Carnegie Mellon

Department of Civil Engineering
Carnegie Institute of Technology
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213-3890
412-268-2940

September 12, 1986

Mr. Hershel J. Richman
Cohen, Shapiro, Polisher, Shiekman and Cohen
PSFS Building
12 South 12th Street
Philadelphia, PA 19107

Dear Mr. Richman:

Enclosed are my comments regarding the EPA Focused Feasibility Study and related documents for the Tyson's dump site.

Sincerely,

Richard G. Luthy
Professor and
Associate Dean

RGL/grb

Enclosure

Attachment 1

COMMENTS ON THE EPA FOCUSED FEASIBILITY STUDY FOR THE TYSON'S DUMP SITE

Richard G. Luthy

Department of Civil Engineering
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213-3890

September, 1986

Attachment 1

AR312047

Introduction

The following discussion presents general observations and comments regarding the description of the situation and the proposed solution for the groundwater contamination problem existing at the Tyson's dump site as presented in the Focused Feasibility Study. The discussion is principally directed towards an evaluation of the following documents:

a) Focused Feasibility Study, Tysons Dump Site, July 1986,

b) Risk Assessment of the Tysons Dump Site, Montgomery County, Pennsylvania, prepared by ICF-Clement and ICF-SRW Associates, ("RA"),

c) Tyson's Dump Site, Montgomery County, Pennsylvania, Final Remedial Investigation Report, prepared for NUS Corp., Baker/TSA, July 1985, ("RI"), and

d) Supplemental Site Assessment, submitted to the U.S. Corps of Engineers, Woodward and Clyde, August 1985.

After reviewing these documents it may be concluded that: (i) a groundwater contamination problem exists at the Tyson's site, and (ii) the EPA, other governmental agencies, and their consultants are well-intended in trying to remedy the problem. However, it is my professional opinion that these organizations have overlooked, or have chosen to ignore, certain relevant fundamental issues that may have significant impact on the proposed remedial action. Until these issues are resolved, it is unwise to proceed with the proposed remedial action strategy. There are certain fundamental issues that must be resolved in order to present a correct picture of the existing groundwater contamination problem. The resolution of these issues would then serve as a basis from which to begin to formulate a rational strategy to resolve the problem.

At present there is incomplete and imprecise knowledge of the nature of the existing groundwater contamination problem. This state of understanding cannot serve as a framework from which one may formulate a viable remedial action strategy. Resources will be wasted if the proposed remedial action strategy for site cleanup is implemented because there is a strong likelihood that the proposed action will have minimal effect on protecting public health and aquatic life.

It is emphasized that these comments and the following discussion are not necessarily restricted to the more narrow issue of resolving the problem of the "apron area" as presented in the Focused Feasibility Study; rather the comments are broadly applicable to the general lagoon area and the site as a whole. It is further emphasized that the following comments are not intended to belittle the problem, nor are the comments

intended to be disparaging towards any of the various participants involved in the assessment of these issues.

Synopsis

The following items are discussed in turn below:

i) Environmental Protection: It is the duty of the various parties to protect the environment from an informed, knowledgeable viewpoint, and then proceed to develop and implement an efficient remedial action strategy.

ii) The Sandstone Quarry: The chemical wastes were disposed on fractured rock. The migration of chemicals in fractured rock needs to be addressed.

iii) Site Characterization: Most of the investigation at the site was directed towards identifying chemical wastes and areal extent of the former lagoons. This sampling strategy does not provide an adequate basis from which to assess important hydrogeologic components related to chemical transport in the groundwater.

iv) Complicated Hydrogeologic Setting: The site consists of a complicated hydrogeological setting including: fractured bedrock close to the surface, a "surficial" aquifer, and a steep bank, or cut, with possible outcroppings. The interaction of these hydrogeologic features on groundwater transport needs to be addressed.

v) Organic Liquids and Chemicals Disposed at the Site: The form of the organic chemicals disposed at the site may have a significant effect on transport. If the organic chemicals were disposed as bulk solvents, then these chemicals may be migrating in fractured media as a dense, heavier-than-water, separate phase.

vi) Transport Model Verification: The proposed transport model is unverified. Additional sampling and mass balance calculations need to be performed. The model should explain the fate of chemical inorganic wastes and septic wastes, as well as the fate of heavy, immissible solvents.

vii) Environmental Exposure: Remedial action strategies should be directed towards protection of river water quality and groundwater quality, if any is pumped for use. Action levels should not be based on conditions within the on-site aquifer.

