31, 32 and 33.

TABLE 31

COAL GASIFIER SAMPLING AND ANALYSIS COSTS

LEVEL 1

I. TOTAL SAMPLING COSTS		
A. Preliminary Arrangements and Pre-site Survey		
1. Labor	11.0 c.u.	
2. ODC's	3.0 c.u.	
	14.0 c.u.	$ 3,500
B. Trip Planning and Preparations (variable)		
1. Site Preparations	3.5 c.u.	
2. 1.5 x Field Sampling Labor Costs	42.9 c.u.	
	46.4 c.u.	$11,600
C. Field Sampling Costs (2-Man Team)		
1. Travel and Misc. ODC's (1000 Miles)	19.0 c.u.	
2. Field Sampling Labor and Per Diem	28.6 c.u.	
	47.6 c.u.	$11,900
D. Correlation, Reporting, Etc.		
0.20 x Field Labor Costs	5.7 c.u.	$ 1,430
E. Total Sampling Costs	113.7 c.u.	$ 28,425
II. ANALYSIS COSTS		
A. Direct Analysis Costs	314.1 c.u.	$78,525
B. Analysis Set-up Time, Duplicates, Etc.		
0.20 x Direct Analysis Costs	62.8 c.u.	$15,705
C. Correlation, Reporting, Etc.		
0.20 x Direct Analysis Costs	62.8 c.u.	$15,705
D. Total Analysis Costs	439.7 c.u.	$109,925
III. TOTAL SAMPLING AND ANALYSIS COSTS	553.4 c.u.	$ 138,350
	4323 Hrs. @ $32/Hr.	

TABLE 32

COAL GASIFIER SAMPLING AND ANALYSIS COSTS

LEVEL 2

I. TOTAL SAMPLING COSTS		
A. Preliminary Arrangements and Pre-Site Survey		
1. Labor	4.0 c.u.	$1,000
2. ODC's (included in Level 1)		
B. Trip Planning and Preparations (Variable)		
1. Site Preparations	5.0 c.u.	
2. 1.0 x Field Sampling Labor Costs	34.5 c.u.	
	39.5 c.u.	$9,875
C. Field Sampling Costs (7-Man Team)		
1. Travel and Miscellaneous ODC's (1000 Miles)	23.0 c.u.	
2. Field Sampling Labor and Per Diem	34.5 c.u.	
	57.5 c.u.	$14,375
D. Correlation, Reporting, Etc.		
0.20 x Field Labor Costs	6.9 c.u.	$1,725
E. Total Sampling Costs	107.9 c.u.	$26,975
II. ANALYSIS COSTS		
A. Direct Analysis Costs	1641.6 c.u.	$410,400
B. Analysis Set-Up Time, Duplicates, Etc.		
0.20 x Direct Analysis Costs	328.3 c.u.	$82,075
C. Correlation, Reporting, Etc.		
0.20 x Direct Analysis Costs	328.3 c.u.	$82,075
D. Total Analysis Costs	2298.2 c.u.	$574,550
III. TOTAL COST - PROCESS CONDITION NUMBER 1	2406.1 c.u.	$601,525
IV. TOTAL COST - PROCESS CONDITION NUMBER 2	2406.1 c.u.	$601,525
V. GRAND TOTAL LEVEL 2 COSTS	4812.2 c.u.	$1,203,050
	37,595 Hrs. @ $32/Hr.	

