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ANALYSIS OF THE LAKE MICHIGAN BASIN PHOSPHORUS REMOVAL POLICY IN WISCONSIN

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PREFACE

Wisconsin's commitment to achieve effective phosphorus removal from point sources discharging directly or indirectly to Lake Michigan provided the stimulus for this study; the original goal of accomplishing this by the end of 1972 allowed for the opportunity to evaluate the effectiveness of the program and to develop the requisite data base to price current and alternative policies. The study and findings described in this report were undertaken by Mr. Daryl Braasch under the supervision of Professor Erhard F. Joeres as part of the requirements for the M.S. program in Civil and Environmental Engineering at the University of Wisconsin-Madison. As such it represents an independent effort and reflects the bias and judgement of the authors.

We would like to give particular thanks to the Wisconsin Department of Natural Resources for providing the initial funding for this project. The DNR support served as a valuable stimulus towards the broader policy studies now under way as part of the University of Wisconsin Sea Grant College Program.

We are indebted to the many city officials and local treatment plant operators who extended their hospitality to us and who willingly shared their time and experience; particular thanks are also due the Wisconsin State Water Chemistry Laboratory and Mr. Robert Krill of the Wisconsin DNR for their support of this work. We owe a special note of thanks to our coworkers on this project: Professor Martin David, Mr. James Jeffrey Peirce and Mr. Frederick Schroeder for their patient and critical participation.

ABSTRACT

A Federal Enforcement Conference among tributary states to deal with the eutrophication control of Lake Michigan led to the implementation of a 1969 order by Wisconsin's Department of Natural Resources, requiring fifty-three municipal wastewater treatment plants in Wisconsin's Lake Michigan basin to remove 85% of their influent phosphorus load by January of 1973. This study centers on a survey of the compliance observed and overall success of this order. Phosphorus removal methods implemented and corresponding costs are investigated. A range of treatment-cost alternatives is developed for each of the fifty-three plants, which serves as the data base for a dynamic programming model used to determine an alternative cost-efficient treatment policy. The cost of this policy is compared to the costs of uniform percentage and effluent standard removal requirements.

CHAPTER I

HISTORY OF THE DECISION

A. Federal Policy Objective

Early in 1968, the states bordering Lake Michigan held a Federal Enforcement Conference in Chicago. The purpose was to determine policy to control the eutrophication of Lake Michigan. A year later, on February 25, 1969, a decision was made to achieve an 80% overall reduction in the total phosphorus load to Lake Michigan from all point sources in the drainage basin. A January, 1973, deadline was agreed upon to achieve this goal. The policy was adopted based on testimony that phosphorus was the major controllable cause of eutrophication in Lake Michigan, and on testimony by engineers that the 80% level was technically practical. Implementation of this policy was left to the individual states.

B. Wisconsin DNR Policy

In Wisconsin, the Department of Natural Resources, Environmental Protection Division, was responsible for implementing the policy for the Wisconsin portion of the Lake Michigan Basin. The DNR noted that the phosphorus removal costs for small communities were disproportionately high. Also, 44 of the 177 sources in the basin contributed about 95% of the total phosphorus load in 1969. These 44 sources were most easily defined in terms of population or population equivalent. Essentially, the decision in Wisconsin was to require 85% phosphorus removal by all communities with a population of 2500 or more and of all industries with an equivalent or greater contribution. A January 1, 1973, compliance deadline was established. The number of plants now effected by this order has increased to 53.

With the issuance of discharge permits in 1974, the DNR order has taken a somewhat different form. The objective is now a 1 mg/1 as P effluent total phosphorus concentration at each plant. The effluent standard approach will take effect and the uniform 85% phosphorus reduction requirement will be phased out as discharge permits are issued during the course of 1974. Some time lag can be expected before the objective of 1 mg/1 at each of the plants will be realized. As an interim measure, some of the permits now issued allow effluent phosphorus levels in excess of 1 mg/1, taking into account such local conditions as hydraulic overload; excessively high and variable influent phosphorus concentrations; inability of applying high chemical dosages to achieve acceptable phosphorus removals; critically overloading present sludge handling facilities; or other more specific plant conditions or problems. Thus, until major plant upgrading programs or expansions are completed, high phosphorus removals cannot be expected and the 1 mg/1 effluent standard may not be realized without extensive construction resulting in expense and time lags.

C. Previous Investigation

In the summer of 1971, a study was completed by Ronald Fait and Erhard F. Joeres as part of a broader investigation into water resources policy in SE Wisconsin carried out under the auspices of the U.W. Water Resources Center. Fait(1) conducted extensive research into the methods and probable costs of phosphorus removal in Wisconsin. He listed alternate removal policies and associated costs at each of the 44 treatment plants in the Wisconsin Lake Michigan Basin. Fait's study was a predictive study based on cost information from literature and personal interviews. The alternative removal possibilities postulated by Fait were used as input to a computer model developed in the spring of 1971 by Joeres(2). The model used develops optimal removal policies based on the objective of economic efficiency. The papers by Fait and Joeres will be cited frequently in this report.

CHAPTER II

PRESENT STUDY OBJECTIVES

The objectives of the present study are to:

(1) Investigate actual decisions at each point source affected by the DNR order in terms of removal method implemented and corresponding cost; and in so doing assess the success of the DNR order and contribute to an updated data base for the computer policy model.

(2) Develop updated alternative removal possibilities available at each plant, based on knowledge of the specific plant conditions, implemented decisions, and phosphorus treatment processes and costs as described in the recent literature.

(3) Analyze the updated data base of (1) and (2) by means of the optimum policy model; more specifically, to investigate cost differences between uniform removal versus economic efficiency oriented policies.

CHAPTER III

IMPLEMENTATION OF THE ORDER

A. Date of Compliance

The cities encountered a problem which, in many cases, may have been the main reason why most of them missed the January, 1973, deadline of the order (see Table 1). This problem was the hold on federal funding for wastewater treatment purposes. The cities had hoped to be at least partially funded for the capital expenditure on chemical feed facilities for phosphorus removal. Thus, many waited until the deadline was very near before taking any significant steps. A related problem may have been the resultant difficulty in obtaining chemical feed equipment soon enough to meet the deadline.

Realizing the problems the cities were having in meeting the January, 1973, date, the Wisconsin Department of Natural Resources extended the deadline to March, 1973, and further relaxed its position by asking that merely a serious attempt be made to treat for phosphorus by this time, with full compliance as soon as possible.

The nature of the order and the funding problem resulted in some very temporary and makeshift chemical feed facilities. It was not uncommon to find a number of plants dosing chemicals directly out of 55 gallon drums. Several plants used back-yard style swimming pools for storing liquid alum. Other plants installed only the bare necessity in chemical storage and feed equipment with additions planned when funds would become available. For some plants, any sizeable capital investments were undesireable because of construction or plans to construct a new plant, with scheduled abandonment of existing plants in some cases. Table 1 is a list of the number of plants on line with some form of phosphorus removal and the dates on which this treatment was initiated. The DNR initiated steps through the Wisconsin Attorney General's Office causing a number of plants to be fined heavily for not taking any steps to meet the order.

Although fifty-three cities are affected by the Lake Michigan order, three of them will not be included in the summaries which follow in this section. Germantown, Holland, and Neenah-Menasha currently have no treatment specifically for phosphorus removal. Union Grove initiated treatment in November, 1972, and discontinued it in March, 1973. There has been no treatment for phosphorus removal since then, but since performance levels and costs were reported, Union Grove is included in the summary. The information which is summarized here is taken from Appendix A, which includes treatment process diagrams, phosphorus removal methods, and associated costs for each individual plant. Appendix B contains average monthly flow and phosphorus levels for each plant along with plant process changes and corresponding approximate dates when they were initiated.

B. Treatment Efficiency

Table 2 shows the reduction in the total phosphorus load to Lake Michigan and its tributaries under several different conditions. Approximately 40% of the influent load was removed under existing treatment. Under (a) in Table 2, special note is made of the Milwaukee-Jones Island plant. Prior to January, 1973, the Jones Island plant was involved in a research project to study the effects of waste pickle liquor addition for phosphorus removal (14). Thus, Jones Island had been treating at 85% and higher for several years before the actual deadline.

The 1 mg/l effluent limit is somewhat less demanding for the entire watershed than the 85% removal requirement--353 lb/day less. The 1 mg/l requirement will require more phosphorus removal than the 85% standard at plants with higher influent phosphorus concentrations, and allow less removal at plants with small influent concentrations. This limit is independent of the plant flow. Consequently, neither the effluent standard nor the uniform percentage reduction actually limits the total phosphorus load in terms of lb/day P removed. This point is also noted in the EPA Process Manual for Phosphorus Removal by Black and Veatch (3). Figure 1 illustrates the distribution of phosphorus removal percentages corresponding to the 1 mg/l requirement.

Tables 3 and 4, showing the number of plants having to make treatment changes under various restrictions, seem to indicate that the plants generally are having as much trouble meeting the removal requirements as they had meeting the time deadline. The distribution of influent phosphorus concentrations is listed in Table 5.

Problems in meeting the removal requirements are sometimes the results of a hydraulically overloaded plant. Thus, even though a plant may be dosing chemicals properly and forming a floc, inadequate detention times may hinder effective settling and phosphorus removal. In Table 6, the percentage of design flow shown is the average flow for the specific period of treatment--as noted on individual information sheets in Appendix A--divided by the reported design flow. The design flow is usually the average design flow. When both average and maximum design flows are reported, the average design flow is used. Care should be taken in interpreting this table since the appropriate period of record is short in some cases. Table 6 does provide a general overview of the overload problem at several of the 53 plants.

Tables 7 and 8 show the distribution of the actual phosphorus influent and effluent loads in lb/day of P at the 50 plants included here. Note that 30 of the 50 plants each have less than 100 lb/day of influent P, while 10 plants are each discharging more than 100 lb/day of P. This occurs because a number of large plants are either without full-scale treatment facilities, or are now under construction on a new or expanded plant.

The distribution of present phosphorus treatment costs is given in Table 9. It is important to note that these costs correspond to various treatment or removal levels. The costs indicated do seem to fall within the ranges generally reported in the recent literature (3, 4, 7, 8). Costs are discussed more thoroughly elsewhere in this report.

CHAPTER IV

DISCUSSION OF ACTUAL TREATMENT PERFORMANCE

A. Treatment Methods

The consulting engineers' approach to the problem of designing adequate treatment for phosphorus removal has been to use existing plant processes whenever possible. When this practice may be followed, large capital investments can be avoided (4). Individual plant process diagrams and summaries of chemical treatment, with related costs and observations for each of the 53 plants, are included in Appendix A.

This report makes no attempt at drawing any conclusions about the physical/chemical characteristics of phosphorus treatment. BOD, suspended solids and pH levels are not considered here as they would be in a comprehensive study of one or several of the plants. This investigation deals with 53 plants with varying treatment systems and individual plant conditions. Thus, tables indicating various treatment methods or points of application are given only for information. Nickerson et al. (13), Kumar and Clesceri (4), and Melkersson (6) have all specifically stressed an individual approach to phosphorus treatment systems dependent on many local factors.

Also, observations showing better phosphorus reduction with one chemical over that of another must be taken within the full context of varying treatment conditions. The effect of a chemical at plant A may not be the same as at plant B, even though the plants have some similarities. Only complete preliminary and pilot plant tests at an individual plant can determine which chemical is best suited to its needs. In some instances, chemical addition must be at full scale to evaluate the actual effects on the treatment processes.

Table 10 is a summary of the plant and phosphorus removal treatment systems. Activated sludge and trickling filter designations refer to the principal secondary or biological treatment process of the plant. Activated sludge includes such modifications as contact-stabilization, step aeration, and the Kraus process. The phosphorus treatment process is classified as one of four categories in this report.

PRIMARY: refers to the addition of chemical prior to or at the primary sedimentation tanks with the intent of removing most of the phosphorus in the primary stage.

CHEMICAL-BIOLOGICAL: includes the addition of chemical just prior to, or at the biological treatment process.

POST-BIOLOGICAL: refers to the addition of chemical at some point after biological treatment. For the plants included here, this is usually chemical addition just preceeding the final clarifier.

PRIMARY/POST-BIOLOGICAL: includes chemical addition at the primary tanks and after the biological treatment.

In the designations above, "chemical" refers to alum, $FeCl_3$, etc., and does not apply to or include consideration of the use of polymers.

B. Chemicals Used

Table 11 indicates the chemicals used at the plants involved in this study. Liquid alum, used most commonly, is available as $Al_2(SO_4)_3 \cdot 14.3\ H_2O$. Alum weighs 5.4 lb/gal and contains approximately 9% Al by weight. Reported average costs range from \$54-\$60 per ton (dry alum) delivered. Dosages ranged from Al:P $\leq$ 1:1 to 2:1 (weight ratio of Al to total influent P). Dry alum at 36% Al is also available--either bagged or in bulk.

Another source of tri-valent aluminum is sodium aluminate. Liquid sodium aluminate is available from 5-27% Al_2O_3 by weight (3). The plants which use this chemical generally obtained a solution with approximately 19.9% Al_2O_3 at approximately 12 lb/gal of solution. Liquid sodium aluminate is available in 30 gallon drums, or in 20 T tanker loads at an average cost of approximately 8¢/lb (3,21). Sodium aluminate is an alkaline product which may be used more effectively than alum in waste waters with low natural alkalinity (1). Dry aluminate is available at approximately 41-46% Al_2O_3 (21).

Tri-valent Fe is available in liquid form at approximately 40% $FeCl_3$, either in drums or in tanker shipments. $FeCl_3$ weighs 11.6 lb/gal of solution and costs can range from $100-160/T of anhydrous $FeCl_3$, depending on the shipping charges (22,23,24).

Waste pickle liquor is used by plants included here from either local industrial sources or from suppliers. Thus the iron content can vary over a wide range, but is usually available from 4-14% Fe. Waste pickle liquor is generally available at about 10.8 lb/gal of solution with costs varying with the source of supply and associated iron content. Pickle liquor addition is used at several large plants in heavy industrial areas as well as at a number of smaller plants. One of the most extensive recent publications on pickle liquor addition involves the treatment system at Milwaukee-Jones Island (14). Of particular interest is the excellent removals of phosphorus--86%--associated with one of the two plants operated in parallel. This plant has no direct pickle liquor addition, but instead receives iron bearing filtrate and return sludge from the other plant.

Anionic and cationic polymers have been used effectively with $FeCl_3$ and with the aluminum compounds. Nickerson et al. (13), reporting on chemical addition at trickling filter plants, noted considerable success with the addition of a catiomic polymer ahead of the primaries, and an anionic polymer at the final clarifiers. The polymers complemented $FeCl_3$ addition prior to the grit chamber.

The major problem in achieving success with polymer addition is to find the right polymer. There is a large variety of polymers available, and the only way to determine which is best suited to a specific plant is actually to use it. Polymers are available at approximately $1.20-$2.00/lb, depending on the quantity ordered.

C. Effects on Sludge Handling and Disposal

Polymers have been added to sludge lines at several plants to aid in thickening and generally to alleviate a potential overload to the sludge system. Sheboygan uses this method with some success even though the system is overloaded. The increased sludge load and the associated cost resulting from the addition of phosphorus removal chemicals have each been mentioned in many of the references cited (1,3,5,6,13,18,29). Actual reported data are, however, very limited. This problem seems to be an important one and conditions in sludge handling and disposal systems vary markedly from plant to plant.

Theoretically, the addition of 1 lb. of Al^{+3} in the presence of PO_4 produces approximately 4.5 lb. of $AlPO_4$; and 1 lb. Fe^{+3} yields about 2.7 lb. of $FePO_4$ (10,29). Sludge conditions resulting from the addition of phosphorus removal chemicals at the individual plants are reported qualitatively in this study. Some operators and plant superintendents have noted no increases in sludge volume while others report increases in volume of up to 100%. Most plants reporting have noted better dewatering or thickening properties with chemical addition. A specific exception to this general rule was noted at Fond du Lac, where a "thinner" sludge--decreased % solids--

was reported. The problem there seemed to be hydraulically overloaded final clarifiers--particularly in reference to exceeding clarifier thickening design.

The quantity of extra sludge produced must be considered in planning for phosphorus removal treatment, especially at existing plants operating near design levels. But, the character of the sludge must also be evaluated. The nature of the sludge will generally change from a biological to a chemical-biological sludge. For example, difficulties with the incineration process were reported at Sheboygan, where additional fuel was required for burning.

Added costs associated with sludge handling and disposal are indicated on individual plant information sheets in Appendix A. Unfortunately, limited cost information is available on this part of the treatment process at this time. Additional sludge costs are thus not included in the analysis which follows in this report.

D. Particular Treatment Situations

Digester supernatant and recirculation return flows have been noted as a possible hindrance in achieving acceptable phosphorus removals (6, 12,13). Ericsson (12) has noted that reduction of the ferric iron to the ferrous state during anaerobic stabilization and the resulting release or solubilizing of phosphorus is a possibility which must be investigated. In the specific plant he studied phosphorus was not released, but actually underwent additional removal because of precipitation of the phosphorus released from the biological sludge.

The apparent release of phosphorus was particularly important at Clintonville, where an extensive revision of sludge handling and disposal methods was required to meet acceptable phosphorus removals. The digester supernatant return was also indicated as a problem at Racine. McGinness and Harriger (8) reported that separate biological treatment of the supernatant is employed at Sandusky, Ohio.

Nickerson <u>et al</u>. (13) reported that decreasing the generally recommended recirculation rates at overloaded trickling filter plants resulted in considerable success in achieving treatment efficiency. Recirculation was specifically noted as a problem or potential problem at the trickling filter plant at Manitowoc.

Sheboygan Falls and Ripon reported dosing chemicals directly preceeding the trickling filters. At Sheboygan Falls, alum was used and filter clogging resulted, so the point of addition was changed. Ripon reports dosing waste pickle liquor ahead of the trickling filter at Fe:P $\cong$ 4:1 with a 61% average removal of phosphorus.

Trickling filter plants generally are not achieving acceptable phosphorus removals. The maximum removal reported was at Oconto Falls, where $FeCl_3$ at Fe:P $\cong$ 3:1 resulted in 75% removal. Peshtigo reported 65% removal at Fe:P $\cong$ 2.5:1. Many of the trickling filter plants are overloaded and awaiting construction of new plants or expansions. Construction is scheduled at the larger facilities, and some smaller plants are due to be phased out with the construction of regional treatment systems.

Green Bay, Oconto Falls, and Peshtigo are currently trickling filter plants which are scheduled to initiate combined treatment with industrial wastes as new wastewater treatment plants are constructed in these communities. The industrial wastes to be included will be essentially void of phosphorus, resulting in very low plant influent phosphorus concentrations. Thus the nutrients required for biological activity may be near the critical level. The general BOD:P ratio required for efficient biological activity is 100:1 on a weight basis (27).

Davies and Unz (9) report that the addition of alum to activated sludge mixed liquor provides no threat to the microbial population and may aid in "coalescing bacteria which normally exist in dispersed phased in the mixed liquor." The addition of iron at Milwaukee Jones Island did not create any problems with biological systems at acceptable phosphorus removal levels (14). Ross and McKinney (15) have concluded research which indicates that a proper balance of iron made available to the microorganisms may actually increase the metabolism rate.

A decreased biological efficiency was noted when chemical was dosed at the primary tanks in Waupaca's activated sludge plant. Melkersson (6) and Ericsson (12) have noted this experience with primary or pre-precipitation processes. An unfavorable BOD:P ratio in the activated sludge system can result in decreased efficiency.

The three plants which are currently operating as contact-stabilization units reported excellent removals at Al:P $\cong$ 1:1.

Butte des Morts	- 86%
North Park S.D.	- 92%
Menasha S.D.	~90%

At Menasha, Al:P $\cong$ 1.5:1 was necessary to maintain a 90% reduction. This information is limited, however, and cannot be supported here by any data from publications or articles.

One plant employs POST-BIOLOGICAL treatment at a concentrated substream. Cedarburg has used alum addition at the influent and effluent of the sludge thickener. Phosphorus removal has averaged only 67% with 2.6 mg/l as P in the effluent. Jones (7) indicates that acceptable phosphorus removals of 80% and higher can be obtained when treating substreams of this type. However, he offered very limited evidence from a literature survey to substantiate adequate treatment levels.

Industrial wastes have caused an effect at several plants. Most notably, dairy waste discharges to small plants ($\leq$ 1 MGD) have resulted in influent phosphorus concentrations greater than 15 mg/l as P. Where industries are charged based on their phosphorus discharge to the treatment plants, the amount of the charge may become meaningful in further cost evaluations of phosphorus treatment in Wisconsin. As the variety of conditions encountered indicate, the converse may also hold. At Ripon, for example, the plant superintendent noted increased removals of phosphorus when a local aluminum industry discharged its wastes to the plant.

CHAPTER V

COST INFORMATION

Figure 2 illustrates the distribution of reported capital investment on equipment for phosphorus treatment. Estimated costs from various sources are also shown on the log-log plot. The curves shown do not include allowances for polymer addition facilities or chemical feed buildings. Specific variations in the reported data are noted with different designations. The points designated as "chemical feed equipment" pertain to plants which reported that no further additions to chemical storage and feed equipment were planned. This excludes the possible addition of chemical feed buildings. Several plants which have installed full-scale polymer feed facilities are specifically designated. Some plants have been using polymer, on a part-time or experimental basis, and have only temporary or make-shift feed facilities. These plants are not included in this category, so that a representative cost comparison can be made.

Three of the plants are designated as having major revisions. These plants are Sturgeon Bay, Clintonville, and Chilton. Capital costs at Chilton and Sturgeon Bay include the addition of chemical feed buildings. The costs at Clintonville includes a major modification of the sludge handling and disposal system. Clintonville's problem with disposing of the digester supernate has been discussed more thoroughly in Appendix A and in the discussion of treatment methods on page 13.

Low cost or temporary facilities are those where additions to chemical storage or feed equipment are planned. Plants where capital investment was admittedly kept low because of expansions or new plants are also included in this category. Several plants having seemingly low capital investment, but not included in this category, are in cities where new plants or expansions had just gone on line. The capital cost in these cases does not include a complete accounting of installation costs and costs for piping and electrical works. These costs were inseparable from the total cost breakdowns.

The cost curves shown are those estimated for liquid chemical feed facilities, with the flexibility to dose any one of several chemicals available. The curves shown include costs for chemical storage and feed pumps. Although estimated costs for chemical feed buildings are reported in the literature [Kumar & Clesceri (4)]. These costs are not included on the curves shown. Costs for polymer addition facilities are also reported by Kumar and Clesceri (4) to be $2,500 for a 1 MGD plant; $8,600 for a 10 MGD plant; and $20,000 for a 100 MGD plant. The initial cost of adding polymer feed facilities to an existing plant were also reported by Black and Veatch (3). Costs reported are $5,810 for 1 MGD; $26,740 for 10 MGD; and $203,000 for 100 MGD.

Costs reported in the literature for chemical storage are generally based on a 10-15 day storage capacity. However, the actual breakdown is sometimes more difficult to determine. Cost curve information by Black and Veatch (3) and by Fait (1) does not include any allowance for associated piping and electrical works, while information supplied by Kumar and Clesceri (4) includes an accounting--based on estimated percentages of process equipment cost-- of piping, plant electrical works, instrumentation, engineering and construction, modification and start-up, spare parts, contingencies, and consultant's fees. Reported costs generally include storage and feed equipment; associated piping and electrical works; and costs for engineering, construction, and installation. Reported costs seem to be more in agreement with costs reported by Fait (1) and by Black and Veatch (3). For this study capital costs are adjusted to 1973 levels by the ratios of construction cost indices for sewerage treatment works (30). Capital investment costs were discounted at 7% and from 10-25 years, depending on the permanency and quality of the installation.

Annual operating labor cost due to the phosphorus treatment is plotted against plant capacity in Figure 3. These costs may include mixing polymer, checking and adjusting chemical feed rates and performing analysis for phosphorus. The reported values show no apparent relation to plant size and average between $2,000/yr to $3,000/yr (excludes the estimates at the 120 MGD Milwaukee South Shore plant). Curves are also shown based on information used by Fait (1) and data on operating labor costs from Kumar and Clesceri (4) and Powell and Crawford (5). Information from Fait (1) is adjusted to 1973 costs by using the sewerage treatment plant cost index (30). Fait (1) included maintenance, labor, and operating labor as a single cost.

Only four plants reported annual operating labor cost above $4,000--Milwaukee, Oconto, Sturgeon Bay, and Thiensville. Oconto and Sturgeon Bay reported extremely high values of approximately $9,000/yr. Each of these plants, however, just went on line with plant expansions and upgrading along with phosphorus treatment. Although that data is plotted as reported here, it was not used for the data base and the computer analysis. An average of the other twenty-five reported values was used since the total operating cost increase was not entirely because of phosphorus treatment. At Thiensville, the value of approximately $5,800 was assumed to be inflated at an estimated hourly rate of $8.

Where operating labor costs were not reported, labor costs were assumed at approximately $1,460/yr. This assumption was used mostly at plants of less than 5 MGD size. Large plants and some smaller plants reported operating cost as one value with no breakdown for labor, electrical power, etc.

Included in the operating cost was an estimate of electrical power cost. Actual values were used when reported. When no estimate was given, the electrical power cost due to phosphorus removal was calculated as a function of the storage capacity provided and whether the storage tank was provided with electrical heat tapes or was installed inside of new or existing buildings--to prevent crystallization of chemicals at low temperatures. Electrical costs for heating elements were computed for full operation for approximately nine months of the year. The following values were used:

Chemical Feed Pump: 1/3 hp. @ approximately 2¢/kw -- $ 44/yr.

Heating 4,000 gallon storage @ 2,530 watts -- $332/yr.

Heating 10,000 gallon storage @ 5,200 watts -- $683/yr.

These values are based on information on electrical heat tapes provided by several of the consulting engineers. These values also seem to coincide with values reported by Powell and Crawford (5)--$30/yr. for pump only; and by Kumar and Clesceri (4)--$694/yr. for 1 MGD and 6,000 gallon storage; and $2,044/yr. for 10 MGD and 32,000 gallon storage.

Maintenance costs were generally difficult to determine. Larger plants did keep an accounting of expected maintenance costs, but smaller plants, especially of less than 1 MGD capacity, had no estimates. When no information was available, an estimate of 10% of the annual capital and operating cost (excluding chemical cost) was included in the operating costs. Fait (1) used this same procedure for estimating maintenance costs.

Some information on costs of sludge handling and disposal attributed to phosphorus removal is available in the literature (4,5). As indicated on page 12, no conclusions can be drawn from qualitative estimates of whether sludge volumes or masses increased or decreased. Any estimates or assumptions of quantity or of costs of increased sludge at any of the plants involved here would be premature and possibly very inaccurate. Emphasis should again be placed on individual plants and individual treatment conditions. Sludge handling and disposal systems are of different types and are operated differently.

In a few cases, sludge costs are reported and should be noted--c.f. individual plant information sheets in Appendix A. Sludge handling and disposal costs are of importance in phosphorus treatment, but no attempt at trying to assign quantitative values is made in this report. Where sludge costs are reported, they are not included in the data base and computer analysis. However, a qualitative understanding of the specific sludge handling system and possible overload conditions at each plant is essential in determining maximum chemical dosages and associated removal possibilities.

Cost information from the literature is used only as an illustration of how the actual reported values compare. Only actual reported values are used for the derivation of the alternatives presented in subsequent sections of this report.

CHAPTER VI

DEVELOPMENT OF TREATMENT ALTERNATIVES

The dynamic programming model presupposes the knowledge of various levels of treatment or phosphorus removal alternatives and the corresponding cost of each alternative at each plant. Essentially, this would be the definition of a phosphorus removal cost curve. In the dynamic programming terminology, the phosphorus removal alternatives are the decisions at each plant, and the associated costs represent returns at each plant or stage. The problem then becomes one of attaining or generating a treatment-cost curve at each plant.