Environmental Protection

It is the duty of environmental engineers, and allied professionals who deal with water resources, to protect human health, to safeguard the well-being of aquatic habitats, and to preserve the beneficial uses of water. The implementation of these goals requires the expenditure of public and private funds, and therefore it is also the responsibility of environmental engineers to be attentive to the efficient use of these funds in order that the greatest benefit may be achieved.

The Tyson's site served as a dump for chemical wastes. This situation is regrettable, and it is a cause for concern. Nevertheless, we must deal with this problem in a logical, rational manner. Our resolution of the problem must recognize the salient features of this situation. We cannot ignore basic principles of environmental engineering science as they apply to the facts in this situation. Wishful thinking will not solve the problem; action without sufficient understanding will not solve the problem. If action precedes understanding the public will be misled, funds will be wasted, and the beneficial uses of water will not be given proper protection.

The Sandstone Quarry

"Tyson's Dump Site is an abandoned spectic and chemical waste disposal site situated within an old sandstone quarry." This is the first sentence in the Focused Feasibility Study. We should appreciate that this situation is not necessarily unique, as there are numerous instances of chemical and other wastes having been disposed in old quarries (Geraghty and Miller, "Ground Water Contamination in the Northeast States", US EPA, NTIS PB-235702, 1974). These situations arose because old quarries often presented a convenient hole in which wastes and other materials could be deposited.

A key word is the above quoted sentence is "quarry." This word should trigger certain questions which should focus and direct our attention in order to begin to understand the groundwater contamination problem. It is unfortunate, but none of the documents which I reviewed gave thoughtful consideration to the implications for groundwater contamination as a result of disposal of chemical wastes in an old quarry.

Tyson's site is an abandoned sandstone quarry, not a sand and gravel quarry. The documents prepared by the EPA and its consultants do not address this fact. The documents present a simplistic picture in which contaminants are migrating away from the site in a "surficial aquifer". It is my opinion that this scenario has not been adequately demonstrated, and that this scenario ignores the principal geologic feature of the site in which the wastes were disposed.

The quarrying of the sandstone requires that loose and unconsolidated overburden would be removed. The quarry was in business to recover stone, i.e. "rock"; and therefore necessarily involved drilling and blasting. Hence, this situation suggests from the outset that the chemical wastes were disposed on bedrock. Therefore, a major issue to be addressed is the extent to which the chemical wastes are being transported in the bedrock. Shallow, sandstone bedrock does not exist as an impervious, monolithic formation. The sandstone will contain numerous cracks and fissures which can serve as primary conduits for transport of water. Indeed, this enables the bedrock in the vicinity of the site to serve as a "relative good water bearing formation" (RI Report, pg. 12).

It is reported that the depth to the bedrock is shallow (RI, report pg. 10). Importantly, "shallow bedrock in the vicinity of the site was observed to be highly fractured" (RA Report, pg. 1-3). In addition, the quarrying operations themselves at the Tysons site must certainly have contributed to the extent to which the chemical wastes were initially disposed on fractured rock.

The various documents which I reviewed are silent on the possibility of contaminant transport within the fractured bedrock; yet, the possibility for chemical transport within the fractured bedrock must be addressed in order to arrive at adequate understanding. The obvious implications are that chemical contaminants may be present in significant quantities in the underlying bedrock, and that the chemicals are migrating in this formation under gradients and physiochemical processes which are largely independent of conditions in the overburden. It is wishful thinking to choose to ignore the situation in the underlying bedrock. The excavation and removal of contaminated surficial soils, as currently proposed, may serve little useful purpose compared to the more important problem of contaminant migration in the fractured sandstone media.