TABLE 33

COAL GASIFIER SAMPLING AND ANALYSIS COSTS

DIRECT LEVEL 2

I. TOTAL SAMPLING COSTS			
A. Preliminary Arrangements and Pre-site Survey			
1. Labor	16.0 c.u.		
2. ODC's	5.0 c.u.		
	21.0 c.u.	$5,250.	
B. Trip Planning and Preparations (Variable)			
1. Site Preparations	8.0 c.u.		
2. 2.0 x Field Sampling Labor Costs and Literature Survey	144.2 c.u.	$38,050.	
	152.2 c.u.		
C. Field Sampling Costs (10-Man Team)			
1. Travel and Miscellaneous ODC's (1000 Miles)	33.7 c.u.		
2. Field Sampling Labor and Per Diem	72.1 c.u.		
	105.8 c.u.	$26,450.	
D. Correlation, Reporting, Etc.			
0.20 x Field Labor Costs	14.4 c.u.	$3,600.	
E. Repeat at 35% Items B, C, and D	95.3 c.u.	$23,835.	
F. Total Sampling Costs	388.7 c.u.	$97,185.	
II. ANALYSIS COSTS			
A. Direct Analysis Costs	3108.4 c.u.	$777,100.	
B. Analysis Set-up Time, Duplicates, Etc.			
0.20 x Direct Analysis Costs	621.7 c.u.	$155,425.	
C. Correlation, Reporting, Etc.			
0.20 x Direct Analysis Costs	621.7 c.u.	$155,425.	
D. Repeat at 35% Items A, B and C	1523.0 c.u.	$380,750.	
E. Total Analysis Costs	5874.8 c.u.	$1,468,700.	
III. TOTAL COST - PROCESS CONDITION NUMBER 1	6263.5 c.u.	$1,565,875.	
IV. TOTAL COST - PROCESS CONDITION NUMBER 2	6263.5 c.u.	$1,565,875.	
V. GRAND TOTAL - DIRECT LEVEL 2 COSTS	12,527.0 c.u.	$3,131,750.	
	97,867 Hrs. @	$32/Hr.	

5.7 RESULTS AND CONCLUSIONS

The results of the cost computations are shown in Table 34 and Figure 19 for the wet limestone scrubber and coal gasifier. These totals include sampling and resulting analysis repeats of 35% for both direct level 2 efforts and a replication factor of two in order to obtain samples for two process conditions for <u>all</u> level 2 efforts. Although the scrubber and gasifier differ markedly in size, complexity, basic technology and cost of assessment, the following observations can be made:

- The phased approach was found to be more cost effective in all aspects than the direct approach for both technologies. For the gasifier, this amounted to a factor of 2.3; for the wet limestone scrubber, direct costs were higher by a factor of 2.0.
- The advantages of the phased sampling and analysis approach were found to be approximately proportional to the complexity of the process being sampled. Thus, while the phased approach resulted in a 58% reduction in costs over the direct approach in the gasifier, the corresponding savings for the wet limestone scrubber were 49%.
- Within the phased approach, the level 1 sampling and analysis is only 8-10% of the total cost of the phased effort. Thus, many qualitative judgments including whether or not a full scale endeavor is necessary can be decided before a commitment is made to initiate a detailed final (level 2) assessment.
- The following were found to be cost sensitive items:

  1. Flue gas (particulate) sampling has a significantly higher unit cost on both levels 1 and 2 than another type of sampling.

  2. In level 1, bioassay testing constitutes the major analyses costs. In both the phased and direct level 2 effort, bioassay testing and organic analysis costs followed by inorganic compound identification are the major cost sensitive items.

- Sampling, although very important, consists of about 10% of the total effort.

TABLE 34

SAMPLING AND ANALYSIS
COST SUMMARY ($)

	Limestone Wet Scrubber			Coal Gasifier		
Strategy	Sampling	Analysis	Total	Sampling	Analysis	Total
Level 1	5,100	21,575	26,675	28,425	109,925	138,350
Level 2	18,850	254,450	273,300	53,950	1,149,100	1,203,050
Phased Total	23,950	276,025	299,975	82,375	1,259,025	1,341,400
Direct Level 2	41,450	548,150	589,600	194,370	2,937,400	3,131,770