In many cases only one alternative of removal and a corresponding cost is available at a given plant. Another known value may be the removal at zero cost. Thus, with one or two proven alternatives on the treatment cost curve, a number of additional feasible alternatives must be extrapolated or estimated to provide for a meaningful use of the dynamic programming algorithm and a workable, believeable interpretation of the results.

Fortunately, some plants have operated at different levels of treatment for a sufficient period of time to define at least another point on the treatment-cost curve. The primary variable in achieving different levels of treatment seems to be the required chemical dosage.

Chemical treatment for phosphorus removal is then not an off-on or zero-one system. At the 12.5 MGD Sandusky, Ohio, plant, McGinness and Harriger (8) report that 40-50 mg/l chemical dose is required for 80% removal, but a "95% P reduction is possible by simple adjustment of the alum feed." An operator at a plant might increase his chemical dosage on a washday Monday because he knows the phosphorus load will be higher. To achieve a monthly average of 85% removal or 1 mg/l phosphorus in the effluent, the operator will either adjust his chemical dose according to the expected or known phosphorus load, or will maintain some steady dosage, hoping to meet the average treatment required. Likewise, if the operator notes that he is steadily achieving better than the required removal, he would decrease the chemical dose to keep from dosing more of the expensive chemicals than he would need.

Thus, simply by adjusting the chemical dose, a range of phosphorus removal levels can be attained. The addition of a polymer may also effect improved removals, providing an effective polymer can be found.

Given that changes in the chemical dose will produce different levels of removal, attention should focus on the general functional relationship between these variables. Then, knowing the chemical dose, the chemical cost can be calculated directly. The result is the desired treatment-cost relationship, assuming that the cost of chemicals is the major variable cost in phosphorus treatment and that increases in other operating costs are relatively negligible.

The relationship between treatment cost and phosphorus removal levels used in this study is a logarithmic or exponential relation. This relationship seems to be substantiated by Long et al. (17), who indicated that effluent phosphorus levels increased rapidly with decreasing Al:P ratios below 2:1. Kumar & Clesceri (4) also note that the chemical dose required increases exponentially with decreasing effluent phosphorus concentrations. In Figure 4, taken from the EPA Process Manual for Phosphorus Removal (3), the chemical dose is reported as metal to soluble phosphorus on a weight basis. If the ratio of soluble phosphorus to total phosphorus for a given wastewater remains fairly constant, the exponential relationship between chemical dose and effluent phosphorus would again be supported. Total phosphorus levels only are reported in this study and chemical dose ratios are metal to influent total P. The soluble phosphorus to total phosphorus influent concentration ratio seemed to remain fairly constant at Milwaukee over a long period (14) and in pilot plant tests reported by Jones (7).

Two approaches were considered in attempting to supplement the reported or known treatment levels in the basin. One approach would be to use only reported values on chemical dosage vs. phosphorus removal percentage and plot the collective values from all plants on semi-log paper. After fitting a line through the data, appropriate dosages and removals could be read directly from the graph and applied to individual plant phosphorus levels for a cost determination. This kind of an approach to the problem would not include any consideration of individual plant processes, treatment conditions, and important local problems in treatment. This approach could also possibly lead to some conclusion about changing from one chemical to another, which would under any circumstances be a questionable practice without any basis on pilot plant or jar tests.

The second approach, which was used in supplementing treatment alternatives for this report, is to derive individual relationships for each of the plants involved. This approach uses the semi-log relation as a general guide for relating chemical dosage to phosphorus removal. Specific treatment conditions, however, such as hydraulic overload, sludge problems, or industrial waste problems are taken into full consideration, especially in determining maximum treatment alternatives. Construction, or plans for expansions or new plants, are also an important practical consideration in developing appropriate levels of treatment at old plants which will be abandoned or extensively modified in the near future.

Because extensive tests have already been conducted to determine which chemical and which system of chemical addition (PRIMARY, CHEMICAL-BIOLOGICAL, or POST-BIOLOGICAL) should be used at each plant, no changes in the particular method or chemical are proposed in the potential alternative removal choices postulated. The nature of the initial order of 85% removal at all plants provides the basis for the assumption that each plant has chosen the most economical and effective treatment and chemical under present plant conditions. In some cases, where polymer effectiveness had been demonstrated or is intended, an alternative for polymer addition may be included.

The critical assumption needed is to determine a maximum phosphorus removal attainable at a given plant where no special treatment problems seem to be limiting. Where treatment problems do not seem to control effective removals, and chemical dosages do not exceed approximately 2:1 for alum, and about 3 or 4:1 for iron addition, minimum effluent phosphorus concentrations of 0.3-0.5 mg/l are used here. At dosages greater than levels noted above, overdosing may negatively affect overall plant processes and treatment efficiences. The minimum concentration of 0.3-0.5 mg/l for chemical addition at existing plants is based partly on high performance levels being attained at several of the plants involved in this study. Reporting on phosphorus treatment in Sweden, Melkersson (6) noted minimum effluent total phosphorus concentrations at full scale plants with treatment methods corresponding to the PRIMARY, CHEMICAL-BIOLOGICAL, POST-BIOLOGICAL used here. He reported a range of 0.1 to 0.8 mg/l as P in the effluent. McGinness and Harriger (8) reported the possibility of getting

0.2 mg/l as P in the effluent with alum addition at the aeration tanks. Ericsson (12) also reported on effluent concentrations with primary precipitation at a full-scale plant. He noted effluent total phosphorus concentrations of 0.25-0.5 mg/l as P. Minton and Carlson (10) noted phosphorus residuals of 0.1-0.5 mg/l as P, but also indicated that the inability to remove all the insoluble phosphorus may be a controlling factor. Then the low phosphorus residuals could not be attained without filtration or possibly with effective polymer use.

Several examples on how cost curves were developed are included in Appendix C along with treatment-cost curves at each of the plants involved. The cost alternatives at several plants are modified for one of the computer runs. The modifications generally involve new plants or plant expansions with estimated or assumed levels of treatment.

CHAPTER VII

THE LEAST-COST DYNAMIC PROGRAMMING MODEL

A. An Efficiency Solution

In implementing the federal policy objective of an 80% reduction of the total phosphorus load from all point sources in the watershed, the Wisconsin DNR followed the traditional concepts of fairness and equity. This is true of both the initial 85 percent removal requirement and of the more recent 1 mg/1 effluent objective. The question of economic efficiency was investigated by Joeres (2) in 1970. Joeres (2) used a dynamic programming algorithm to determine a cost efficient policy. As a data base, he used treatment-cost alternatives developed by Fait (1) for each of the 43 municipalities originally expected to be affected by the order. A brief discussion of the model will be included here. The paper by Joeres (2) contains a more detailed description and is the basis for this discussion.

A discussion of the institutional problems associated with the implementation of this policy and the effects on the concept of equity are not considered within the scope of this study.

B. Description of the Model

The problem in attaining efficiency is to minimize the collective total costs for all of the plants ordered to remove phosphorus, subject to an overall removal decision. The model is:

$$\text{Minimize } T = \sum_{n=1}^{53} r_n(l_n)$$

$$\text{for } l_1, l_2, \ldots l_n$$

$$\text{Subject to: } \sum_{n=1}^{53} l_n \geq L$$

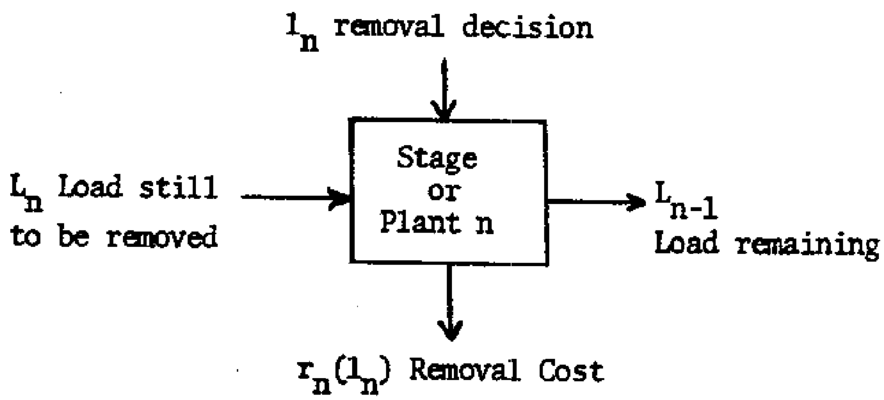
where T = the total removal cost

l_n = the removal decision at plant n

$r_n(l_n)$ = the cost of removing l_n pounds of phosphorus at plant n

L = the total phosphorus load to be removed by the 53 plants to meet the requirement

Each plant is identified as a decision stage, and the situation at each stage can be illustrated as shown below.



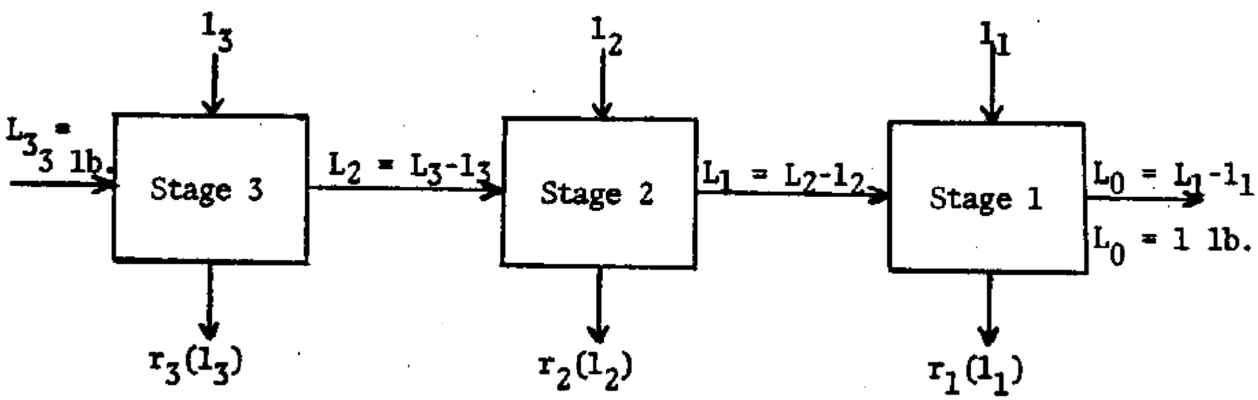
The example which follows, though extremely simple, illustrates the process by which the model minimizes the cost subject to the desired reduction in the phosphorus load.

C. Example of the Model

Consider three wastewater treatment plants, each having a phosphorus load of 1 lb. for a total load to the receiving stream of 3 lbs. The objective will be to minimize the total cost to the plants subject to a removal decision. In this case the removal decision will be to remove 67% of the total load to the receiving stream or 2 lbs. In order to solve the problem a treatment-cost function must be determined at each of the three plants. Individual removal alternatives will be restricted to discrete choices as they are in the full-scale solution. For simplicity, the alternatives here will be to remove either 0 or 1 lb. at each plant. The alternatives at each plant are as follows:

	Removal Decision l_n	Cost $r_n(l_n)$
Plant 1 (n = 1)	0	0
	1	20
Plant 2 (n = 2)	0	0
	1	10
Plant 3 (n = 3)	0	0
	1	30

The system can be depicted as shown below.



The process begins at stage 1, where the maximum possible load under the removal decision is 2 lbs. The minimum possible load at stage 1 is 1 lb. The alternative choices at stage 1 are listed as follows:

Stage 1

L_1	- l_1	= L_0	$r_1(l_1)$	= $f_1(L_1)$
1	0	1	0	0*
2	1	1	20	20*

where $f_1(L_1)$ is the optimum stage 1 return as a function of the input L_1 to stage 1. Then, at stage 2, the maximum possible load is 3 lbs. and the minimum is 2 lbs., again based on the overall removal decision. The asterik designates the optimal policy at this stage for a given load.

Stage 2

L_2	- l_2	= L_1	$r_2(l_2)$	+ $f_1(L_1)$	= $f_2(L_2)$
2	0	2	0	20	20
2	1	1	10	0	10*
3	1	2	10	20	30*

Thus, if we arrive at stage 2 and the total load remaining is L_2 = 2 lbs., we would choose to remove the 1 lb. at stage 2 since $f_2(L_2)$--the return at this stage for $L_2 = 2$--is minimized for $l_2 = 1$.

Stage 3

L_3	- l_3	= L_2	$r_3(l_3)$	+ $f_2(L_2)$	= $f_3(L_3)$
3	0	3	0	30	30*
3	1	2	30	10	40

Since we have arrived at the final stage, the minimum value of $f_3(L_3)$ is the minimum policy cost for this decision. Then if we follow back thru the tables for each stage, we can determine the optimal policy for this removal requirement. In this particular case, plant 3 would not treat, with plants 1 and 2 removing one pound each.

The solution is obvious and many simplifying assumptions have been made so that the computational advantage of the technique may not be immediately apparent, but when 53 plants with approximately 5 removal possibilities at each plant are considered, 5^{53} evaluations of possible policies would be required under a complete enumeration approach. The computational effort is substantially reduced with the use of the dynamic programming algorithm. A copy of the Fortran program of the model is found in Appendix E. For the 53 plants studied, each computer run cost approximately $8.

CHAPTER VIII

PROGRAM RESULTS

A. General Framework of the Computer Analysis

The efficiency solution was originally intended as a planning tool. Based on an examination of costs and methods of phosphorus removal, Fait (1) provided the data base necessary for a predictive or planning analysis of the requirements which should be imposed on the 44 cities under orders to remove phosphorus in December, 1969 (2).

How then does the efficiency solution serve a useful purpose at this time? Although a number of facilities are of a temporary nature, most plants have had chemical feed and storage equipment installed. Then, using the program to determine who should treat and at what level would seem to be an "after-the-fact" analysis. However, the major cost associated with phosphorus treatment is not the initial capital investment. It is, for all 53 individual cases, the chemical or operating cost which is the major factor. The chemical cost--and the related chemical dose--is the key variable in phosphorus treatment. The flexibility of the chemical treatment system in achieving a wide range of removals is discussed in the study on page 23.

It does not serve any useful purpose at this time to determine whether a plant should initiate chemical treatment. A plant would not however, be incurring zero cost with no chemical addition. Essentially, the cost without chemical addition is now the discounted capital investment. If this cost is introduced as a part of the alternatives at each plant, the data base will be a realistic one and will provide results which can be discussed and compared in a practical sense. The program has been modified very slightly to allow for reading in these capital investment costs. This will prevent the fallacy of discussing results which indicate that a plant which has already made considerable investments, should not be treating at all in the efficiency solution.

The efficiency solution may have some value as a means of deciding on individual treatment levels, at least on a temporary basis. The system which is now in effect allows for different levels of treatment at different plants because of specific treatment problems and planned expansions. This system will not achieve significant total removals without considerable construction and resultant time delays and expense. The efficiency solution may be a guide to the problem of obtaining high performance under temporary and changing conditions. The assumption is that all plants have optimized their individual operations with respect to which chemical and which treatment to apply under present plant conditions. No changes in the chemicals or treatment methods are introduced with the alternatives.

The efficiency solution is based on choosing removal alternatives at each plant in terms of cost per pound of phosphorus removed. This solution has the characteristic of regulating phosphorus in terms of lbs/day, while the percentage and effluent standard removal requirements have been criticized for failing to regulate the actual load of phosphorus in pounds (3).

The program exhibits the flexibility of accounting for changes in the treatment conditions at any of the plants. Several computer runs were made to illustrate the effect of new plants entering at higher phosphorus removal levels. The first run, designated as DPI is under conditions which exist to date. Adjustments are made to include Milwaukee South Shore in DP2 and to include new plants at Green Bay, Oshkosh, Shawano, and Racine with DP3.

Also included in DP3 are adjustments in the alternatives at Ripon and Two Rivers to allow for resolution of current treatment problems.

B. Computer Runs

1. Condition I - DP1

The conditions of this first run correspond to treatment levels currently attainable at the 53 treatment plants in the basin. These treatment alternatives do not account for any major process changes at any of the plants and are restricted only with regard to specific treatment problems or possible overdosing of chemicals. Under these present conditions, the actual overall treatment level now attained is at 73% removal--based on the influent phosphorus levels used in this study. This is substantially below the 85% requirement. Figure 5 illustrates the cost curves for both the uniform percentage requirement and the efficiency solution of DP1.

The number of plants without an alternative capable of meeting the specific requirements is noted. This is a very real and practical situation which the Wisconsin DNR has also recognized in its current policy of tempering its treatment requirement because of interim facilities; serious particular treatment problems; or planned expansions. Plants which are assigned maximum alternatives less than the requirements are listed in Tables 12 and 13. Specific revisions used in later computer runs are also noted. Treatment costs at these plants are included in the uniform treatment curve. These plants are assumed to operate at the maximum alternative assigned. The cost at the maximum alternative is used when the requirement cannot be met.

In each of the computer runs used here the efficiency solution curve and the uniform treatment curve tend to converge. This occurs because the dynamic programming solution approaches the maximum possible removal allowed by the particular data base, and the uniform treatment requirement is limited at the high removal levels by the number of plants unable to meet particular percentage requirements. Thus, the uniform solution cost curve does not exhibit the exponential treatment-cost relationship which might have been expected.

Table 14 is the output from the program run under Condition I. The table illustrates the dynamics of compliance required at each individual plant under varying overall removal requirements. Figures 6 and 7 illustrate the number of plants required to treat at various levels under the efficiency solution. Comparisons are made on a percentage removal and effluent standard basis.

2. Condition II - DP2

The only change from the present treatment situation used for DP1 is the inclusion of the Milwaukee Southshore plant. This plant is a large plant of approximately 70 MGD average flow with full-scale phosphorus treatment facilities due on line by January, 1975. The inclusion of this plant at high removal levels increases the maximum possible total basin removal to 85%.

Under the 1 mg/l requirement, a significant increase in the overall removal can be realized if the Milwaukee plants do not cut back treatment from levels less than 1 mg/l. With the Jones Island plant remaining at current levels, and the 1 mg/l requirement in effect everywhere else, 85% overall removal could be achieved. This represents a 2% increase from the 83% level with all plants reaching 1 mg/l P effluent concentrations. If the Southshore plant can also maintain effluent phosphorus levels significantly less than 1 mg/l, an 87% overall phosphorus reduction is possible, with all remaining plants averaging 1 mg/l effluent P. Thus, the large plants in the basin are of key importance in the reduction of the total phosphorus load to Lake Michigan, regardless of which form the implementation order takes.

Figure 8 illustrates the cost curves for the uniform percentage requirement and the efficiency solution under Condition II - DP2. Again, the number of plants unable to meet each requirement is specifically indicated. Table 15 is the list of plants and the dynamics of compliance required for the efficiency solution under Condition II. Figures 9 and 10 illustrate the number of plants required to treat at various percentage and effluent levels.

3. Condition III - DP3

This computer run includes significant changes from Condition II in the treatment-cost alternatives available at six plants. Condition III accounts for new plants or expansions at Green Bay, Oshkosh, Racine, and Shawano. All four plants will possibly be fully operational sometime in 1975 or early 1976. Other changes are made in the alternatives at Two Rivers and Ripon. Two Rivers is reportedly dosing alum at Al:P $\cong$ 2:1 and achieving low and variable removal efficiences. Ripon is reportedly dosing pickle liquor at Fe:P $\geq$ 4:1 with only approximately 60% removal. It is assumed for Condition III that treatment problems can be resolved and that higher dosages can result in higher removals. The alternatives used in all six cases are included in the treatment-cost curves in Appendix C. Figure 11 is the comparison of cost curves for the uniform percentage requirement and the efficiency solution under condition III - DP3. The performance at the 1 mg/l effluent standard is also indicated. Again the number of plants unable to meet each requirement is specifically indicated. The maximum possible overall phosphorus removal under Condition III - DP3 is approximately 89%. Table 16 is the computer output for this condition. The table indicates the dynamics of compliance required at each plant for the efficiency solution. Figures 12 and 13 show the number of plants required to treat at various removal percentages and effluent levels.

C. Cost Savings

Figure 14 shows the cost savings of the efficiency solutions over the uniform treatment requirements. The cost savings over the 1 mg/l effluent standard are as follows:

	DP2	DP3
Overall Removal Percentage	83	83
Annual Cost Savings ($\$10^6$)	0.15	0.62
Number of plants unable to meet the 1 mg/l requirement	17	13

The cost savings noted here are likely to be somewhat conservative because of the number of plants not provided with an alternative to meet the 1 mg/l objective under the conditions discussed in this chapter. The cost of the maximum removal alternative at each of these plants is included.

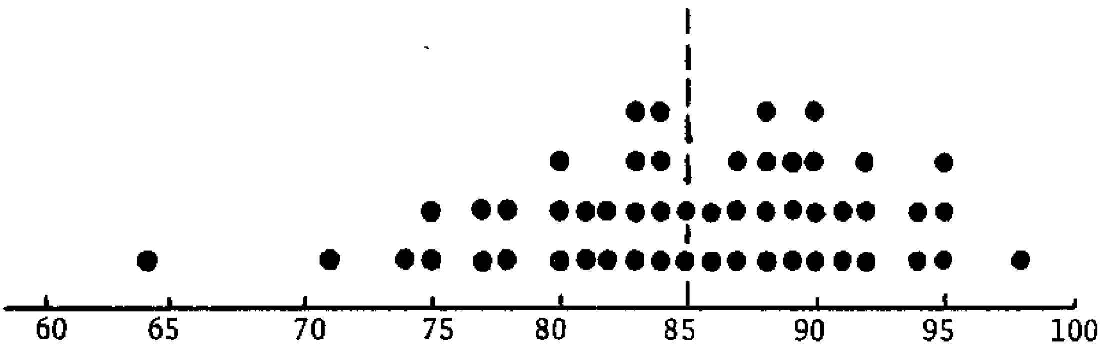
The important cost which does not show up in the cost savings calculations here is the cost of implementing the various policies. Implementation costs and problems are not considered in the scope of this study, but must be thoroughly evaluated to determine the comparative advantages or disadvantages of each policy. If the net implementation costs are less than the cost savings illustrated in this study, the dynamic programming efficiency solution deserves careful consideration.

This study and the results of the efficiency solution are restricted to the objective of a reduction in the total phosphorus load to Lake Michigan and its tributaries. Any additional local water quality objectives can and must be evaluated separately from the overall Lake Michigan Basin objective.

FIGURES

FIGURE 1

Distribution of Affected Plants by
Phosphorus Removal Percentages at Each Plant
Corresponding to the 1 mg/l Effluent Standard



% of Total Influent Phosphorus Required
To Be Removed Under The 1 mg/l Effluent Standard

FIGURE 2

Capital Investment
on Phosphorus Removal Facilities
Capital Cost vs. Plant Size

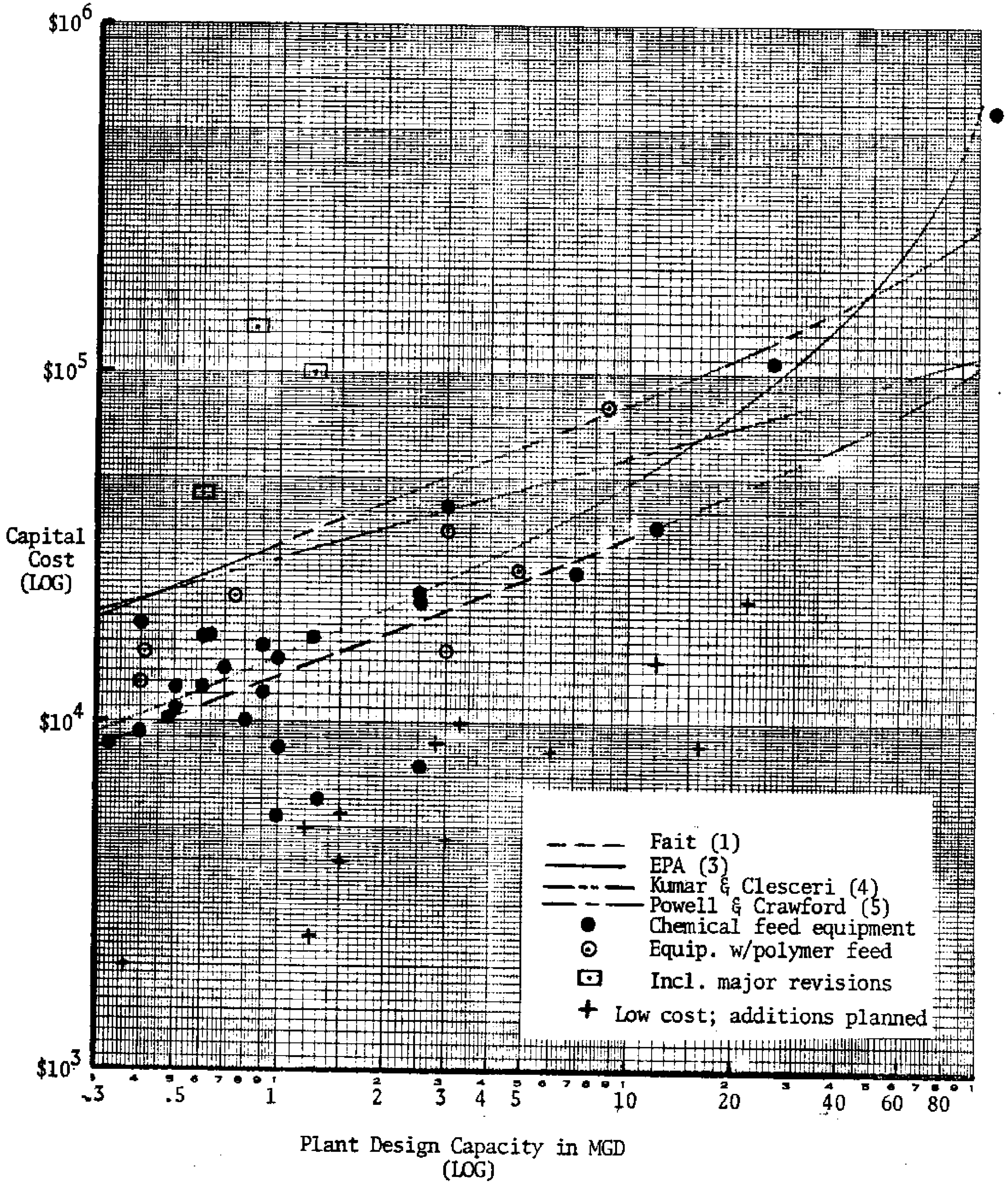
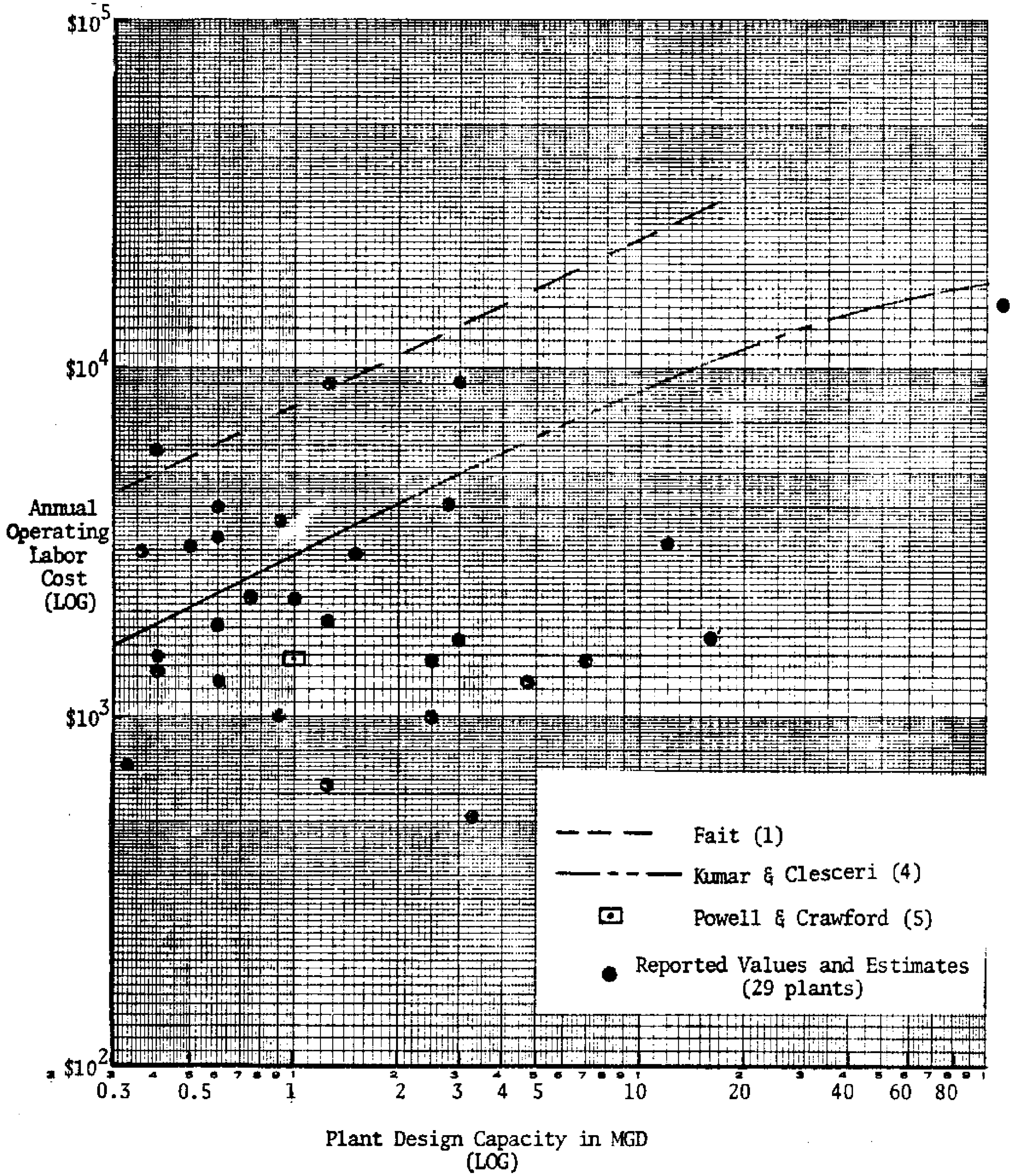