Site Characterization

A major difficulty with the data and discussion presented in the above cited documents is the lack of sufficient attention given to characterization of the hydrogeologic conditions at the site. This is particularly evident in the Remedial Investigation Report, which serves as the foundation for the site characterization and all subsequent discussion. Conclusions in these documents regarding the hydrogeologic conditions at the site, and suppositions regarding groundwater flow, are made from limited, or no, information.

These suppositions are then carried forward as scientific conclusions in subsequent documents. In each case in the subsequent documents, the limited site characterization work is not challenged; rather, the work is presented as being reasonably complete with adequate interpretation.

The principal site characterization activities described in the Remedial Investigation Report and the Supplemental Site Assessment Report was directed towards identification of the types of chemical wastes which were disposed in the lagoons, and identification of the general planar dimensions of the former lagoons. Very little of this work focused on identifying the three-dimensional extent of contamination at the site. The work performed to date has demonstrated that residues from the former chemical waste disposal practices are present at the site, and that there is evidence of these chemicals being transported beyond the site boundary. While this information is useful, it by no means comprises an adequate site characterization from which to understand the movement of groundwater and the transport of solutes through the site and beyond the property limits.

The site sampling and characterization strategies employed in the Remedial Investigation Report and Supplemental Site Assessment Report are restricted principally to organic compound analyses of soil and water samples obtained from the surface and shallow borings. This is evident in these reports from the sheer volume of documentation devoted to organic compound identification of these samples.

By contrast, there is only minimal data presented which relates to a description of the hydrogeologic conditions at the site, and this limited information is largely inferred from sampling strategies which were designed to determine the areal extent of the former lagoons, not the mode of groundwater transport through the site. There is total lack of evaluation of the hydrogeologic conditions in the bedrock regime.

As mentioned previously, the chemical wastes were disposed in a highly fractured bedrock. Yet the Remedial Investigation Report and the Focused Feasibility Study Report make no mention of concern for groundwater movement and contaminant migration in highly fractured bedrock. The Remedial Investigation Report supposes a continuous shallow, surficial aquifer as the principal geologic feature responsible for organic solute transport from the site. This was deduced without investigation of the conditions existing in the fractured bedrock.

The generalized geologic section presented in the Remedial Investigation Report, Figure II-2, serves as the basis from which the remedial action strategies are assessed. However, the simplistic situation described by the supposed generalized geologic section for the surficial aquifer is not adequately justified. Careful reading of the Remedial Investigation Report shows that this Figure was generated from limited data and very limited interpretation. The Figure is inferred principally from a sampling strategy designed to determine the extent of near surface chemical contamination and the location of the former lagoons, not the mode of groundwater transport through the site. There is not sufficient data from which to conclude that the surfical aquifer is

directly and continuously hydraulically connected from the site to the river without interruption. Other details, such as layers and lenses of relatively more or less permeable material, which may be important are unknown.

In summary, the supposed generalized geologic section is constructed from inadequate site characterization data. Only several pages, mainly pages 9 and 10 in the Remedial Investigation Report, are devoted to the development and discussion of this most important Figure, a Figure which sets the stage for all subsequent evaluation and decisions. The lack of engineering and scientific rigor with which the generalized geologic section has been presented and scrutinized points to a basic problem regarding the level of understanding exhibited by the EPA and its contractors.

Complicated Setting

The generalized geologic section, and related discussion in the above-cited documents on the nature and extent of soil contamination at the Tyson's dump site, ignores the complicated setting at the site. These documents do not give adequate attention to the special hydrogeologic features of the site. The site contains a steep hillside, dug pits, a shallow surfical aquifer, fractured bedrock close to the surface, a substantial hillside slope and cut to accommodate railroad tracks, drainage devices along the side and underneath the railroad tracks, a swampy area, and a river. These components represent an assemblage of interacting hydrogeologic elements that impact groundwater flow through the site, and which thereby affect contaminant transport. An adequate appreciation for the interplay of these elements on the transport of chemical contaminants at the site has not been demonstrated.