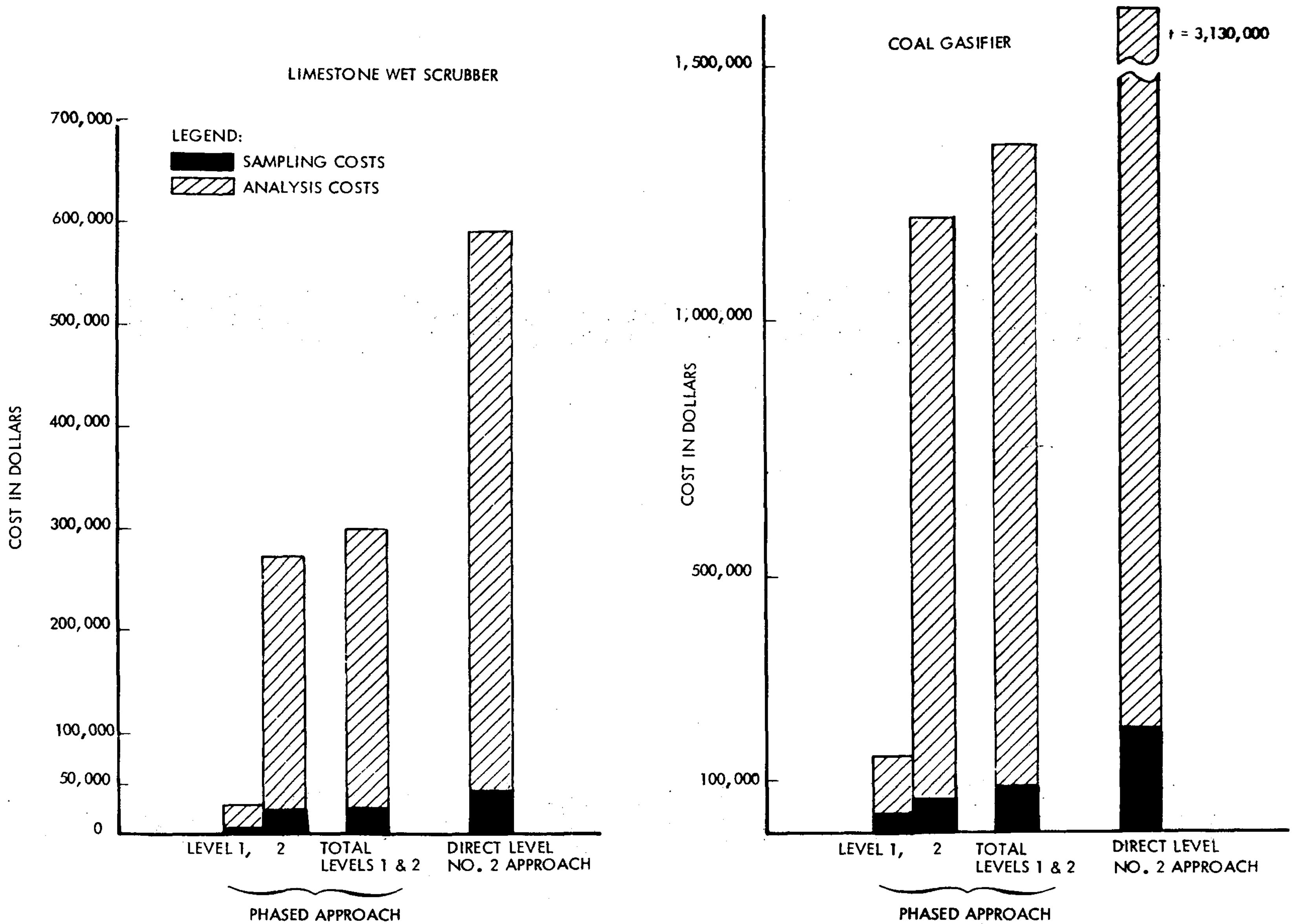


Figure 19. Summary of Sampling and Analysis Costs

6.0 REFERENCES

1. ASTM Committee D-19 and D-22, "Water; Atmospheric Analysis", 1971 Annual Book of ASTM Standards", Part 23, D1357-57,"Planning the Sampling of the Atmosphere", p. 291-297.
2. Brenchley, D. L., C. D. Turley and R. G. Yaime, "Industrial Source Sampling", Ann Arbor Science, Ann Arbor, Michigan, 1973.
3. Deming, W. E., "Some Theory of Sampling", John Wiley and Sons, Inc., New York, 1955.
4. Hamersma, J. W., Reynolds, S. L., "Tentative Procedures for Sampling and Analysis of Coal Gasification Processes", TRW Systems Group, Document No. 24916-6016-TU-00, 1975.
5. Radian Corporation, "Sampling and Analytical Strategy for Potentially Hazardous Compounds in Petroleum Refinery Streams", draft for review, August, 1975.
6. Stern, A. C., editor. "Air Pollution", Dynamic Press, New York, Second Edition, Volumes I, II, and III, 1968.
7. Dorsey, J. A., Draft Copy, "Environmental Assessment Guideline Document", Environmental Protection Agency, Research Triangle Park, N. C., 1975.
8. Griefer, B. and J. K. Taylor , "Pollutant Analysis Cost Survey", National Bureau of Standards, PB-241-991, December, 1974.
9. Accu-Labs Research, Inc., "Sampling and Analytical Services Fee Schedule", April, 1975.
10. Barringer Research, "Sampling and Analytical Services Fee Schedule", January, 1975.
11. Petroleum Analytical Research Corporation, "Sampling and Analytical Services Fee Schedule", January, 1975.
12. Personal Communication; SASS multicyclone train operational costs. J. W. Hamersma, TRW Systems Group, and R. M. Statnick and J. Dorsey, EPA. August, 1975.
13. Mudge, L. K., G. F. Schiefelbein, C. T. Li, and R. H. Moore, "The Gasification of Coal", Battelle Memorial Institute, Battelle Energy Program Report, July, 1974, 60 p.

14. Shaw, H., and E. M. Magee, "Evaluation of Pollution Control in Fossil Fuel Conversion Processes", Gasification; Section 1, Lurgi Process, July, 1974, EPA-650/2-74-009-C.