FIGURE 3

Annual Operating Labor Cost for Phosphorus Treatment
Annual Cost vs. Plant Size



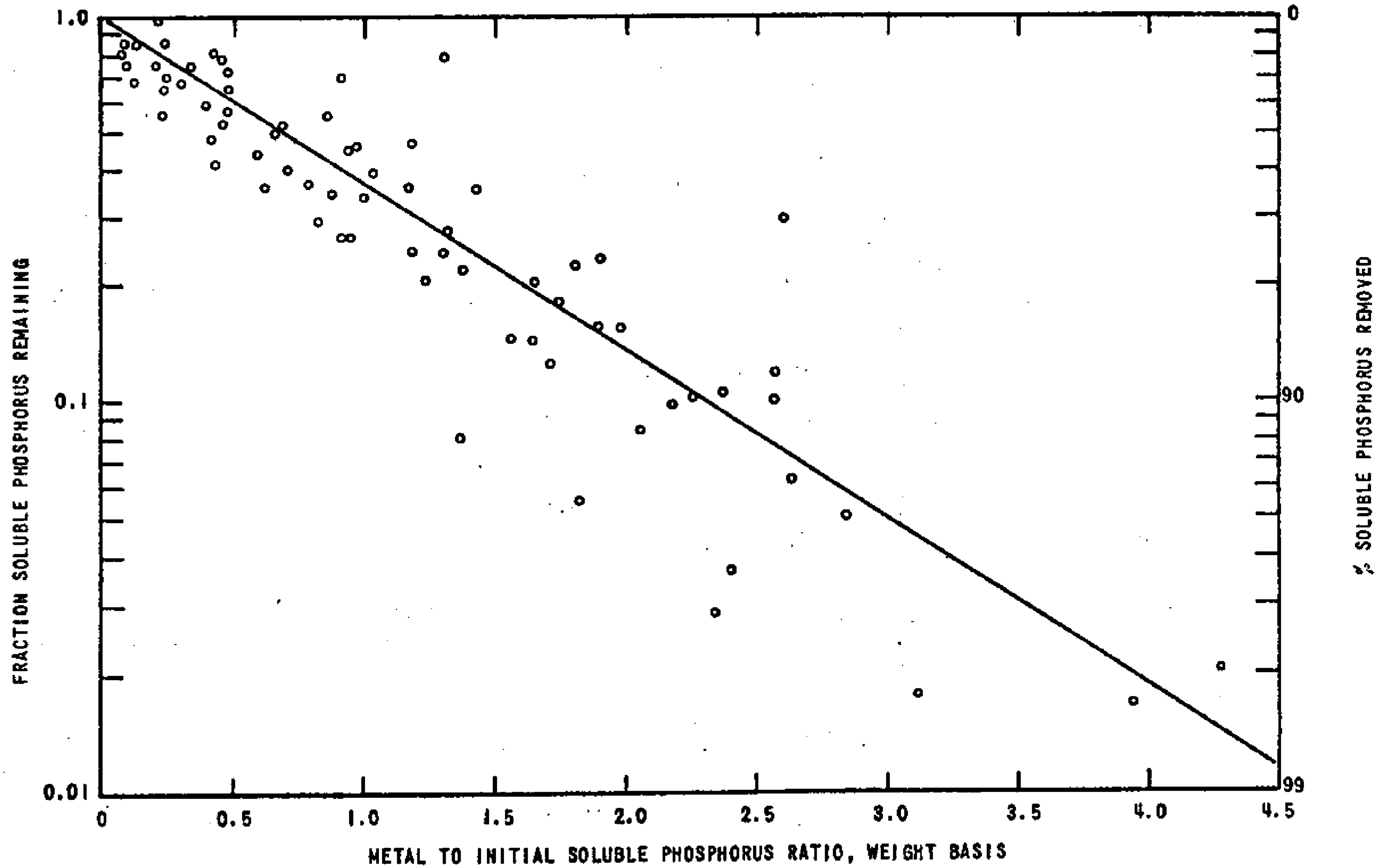


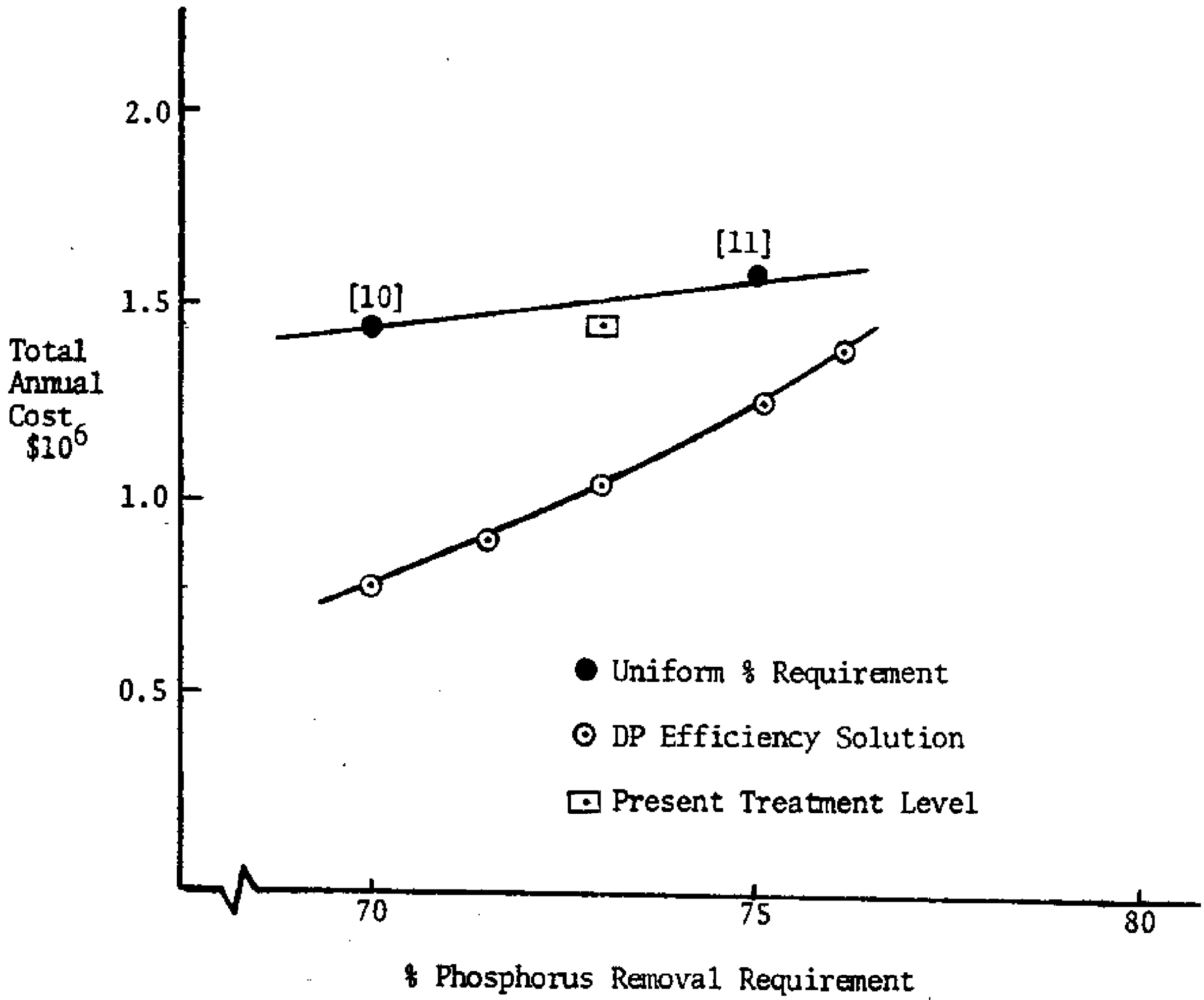
FIGURE 4 SOLUBLE PHOSPHORUS REMOVAL BY FERRIC CHLORIDE ADDITION

[From EPA Process Manual for Phosphorus Removal (3)]

Figure 5

Total Annual Cost vs. Phosphorus Removal Requirement
Condition I - DPI

[Bracketed numbers indicate the number of plants not provided with an alternative to meet the specific requirement under the conditions of this run. Costs for the maximum removal alternative at these plants are included.]



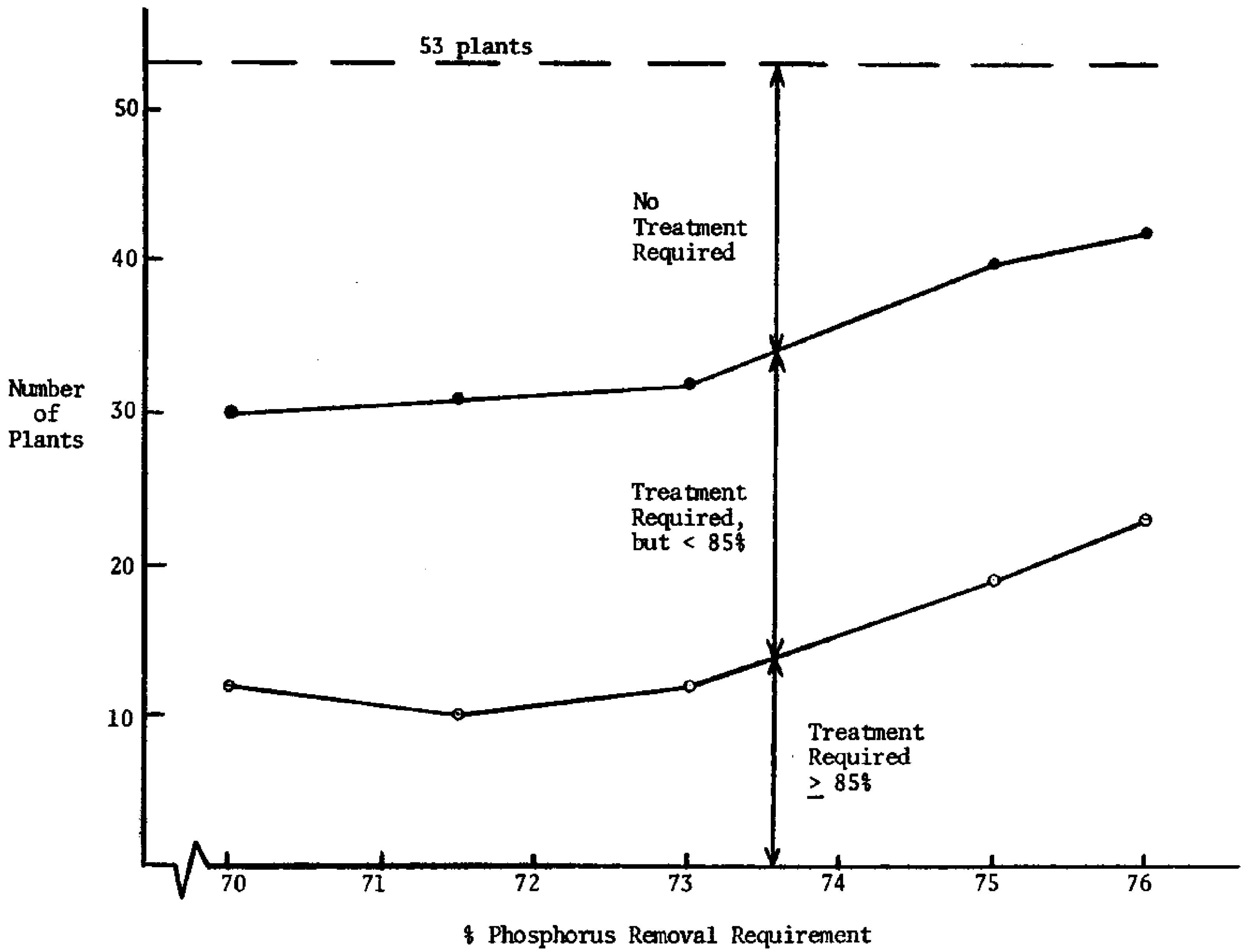


Figure 6 Number of plants required to treat under Condition I - DPI [Removal percentage basis]

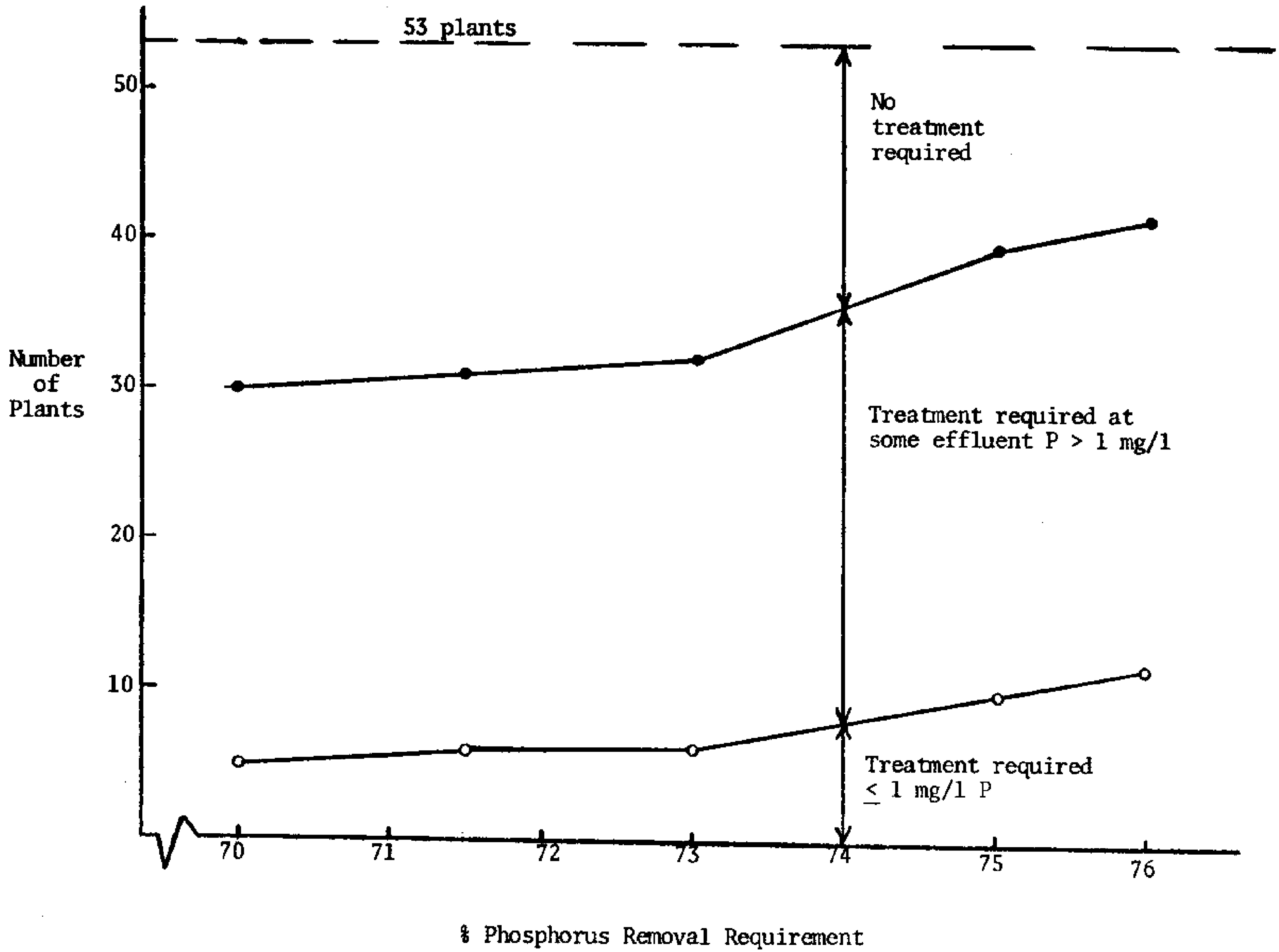
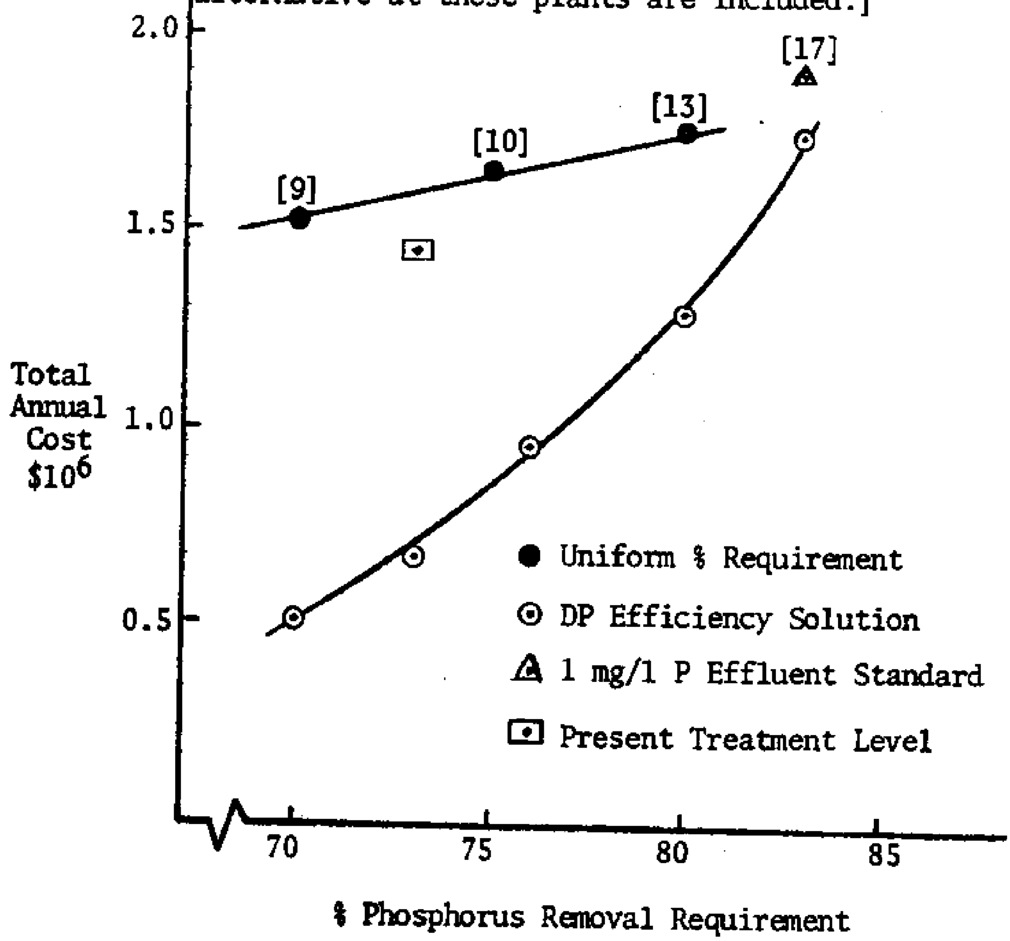


FIGURE 7 Number of plants required to treat under condition I - DPI [Effluent standard basis]

Figure 8

Total Annual Cost vs. Phosphorus Removal Requirement
Condition II - DP2

[Bracketed numbers indicate the number of plants not provided with an alternative to meet the specific requirement under the conditions of this run. Costs for the maximum removal alternative at these plants are included.]



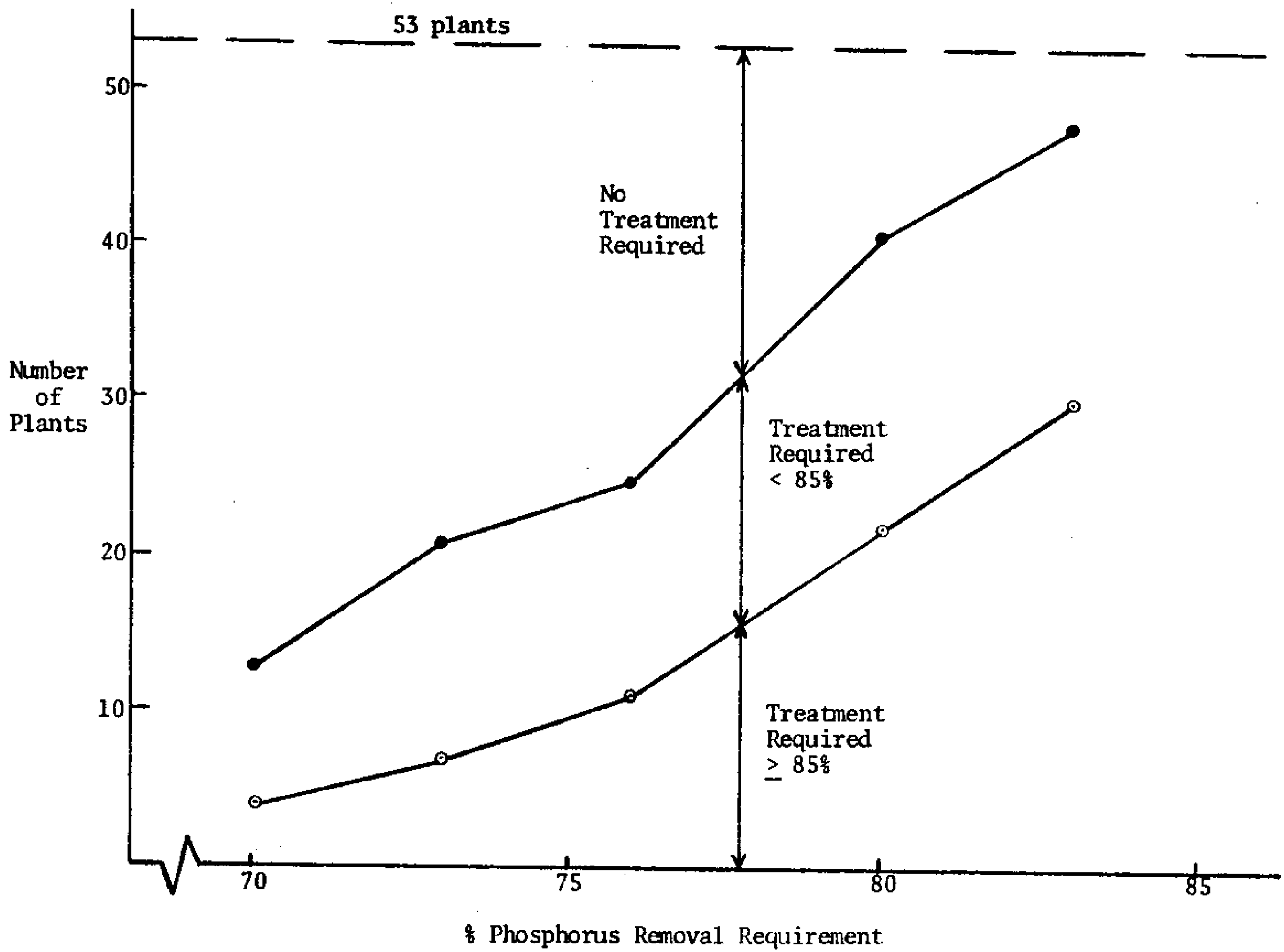


Figure 9 Number of plants required to treat under Condition II - DP2 [Removal Percentage Basis]