The need for considering flow through fractured bedrock media has already been discussed. The significance of the hillside cut and railroad embankment along the northern boundary of the site, and the significance of drainage and seeps along this feature have not been considered. The Remedial Investigation Report refers to several accounts of leachate or seeps being evident along the hillside: leachate from the site entered a ditch running eastward along the tracks (pg. 7, RI); in the northeastern corner of the site...a small seep in this area (pg. 7, RI); immediate actions taken by the EPA were to lessen the amount of seepage from the site in order to prevent contaminants from entering the eastern tributary on the south side of the railroad tracks (pg. 8, RI). These field observations clearly show that the hillside between the Tysons site and the railroad tracks has some special hydrogeologic characteristics not considered by the EPA. The presence of seeps suggests that at times the site may exist in a saturated condition, rather than an unsaturated condition. The occurence of seeps also suggests that there may be an impervious material bounding the site, down gradient, towards the railroad tracks. The presence of seeps also indicates that loose, unconsolidated, surficial aquifer material

may not be prevalent along the hillside. The occurrence of seeps and the close association of fractured bedrock at the site suggests again that the supposed generalized geologic section is in error.

The railroad tracks and the drainage ditch along the southern side of the railroad tracks present significant features that can divert the flow of groundwater in the surficial aquifer. Gravel and other coarse-grained material which are used to construct foundations for railroad tracks may rest on or near the shallow bedrock. This material and the drainage ditch could then act as conduits that would intercept the movement of chemical contaminants in the surficial aquifer.

Organic Liquids and Chemicals Disposed at the Site

The Remedial Investigation Report and the Supplemental Site Assessment Report show that chemical wastes have been disposed at the site. However, concern for the form and the nature of these wastes in relation to contaminant transport have not been addressed. The chemical wastes disposed at the site are known to consist of organic substances, and it is also likely that there were various aqueous solutions containing salts and spent brines and liquors.

If the organic chemicals were disposed as mixed solvents, or concentrated solvent-water immiscible mixtures, then the organic solvents may have moved as a separate phase. Many of the organic contaminants found at the site are relatively low molecular weight, chlorinated organic solvents, which are denser than water. If these heavier-than-water organic solvents were disposed at the site as bulk liquids this would result in pools or pockets of chemical solvents that would migrate to the fractured bedrock. Hence the principal groundwater contamination problem could very well involve migration of organic solvents as an immiscible, heavier-than-water phase.

Separate organic liquid phases may account for most of the organic liquids present at the site. The movement of this type of material would be governed by various phenomena, such as pore wetting and filling, capillary forces, and phase density differences. These phenomena are not particularly relevant for the migration of soluble solutes in saturated groundwater. The fringes of a region of heavy, immiscible organic solvent phase may exhibit differential movement, or fingering, as observed in the case of movement of heavy oils in water-saturated porous media.

Organic solutes will be released to the groundwater at the interface between the organic solvent phase and the aqueous phase as a result of aqueous solubilization. Since the chlorinated organic solvents exhibit only limited solubility in water, it would be expected that the groundwater would show low levels of organic solvent

components in the aqueous phase, compared to exceptionally high levels that would be evident in the immiscible phase. The possibility for this situation to exist was not addressed in the Focused Feasibility Study or in the other documents. The understanding of this problem requires that additional sampling be conducted in the fractured media.

The practical implications of the presence of immiscible, heavier-than-water solvents at the site is that removal of surficial deposits may have no relevance to the existing contamination problem. The immiscible organic solvents may reside in the pores and fractures in the bedrock, and slowly release contaminants by dissolution for years.

It is very probable that some of the chemical wastes disposed at the site consisted of inorganic salt solutions, brines, spent liquors, and acidic or caustic solutions. The principal ions associated with these materials, e.g. sodium, potassium, chloride, and perhaps nitrate and sulfate, should be traceable. In addition, the septic wastes would have introduced large quantities of soluble organic residues which would be identifiable as COD or TOC; ammonia and nitrate may be associated also with the septic waste. These materials would undergo groundwater transport in a manner similar to leachate from a sanitary landfill resulting in an identifiable groundwater contamination plume. It is significant that the various documents present no evidence of an identifiable groundwater contamination plume comprised of inorganic or septic waste components. This further suggests that the principal mode of groundwater transport and contamination was not characterized, and that transport in the fractured bedrock may be the dominant transport mechanism.