15. ASTM Committee D-3, "Gaseous Fuels; Coal and Coke", 1971 Annual Book of ASTM Standards, Part 19, D1274-54, "Standard Method of Sampling and Manufactured Gas", p. 22-231.

16. ASTM Committee D-2, "Petroleum Products", 1971 Annual Book of ASTM Standards, Part 18, D270-65, "Standard Method of Sampling Petroleum and Petroleum Products", p. 47-71.

17. Seeley, J. L. and R. K. Skogerboe, "Combined Sampling-Analysis Method for the Determination of Trace Elements in Atmospheric Particulates", Anal. Chem., 46, (3), 415-421, March, 1974.

18. ASTM Committees D-19 and D-22, "Water, Atmospheric Analysis", 1971 Annual Book of ASTM Standards, Part 23, D2009-65, "Standard Recommended Practice for Collection by Filtration and Determination of Mass, Number, and Optical Sizing of Atmospheric Particulates", p. 506-513.

19. Flegal, C. A., J. A. Starkovich, R. F. Maddalone, M. L. Kraft, C. A. Zee and C. Lin, "Draft Final Report Measurement Techniques for Inorganic Trace Materials in Control System Streams", TRW Systems Group, Contract No. 68-02-1393, 1975.

20. ASTM Committee D-19 and D-22, Water; Atmospheric Analysis", 1971 Annual Book of ASTM Standards", Part 23, D1605-60, "Sampling Atmospheres for Analysis of Gases and Vapors", p. 349-380.

21. EPA, "Protection of the Environment", Federal Register, Vol. 36, No. 247, 23 December 1971.

22. Epstein, M., C. C. Leivo, C. H. Rowland and S. C. Wang, "Test Results from the EPA Lime/Limestone Scrubbing Test Facility", EPA 650/2-74-038, Proceedings: Flue Gas Desulfurization Symposium, December, 1973.

23. "El Paso Natural Gas Company Burnham Coal Gasification Complex - Plant Description and Cost Estimate", Application of El Paso Natural Gas Co. before U. S. Federal Power Commission, Docket No. CP 73-131, 16 August 1972 (Rev. 20 September 1972).

24. Personal Communication, Ike Foster, "Ash and Ash Slurry Sampling", Telecon, February, 1975.

25. Personal Communication: Dr. Brown, Accu-Labs, Research, Inc., "Analysis costing for aqueous samples and for organic class analysis", June 1975.