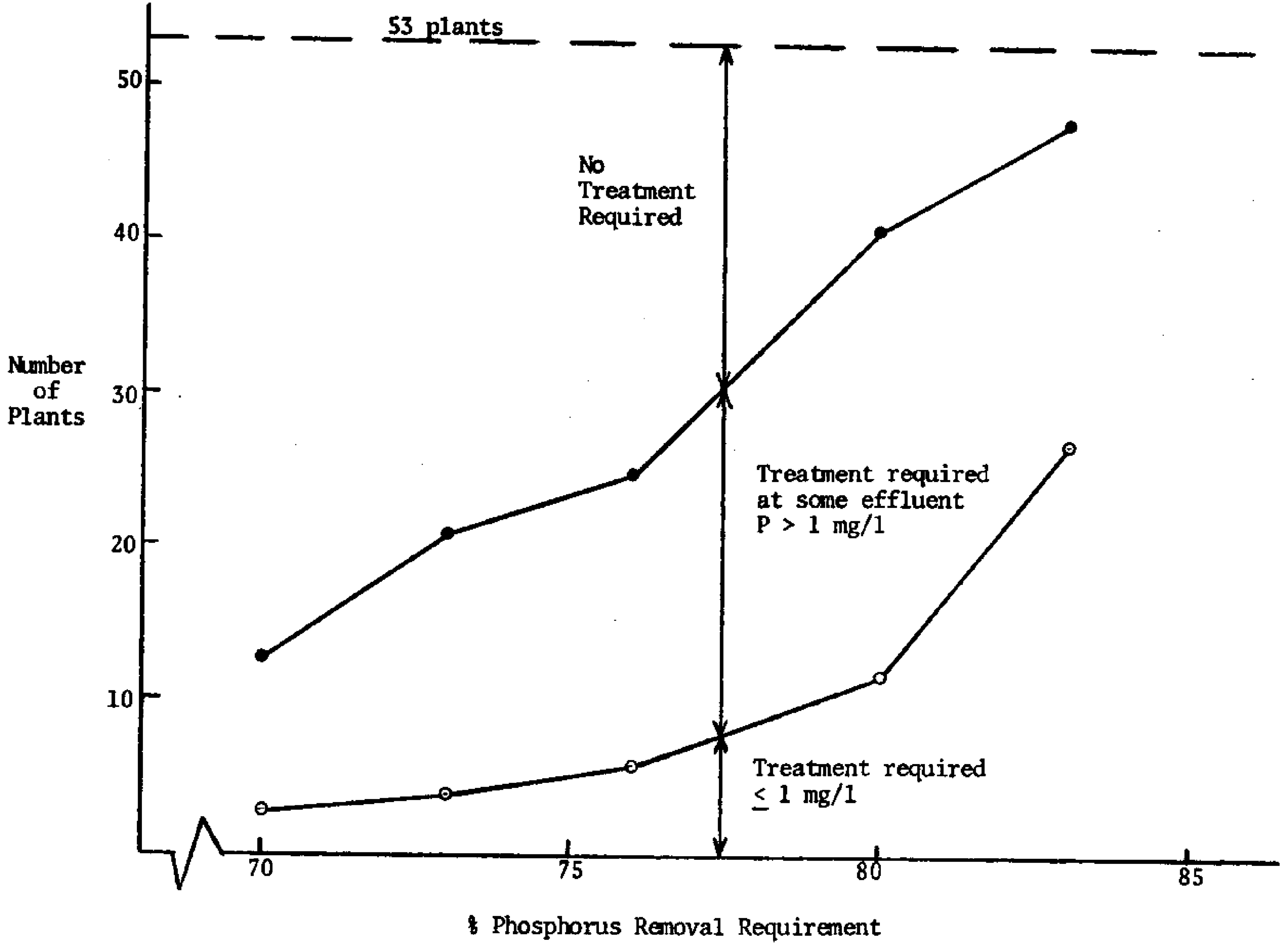
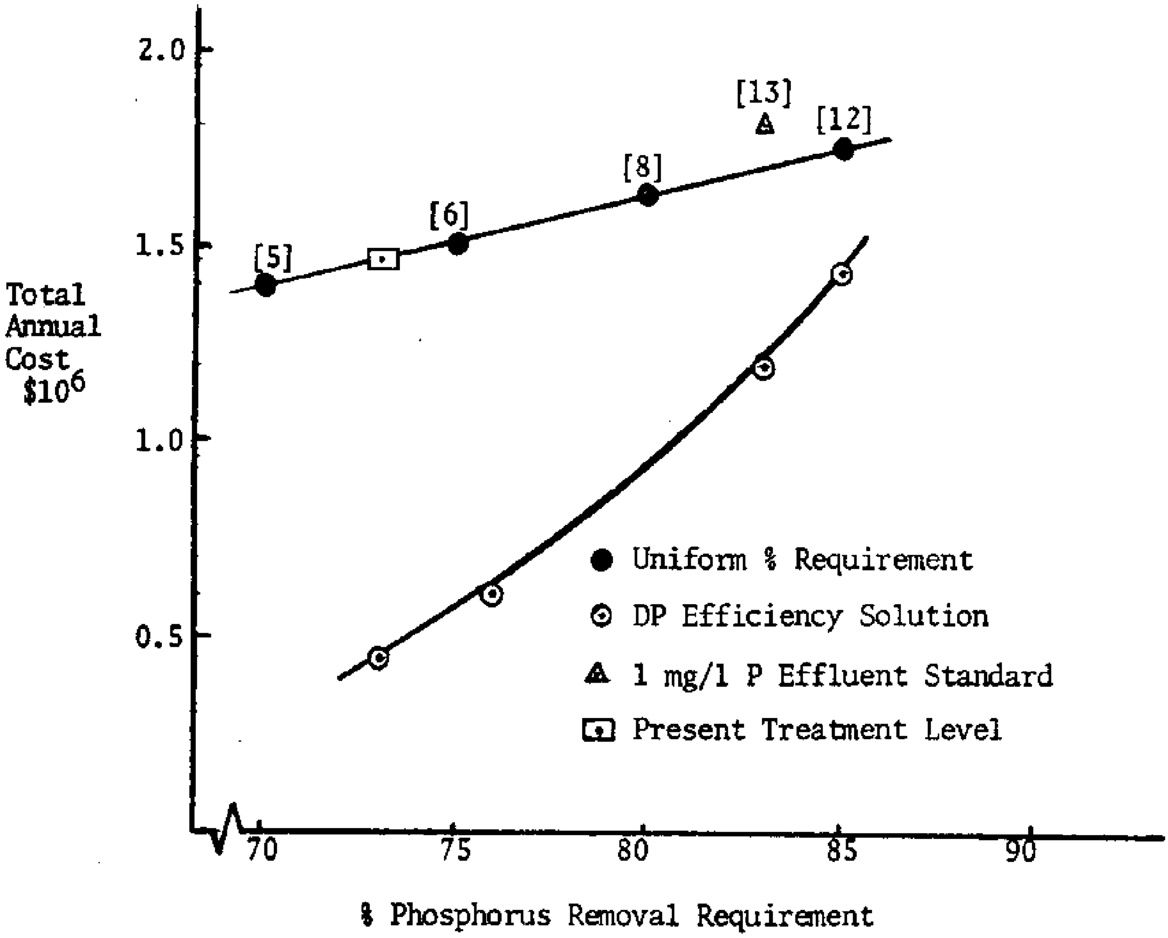


Figure 10 Number of plants required to treat under Condition II - DP2 [Effluent standard basis]

Figure 11

Total Annual Cost vs. Phosphorus Removal Requirement
Condition III - DP3

[Bracketed numbers indicate the number of plants not provided with an alternative to meet the specific requirement under the conditions of this run. Costs for the maximum removal alternative at these plants are included.]



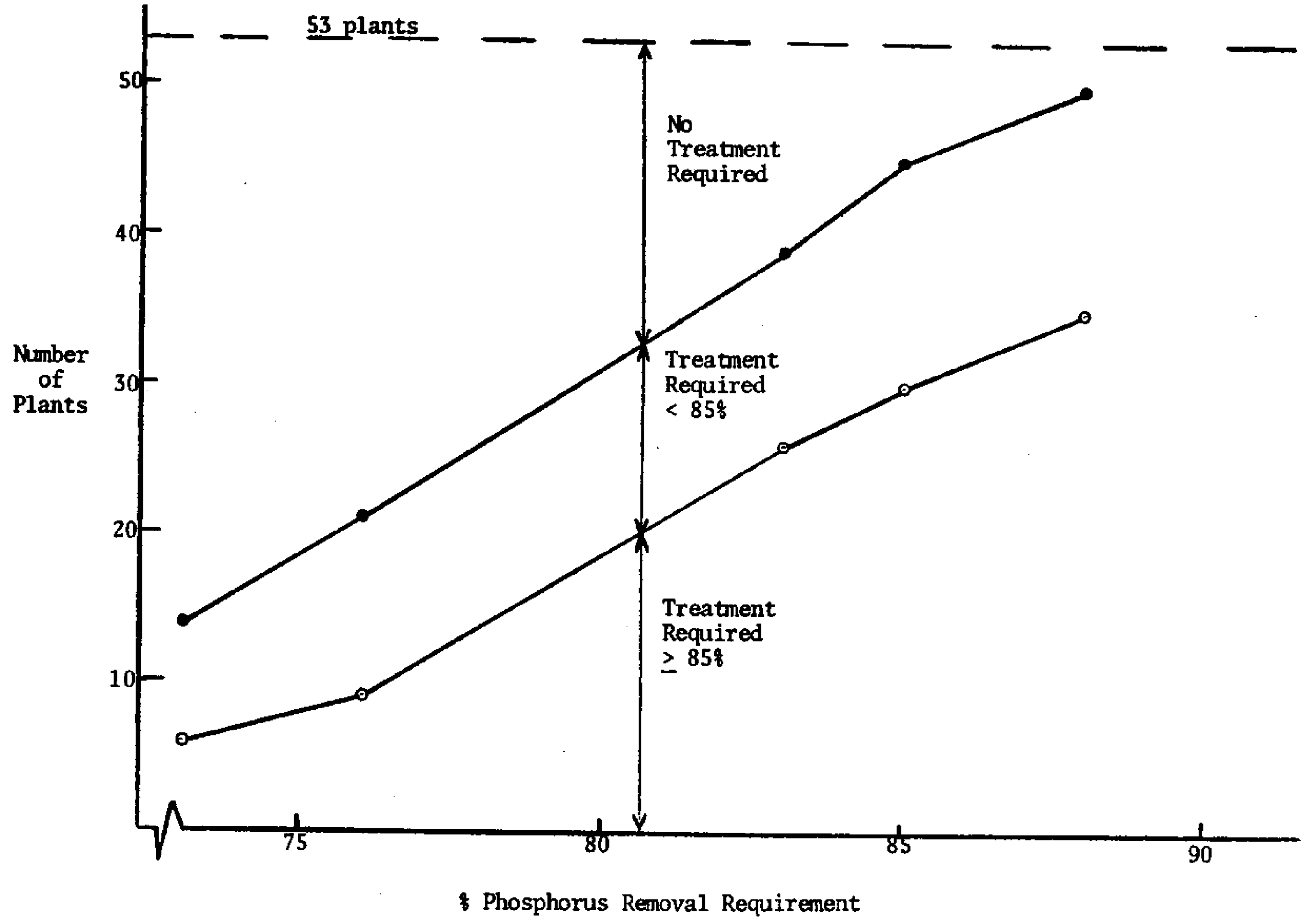


Figure 12 Number of plants required to treat under Condition III - DP3 [Removal percentage basis]

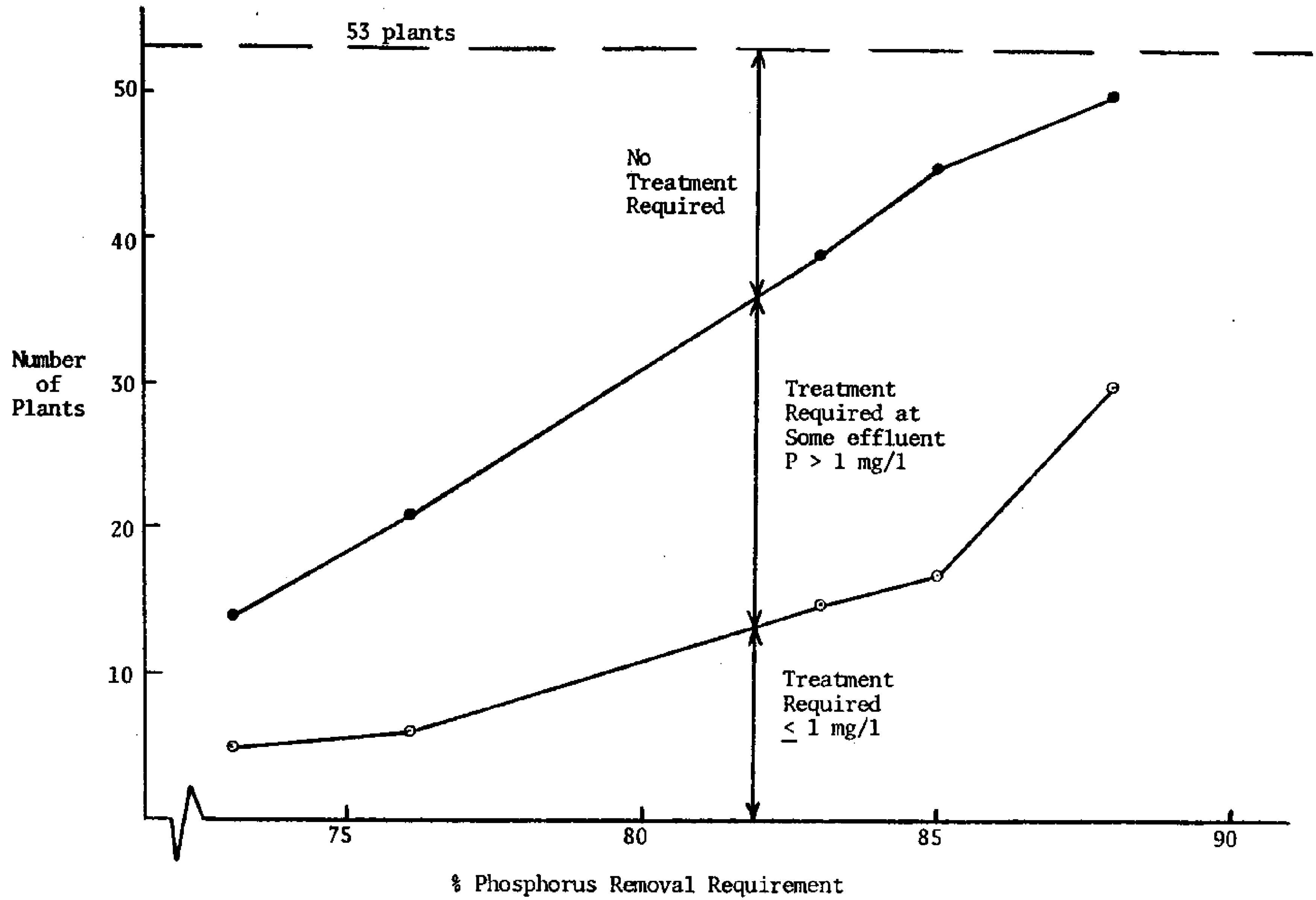
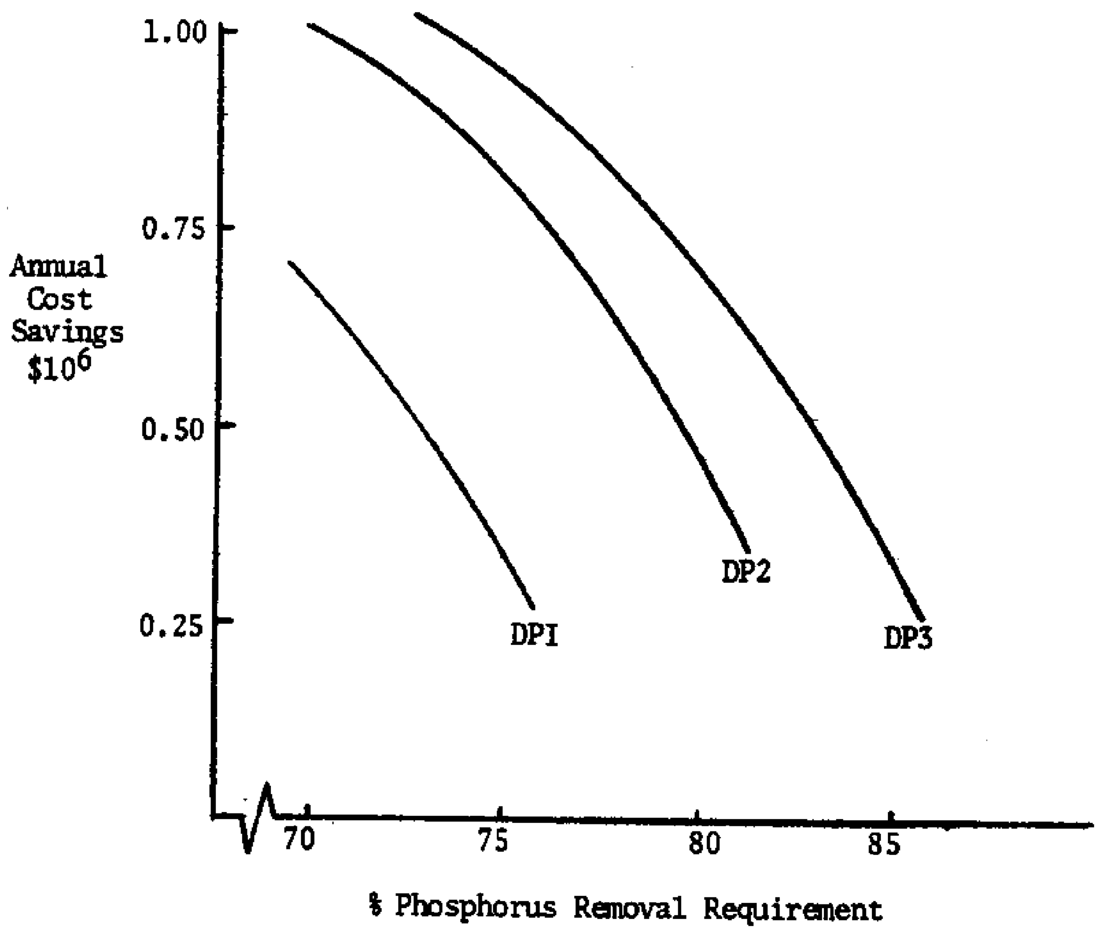


Figure 13 Number of plants required to treat under Condition III - DP3 [Effluent standard basis]

Figure 14

Annual Cost Savings of Efficiency Solution Over Uniform % Requirement



TABLES

Table 1

DATE OF COMPLIANCE

Date of Compliance	Total Number of Plants With Phosphorus Treatment*
January 1973 (or before)	16
February	22
March	37
April	41
May 1973	44

July 1974	50

* Of the 53 plants involved in this study, the following are not included in the table above:

Germantown--Initiating treatment in August or September 1974.

Holland S.D.--0.1 MGD plant with no specific treatment for phosphorus removal to date.

Neenah-Menasha--Has a very low influent P concentration and an effluent P concetration near 1 mg/l without specific treatment for phosphorus removal.

Table 2

Reductions in the Total Phosphorus Load Tributary to Lake Michigan*

	Total Phosphorus Removal	
	lb/day P	% Removal
a. No specific treatment for phosphorus removal	8,345	40
b. Same as (a) above except with Milwaukee-Jones Island at current treatment level	11,260	54
c. Present treatment levels (August, 1974)	15,323	73
d. Removal required at 1 mg/l P effluent standard	17,348	83
e. Removal required at 85% uniform standard	17,721	85

*Based on calculated total influent phosphorus load at 53 plants--20,848 lb/day P.

Table 3

PHOSPHORUS REMOVAL EFFICIENCY

% Influent Total P Removed	Number of Plants
≥ 85	17
80-85	7
70-80	5
50-70	16
< 50	5

Table 4

EFFLUENT TOTAL PHOSPHORUS CONCENTRATIONS

Effluent Total P (mg/l as P)	Number of Plants
≤ 1.0	13
1-2	15
2-5	20
> 5	2

Table 5

INFLUENT TOTAL PHOSPHORUS CONCENTRATIONS

Influent Total P (mg/l as P)	Number of Plants
> 15	5
10-15	6
7-10	13
5-7	16
< 5	10

Table 6

HYDRAULIC OVERLOAD*

% of Design Flow	Number of Plants
≤ 100	23
100-150	17
> 150	8

* Two plants are not included above: at Racine, the secondary treatment is capable of handling only approximately half the average flow; at Green Bay, the primary treatment is capable of handling approximately half the average flow.

Table 7

INFLUENT TOTAL PHOSPHORUS LOAD

lbs/day P	Number of Plants
< 20	1
20-50	16
50-100	13
100-200	9
200-500	3
500-1000	4
> 1000	4

Table 8

EFFLUENT TOTAL PHOSPHORUS LOAD
(at current treatment levels)

lbs/day P	Number of Plants
< 5	5
5-20	22
20-50	9
50-100	4
> 100	10

Table 9

PHOSPHORUS TREATMENT COSTS

¢/1000 gal.	Number of plants
≤ 1	5
1-3	12
3-6	21
6-10	10
> 10	2

$/lb P Removed	Number of plants
< $0.20	3
$0.20-$0.60	14
$0.60-$1.00	14
$1.00-$2.00	14
> $2.00	5

Table 10

TREATMENT SYSTEMS[a]

	Number of Plants	
	Activated Sludge	Trickling Filter
PRIMARY	15	6
CHEMICAL-BIOLOGICAL	13	1
POST-BIOLOGICAL	6	5
PRIMARY/POST-BIOLOGICAL	0	2
	34	14

[a] Oshkosh presently has no secondary treatment system; Menomonee Falls uses both activated sludge and trickling filter systems. Both employ PRIMARY chemical addition.

Table 11

CHEMICALS USED[b]

	Number of Plants
Liquid alum	25
$FeCl_3$	9
Waste pickle liquor	10
Liquid sodium aluminate	3
Powdered alum	2
Powdered sodium aluminate	1

[b] Polymer is used with the chemicals shown at 15 plants--seven with liquid alum; six with $FeCl_3$; and two with liquid sodium aluminate.

Tab. 12

Plants Assigned Maximum Alternatives
Less Than the Uniform Percentage Requirements

	Maximum % Alternative
Milwaukee South Shore	59 (95)*
Two Rivers	58 (85)**
Racine	36 (89)**
Ripon	61 (80)**
Holland S.D.	50
Neenah-Menasha	62
Berlin	65
Peshtigo	65
Sheboygan	65
Fond du Lac	70
Green Bay	75 (90)**
Oconto Falls	75
Plymouth	75
Oshkosh	80 (92)**
North Fond du Lac	80
Sheboygan Falls	80
Portage	80
Manitowoc	80

*Revised under Condition II - DP2

**Revised under Condition III - DP3

Table 13

Plants Not Assigned Alternatives
To Achieve 1 mg/1 Effluent P

	% Removal at 1 mg/1 Effluent	Max. % Removal Alternative
Milwaukee South Shore*	85	59
Green Bay*	84	75
Racine*	77	36
Two Rivers*	82	58
Shawano*	92	26
Ripon	83	61
Holland S.D.	98	50
Neenah-Menasha	71	62
Oconto Falls	86	75
North Fond du Lac	85	80
Berlin	74	65
Manitowoc	90	80
Fond du Lac	86	70
Sheboygan	83	65
Sheboygan Falls	89	80
Plymouth	89	75
Portage	88	80
Peshtigo	80	65

*Alternatives are revised for DP2 and DP3 to allow removal to 1 mg/1.

Table 14

DYNAMIC PROGRAMMING EFFICIENCY SOLUTION

CONDITION I – DP1

POLICY PERCENTAGES:	.700	.715	.730	.750	.760
DAILY TOTAL POUNDS:	14594	14906	15217	15636	15844
DAILY TOTAL COSTS :	2121.41	2480.90	2869.99	3459.97	3797.54
REMOVAL DECISIONS AT EACH PLANT:					
MILWAUKEE-JONES IS	.890	.890	.890	.890	.890
GREEN BAY	.620	.750	.750	.750	.750
APPLETON	.870	.870	.870	.870	.870
MANITOWOC	.330	.500	.800	.800	.800
KENOSHA	.850	.850	.850	.850	.940
SHEBOYGAN	.200	.200	.200	.200	.200
OSHKOSH	.670	.670	.670	.670	.800
RACINE	.360	.360	.360	.360	.360
MENOM FALLS	.850	.850	.850	.850	.850
DE PERE	.810	.810	.810	.810	.810
FONDULAC	.200	.200	.200	.700	.700
GRAFTON	.900	.900	.900	.900	.900
WESTBEND	.900	.900	.900	.900	.900
KAUKAUNA	.800	.800	.800	.880	.880
CEDARBURG	.600	.600	.600	.850	.850
SOUTH MILWAUKEE	.700	.700	.700	.700	.700
PORT WASHINGTON	.850	.850	.850	.900	.950
NEW LONDON	.800	.800	.800	.800	.800
KIEL	.300	.800	.800	.800	.800
PLYMOUTH	.750	.750	.750	.750	.750
NORTH PARK S.D.	.850	.850	.850	.920	.920
CHILTON	.850	.850	.850	.850	.850
STURGEONBAY	.750	.750	.750	.850	.850
GERMANTOWN	.920	.800	.920	.920	.920
SHEYBOYGAN FALLS	.640	.180	.180	.800	.800
MARINETTE	.300	.300	.300	.700	.700
KEWASKUM	.700	.700	.820	.820	.820
KIMBERLY	.650	.650	.650	.850	.850
OCONTO	.250	.250	.250	.250	.250
RIPON	.200	.200	.200	.500	.500
STURTEVANT	.800	.800	.800	.800	.850
CLINTONVILLE	.700	.800	.800	.860	.860
PORTAGE	.210	.210	.210	.210	.210
THEINSVILLE	.330	.330	.330	.750	.850
MENASHA S.D.(EAST)	.900	.900	.900	.900	.900
NEW HOLSTEIN	.200	.200	.200	.550	.850
LITTLE CHUTE	.700	.700	.800	.800	.800
UNIONGROVE	.300	.300	.300	.300	.850
ALGOMA	.420	.420	.420	.420	.420
WAUPACA	.400	.400	.400	.400	.400
KEWAUNEE	.320	.320	.320	.700	.800
SHAWANO LAKE S.D.	.150	.260	.260	.260	.260
PESHTIGO	.200	.200	.200	.200	.200
BUTTE DES MORTS	.800	.800	.800	.860	.860
WEYAUWEGA	.850	.300	.850	.850	.850
TWO RIVERS	.450	.450	.450	.450	.450
KOHLER	.300	.300	.300	.890	.890
BERLIN	.200	.200	.200	.200	.200
NORTH FOND DU LAC	.200	.200	.200	.200	.800
OCONTO FALLS	.500	.500	.500	.500	.500
MILWAUKEE SS	.590	.590	.590	.590	.590
NEENAH MENASHA	.620	.620	.620	.620	.620
HOLLAND S.D.	.500	.500	.500	.500	.500

DYNAMIC PROGRAMMING EFFICIENCY SOLUTION
CONDITION II - DP2

POLICY PERCENTAGES:	.700	.730	.760	.800	.830
DAILY TOTAL POUNDS:	14594	15219	15844	16678	17304
DAILY TOTAL COSTS :	1364.62	1821.17	2468.28	3555.49	4750.46
REMOVAL DECISIONS AT EACH PLANT:					
MILWAUKEE-JONES IS	.890	.890	.890	.890	.890
MILWAUKEE SS	.950	.950	.950	.950	.950
GREEN BAY	.500	.500	.750	.750	.750
APPLETON	.870	.870	.870	.870	.950
MANITOWOC	.330	.330	.330	.800	.800
KENOSHA	.780	.850	.850	.940	.940
SHEBOYGAN	.200	.200	.200	.200	.200
OSHKOSH	.100	.670	.670	.670	.800
RACINE	.360	.360	.360	.360	.360
MENOM FALLS	.640	.780	.850	.850	.850
DE PERE	.700	.700	.810	.810	.900
FONDULAC	.200	.200	.200	.200	.700
GRAFTON	.850	.850	.900	.900	.900
WESTBEND	.700	.820	.900	.900	.930
KAUKAUNA	.800	.800	.800	.880	.950
CEDARBURG	.260	.600	.600	.850	.850
SOUTH MILWAUKEE	.300	.300	.700	.700	.700
PORT WASHINGTON	.800	.850	.850	.950	.950
NEW LONDON	.650	.800	.800	.800	.940
KIEL	.300	.300	.300	.800	.950
PLYMOUTH	.040	.400	.750	.750	.750
NORTH PARK S.D.	.700	.850	.850	.920	.920
CHILTON	.250	.700	.850	.850	.950
STURGEONBAY	.300	.300	.750	.850	.950
GERMANTOWN	.390	.800	.800	.920	.960
SHEYBOYGAN FALLS	.180	.180	.180	.800	.800
MARINETTE	.300	.300	.300	.700	.820
KEWASKUM	.300	.700	.700	.820	.950
KIMBERLY	.130	.500	.650	.850	.900
OCONTO	.250	.250	.250	.250	.800
RIPON	.200	.200	.200	.500	.500
STURTEVANT	.220	.220	.800	.850	.850
CLINTONVILLE	.300	.300	.800	.800	.940
PORTAGE	.210	.210	.210	.210	.800
THEINSVILLE	.330	.330	.330	.750	.900
MENASHA S.D.(EAST)	.550	.550	.900	.900	.940
NEW HOLSTEIN	.200	.200	.200	.850	.850
LITTLE CHUTE	.300	.550	.700	.800	.890
UNIONGROVE	.300	.300	.300	.850	.900
ALGOMA	.420	.420	.420	.420	.850
WAUPACA	.400	.400	.400	.400	.800
KEWAUNEE	.320	.320	.320	.800	.800
SHAWANO LAKE S.D.	.150	.150	.260	.260	.260
PESHTIGO	.200	.200	.200	.200	.200
BUTTE DES MORTS	.300	.300	.800	.860	.920
WEYAUWEGA	.300	.300	.300	.850	.850
TWO RIVERS	.450	.450	.450	.450	.450
KOHLER	.300	.300	.300	.890	.890
BERLIN	.200	.200	.200	.200	.650
NORTH FOND DU LAC	.200	.200	.200	.800	.800
OCONTO FALLS	.200	.200	.200	.200	.500
NEENAH-MENASHA	.620	.620	.620	.620	.620
HOLLAND S.D.	.500	.500	.500	.500	.500

DYNAMIC PROGRAMMING EFFICIENCY SOLUTION
CONDITION III - DP3

POLICY PERCENTAGES:	.730	.760	.830	.850	.880
DAILY TOTAL POUNDS:	15202	15827	17285	17701	18326
DAILY TOTAL COSTS :	1198.05	1644.07	3243.55	3927.69	5336.60
REMOVAL DECISIONS AT EACH PLANT:					
MILWAUKEE-JONES IS	.890	.890	.890	.890	.890
MILWAUKEE SS	.950	.950	.950	.950	.950
RACINE	.890	.890	.890	.890	.890
GREEN BAY	.500	.500	.850	.850	.850
APPLETON	.870	.870	.870	.870	.950
MANITOWOC	.330	.330	.800	.800	.800
KENOSHA	.780	.850	.850	.940	.940
SHEBOYGAN	.200	.200	.200	.200	.650
OSHKOSH	.300	.850	.850	.850	.920
MENOM FALLS	.640	.780	.850	.850	.850
DE PERE	.700	.700	.810	.810	.900
FONDULAC	.200	.200	.200	.700	.700
GRAFTON	.850	.900	.900	.900	.900
WESTBEND	.700	.820	.900	.900	.930
KAUKAUNA	.800	.800	.880	.880	.950
CEDARBURG	.260	.600	.850	.850	.850
SOUTH MILWAUKEE	.300	.300	.700	.700	.700
SHAWANO LAKE S.D.	.300	.850	.850	.850	.850
PORT WASHINGTON	.800	.800	.950	.950	.950
NEW LONDON	.650	.800	.800	.800	.940
KIEL	.300	.300	.800	.800	.950
PLYMOUTH	.040	.040	.750	.750	.750
NORTH PARK S.D.	.850	.850	.920	.920	.920
TWO RIVERS	.450	.450	.450	.800	.850
CHILTON	.250	.700	.850	.850	.950
STURGEONBAY	.300	.300	.850	.850	.910
RIPON	.200	.650	.800	.800	.800
GERMANTOWN	.800	.800	.920	.920	.960
SHEYBOYGAN FALLS	.180	.180	.800	.800	.800
MARINETTE	.300	.300	.700	.700	.820
KEWASKUM	.300	.700	.820	.900	.900
KIMBERLY	.130	.500	.850	.850	.900
OCONTO	.250	.250	.250	.250	.800
STURTEVANT	.220	.220	.850	.850	.850
CLINTONVILLE	.300	.300	.860	.860	.940
PORTAGE	.210	.210	.210	.800	.800
THEINSVILLE	.330	.330	.750	.850	.900
MENASHA S.D.(EAST)	.550	.550	.900	.900	.940
NEW HOLSTEIN	.200	.200	.850	.850	.850
LITTLE CHUTE	.300	.300	.800	.880	.880
UNIONGROVE	.300	.300	.300	.850	.900
ALGOMA	.420	.420	.420	.420	.850
WAUPACA	.400	.400	.400	.400	.800
KEWAUNEE	.320	.320	.800	.800	.800
PESHTIGO	.200	.200	.200	.200	.200
BUTTE DES MORTS	.300	.300	.860	.920	.920
WEYAUWEGA	.300	.300	.850	.850	.850
KOHLER	.300	.300	.890	.890	.890
BERLIN	.200	.200	.200	.200	.650
NORTH FOND DU LAC	.200	.200	.200	.800	.800
OCONTO FALLS	.200	.200	.200	.500	.500
NEENAH-MENASHA	.620	.620	.620	.620	.620
HOLLAND S.D.	.500	.500	.500	.500	.500

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APPENDIX A

Plant Information Sheets

This appendix consists of information sheets on each of 53 wastewater treatment plants in Wisconsin's Lake Michigan Basin under orders to remove phosphorus. Major plant processes are shown in the sketches which also illustrate points of addition of phosphorus removal chemicals. These sketches are not meant to represent physical plant layouts. For purposes of clarity and simplicity, minor processes such as screening, comminution, and chlorination are omitted. Some waste and sludge flows may not be shown or labelled. The key of abbreviations and symbols follow this discussion.