Transport Model Verification

The transport model presented in the Risk Assessment Report and the Focused Feasibility Study is flawed for the reasons presented above. There are additional difficulties associated with this model. Some of these issues and concerns are listed below:

i) The model does not consider the physical and chemical behavior of immiscible, heavy, organic solvents on groundwater quality.

ii) The model does not consider transport through fractured bedrock.

iii) The model assumes instantaneous and reversible desorption of contaminants from unsaturated media. Neither of these assumptions are justified; in fact there is much current research which demonstrates that a certain portion of sorbed hydrophobic contaminants are slowly or "irreversibly" sorbed, and that transport of contaminants through immobile pore water further impedes the progress towards the equilibrium condition. Page 13 of the Focused Feasibility

Study recognizes part of the problem ("the desorption rate is unknown"), but there is no attempt to reconcile this difficulty.

iv) No pore water measurements of contaminants were taken to justify the equilibrium assumption.

v) *The model is not verified or reconciled with field data. The general absence of contamination in* the swampy area north of the railroad tracks suggests that the model is in error. The only installed deep well, ERT-1 in the swampy region, shows contamination in the "deep aquifer" (RI Report, Table III-24); this is unexplained.

vi) No mass balances are presented to check the method of computation for movement of water through the site, nor are similar mass balances presented for transport of organic chemicals. Mass balances are necessary in order to clearly delineate model assumptions, as well as to provide a check against the possibility of mathematical errors.

vii) The model does not consider volatilization or biological degradation of contaminants.

viii) Contaminant transport in fractured materials can be quite different than processes in granular media. The model does not recognize the special physical and chemical phenomena associated with transport in fractured media. Although the fractures may comprise only a small fraction of the bulk volume of the media, the average groundwater velocity in the fracture can be large. The process of mechanical dispersion is also different in fractured materials, as fractured geologic materials are notoriously anisotropic with respect to the orientation and frequency of fractures. Hence, the dispersion of solutes during transport through fractured rocks cannot be described by equations developed for granular media (Freeze and Cherry, Groundwater, Prentice Hall, 1979). The process of sorption and retardation must also be handled differently, as it is more appropriate to express the distribution coefficient on a per-unit-surface area basis rather than on a basis of unit mass of the medium in the dry state. Other processes affecting contaminant transport in fractured media with an immiscible organic phase include: molecular diffusion from the fracture into the matrix of the unfractured material; the effect of wetting and capillary forces on migration; spreading of a separate phase along a confining layer; dissolution of components from the organic phase to water; and effects of a fluctuating water table.

Environmental Exposure

The determination of soil removal action levels is used to identify general response actions from which excavation alternatives based on receptor points are evaluated. This methodology was summarized in the *Focused Feasibility Study from Information presented in the Remedial Investigation and Risk Assessment* Reports. Although this methodology is presented in a formalistic style, this procedure is not a substitute for

intellectual rigor. The study concludes that the action level should be based on conditions within the on-site aquifer, and that this can only be achieved by excavation. It is difficult to justify either of these decisions on the basis of the facts presented in these documents.

For example, the contaminant transport model proposed by the EPA is precipitation-event driven. Therefore if infiltration from precipitation were prevented, i.e. by capping the site with an impervious material, this would be an effective solution. In addition, there is risk associated with excavation, and this was not considered, i.e. release of volatile material, transport of large volumes of material over public areas, etc.

The action proposed by the EPA dismisses the simple fact that the most important environmental concern is to protect the quality of the river, as well as to ensure against transport to any local wells. It is inferred in the *Remedial Investigation and Risk Assessment Reports that there is very little likelihood that the site, or the* area between the site and the river, would ever be developed or that the immediate groundwater resource would be utilized. There are no wells in this region, the area is bounded by steep hillsides to the south, and railroad tracks and swampy regions to the north. Hence the selection of the on-site aquifer as the receptor point for the calculation of action level serves no rational purpose.