26. Personal Communication: L. Johnson, J. A. Dorsey,and R. M. Statnick, EPA, "Cytotoxicity, mutagenicity, carcinogenicity; technical applications and costing problems", August 1975.

27. Olsen, D. A., "Air Pollutional Aspects of Organic Carcinogens", Litton Industries, p. 59-67.

28. Taras, M. J., Greenberg, A. E., Hoak, R. D., and Rand, M. C., "Standard Methods for the Examination of Water and Wastewater", American Public Health Assoc., 13th Edition, 1971.

29. Dominick, D. D., "Methods for Chemical Analysis of Water and Wastes, 1971", Environmental Protection Agency, Water Quality Office, Analytical Quality Control Laboratory.

30. Samedov, I. G., and A. S. Kurbanov, "Pollution of the Air with Carcinogenic Substances by Baku Petroleum Refineries", Azerbaydzhanskiy Medit. Zh. 28(11), 62-67 (1971).

31. Plunkett, Edmond R., Handbook of Industrial Toxicology, Chemical Publishing, New York, 1966.

32. Cropper, F. R., and S. Kaminsky, "Determination of Toxic Organic Compounds in Admixture in the Atmosphere by Gas Chromatography", Anal. Chem., 35 (6), 735-743, May 1963.

33. Sawicki, E., T. W. Stanley, and H. Johnson, "Direct Spectrofluorometric Analysis of Aromatic Compounds on Thin-Layer Chromatograms", Microchem. J., 8, 257-284, (1964).

34. Sawicki, E., and H. Johnson, "Characterization of Aromatic Compounds by Low-Temperature Fluorescence and Phosphorescence. Application to Air Pollution Studies", Microchem, J., 8, 85-101, 1964.

35. Moore, G. E., R. S. Thomas, and J. L. Monkman, "The Routine Determination of Polycyclic Hydrocarbons in Airborne Pollutants", J. Chromatog., 26, 456-464, 1967.

36. Tye, E., A. Horton and I. Rapien, "Benzo (A) Pyrene and Other Aromatic Hydrocarbons Extractable from Bituminous Coal", Am. Ind. Hyg. Assoc. J., 27, 25, 1966.

37. Sawicki, E., F. T. Fox, W. Elbert, T. R. Hauser and J. Meeker, "Polynuclear Aromatic Hydrocarbon Composition of Air Polluted by Coal-Tar Pitch Fumes", Am. Ind. Hyg. Assoc. J., 23, 482, 1962.

38. Sawicki, E., T. W. Stanley, S. McPherson, and M. Morgan, "Use of Gas-Liquid and Thin-Layer Chromatography in Characterizing Air Pollutants by Fluorometry", Talanta, 13, 619-629, 1966.

39. Cantuti, V., G. P. Cartoni, A. Liberti and A. G. Torri, "Improved Evaluation of Polynuclear Hydrocarbons in Atmospheric Dust by Gas Chromatography", J. Chromatog., 17, 60-65, 1965.

40. Lao, R. C., R. S. Thomas, H. Oja, and L. Dubois, "Application of a Gas Chromatography-Mass Spectrometer-Data Processor Combination to the Analysis of the Polycyclic Aromatic Hydrocarbon Content of Air-borne Pollutants", Anal. Chem., 45,(6), 908-915, May, 1973.

41. Personal Communication: P. W. Jones, Battelle Research, Columbus, Ohio, "Level 1 Organic Analysis", July, 1975.

42. Level 2 organic analysis. Conference of EPA contractors for the Radian report on the sampling and analytical strategy for potentially hazardous compounds in petroleum refinery streams, July, 1975.

43. Forney, A. J., S. J. Gasior, W. P. Haynes, and S. Katell, "Analysis of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process", U. S. Department of the Interior, Technical Report No. 76, January, 1974.

44. Personal communication: Inorganic compound analysis. J. W. Hamersma. TRW Systems, and R. M. Statnick and J. Dorsey, EPA, September, 1975.

45. Flegal, C. A., J. A. Starkovich, R. F. Maddalone, C. A. Zee, M. L. Kraft and C. Lin, "Approved Procedures for Process Measurements - Trace Inorganic Materials", TRW Systems Group, EPA Contract No. 68-02-1393, February, 1975.