The data listed is that which is generally typical of the performance in removing phosphorus and is based on flows and phosphorus concentrations for the specific period of treatment noted. Design flows are for average flows and maximum flows, where available. In compiling information from the plant data sheets, all available information is considered and all sources are contacted so that phosphorus levels and treatment can be accurately correlated.

The total phosphorus load in lb/day P is the product of the average flow (MGD), the phosphorus concentration (mg/l as P), and the conversion constant (8.34).

Treatment is classified as follows:

PRIMARY - When chemical is added ahead of, or at primary settling tanks, with the intention of precipitating and settling phosphorus in this process.

CHEMICAL-BIOLOGICAL - When chemical is added just ahead of or directly to the biological treatment process.

POST-BIOLOGICAL - When chemical is added just ahead of or directly to a final settling tank or any other unit succeeding the biological treatment process.

PRIMARY/POST-BIOLOGICAL - Indicates a combination of the two methods described above.

"Chemical" does not include the addition of polymer in the above definition.

In some cases, it was difficult to determine the actual chemical dose because of adjustments based on the operator's visual inspection. Average chemical doses were calculated based on the amount of chemical used over some period of time--or how long it took to deplete a known load of chemical.

Phosphorus removal efficiency prior to chemical addition is based on actual data, whenever available. If the treatment percentage is indicated as an estimate, it is the estimate of one of the people listed in the sources. Where the treatment level is indicated as an assumed value, one of the following assumptions has been made:

Treatment Process	% P Removal
Primary settling only	10%
Trickling filter	20%
Act. sludge and trickling filter	25%
Activated sludge	30%

Although phosphorus removals without chemical treatment can vary considerably, the assumptions above are in general agreement with treatment levels reported in the literature (1,3,4,6,17,27).

Capital costs are as reported by plant superintendents, city officials, or consulting engineers. The capital cost generally includes: the costs of a chemical storage tank, and the cost of chemical feed pumps and necessary piping and electrical works. Facilities were generally designed to allow flexibility in the choice of chemical. Costs reported are installed costs of facilities. In some cases, the equipment cost includes polymer feed facilities. Capital costs are discounted at 7%. The time period will vary from 10-25 years depending on the permanency and quality of the equipment.

Operating costs include estimates of additional personnel required because of phosphorus treatment--for mixing polymer, analyzing for phosphorus, etc. Operating costs also include additional costs of providing electrical power. Because of the short period of treatment and the temporary quality of the facilities at many plants, no estimate of annual maintenance cost was available. When estimates were not reported, an allowance of 10% of the annual capital and operating cost--excluding chemical cost--was used.

Sludge handling and disposal costs are not included unless they are specifically noted.

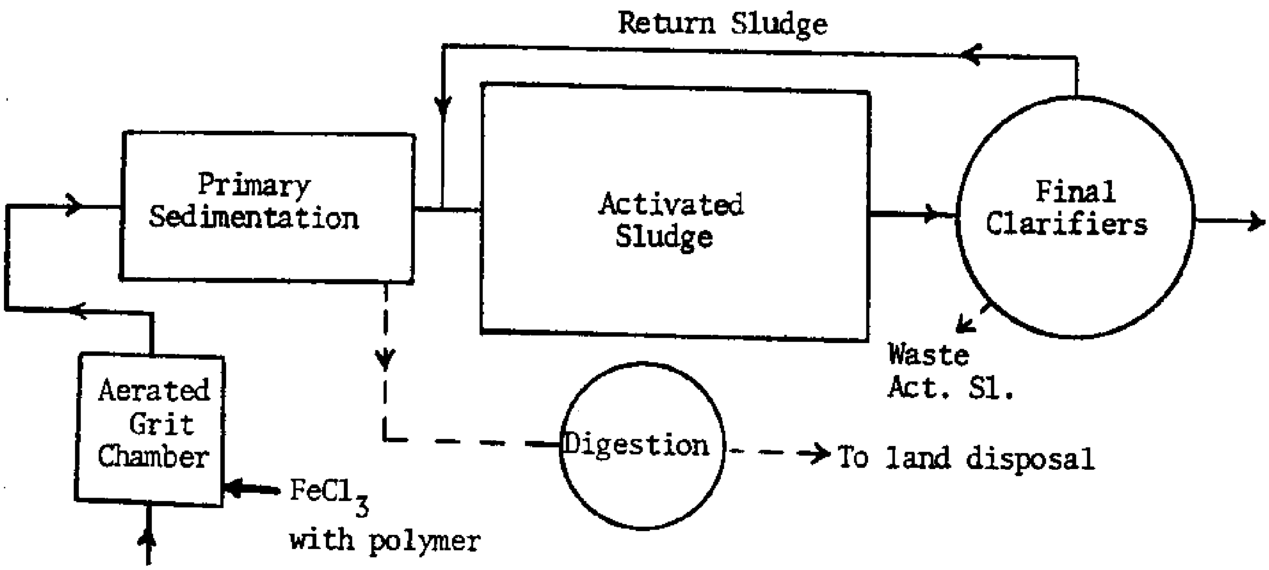
An additional discussion of phosphorus removal costs is included in Chapter V, page 17.

Key to Symbols and Abbreviations Used in Appendix A

—→—	Raw sewage and clarified effluent flows
– → –	Settled sewage or sludge flows*
➡	Point of chemical or polymer addition
A.S.	Activated sludge process
T.F.	Trickling filter process
Aerob.	Aerobic Digestion
Anaerob.	Anaerobic Digestion
W.A.S.	Waste or excess activated sludge
P.L.	Waste pickle liquor
Al:P or Fe:P	Weight ratio of metal ion dose to influent total P
MGD	Million gallons per day
gpd	gallons per day
gph	gallons per hour
ml/min	milli-liters per minute
STP	Sewage treatment plant
Supt.	Superintendent
S.D.	Sanitary District

*Return sludge, recirculation and supernatant flows are specifically labelled.

ALGOMA



Design flow: 0.750 MGD (Max 2.225 MGD)
Average flow: 0.828 MGD
Average flow exceeds design flow: 7 of 16 months
Maximum design not exceeded.

Average influent total P: 6.1 mg/l as P; 42 lb/day P
Average effluent total P: 0.66 mg/l as P; 5 lb/day P

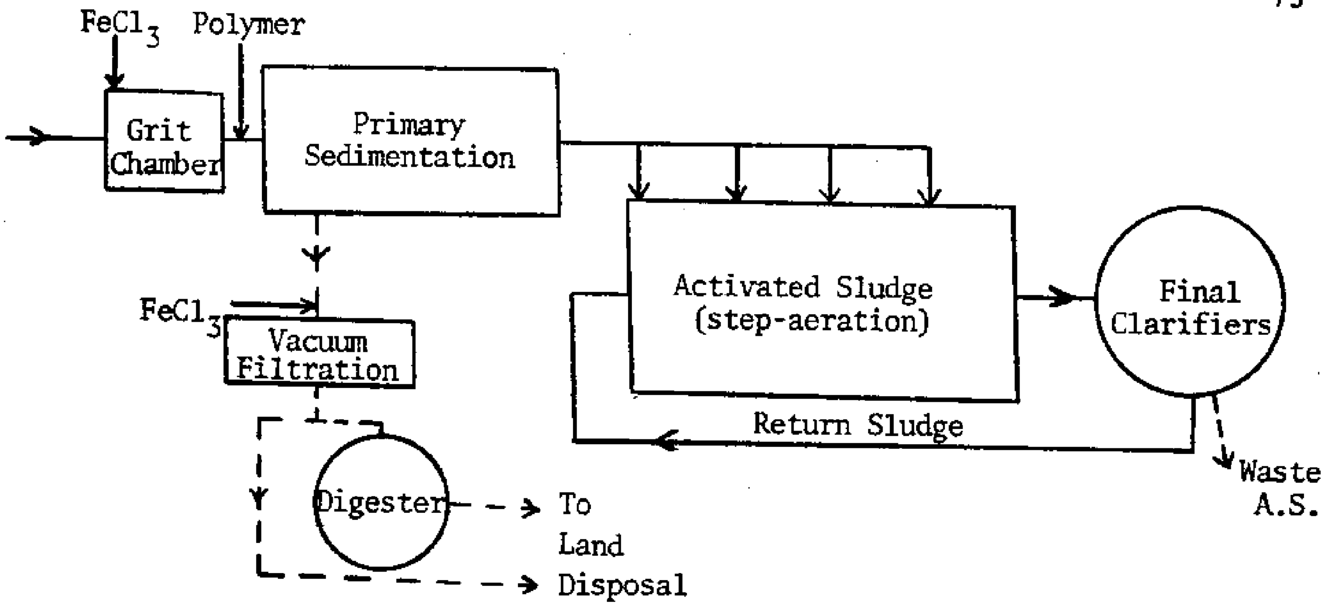
Treatment: PRIMARY
Averaging 75 gpd $FeCl_3$ with polymer at grit chamber.
$Fe:P \geq 3:1$

P Removal Efficiency: Prior to chemical addition -- 42%
$Fe:P \approx 4:1$ with polymer -- 89%

	Cost	Annual Cost	¢/1000 gal.
Capital	$23,000	$ 2,171	0.72
Operating		2,970	0.98
Chemical		13,500	4.47
		$18,641	6.17¢/1000 gal. or $1.38/lb P removed

Comments: There is no accounting of increased sludge or sludge handling and disposal costs. Mr. Groll did indicate sludge quantity had noticeably increased; and also noted better settling performance.

Sources: Donahue & Associates, Sheboygan
Allen Groll, STP Supt.



[Treatment levels reported here are based on data from March 1974-May 1974.]

Design flow: 12 MGD
Average flow: 16.04 MGD
Average flow exceeds design flow: 17 of 17 months

Average influent total P: 10.11 mg/l as P; 1352 lb/day P
Average effluent total P: 1.34 mg/l as P; 179 lb/day P

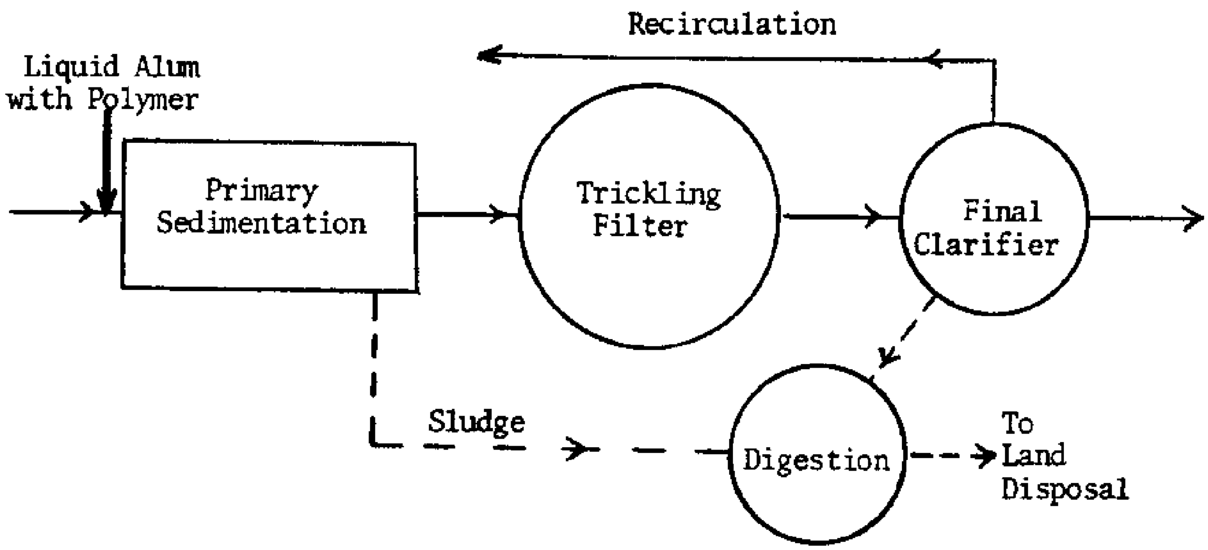
Treatment: PRIMARY
50 gal/mg $FeCl_3$ at grit chamber with polymer before primary tank;
Fe : P ≅ 1 : 1; 14 lb/day polymer;
P Removal Efficiency: Prior to chemical addition -- 50%
Fe : P ≅ 1 : 1 with polymer -- 87%

	Cost	Annual Cost	¢/1000 gal.
Capital	$15,000	$ 1,416	0.03
Operating		15,000	0.28
Chemical		82,016	1.40
		$98,432	1.71¢/1000 gal. or $0.23/lb P removed

Comments: Appleton had used $FeCl_3$ for sludge conditioning prior to the phosphorus order. Mr. Colbert reported achieving 50% P removal under these conditions. Capital expenditure was small at this time because of expected expansion in the near future; also because of existing $FeCl_3$ storage. Mr. Colbert noted problems keeping the chemical feed pump operational in the early months of treatment. In June 1974, $FeCl_3$ was dosed ahead of the finals to control settling and hopefully reduce the dose at the grit chamber.

Sources: Consoer-Townsend Engr., St. Louis, MO
Bob Miller, Director of Public Works
Wayne Colbert, STP Supt.

BERLIN



[Treatment levels are based on data from May 1974-June 1974.]

Design flow: 0.905 MGD (Max. 1.5 MGD)
Average flow: 1.452 MGD
Average flow exceeds design flow: 11 of 11 months reported
(Exceeds maximum design 5 of 11 months)

Average influent total P: 3.9 mg/l as P; 47 lb/day P
Average effluent total P: 2.2 mg/l as P; 27 lb/day P

Treatment: PRIMARY
120 gpd liquid alum with polymer at primaries;
Al:P ≅ 1.2:1

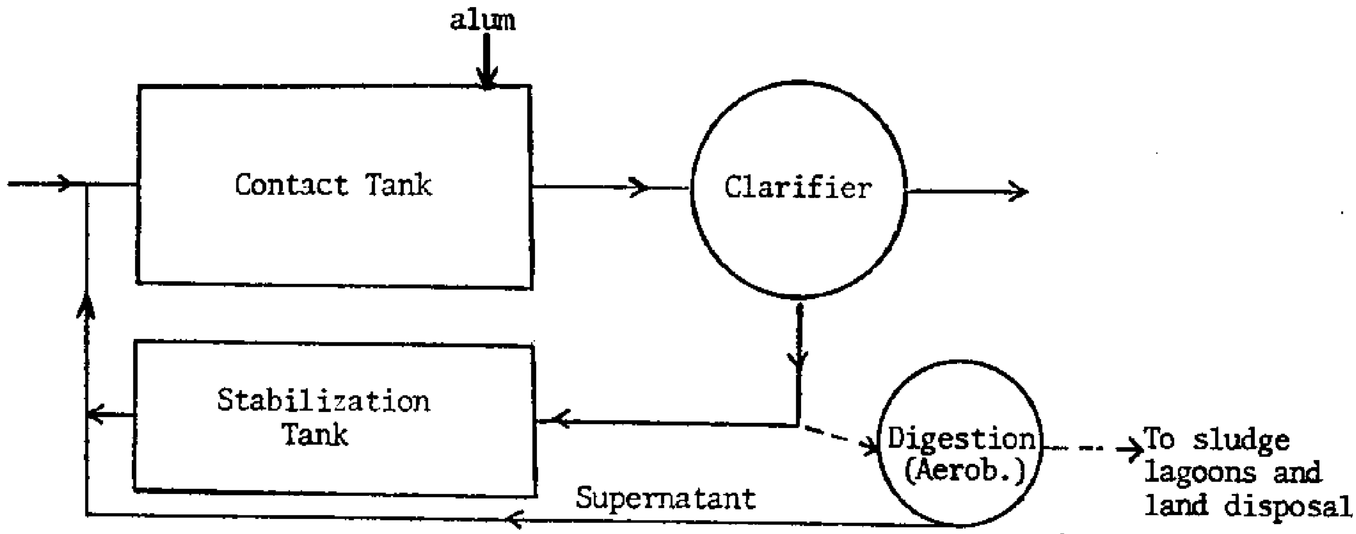
P Removal Efficiency: prior to chemical addition -- 20% (assumed)
Al:P ≅ 1.2:1 with polymer -- 44%

	Cost	Annual Cost	¢/1000 gal.
Capital	$5,500	$ 519	0.10
Operating		3,521	0.66
Chemical		8,259	1.56
		$12,299	2.32¢/1000 gal. or $1.68/lb P removed

Comments: Plant is overloaded hydraulically and has a low influent phosphorus concentration. Berlin is waiting funds for a new plant. A major industry served by the plant is a local tannery.

Sources: John Strand & Associates, Madison
Neil Osterburg, STP Supt.
Plant Operator

BUTTE DES MORTS U.D.



[Treatment levels are based on data for March-May 1974; the system above has been modified (air wall pulled out of contact tank) and is now being operated more as a conventional aeration system.]

Design flow: 0.60 MGD (max 1.30 MGD)
Average flow: 0.694 MGD

Average influent total P: 6.1 mg/l as P; 35 lb/day P
Average effluent total P: 0.88 mg/l as P; 5 lb/day P

Treatment: 3.5 gph liquid alum at old contact tank.
Al:P ≅ 1.2:1

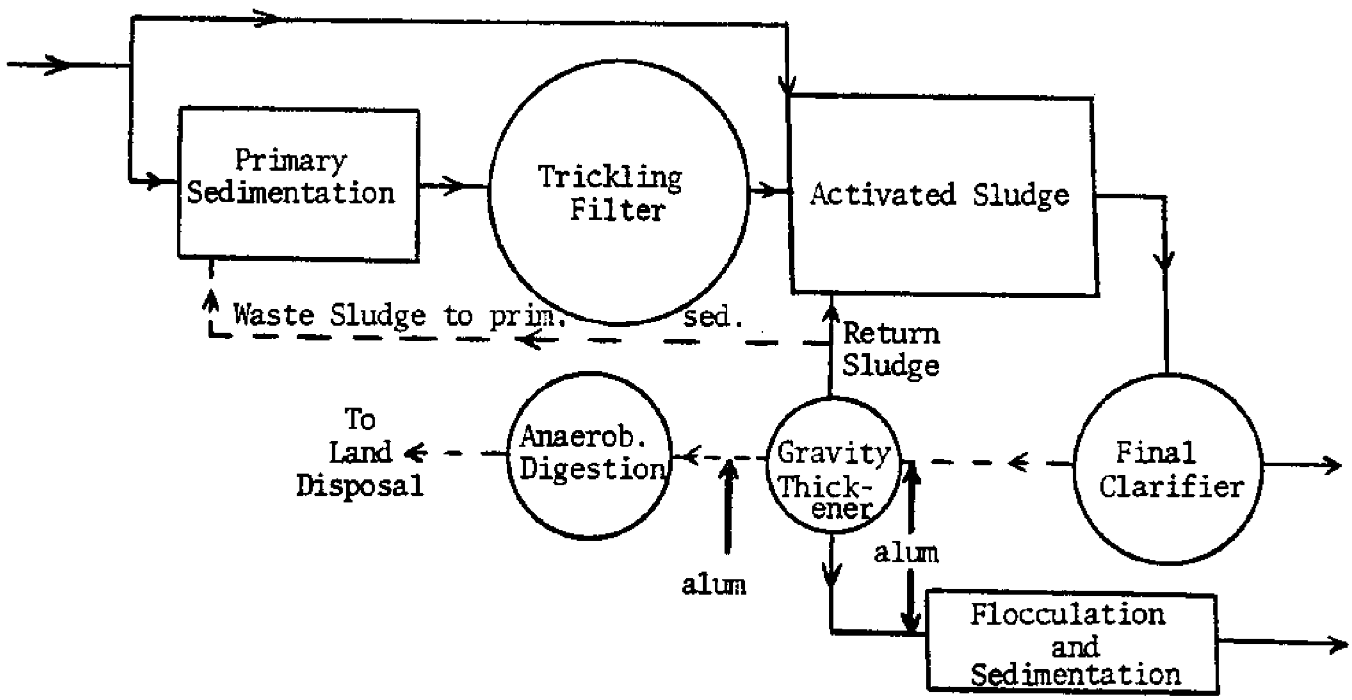
P Removal Efficiency: Prior to chemical addition -- 30% (assumed)
Al:P ≅ 1.2:1 -- 86%

	Cost	Annual Cost	¢/1000 gal.
Capital	$12,650	$1,085	0.43
Operating		2,916	1.15
Chemical		4,387	1.73
		$8,388	3.31¢/1000 gal. or $0.77/lb P removed

Comments: Mr. Huntoon indicated that he was considering dosing alum directly to the aeration tank. He noted that overfeeding or saturating with alum did not work and created foaming conditions. An increase in gallons and % solids of the sludge was reported.

Sources: Donahue & Associates, Sheboygan
Doug Huntoon, STP Supt.

CEDARBURG



[Treatment levels are based on data from June 1973-May 1974.]

Design flow: 3 MGD (Max 6 MGD)
Average flow: 2.076 MGD
(3 MGD design flow was not exceeded.)

Average influent total P: 7.7 mg/l as P; 133 lb/day P
Average effluent total P: 2.55 mg/l as P; 44 lb/day P

Treatment: 3 point addition of dry alum (500 lb/day)
Al:P ≅ 1.3:1

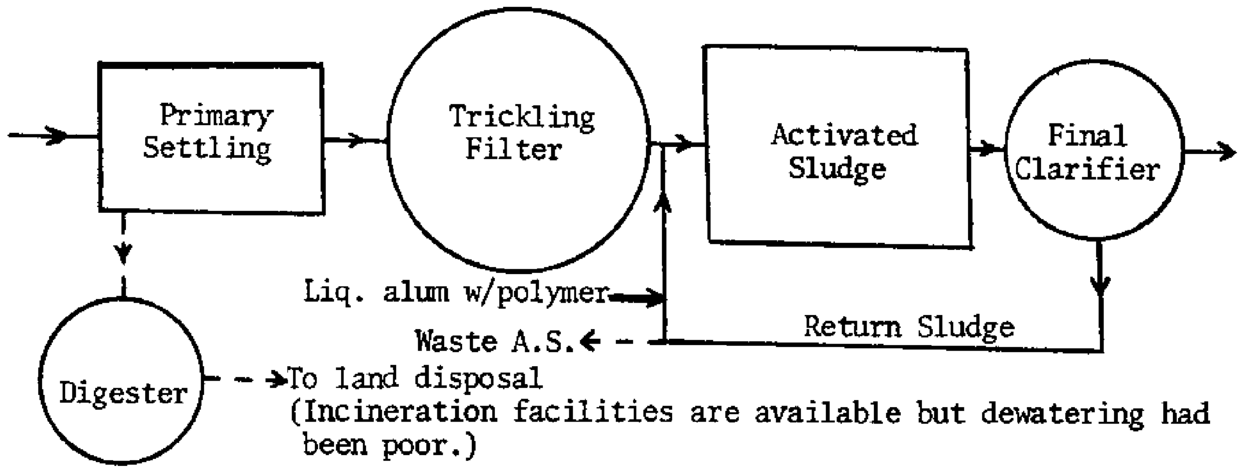
P Removal Efficiency: Prior to chemical addition -- 26%
Al:P ≅ 1.3:1 -- 67%

	Cost	Annual Cost	¢/1000 gal.
Capital	$42,500	$ 3,647	0.48
Operating		2,227	0.29
Chemical		13,140	1.74
		$19,014	2.51¢/1000 gal. or $0.61/lb P removed

Comments: Plans are to switch to liquid chemical feed. Present system did not provide the removals necessary. Handling and operating ease are additional reasons for the proposed switch.

Sources: Nicholson and Associates, South Milwaukee
Robert Boivin, STP Supt.

CHILTON



[Treatment levels are based on data from Oct. 1973-April 1974.]