The proposed remedial action ignores the fact that excavation of waste material only relocates the problem to another site.

Engineering intervention through waste treatment, on-site remediation, interception wells, and the like, is not even considered. The contamination problem should be managed through on-site intervention to the maximum possible extent. River water quality should be protected foremost, and in this regard, if most of the chemical contaminants are in the bedrock regime, this will necessitate treatment rather than excavation.

September 1986

GENERAL PROFESSIONAL BIOGRAPHY

Full Name: Richard Godfrey Luthy

Born: 11 June 1945

Citizenship: United States

Social Security Number: 548-62-8855

Spouse's Name: Mary Frances Luthy

Names of Children (Birthdates): Matthew (1970), Mara (1974), Jessica (1975)

Residence: 620 South Linden Ave., Pittsburgh, PA 15208 (412-441-7893)

Office: Department of Civil Engineering, Carnegie Institute of Technology, Carnegie-Mellon University, Pittsburgh, PA 15213-3890 (412-268-2949)

Carnegie-Mellon University Appointments:

I Assistant Professor, Department of Civil Engineering, Carnegie Institute of Technology (1975-1980)
II Associate Professor, Department of Civil Engineering, Carnegie Institute of Technology (1980-1983).
III Professor, Department of Civil Engineering, Carnegie Institute of Technology (1983-present), Acting Head, Department of Civil Engineering (July, 1985 - January, 1986).
IV Carnegie Institute of Technology, Faculty Chairman-Chairman/Elect (1984-1986).
V Associate Dean, Carnegie Institute of Technology (1986 -).

Previous Professional Positions:

I Junior Chemical Engineer, Hercules Incorporated, Hercules, California (Summer, 1966).
II Research Aide, Stanford Electronics Laboratory, Stanford University (Summer, 1967).
III Graduate Assistant, International Business Machines, Data Processing Center, Honolulu, Hawaii (Summer, 1969).
IV Research Assistant, Department of Civil Engineering, University of Hawaii, Honolulu, Hawaii (1968-1969).
V Research Assistant, Division of Sanitary and Hydraulic Engineering, Department of Civil Engineering, University of California, Berkeley, California (1973-1975).

Education:

I BS in Chemical Engineering, University of California, Berkeley, California (1967).
II MS in Civil Engineering (Ocean Engineering), University of Hawaii, Honolulu, Hawaii (1969).
III MS in Civil Engineering (Sanitary Engineering), University of California, Berkeley, California (1974).
IV PhD in Civil Engineering, University of California, Berkeley, California (1976).

Military Status:

I U.S. Navy Civil Engineer Corps, Ensign, Research Project Officer, U.S. Navy Civil Engineering Laboratory, Port Hueneme, California (1970-1971).
II U.S. Navy Civil Engineer Corps, Lieutenant Junior Grade, Assistant Officer in Charge, Underwater Construction Team, Davisville, Rhode Island (1971-1972).
III U.S. Navy Civil Engineer Corps, Lieutenant, Inactive Reserve (1973-1979).

Memberships in Honorarles, Societies, Associations:

I American Society of Civil Engineers
II American Water Works Association
III Water Pollution Control Federation
IV International Association on Water Pollution Research
V Association of Environmental Engineering Professors
VI *American Academy of Environmental Engineers*, Diplomate

Awards, Honors:

I George Tallman Ladd Award, Carnegie Institute of Technology; research award presented to young engineering faculty, (1977).
II Nalco Award, presented by the Association of Environmental Engineering Professors for significant chemical research in industrial waste treatment, with R.E. Selleck (1978).
III Harrison Prescott Eddy Medal, presented by the Water Pollution Control Federation for outstanding research in fundamentals of wastewater treatment (1980).
IV Nalco Award, presented by the Association of Environmental Engineering Professors for significant chemical research in industrial waste treatment, with R.W. Walters (1982).
V Founders Award, presented by the USA National Committee of the International Association on Water Pollution Research and Control, for the outstanding paper by an US author in Water Research for 1984/1985. Presented at the 13th Biennial International Conference, Rio de Janeiro (1986).