46. ASTM Committees D-19 and D-22, "Water, Atmospheric Analysis", ASTM Committee D-22, 1971 Annual Book of ASTM Standards, Part 23, D1704-61, "Standards Method of Test for Particulate Matter in the Atmosphere, Optical Density of Filtered Deposit", p. 418-424.

47. Silverman, L., C. Billings, and M. First, "Particle Size Analysis in Industrial Hygiene", Academic Press, 1971.

48. Lowry, H. H., "Chemistry of Coal Utilization", Suppl. Vol., John Wiley & Sons, New York, 1963.

49. ASTM Committee D-3, "Gaseous Fuels; Coal and Coke", 1971 Annual Book of ASTM Standards, Pt. 19, D271, "Laboratory Sampling and Analysis of Coal and Coke."

50. Personal Communication: Robert Brown of Accu-Labs Research, Inc., "Trace Inorganic Materials Identification Via SSMS", October, 1975.

51. Veal, D. J., "Nondestructive Activation Analysis of Crude Oils for Arsenic to One Part Per Billion, and Simultaneous Determination of Five Other Trace Elements", Anal. Chem. 38(8), 1080-3, (1966).

52. Von Lehmden, D. J., R. H. Jungers and R. E. Lee, Jr., "Determination of Trace Elements in Coal, Fly Ash, Fuel Oil and Gasoline--A Preliminary Comparison of Selected Analytical Techniques", Anal. Chem. 46(2) 239 (1974).

53. Thomson, S. J., "Techniques for Reducing Refinery Wastewater", Oil Gas J. 68 (40), 93-8 (1972).

54. Leithe, W., "The Analysis of Organic Pollutants in Water and Wastewater", Ann Arbor Science, New York, 1972.

55. McCoy, J. W., "Chemical Analysis of Industrial Water", Chemical Publishing Co., New York, 1969.

56. Hach Chemical Co., Sampling and Analytical Fee Schedule, 1975.

57. ASTM Committees D-19 and D-22, "Water; Atmospheric Analysis", 1971 Annual Book of ASTM Standards, Part 23, D2580, "Standard Method of Test for Phenols in Water by Gas-Liquid Chromatography", p. 690-97.

58. Weston, R. F., "Separation of Oil Refinery Wastewaters", I & EC 42(4), 607 (1950).

59. Personal Communication: Dr. J. W. Eichelberger, "Direct aqueous injection techniques for GLC analysis of organic water pollutants", June, 1975.

60. Leibrand, R. J., "Atlas of Gas Analyses by Gas Chromatography", Applications Laboratory Report 1006, March, 1966.

61. Greene, S. A., Moberg, M. L., and Wilson, E. M., "Separation of Gases by Gas Absorption Chromatography", Anal. Chem., citation unknown.

62. Perry, R., and J. D. Twibell, "A Time Based Elution Technique for the Estimation of Specific Hydrocarbons in Air", Atmos. Environ., 7(10), 1973, 929-937, Aptic No. 54931.

63. Obermiller, E. L., "Gas Chromatographic Separation of Nitrogen, Oxygen, Argon, Carbon Monoxide, Carbon Dioxide, Hydrogen Sulfide, and Sulfur Dioxide", J. of Gas Chrom. 6, 446-447, August, 1968.

64. Doran, T. and J. P. Cross, "Single Sample Analysis of the Mixture O2, N2, CH4, CO, CO2, C2H6, and N-C4H10", J. of Gas Chrom., 260-262, July, 1966.

65. Kim, A. G. and L. J. Douglas, "Gas Chromatographic Method for Analyzing Gases Associated with Coal", Bureau of Mines Report of Investigations, RI-7903, 1974.

66. Sussman, V. H., "Atmospheric Emissions from Catalytic Cracking Unit Regenerator Stacks", NTIX, PB-216-644, June, 1957, 60p.

67. Brocco, D., V. Depalo, and M. Possanzini, "Improved Chromatographic Evaluation of Alkanes in Atmospheric Dust Samples", Chromatog., 86(1), 234-238, November, 1973.