Design flow: 0.650 MGD
Average flow: 0.507 MGD
Average flow exceeds design flow: 1 of 7 months (April 0.68 MGD)

Average influent total P: 19.8 mg/l as P; 84 lb/day P
Average effluent total P: 2.2 mg/l as P; 9 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
200 gpd liquid alum at return sludge line; polymer ahead of final clarifiers; Al:P ≅ 1.2:1

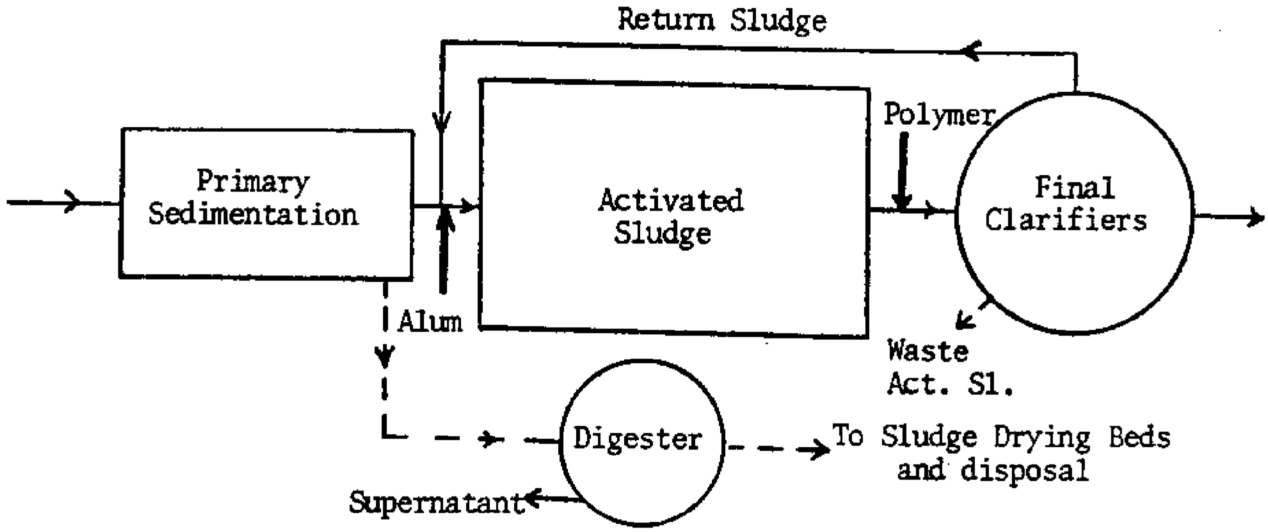
P Removal Efficiency: Prior to chemical addition -- 25%
Al:P ≅ 1.2:1 with polymer -- 89%

	Cost	Annual Cost	¢/1000 gal.
Capital	$45,000	$ 3,861	2.09
Operating		4,048	2.19
Chemical		12,000	6.48
		$19,909	10.76¢/1000 gal. or $0.73/lb. P removed

Comments: Capital investment includes building to house chemical feed facilities. Waste contributors include metal plating, aluminum, and malting industries. Mr. Muehl noted occasional PH problems.

Sources: McMahon & Associates, Menasha
Walter Muehl, Director of Public Works
Al Bauman, STP Supt.

CLINTONVILLE



[Treatment levels are based on data from April 1974-June 1974.]

Design flow: 1.0 MGD
Average flow: 1.058 MGD

Average influent total P: 4.94 mg/l as P; 44 lb/day P
Average effluent total P: 0.70 mg/l as P; 6 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
80 gpd liquid alum ahead of aeration; polymer ahead of finals;
Al:P ≅ 1:1

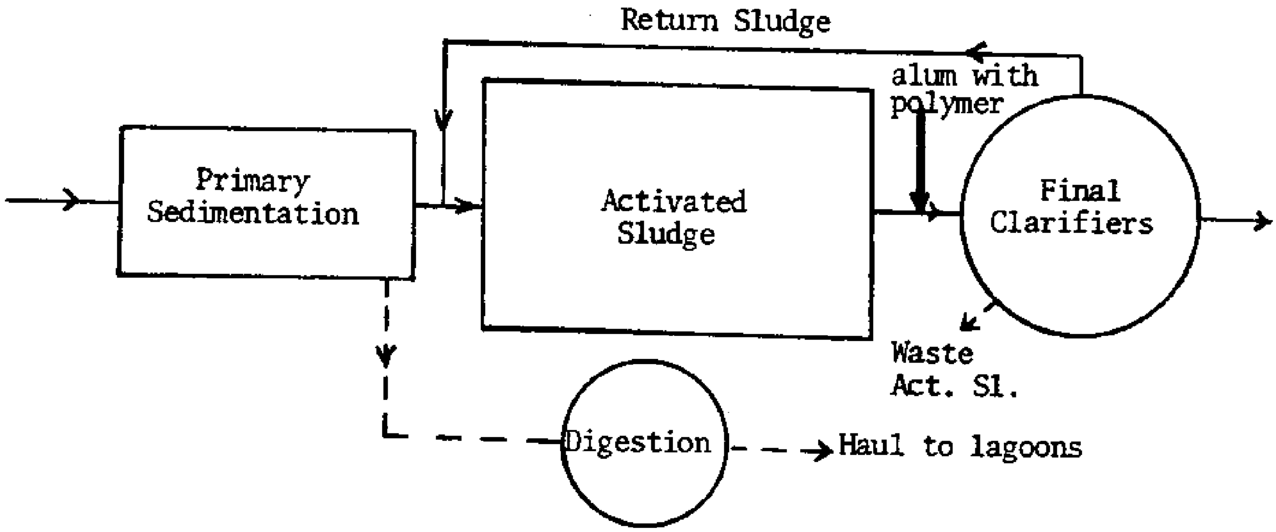
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1:1 with polymer -- 86%

	Cost	Annual Cost	¢/1000 gal.
Capital	$135,372	$12,778	3.30
Operating		4,006	1.04
Chemical		4,753	1.23
		$21,537	5.57¢/1000 gal. or $1.55/lb P removed

Comments: Capital cost is high, but includes a vastly revamped sludge handling and disposal system. Apparently, the phosphorus became soluble in the digester and created problems when supernatant was returned to the plant. The proposed sludge system is designed to solve this problem.

Sources: Foth & Van Dyke and Associates, Green Bay
Don Zarda, STP Supt.

DE PERE



[Treatment levels are based on data from July 1973-June 1974.]

Design flow: 2.88 MGD (max)
Average flow: 2.663 MGD
Average flow exceeds design flow: 2 of 9 months

Average influent total P: 8.66 mg/l as P; 192 lb/day P
Average effluent total P: 1.68 mg/l as P; 37 lb/day P

Treatment: POST-BIOLOGICAL
Approximately 400 gpd liquid alum with polymer ahead of final clarifiers; Al:P ≅ 1:1

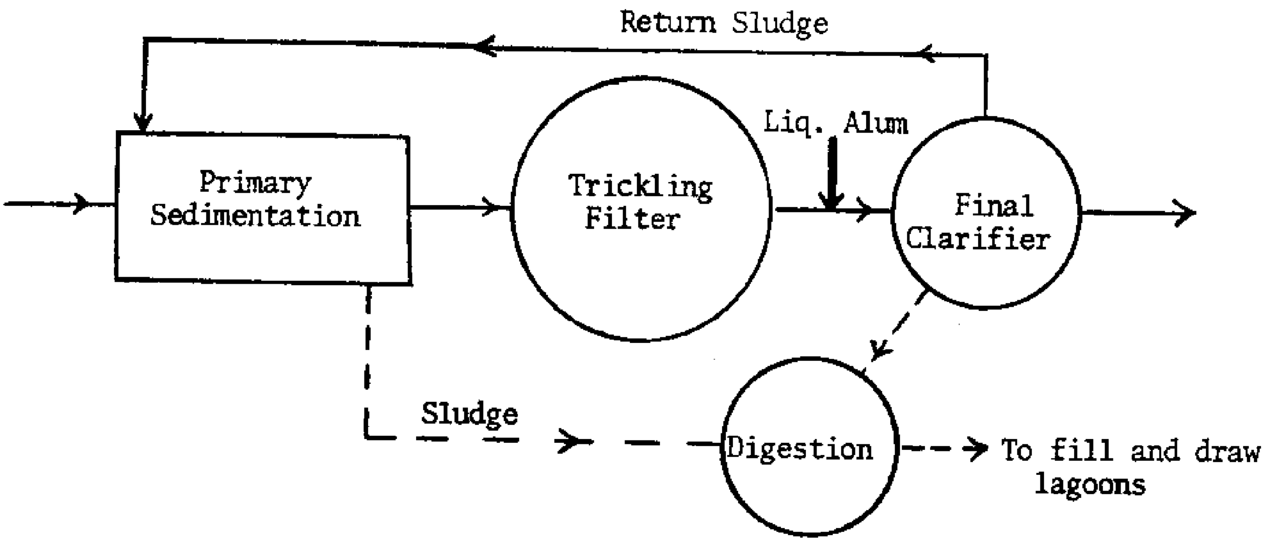
P Removal Efficiency: Prior to chemical addition -- 7%
Al:P ≅ 1:1 with polymer -- 81%

	Cost	Annual Cost	¢/1000 gal.
Capital	$8,783	$ 748	0.08
Operating		4,304	0.44
Chemical		25,893	2.66
Extra Sludge Hauling	$100/wk.	5,200	0.53
		$36,145	3.71¢/1000 gal. or $0.64/lb P removed

Comments: Low capital investment now because of plant modifications including additional settling tanks; vacuum filtration-incineration for sludge processing; and denitrification-tertiary treatment. Dairy and packing wastes contribute to the phosphorus load. Influent phosphorus concentrations are reported to be highly variable.

Sources: Clarence Van den Berg, STP Supt.
Plant operator

FOND DU LAC



[Treatment levels are based on data from Oct. 1973-June 1974.]

Design flow: 7 MGD (Avg.)
Average flow: 6.677 MGD
Average flow exceeds design flow: 3 of 9 months

Average influent total P: 6.9 mg/l as P; 384 lb/day P
Average effluent total P: 3.2 mg/l as P; 176 lb/day P

Treatment: POST-BIOLOGICAL
1550 gpd liquid alum ahead of finals;
Al:P ≅ 2:1

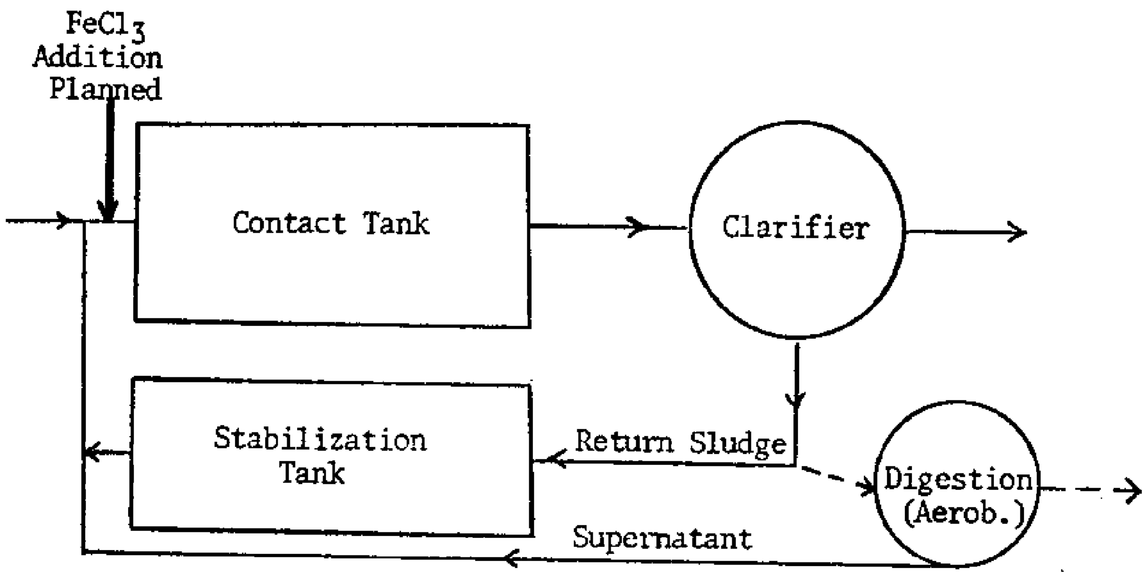
P Removal Efficiency: Prior to chemical addition -- 20%
Al:P ≅ 2:1 -- 54%

	Cost	Annual Cost	¢/1000 gal.
Capital	$26,443	$ 2,269	0.09
Operating		3,430	0.14
Chemical		87,069	3.57
		$92,768	3.8¢/1000 gal. or $1.22/lb P removed

Comments: Overloaded final clarifiers are the key problem at the plant. Did not receive chemical feed equipment until August 1973. State lab results and personal conversations would indicate highly variable influent phosphorus concentrations averaging about 10 mg/l as P. Operator's data (Oct. 1973-June 1974) did not confirm this. A dairy industry contributes to the plant's phosphorus load. Mr. Gaber noted more gallons (with alum addition) of sludge but also a thinner sludge--due to clarifier overload.

Sources: Metcalf & Eddy, Boston
Mr. Bob Gaber, STP Supt.

GERMANTOWN



Design flow: 1 MGD
Average flow: 0.743 MGD
Average flow exceeds design flow: 1 of 8 months

Average influent total P: 12.4 mg/l as P; 77 lb/day P
Average effluent total P: 7.6 mg/l as P; 47 lb/day P

Treatment: No chemical addition for phosphorus removal to date.
P Removal efficiency without treatment -- 39%
Expected efficiency Fe:P ≅ 1.6:1 -- 85%

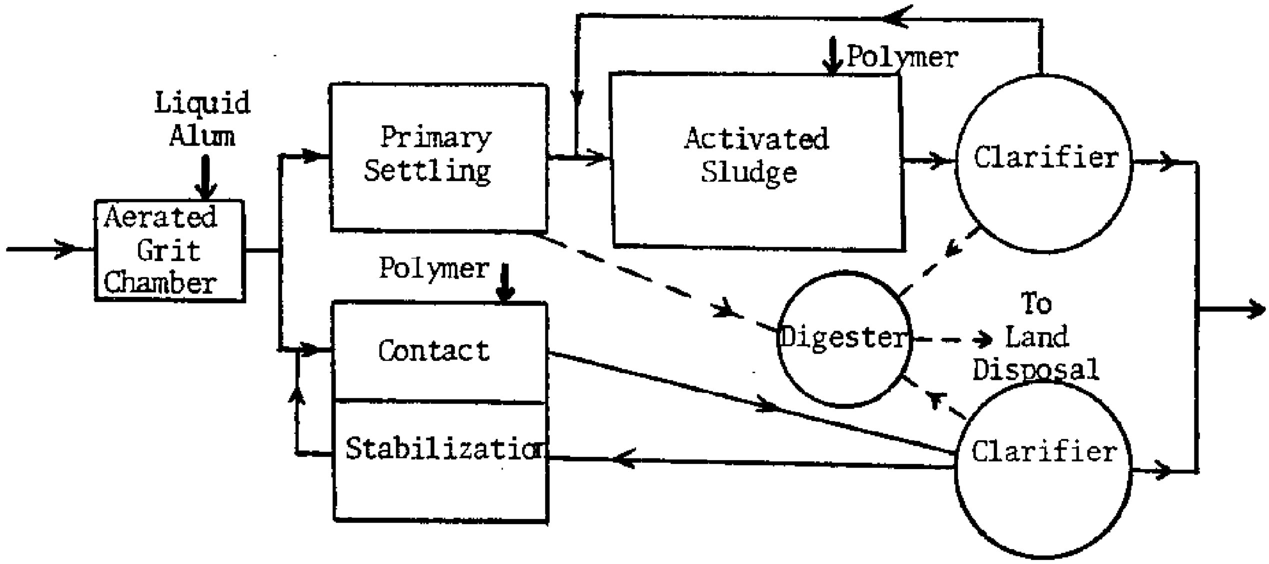
[Expected Costs]

	Cost	Annual Cost	¢/1000 gal.
Capital	$8,300	$ 708	0.26
Operating		1,677	0.62
Chemical		7,500	2.76
		$9,885	3.64¢/1000 gal. or $0.42/lb P removed

Comments: Germantown reported problems in getting a chemical storage tank. Mr. Muth noted that they had extended a grant to remodel the existing plant for inclusion of phosphorus treatment, but funding was hung up and Germantown was involved in litigation. The system above is also operated as extended aeration. A dairy industry contributes to the phosphorus load at the plant. In the future, Germantown is expected to tie in to the Milwaukee system.

Sources: Baudhuin & Associates, Germantown
Tom Muth, Utility Commission
STP operator

GRAFTON



[Treatment levels are based on data from Jan. 1974-June 1974.]

Design flow: 1 MGD (avg) [0.4 MGD Act. Sludge; 0.6 MGD Cont.-Stab.]
Average flow: 1.228 MGD
Average flow exceeds design flow: 6 of 6 months

Average influent total P: 15.4 mg/l as P; 158 lb/day P
Average effluent total P: 1.58 mg/l as P; 16 lb/day P

Treatment: PRIMARY
200 gpd liquid alum at grit chamber; polymer at aeration and at contact tank.

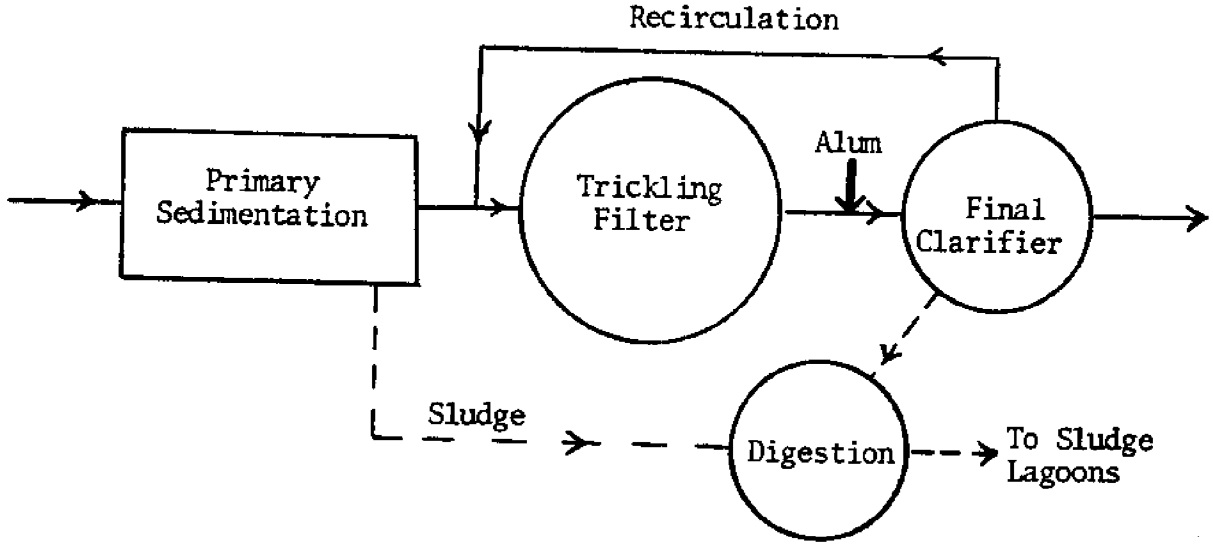
P Removal Efficiency: prior to chemical addition -- 20%
Al:P ≅ 0.6:1 with polymer -- 90%

	Cost	Annual Cost	¢/1000 gal.
Capital	$4,3000	$ 406	0.09
Operating		2,863	0.64
Chemical (Alum)		12,045	2.69
(Polymer)		1,095	0.24
		$16,409	3.66¢/1000 gal. or $0.32/lb P removed

Comments: Originally, sodium aluminate and waste pickle liquor were tried at Grafton with poor results. Mr. Krueger noted that sludge production had tripled since chemical addition for phosphorus removal.

Sources: Donahue & Associates, Sheboygan
Ed Krueger, STP Supt.

GREEN BAY



[Treatment levels are based on state lab data and on personal communication with Mr. Duehring.]

Design flow: Primary--9 MGD; T.F. and Finals--22 MGD
Average flow: 20.43 MGD

Average influent total P: 6.1 mg/l as P; 1039 lb/day P
Average effluent total P: 2.3 mg/l as P; 392 lb/day P

Treatment: POST-BIOLOGICAL
2200 gpd liquid alum ahead of finals; Al:P ≅ 1:1 to 1.2:1

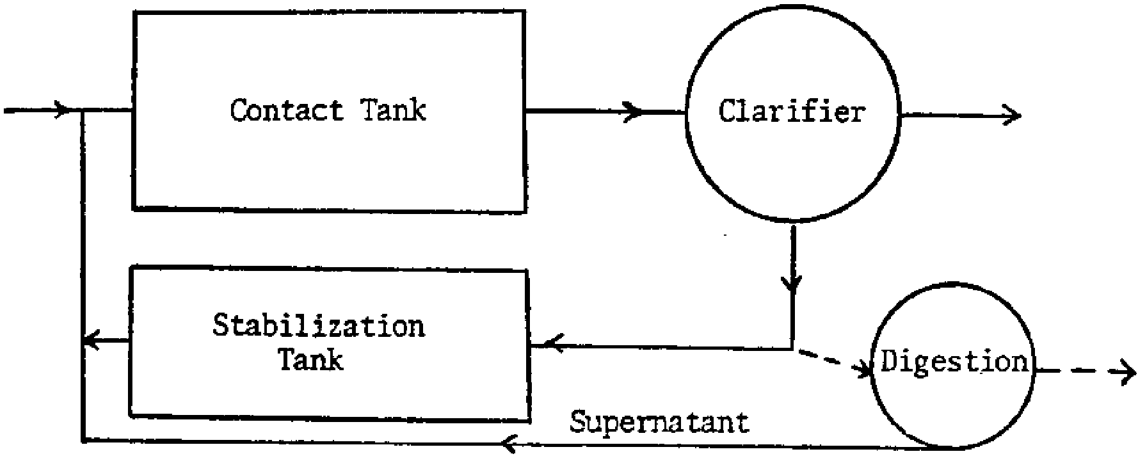
P Removal Efficiency: prior to chemical addition -- 2%
Al:P ≅ 1:1 -- 62%

	Cost	Annual Cost	¢/1000 gal.
Capital	$11,500	$ 1,085	0.01
Operating		2,674	0.04
Chemical		119,246	1.60
		$123,005	1.65¢/1000 gal. or $0.52/lb P removed

Comments: Higher alum doses were tried, but poor settling prevented higher removal efficiencies. Green Bay has received polymer feed equipment, but it was damaged and is not operational. Mr. Duehring noted that $FeCl_3$ had been tried, but without success. Influent phosphorus concentrations are variable and can range from 4 to 10 mg/l as P. Dairy and canning industries contribute to the waste load. The new plant is under construction. This plant will provide capabilities for conventional activated sludge, contact-stabilization, or step-aeration. Combined treatment with paper mill waste may require Green Bay to operate its biological system near the critical phosphorus requirement.

Sources: Donahue & Associates, Green Bay
Robert Duehring, Lab Director
David Martin, Engr.-Manager

HOLLAND S.D.



Design flow: 0.144 MGD

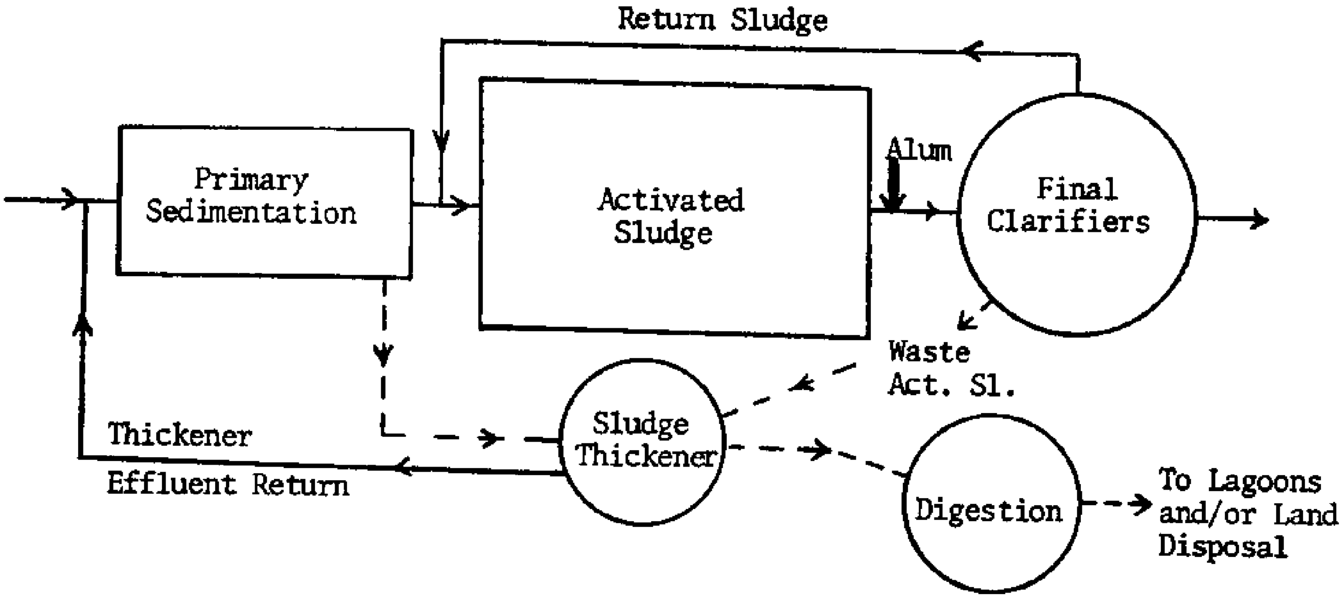
Influent total P: 22-70 mg/l as P; 55 lb/day P

No treatment for phosphorus removal to date.

Comments: Undergoing construction of proposed lagoon system in addition to existing treatment. This is essentially a dairy waste. Polymers have been added to aid settling in the overloaded clarifier. Mr. Herman reported trying alum but could not get settling of the floc in the clarifier. When the system is working properly, Mr. Herman indicated that an effluent concentration of 10-16 mg/l as P can be obtained.

Sources: Mr. Bill Herman
Mr. Ray Van Zeeland
McMahon & Associates, Menasha

KAUKAUNA



[Treatment levels are based on data from Sept. 1973-June 1974.]

Design flow: 2.550 MGD (Max. 4.5 MGD)
Average flow: 2.011 MGD
Average flow exceeds design flow: 3 of 10 months
Maximum design not exceeded.

Average influent total P: 9.7 mg/l as P; 163 lb/day P
Average effluent total P: 1.15 mg/l as P; 19 lb/day P

Treatment: POST-BIOLOGICAL
240-318 gpd liquid alum ahead of finals; Al:P ≅ 1:1

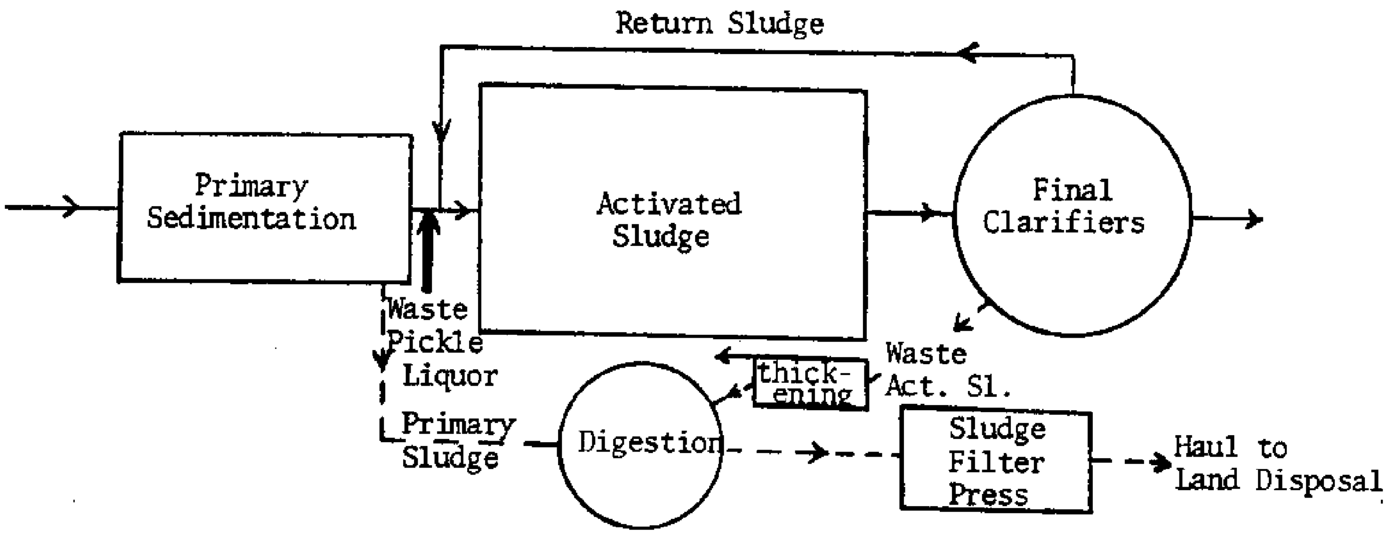
P Removal Efficiency: prior to chemical addition -- 35%
Al:P ≅ 1:1 -- 88%

	Cost	Annual Cost	¢/1000 gal.
Capital	$21,977	$ 1,886	0.26
Operating		2,041	0.28
Chemical		17,910	2.44
		$21,837	2.99¢/1000 gal. or $0.42/lb P removed

Comments: Activated sludge can also be operated as contact-stabilization or step-aeration.