Research Interests or Area of Specialization:

Industrial Waste Treatment--Petroleum, Chemical and Mineral Process Industries

Aquatic Chemistry--Water and Wastewater Treatment

Environmental Engineering Problems in Groundwater Contamination

Environmental Control in Synthetic Fuel Processes

Professional Registration:

Professional Engineer, Commonwealth of Pennsylvania, PE-24546-E.

Patents:

Underwater Angle Measuring Device (with J.B. Ciani), U.S. Patent Number 3,783,624, issued January 8, 1974.

Professional Activities (selected):

I Faculty Advisor, Student Chapter ASCE, Carnegie-Mellon University (1975-1979).
II Joint Task Group Committee for *Standard Methods*: Oil and Grease, Cyanide (1975-present). Chairman, Joint Task Group on Cyanide (1985-present).

III Reviewer--Journal of the Water Pollution Control Federation (1976-present).
IV Reviewer--Environmental Science and Technology (1979-present)
V Reviewer--Water Research (1979-present)
VI Technical Advisor, Allegheny County Health Department, Water Quality and Solid Waste Control (1977-1981).
VII Hazardous Waste Management Committee, American Society of Civil Engineers (1979-1982).
VIII Awards Committee, Water Pollution Control Federation (1981-1984).
IX Director, Pittsburgh Section ASCE (1982-1984).
X Association of Environmental Engineering Professors; Distinguished Lecturer Committee (1982-1984), Chairman (1984-1985); Awards Committee (1983-1984).
XI Research Symposia Subcommittee, Water Pollution Control Federation (1985-1987).
XII Director, Association of Environmental Engineering Professors (1985-1988).

Consulting Assignments:

Municipal Wastewater Treatment

Save San Francisco Bay Association, Citizens Advisory Group, Department of Public Works, City of San Francisco (1975)

Aquatic Chemistry

FMC Corp., Industrial Chemical Group Research and Development, Princeton, NJ, and Kirkpatrick and Lockhart, Pittsburgh, PA (1985).

Environmental Problems--Industrial Waste Treatment

Shell Oil Company, Manufacturing Complex, Martinez, California (1974-1975).
Environmental Research and Technology, Inc., Concord, Massachusetts (1978-1979).
Lancy International, Zellenople, PA (1983-1985).
ERC-Lancy Division of Dart Environment Services Co. (1978-1982).
Mid-American Pipeline Co. (MAPCO), Tulsa, Oklahoma (1978).
J. T. Baker Chemical Company, Phillipsburg, New Jersey (1981-1982)
B. F. Goodrich Company, Brecksville, Ohio (1981)
Koppers Company Inc., Research Center, Monroeville, PA (1982-1983)
U.S. Environmental Protection Agency, Science Advisory Board, Environmental Engineering Committee, Washington, D.C. (1983).
Aluminum Company of America, ALCOA Technical Center, ALCOA Center, PA (1985).
SmithKline Chemicals, SmithKline Beckman Co., Conshohocken, PA and SK and F Lab Co., Guayama, Puerto Rico (1985).
Dravo Corporation, Recovery Systems, Pittsburgh, PA (1985).

Environmental Problems--Surface and Groundwaters

U.S. Steel Corporation, Pittsburgh, Pennsylvania (1979-1982).
Verna Engineering Inc., Carnegie, Pennsylvania (1979-1981).
GAI Consultants Inc., Monroeville, Pennsylvania (1980).
Environmental Research and Technology, Pittsburgh, Pennsylvania (1982-1985).
Vinings Chemical Company and Soil & Materials Engineers Inc., Atlanta, GA (1983-1984).

Koppers Company Inc., Research Center, Monroeville, PA (1984-1985).
Argonne National Laboratory, EES/Geoscience and Engineering Group, Argonne, IL (1985).
SmithKline Beckman Company, Philadelphia, PA (1986).
Battelle Northwest Laboratories, Earth Sciences Dept., Richland, WA (1986).