68. Adams, D. F., R. K. Koppe, "Gas Chromatographic Analysis of Hydrogen Sulfide, Sulfur Dioxide, Mercaptans, and Alkyl Sulfides and Disulfides", Tappi, 42(7), 601-605, July, 1959.

69. "Methods of Air Sampling and Analysis", Intersociety Committee, American Public Health Association", Washington, D. C., 1972.

70. Cropper, F. R., and S. Kaminsky, "Determination of Toxic Organic Compounds in Admixture in the Atmosphere by Gas Chromatography", Anal. Chem., 35(6), 735-743, May, 1963.

71. Hamersma, J. W., and S. L. Reynolds, "Final Report: Review of Process Measurements for Coal Gasification Processes", TRW Systems Group, April, 1975.

72. American Conference of Governmental Industrial Hygienists, "Air Sampling Instruments for Evaluation of Atmospheric Contaminants", Cincinnati, Ohio, 4th edition, 1972.

73. Hollowell, C. D., and R. D. McLaughlin,"Instrumentation for Air Pollution Monitoring", Environmental Science and Technology, 7(11), November, 1973.

74. Watther, J. E., and H. R. Amberg, "Mobile Laboratory for Source Sampling Kraft Mill Emissions", Crown Zellerbach Corporation, Tappi, 51(11), 126-129, November, 1968.

APPENDIX A.
MOBILE LABORATORY UNITS

Mobile laboratories in the form of vans or trailers have been used very effectively for a variety of source assessment efforts such as stack sampling, ambient air sampling and water quality measurements. In general, commercially available vans have been outfitted with a variety of equipment necessary for assessing environmentally significant factors for the source of interest.

A.1 ADVANTAGES

The primary advantages of such vans lie in the fact that many samples may be or are unstable, and delaying the analysis could result in erroneous conclusions. In addition, the results for a given sample are often quite unexpected and the presence of an on-site laboratory allows the immediate re-analysis of a check sample and/or modification of the experimental plan on a real time basis which allows the saving of time, effort and cost.

In the phased and direct sampling efforts for the gasifier, many effluent parameters must be determined on-site due to their unstable nature and it is assumed that most other large scale plants will have similar samples. In addition, the philosophical aims of level 1 testing in the phased approach can be enhanced greatly with an on-site laboratory. A well-equipped laboratory will allow additional level 1 or "semi-level 2" samples to be taken so that the final level 2 effort can be focused in greater detail with a resultant decrease in cost for the level 2 effort. Finally, unanticipated problem areas can be identified in greater detail for the level 2 effort.

Most sampling efforts require the rental of a van or trailer to transport needed equipment, tools and reagents from the laboratory to the sampling source. Additionally, driver and mileage rates must be figured into the overall cost. Insofar as the above costs are incurred as a natural outgrowth of most sampling efforts, the cost effectiveness of a mobile laboratory unit is greatly enhanced, since these normally incurred costs may be applied to the mobile laboratory unit. An additional advantage is that sampling equipment assembly, sample transfer and equipment clean-up will be facilitated by additional work space that is available in the mobile laboratory unit for all phases and types of sampling operations.

A.2 COMPONENTS

An itemized list of items that may be included in an environmental assessment van is shown in Table A-1. Most items are capable of performing both level 1 and level 2 analyses. Some of the proposed specific uses of this unit are described below as they relate to level 1 and level 2 analysis. In general, sampling valves and manifolding systems presently exist in a state of refinement such that specific sampling controls are available for virtually every application. Variable time period sampling panels capable of sequential stream selection and adjustable time/volume sampling parameters for individually monitored streams are commercially available and easily mounted in the mobile unit laboratory via side wall bulkhead mounts. Portable generators facilitate sampling operations in areas where electrical outlet availability is scarce.