Sources: Donahue & Associates, Sheboygan
Robert Natrop, City Engineer
Albert Winter, STP Supt.
Al Schaefer, Operator
City Clerk

KENOSHA



[Treatment levels are based on data for June 1974.]

Design flow: 26 MGD
Average flow: 27.582 MGD

Average influent total P: 4.0 mg/l as P; 920 lb/day P
Average effluent total P: 0.9 mg/l as P; 207 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
Approximately 2000 gpd waste pickle liquor ahead of aeration; (7.5% Fe) Fe:P ≅ 2:1

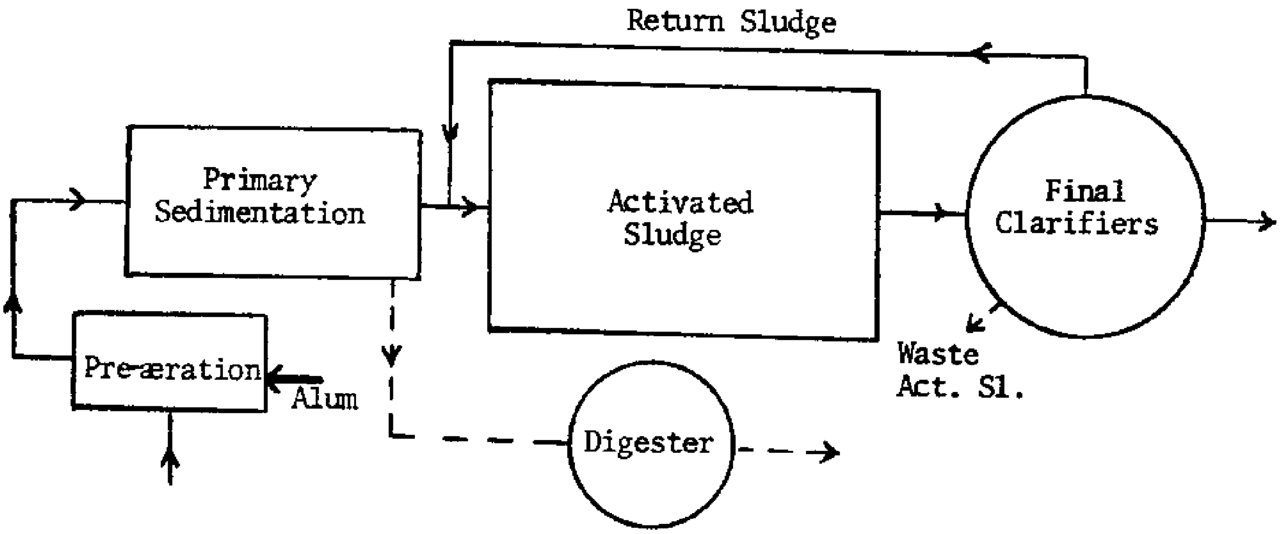
P Removal Efficiency: prior to chemical addition -- 40%
Fe:P ≅ 2:1 -- 78%

	Cost	Annual Cost	¢/1000 gal.
Capital	$118,000	$16,801	0.17
Operating		7,628	0.08
Chemical		30,937	0.31
		$55,366	0.56¢/1000 gal. or $0.21/lb P removed

Comments: Mr. Selin reported problems with the pickle liquor feed system and indicated that June 1974 was the first time everything had operated well. Polymer was tried but was not followed up on to this date. $FeCl_3$ is used for sludge conditioning in conjunction with the filter press. This plant is also provided with a 20 MGD biosorption treatment system for combined sewer overflows.

Sources: Gerald Selin, STP Supt.
Fred Nelson, Kenosha Waster Utility

KEWASKUM



[Treatment levels are based on data from June 1973-Feb. 1974.]

Design flow: 1 MGD
Average flow: 0.443 MGD
Design flow not exceeded

Average influent total P: 19.3 mg/l as P; 71 lb/day P
Average effluent total P: 3.4 mg/l as P; 13 lb/day P

Treatment: PRIMARY
6 gph liquid alum at pre-aeration; Al:P $\cong$ 1:1

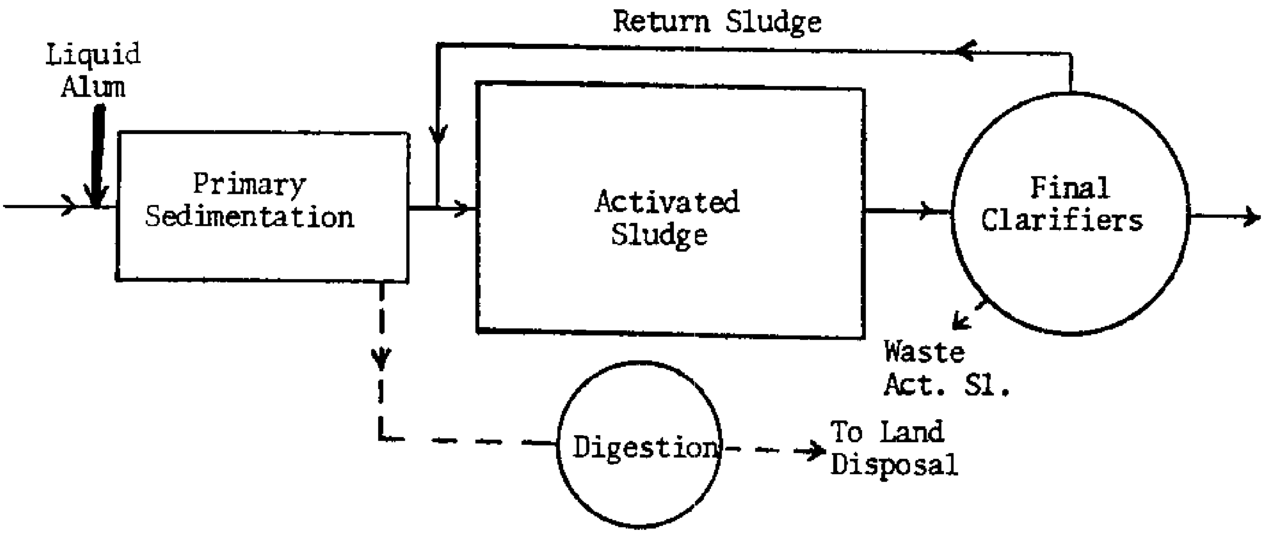
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P $\cong$ 1:1 -- 82%

	Cost	Annual Cost	¢/1000 gal.
Capital	$14,700	$ 1,388	0.86
Operating		2,387	1.48
Chemical		8,373	5.18
		$12,148	7.52¢/1000 gal. or $0.57/lb P removed

Comments: Capital costs above are for the full scale facilities scheduled to be on line soon. Temporary alum feed facilities are used now. A dairy industry contributes to the phosphorus load at the plant. Mr. Albers noted that volume of sludge had increased and % solids had decreased with the addition of alum feed.

Sources: Stone & Robinson Engineers, Brookfield
Pete Albers, STP Supt.

KEWAUNEE



[Treatment levels are based on data from Sept. 1973-June 1974.]

Design flow: 0.326 MGD
Average flow: 0.440 "
Average flow exceeds design flow: 8 of 9 months (Feb.-Sept. 1973 and June 1974)

Average influent total P: 7.72 mg/1 as P; 28 lb/day P
Average effluent total P: 1.52 mg/1 as P; 6 lb/day P

Treatment: PRIMARY
3-5 gph liquid alum ahead of primary tank; Al:P ≅ 1.3:1 to 2:1

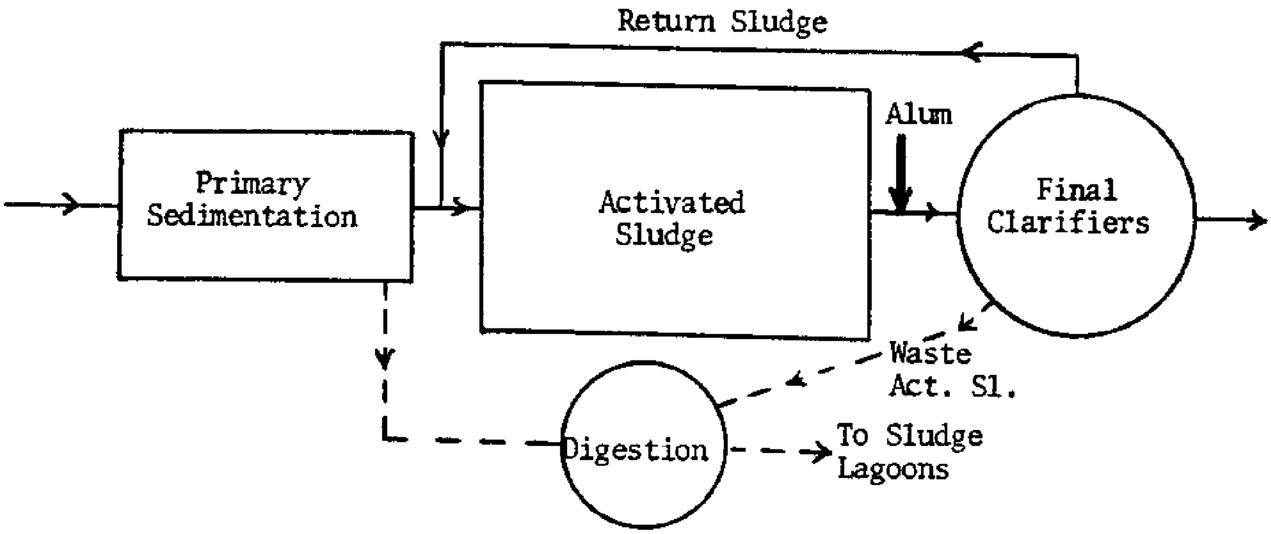
P Removal Efficiency: prior to chemical addition -- 32%
Al:P ≅ 1.6:1 -- 80%

	Cost	Annual Cost	¢/1000 gal.
Capital	$8,620	$ 814	0.51
Operating		2,101	1.31
Chemical		5,497	3.42
		$8,412	5.24¢/1000 gal. or $1.05/lb P removed

Comments: Kewaunee obtained 50-60% P removal with temporary feed of $FeCl_3$ out of drums--Fe:P ≅ 1.5:1. The high influent phosphorus concentration of 28.7 mg/l reported in June 1974 is not confirmed by the state lab's analysis. It is assumed to be reported as PO_4.

Sources: Donahue & Associates, Sheboygan
Dan Roder, City Engineer
Harry Pardowski, STP Supt.
Bruno Haas

KIEL



[Treatment levels are based on data from March 1973-Jan. 1974.]

Design flow: 0.6 MGD
Average flow: 0.75 MGD (Estimated by STP Supt. Walks)

Average influent total P: 18.6 mg/l as P; 116 lb/day P
Average effluent total P: 8.2 mg/l as P; 51 lb/day P

Treatment: POST-BIOLOGICAL
450-700 ml/min. ahead of finals; Al:P ≅ 1:1

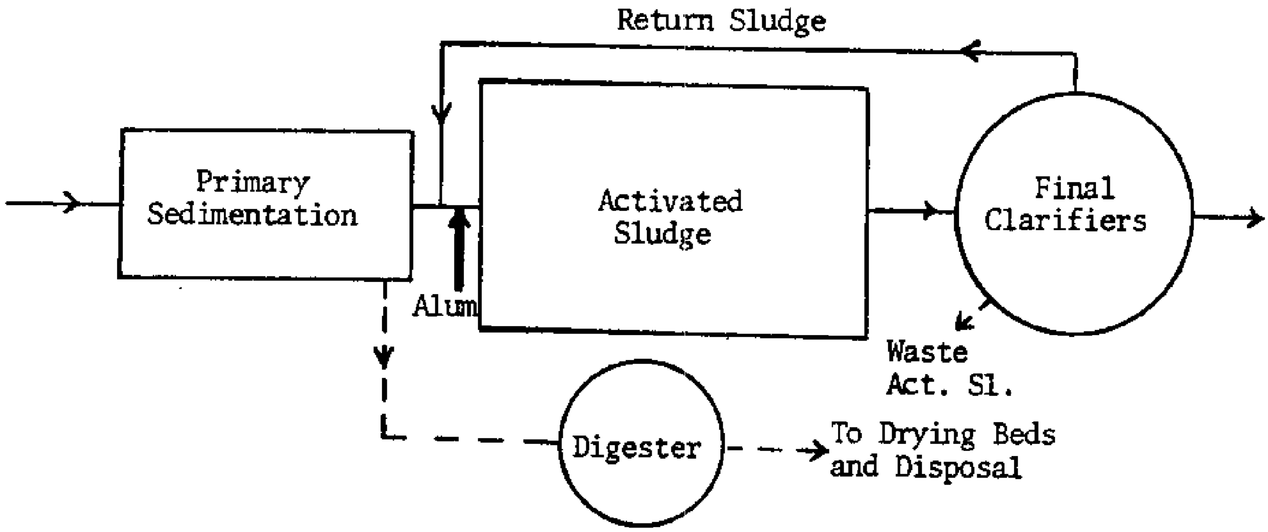
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1:1 -- 56%

	Cost	Annual Cost	¢/1000 gal.
Capital	$17,331	$ 1,487	0.54
Operating		5,766	2.10
Chemical		11,926	4.36
		$19,179	7.00¢/1000 gal. or $0.82/lb P removed

Comments: Highly variable influent phosphorus concentrations are a major problem in trying to obtain efficient phosphorus removal. A dairy industry contributes to the phosphorus load at the plant. The plant is also overloaded hydraulically. The floc is reportedly not settling well in the finals. Mr. Walks tried a polymer, but without success. Sludge increase with alum addition is noted as 2 to 3 times the volume before chemical treatment.

Sources: Donahue & Associates, Sheboygan
Peter Walks, STP Supt.
Mr. Durwockter, City Clerk

KIMBERLY



[Treatment levels are based on data from April 1973-Jan. 1974.]

Design flow: 0.48 MGD
Average flow: 0.538 MGD
Average flow exceeds design flow: 6 of 9 months

Average influent total P: 9.3 mg/l as P; 42 lb/day P
Average effluent total P: 1.4 mg/l as P; 6 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
160 gpd liquid alum ahead of aeration;
Al:P ≅ 2:1

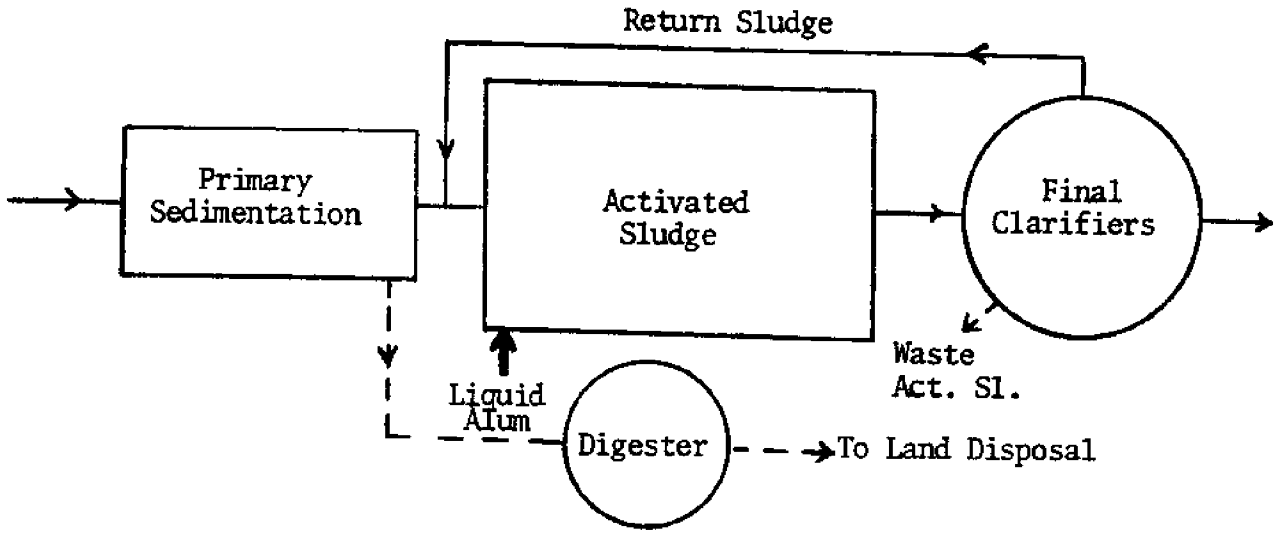
P Removal Efficiency: prior to chemical addition -- 13%
Al:P ≅ 2:1 -- 85%

	Cost	Annual Cost	¢/1000 gal.
Capital	$10,058	$ 949	0.48
Operating		2,501	1.27
Chemical		8,672	4.42
		$12,122	6.17¢/1000 gal. or $0.92/lb P removed

Comments: Operator noted that he might switch the point of alum addition to either the influent to primary or final tanks to keep solids from building up in aeration.

Sources: McMahon & Associates, Menasha
P. Grienier, STP Supt.
K. G. Lochschmidt, Clerk-Treasurer

KOHLER



[Treatment levels are based on data from Oct. 1973-June 1974.]

Design flow: 0.90 MGD
Average flow: 0.553 MGD
Average flow exceeds design flow: 1 of 9 months

Average influent total P: 4.54 mg/l as P; 21 lb/day P
Average effluent total P: 0.96 mg/l as P; 4 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
60-80 gpd liquid alum at aeration;
Al:P ≅ 1.4:1 to 1.8:1

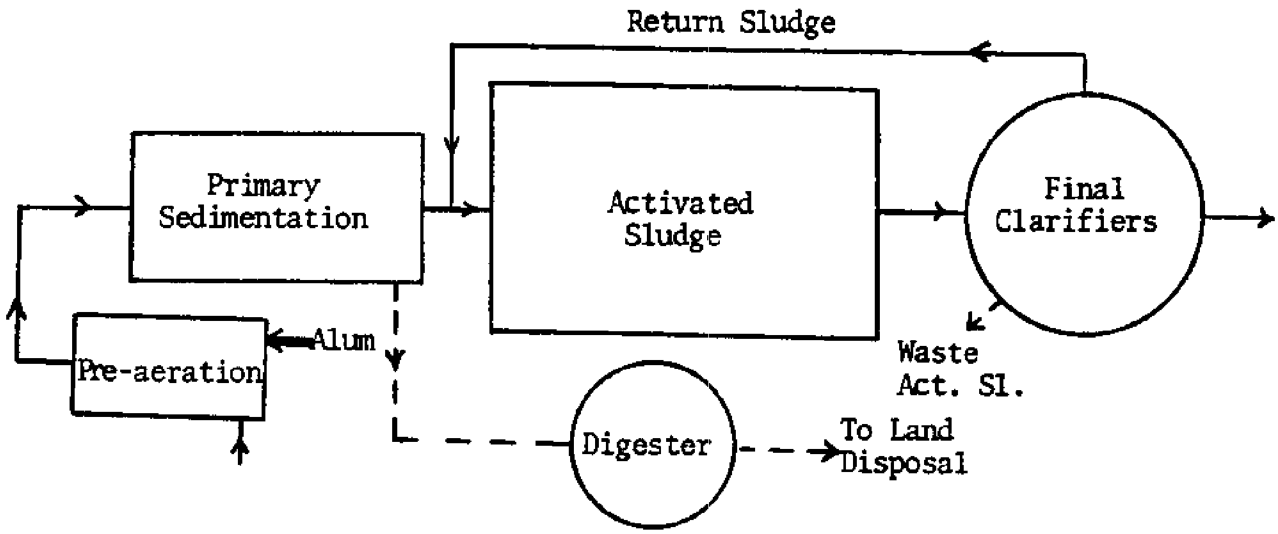
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1.6:1 -- 79%

	Cost	Annual Cost	¢/1000 gal.
Capital	$12,111	$1,143	0.57
Operating		1,263	0.62
Chemical		4,018	1.99
		$6,424	3.18¢/1000 gal. or $1.04/lb P removed

Comments: The influent phosphorus concentration is less than originally expected. Mr. Hoffmann noted that there are no large phosphorus contributing industries. High phosphorus levels reported in 1973 may have been concentrations as PO_4. Operator estimated a 25% increase in sludge with alum addition.

Sources: Donahue & Associates, Sheboygan
Mr. Kopf, City Clerk
Robert Hoffman, STP Supt.
Ray Schuman

LITTLE CHUTE



[Treatment levels are based on data from March 1974-June 1974.]

Design flow: Approximately 0.8 MGD
Average flow: 0.732 MGD
This design flow was not exceeded during this period of record.

Average influent total P: 5.92 mg/1 as P; 36 lb/day P
Average effluent total P: 0.73 mg/1 as P; 4 lb/day P

Treatment: PRIMARY
135 gpd liquid alum at pre-aeration; Al:P ≅ 1.8:1

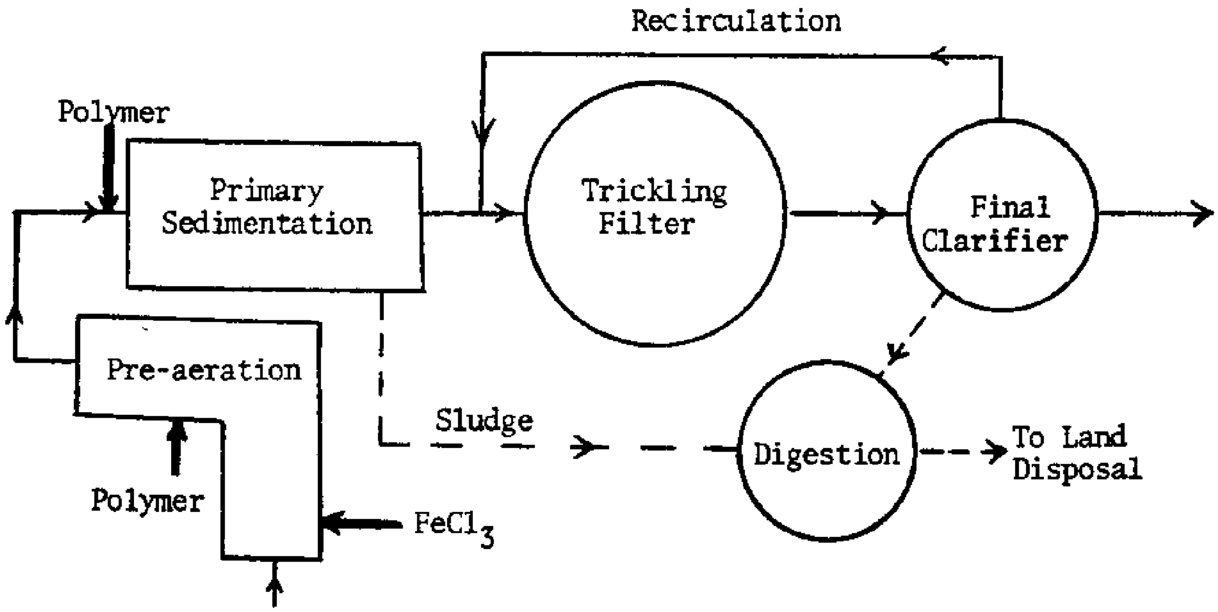
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1.8:1 -- 88%

	Cost	Annual Cost	¢/1000 gal.
Capital	$10,000	$ 944	0.35
Operating		1,697	0.64
Chemical		7,450	2.79
		$10,091	3.78¢/1000 gal. or $0.86/lb P removed

Comments: Mr. Weisky had no problems with a sludge increase because of alum addition. He did note that the sludge was more compact.

Sources: McMahon & Associates, Menasha
Lou Weisky, STP Supt.

MANITOWOC



[Treatment levels are based on data from Jan. 1974-May 1974.]

Design flow: 8.6 MGD
Average flow: 11.03 MGD
Average flow exceeded design flow: 5 of 5 months

Average influent total P: 9.95 mg/l as P; 916 lb/day P
Average effluent total P: 4.03 mg/l as P; 370 lb/day P

Treatment: PRIMARY
1.4 gpm $FeCl_3$ at pre-aeration -- 12 hr/day
0.55 gpm $FeCl_3$ at pre-aeration -- 12 hr/day
Polymer at pre-aeration and ahead of primaries.

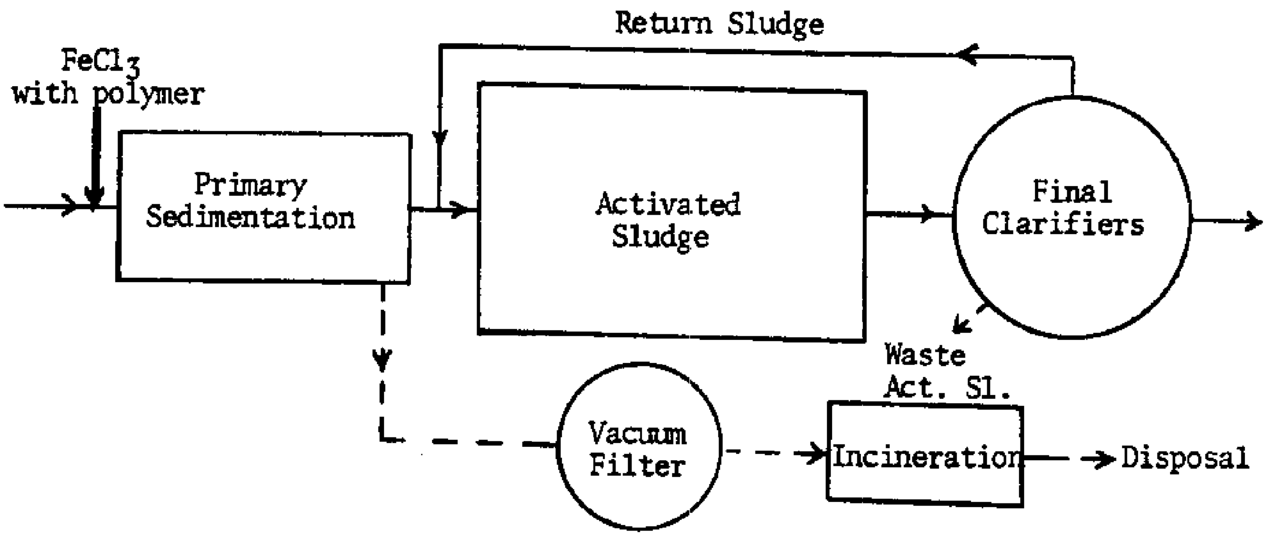
P Removal Efficiency: prior to chemical addition -- 33%
Fe:P $\cong$ 2:1 with polymer -- 60%

	Cost	Annual Cost	¢/1000 gal.
Capital	$80,000	$ 7,551	0.19
Operating		3,160	0.08
Chemical		127,750	3.17
		$138,461	3.44¢/1000 gal. or $0.69/lb P removed

Comments: Treatment plant is badly overloaded. Mr. Templeton noted problems when recirculating sludge. Aluminum and malting industries contribute to the industrial waste load. Future construction will expand plant capacity to 15.5 MGD (avg.) and 30 MGD (max.). New synthetic material trickling filters will be added.