Environmental Control in Coal Conversion Processes

Energy Impact Associates, Pittsburgh, Pennsylvania, Foster Wheeler Energy Corporation, and Memphis Light, Gas and Water. Industrial Fuel Gas Demonstration Program (1980-1981).
Exxon Research and Engineering Company, Exxon Engineering Synthetic Fuels Department, Florham Park, NJ (1980).
International Coal Refining Company (Air Products; Wheelabrator-Frye), Allentown, PA, (1981-1983).
Oak Ridge National Laboratory, Oak Ridge, TN (1982).
Westinghouse Synthetic Fuels Division and SynCo Consultants, Inc., Pittsburgh, PA (1982-1983).

Marketing Research

The Gene Reilly Group, Darien, Connecticut (1985)

Litigation

Lewis and Stokey, P.C., Pittsburgh, Pennsylvania (1978-1979).
Rose, Schmidt, Chapman, Duff and Hasley, Pittsburgh, PA (1985).

Arbitration

U.S. Steel Corporation, Pittsburgh, Pennsylvania (1981-1982).

Funded Research at Carnegie-Mellon University:

"Biological Oxidation of High Strength Coal Refinery Wastewaters," National Science Foundation, $19,900; R.G. Luthy, Principal Investigator (1977-1978).

"Environmental Assessment in the DOE Coal Gasification Development Program," U.S. Department of Energy, $359,000; M.J. Massey and R.W. Dunlap, Principal Investigators; R.G. Luthy, F.C. McMichael and E.S. Rubin, Co-Investigators (1976-1978). J.P. Fillo, R.G. Luthy, M.J. Massey, Principal Investigators 1978-1979 ($380,000).

"Evaluation of Treatment Technologies for Water Reuse in Coal Coking and Coal Gasification," U.S. Department of the Interior, Office of Water Research and Technology, $58,580; R.G. Luthy, Principal Investigator (1978-1979).

"Development of Procedures for Evaluating Wastewater Emulsified Oil Separation," Lancy Division of Dart Environment and Services Co., $23,000; R.G. Luthy, Principal Investigator (1979-1980).

"Removal of Polycyclic Aromatic Compounds in Coke Plant Wastewater," MPC Corporation, Pittsburgh, Pennsylvania; $44,000; R.G. Luthy, Principal Investigator (1979-1980).

"Treatment of Slagging Fixed-Bed Gasification Process Wastewater," Grand Forks Energy Technology Center, Grand Forks, ND; $65,400; R.G. Luthy, Principal Investigator (1979-1980).

"Removal of Organic Constituents from Gasification Wastewater by Solvent Extraction and Powdered Activated Carbon/Activated Sludge Treatment," Argonne National Laboratory, Argonne, IL; $44,000, R.G. Luthy, Principal Investigator (1980).

"Physicochemical Adsorption Phenomena of Polycyclic Aromatic Hydrocarbons in Coal Conversion Wastewaters," U.S. Department of Energy, $101,600, R.G. Luthy, Principal Investigator (1980-1982).

"Water Management and Wastewater Reuse in Coal Conversion Facilities," U.S. Department of Energy, Pittsburgh Energy Technology Center, $138,700, R.G. Luthy, Principal Investigator (1980-1983).

"Treatment of Slagging Fixed-Bed Gasification Process Wastewater: Disposition of Trace Organic Compounds," Grand forks Energy Technology Center (US DOE), $188,500, R.G. Luthy, Principal Investigator (1981-1982).

"Studies for Removal of Organic Constituents in Process Wastewater From Modified In-Situ Oil Shale Retort," Argonne National Laboratory, Argonne, IL, $35,000, R.G. Luthy, Principal Investigator (1981).

"Ion Chromatography for Analysis of Environmental Samples," National Science Foundation, $13,400 Equipment Grant, C.I. Davidson and R.G. Luthy, Principal Investigators (1981-1982).

"Investigation of Limiting Engineering and Chemical Factors for Recycle and Reuse of Blast Furnace Scubber Waters Under the Clean Water Act and RCRA," U.S. Environmental Protection Agency, Washington, D.C., $172,000, R.G. Luthy, and F.C. McMichael, Principal Investigators (1981-1983).

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