Level 1:

- All sampling apparatus and tools may be stored assembled and checked-out and post-sampling sample transfer and equipment clean-up can be performed in a clean laboratory atmosphere necessary for bioassay analysis.
- Hach analysis of water samples for qualitative assessment of aqueous effluents.
- Qualitative ambient particulate determinations with piezoelectric microbalance.
- Qualitative ion measurements using specific ion electrodes.
- NO_x-SO_x concentrations with direct reading instrumentation.
- Qualitative organic and inorganic characterization via infrared spectrophotometry.
- Qualitative determination of trace elements using the ring oven technique.
- Qualitative and semi-quantitative organic and organo-sulfur compound analysis via multiple detector GLC.

TABLE A-1.

ENVIRONMENTAL ASSESSMENT VAN OR TRAILER
MOBILE INSTRUMENTATION AND CHEMICAL LABORATORY

Instruments and Sampling Equipment	Cost
Hewlett Packard #680M Recorders (5)	$ 4,000
Beckman #402 Hydrocarbon Analyzer	6,500
Leco Chemiluminescent NO_x Analyzer	5,000
Meloy Multiple GLC Detector	7,000
High Volume Samplers (4)	4,000
Modified SASS Train	15,000
Digital mV Meter with Multi Channel Switch and Complete Set of Electrodes	4,000
Beckman #865 Infrared Spectrophotometer	5,000
Refrigerator for Water Samples	200
	$50,700
Trailer Outfitting	
Furnishings	$ 1,500
Calibration Gases and Regulators	1,000
Generator (110V)	650
Miscellaneous Bottles, Reagents, Tools, etc.	1,500
Miscellaneous Instruments, pH Meter, Colorimeter, etc.	3,200
Instrument Racks (2)	500
	$ 8,350
TOTAL	$59,050
Additional Costs	
Lease $120-$130/mo. (14 months) for an 8' x 35' trailer with some custom work.	$ 4,500/3 yrs.
Equipment Installation - 600 hrs. (Includes Checkout)	10,000
Average Cost to Move Trailer by Professional Haulers; $1.20/mile	$ 2,400 *

*For 2 x 11,000 mile trip.

Level 2:

- All sampling apparatus and tools may be stored assembled and checked-out and post-sampling sample transfer and equipment clean-up can be performed in a clean laboratory atmosphere necessary for bioassay analysis.
- Quantitative colorimetric analyses or titrations may be performed on impinger solutions, water samples, etc.
- Quantitative ion measurements using specific ion electrodes.
- Reactive organic and organo-sulfur species can be quantitatively and qualitatively determined via multiple detector GLC.
- Semi-quantitative inorganic and organic characterization via infrared and spectrophotometry.

APPENDIX B.

UNIT COSTS FOR WATER ANALYSIS (COMMERCIAL LABORATORY)

Analysis	Cost
Ammonia	$ 12.00
Acidity	5.00
Alkalinity	3.75
BOD	12.00
COD	10.00
Coliform (total)	10.00
Carbon (total)	8.00
Carbon (inorganic)	8.00
Carbon (organic)	17.50
Chloride	4.00
Chromium (high and low range)	3.50
Conductivity	3.50
Cyanide (total)	15.00
Dissolved Oxygen	4.50
Fluoride	12.00
Hardness (total)	4.00
Microscopic (algae determination)	25.00
Nitrate	10.00
Oil and Grease	10.00
Organic Delineation	100.00
pH	1.75
Phenols	16.00
Phosphorous (total)	7.00
Phosphorous (orthophosphate)	5.50
Phosphorous (organic)	7.00
Solids (total residue)	5.25
Sulfide	8.00
Sulfite	5.50
Sulfate	5.50
Tannin & Lignin	10.00
Turbidity	1.75
Packing, Shipping, Tabulation	100.00
	$450.00 Total = 1.8 c.u.

APPENDIX C

SITE PREPARATION COSTS

Site preparation costs for level 2 sampling can be very substantial when special parts or sophisticated sampling equipment must be installed in an optimum location. These costs could involve such items as cutting ports for optimum traversing, installation of mechanical samples for solids, proportional samples for solids and special equipment to sample high pressure streams. For this report, it has been assumed that the above is available because of the newness of the technologies. However, if this is not the case, the following can be taken as reasonable median prices for site preparation:

Particulate	25K
Gas	8K
Liquid	2.5K
Solid	10K