Sources: Richard Manthey, Consoer-Townsend, Engr., Chicago
Leo Templeton, STP Supt.

MARINETTE



[Treatment levels are based on data from Jan. 1974-June 1974.]

Design flow: 4.8 MGD
Average flow: 3.382 MGD
Design flow not exceeded.

Average influent total P: 2.8 mg/l as P; 79 lb/day P
Average effluent total P: 0.5 mg/l as P; 14 lb/day P

Treatment: PRIMARY
Approximately 50 gpd $FeCl_3$ with polymer ahead of primary tanks; Fe:P ≅ 1:1

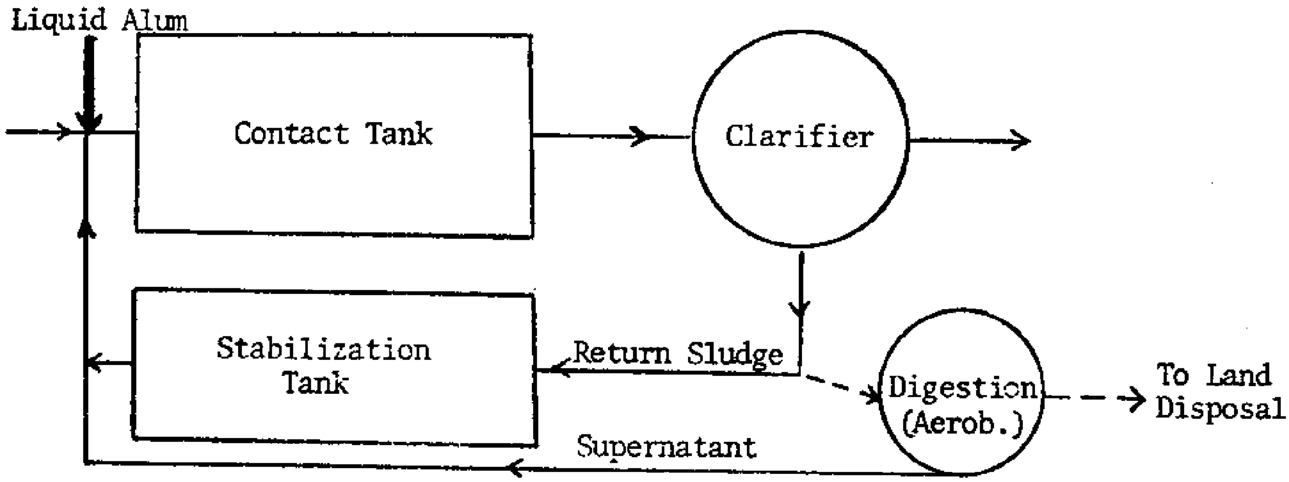
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Fe:P ≅ 1:1 -- 82%

	Cost	Annual Cost	¢/1000 gal.
Capital	$27,115	$ 2,559	0.21
Operating		2,461	0.20
Chemical		19,002	1.54
		$24,022	1.95¢/1000 gal. or $1.01/lb P removed

Comments: Chemical cost as reported is based on an average cost (freight included) for $FeCl_3$ and includes polymer cost. $FeCl_3$ is also probably used in conjunction with vacuum filtration.

Sources: Donahue & Associates, Sheboygan
City Engineer
STP Supt.
City Clerk

MENASHA S.D. 4
(East)



[Treatment levels are based on data from Jan. 1974-June 1974.]

Design flow: 1.5 MGD
Average flow: 0.63 MGD
Design flow not exceeded.

Average influent total P: 13.3 mg/l as P; 70 lb/day P
Average effluent total P: 3.3 mg/l as P; 17 lb/day P

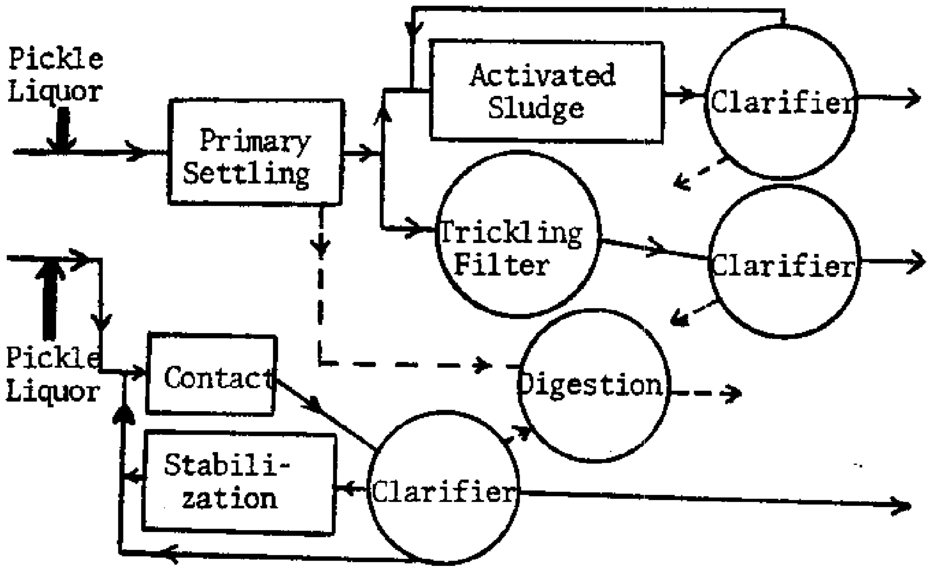
Treatment: CHEMICAL-BIOLOGICAL
Averaging 100 gpd liquid alum; Al:P ≅ 1:1; Influent P concentration as reported above is generally higher than expected average; these averages are based on limited tests--two per month;

P Removal Efficiency: prior to chemical addition -- 55%
Al:P ≅ 1:1 -- 75%

	Cost	Annual Cost	¢/1000 gal.
Capital	$4,000	$ 570	0.25
Operating		1,711	0.74
Chemical		5,381	2.34
		$7,662	3.33¢/1000 gal. or $0.40/lb P removed

Comments: When Al:P ≅ 1.5:1, removals were recorded at approximately 90%. Capital investment is low now and Menasha expects to upgrade chemical feed operation when funds become available. Mr. Quarford noted that with alum addition, the sludge is thicker and heavier.

Sources: McMahon & Associates, Menasha
Jerry Quarford, STP Supt.
Plant Operator



[3 plants at 2 locations--as shown above; each is a 1 MGD plant. The following is the approximate overall treatment level assuming 50% of flow to each plant at Riverside.]

Average flow: 2.77 MGD
Influent total P: 8.7 mg/l as P; 200 lb/day P
Effluent total P: 3.1 mg/l as P; 71 lb/day P

Treatment: PRIMARY
145 pgd waste pickle liquor; Fe:P ≅ 1:1

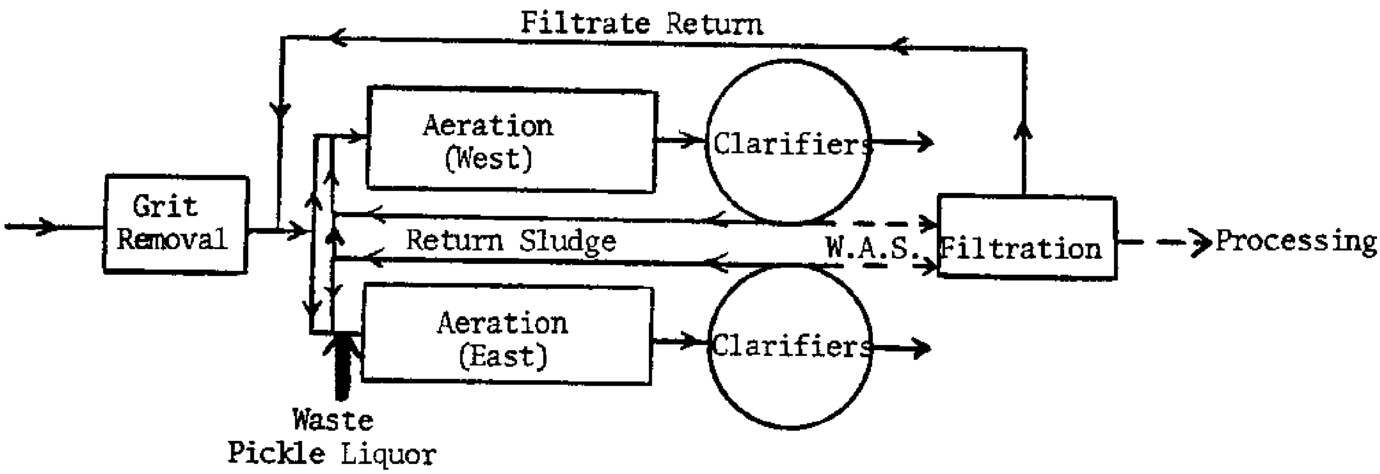
P Removal Efficiency: prior to treatment -- 0%
Fe:P ≅ 1:1 -- 64%

	Cost	Annual Cost	¢/1000 gal.
Capital	$4,540	$ 646	0.06
Operating		2,221	0.22
Chemical		7,410	0.73
		$10,722	1.01¢/1000 gal. or $0.22/lb P removed

Comments: Activated sludge systems are averaging 75% removal, but trickling filter plant is at approximately 35%. Mr. Neterval indicated that polymer use is being considered for the trickling filter plant.

Sources: Mr. Dick Neterval, STP Supt.

MILWAUKEE - JONES ISLAND



[Treatment levels are based on data from Jan. 1973-June 1974.]

	West	East
Design flow:	85 MGD	115 MGD
Average flow:	68.11 MGD	91.96 MGD
Average influent total P:	5.6 mg/l	5.6 mg/l
Average effluent total P:	0.8 mg/l	0.44 mg/l
Average % P Removal:	86%	92%
Average influent lb/day P:	3181	4295
Average effluent lb/day P:	454	337

Treatment: CHEMICAL-BIOLOGICAL
10,000 gpd waste pickle liquor at east plant aeration; Approximately 6% Fe filtrate return; Fe:P ≅ 2:1 (east plant only)

Approximate Cost (based on east plant only): 0.02¢/1000 gal. or $0.005/lb P removed

Discussion: The Milwaukee plant was involved in an EPA study on iron addition for phosphorus removal. Milwaukee began treating for phosphorus in approximately 1970. After course screening, grit chamber treatment, and fine screening, the flow is divided as above. The inflow to the east plant is then combined with the return flow. It is at this point where approximately 10,000 gal/day of waste pickle liquor is added for phosphorus removal (estimated Fe:P ≅ 2:1). The waste water proceeds thru activated sludge and sedimentation. The sludge is conditioned with $FeCl_3$ and dried (dewatered). The final product is a fertilizer--Milorganite--which is packaged at the plant and sold. The west plant receives filtrate with approximately 6% Fe, which provides excellent removals. The plant has a very unique and profitable system of treatment for phosphorus. The possibility of the use of iron to remove phosphorus was pursued for the following reasons:

MILWAUKEE - JONES ISLAND (Cont.)

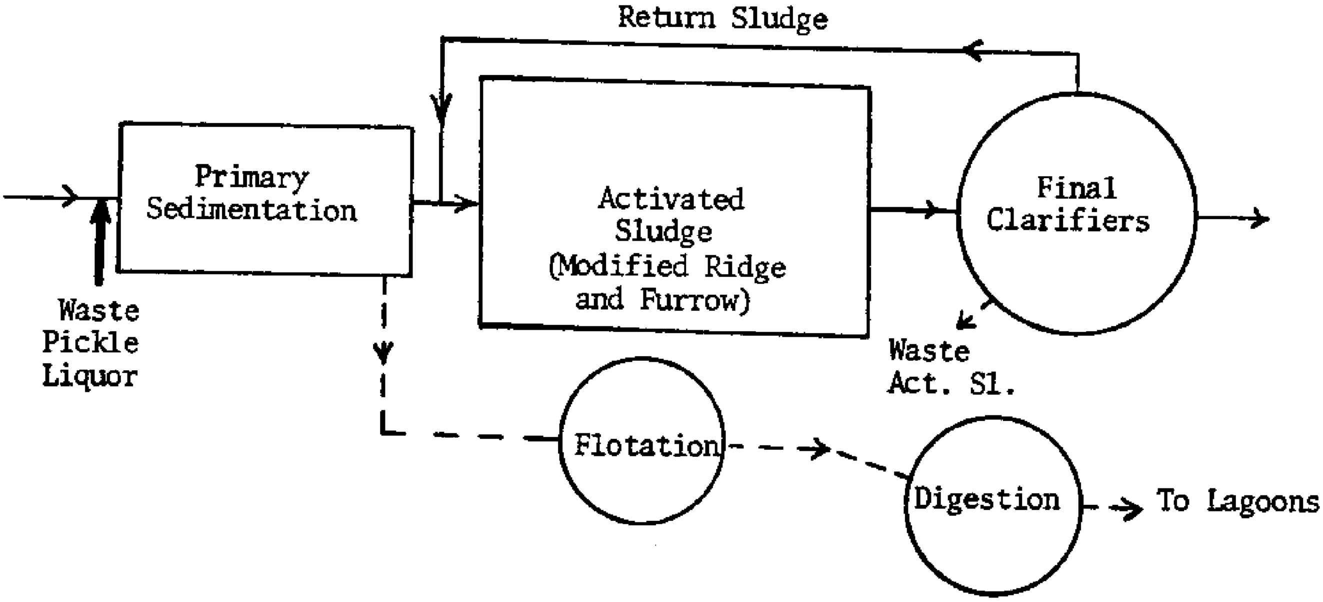
1. No extra sludge problem (as opposed to alum addition)
2. Consistent with existing sludge disposal methods
3. Success experienced at a small A.S. plant
4. Pickle liquor available locally (A. O. Smith)
5. Inexpensive (relatively)

The Commission found the A. O. Smith Company to be extremely cooperative. As part of the agreement, the plant would receive all waste pickle liquor from A. O. Smith. As part of this "joint effort", equipment necessary for iron addition was designed and constructed. The addition of two more 20,000 gallon storage tanks provides a total storage capacity of 100,000 gallons. This large capacity facilitates a more flexible hauling schedule for A. O. Smith and specifically avoids having to pay high overtime wages for delivery during A. O. Smith shutdown periods. The agreement will continue to 1976 under the current 5-year contract. The sewerage commission is hopeful for an extension of the agreement in a similar form.

Equipment and chemical (pickle liquor) costs to Milwaukee are relatively small compared to labor, maintenance, and power costs and are assumed negligible for this analysis. Treatment percentages have been excellent (90+%) and the plant has experienced a decrease in the $FeCl_3$ needed for sludge conditioning. This represents a significant cost savings to the plant. Poor removals of about 50% were reported by the state lab for June and July. Phosphorus removal equipment was down at this time. The values for June and July are not included in this analysis.

Sources: Mr. Lawrence Ernest, STP Supt.

MILWAUKEE SOUTH SHORE



[Treatment levels are based on state lab data only; in interviews with Mr. Dedinsky and Mr. Peyont, they reported P removals of 45-50%. Thus, phosphorus removal efficiencies can be expected to be somewhat lower than those indicated by the limited data used here.]

Design flow: 120 MGD
Average flow: 55.44 MGD
Design flow not exceeded.

Average influent total P: 6.6 mg/l as P; 3052 lb/day P
Average effluent total P: 2.7 mg/l as P; 1248 lb/day P

Treatment: PRIMARY
Present system is set up mainly for neutralization; any phosphorus removal is essentially a side benefit. Present system -- 3600 gpd waste pickly liquor (3-4% Fe) ahead of primaries; Fe:P ≅ 0.5:1

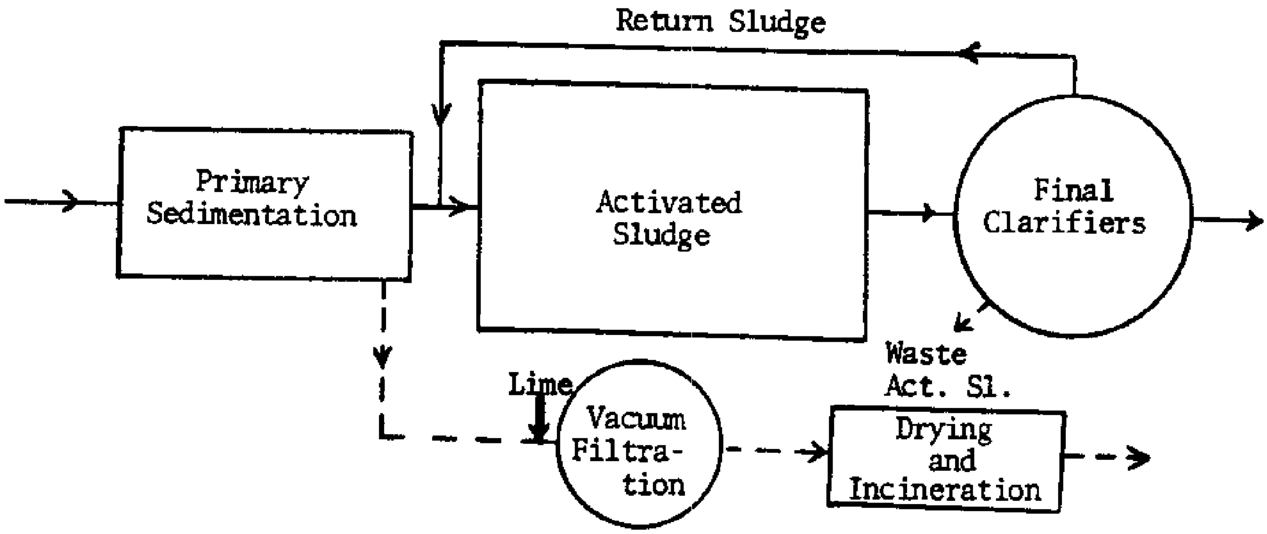
P Removal Efficiency: Fe:P ≅ 0.5:1 -- 59%

	Cost	Annual Cost	¢/1000 gal.
Capital	$558,000	$47,882	0.24
Operating		19,000	0.09
Chemical	negligible		
		$66,882	0.33¢/1000 gal.

Comments: The full scale treatment system will provide the capability of adding pickle liquor at the primaries and ahead of the aeration tanks. The above are expected costs of the full scale facilities.

Sources: Mr. Dedinsky, South Shore plant
Mr. Peyont, South Shore plant

NEENAH-MENASHA



[Treatment levels are based on data from August 1973-June 1974.]

Design flow: 18 MGD
Average flow: 13.407 MGD
Design flow not exceeded for this period of record.

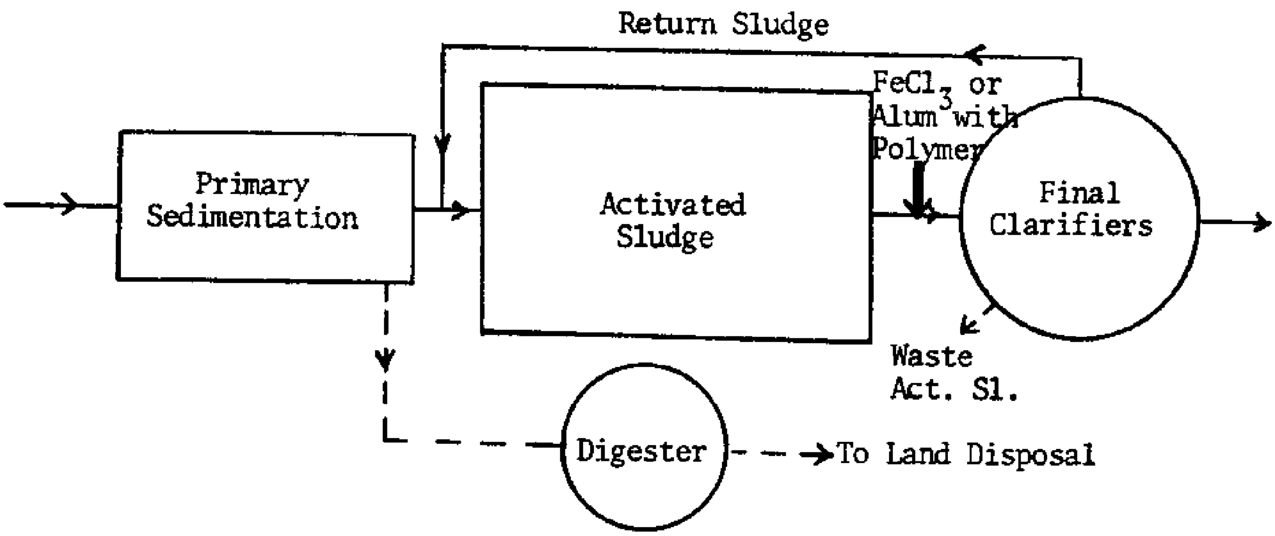
Average influent total P: 3.5 mg/l as P; 391 lb/day P
Average effluent total P: 1.32 mg/l as P; 147 lb/day P

No treatment required to date; 62% P Removal.

Comments: A major plant expansion has been put off because of a lack of federal funding. Neenah-Menasha may eventually have to add nutrients to achieve an efficient biological system. (Influent BOD concentrations now average approximately 200 mg/l.) Mr. Shulke noted that he has used polymer on occasion for suspended solids control.

Sources: Mr. Shulke, STP Supt.

NEW HOLSTEIN



Treatment levels are based on performance at the old plant--activated sludge system with $FeCl_3$ addition for phosphorus removal. The new 1.3 MGD plant became operational in May 1974 with an average flow of 0.6 MGD (May-July). No phosphorus tests have been run at the new plant to date. Liquid alum and polymer are added ahead of the final clarifier with a dose of 20 gpd alum reported.

Average flow: 0.309 MGD
Average influent total P: 13.5 mg/l as P; 35 lb/day P
Average effluent total P: 4.4 mg/l as P; 11 lb/day P
[Based on data reported in a personal interview.]

Treatment: POST-BIOLOGICAL
Approximately 25 gpd $FeCl_3$ out of drums ahead of finals; Fe:P = 1:1

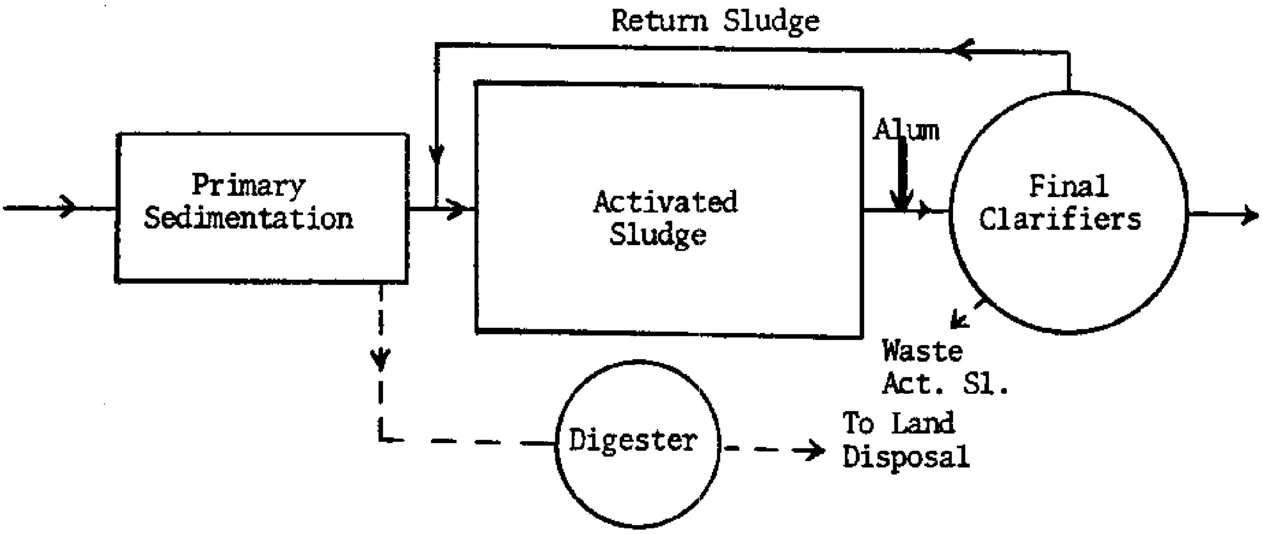
P Removal Efficiency: prior to chemical addition -- 20%
Fe:P = 1:1 -- 69%

	Annual Cost	¢/1000 gal.
Capital	--	--
Operating	$1,504	1.33
Chemical	7,200	6.38
	$8,704	7.71¢/1000 gal. or $0.99/lb P removed

Comments: Phosphorus removal capital cost at the new plant is $6,000. The reported alum dose seems low at the new plant, but tests have not been run yet.

Sources: Robert E. Lee & Associates, Green Bay
Lee Tikalsky
Roger Kapellen

NEW LONDON



[Treatment levels are based on data from Dec. 1973-June 1974.]

Design flow: 1.25 MGD
Average flow: 0.789 MGD
Design flow not exceeded for this period of record

Average influent total P: 16.9 mg/l as P; 111 lb/day P
Average effluent total P: 3.44 mg/l as P; 23 lb/day P

Treatment: POST-BIOLOGICAL
200 gpd liquid alum ahead of finals; Al:P ≅ 1:1

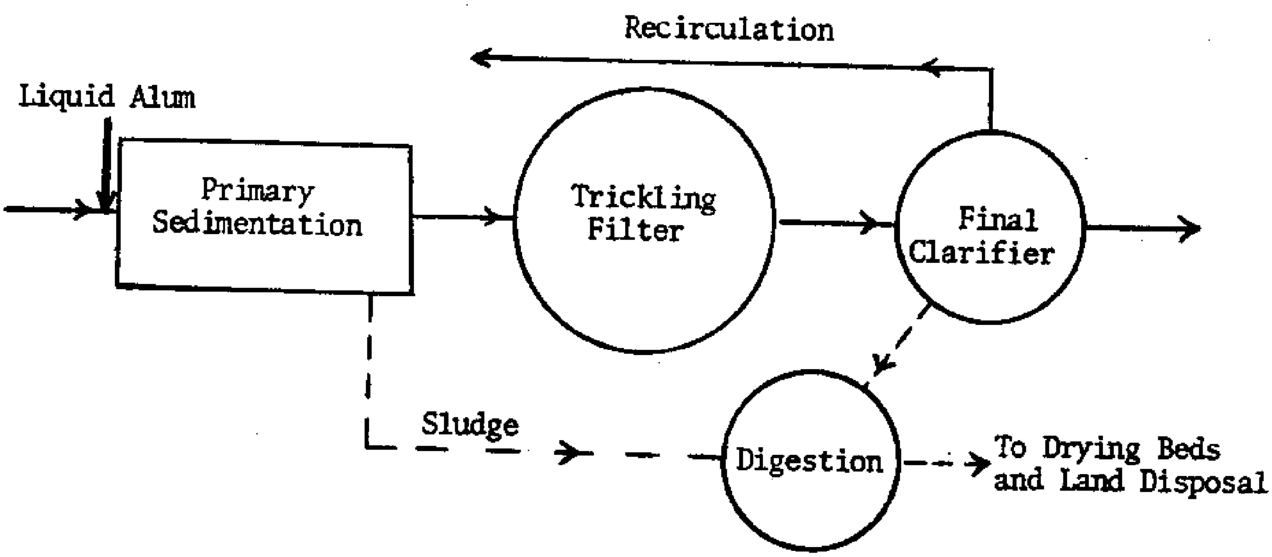
P Removal Efficiency: prior to chemical addition -- 21%
Al:P ≅ 1:1 -- 80%

	Cost	Annual Cost	¢/1000 gal.
Capital	$17,385	$ 1,492	0.52
Operating		1,651	0.57
Chemical		11,235	3.90
		$14,378	4.99¢/1000 gal. or $0.45/lb P removed

Comments: Mr. Martin noted more sludge gallons with chemical addition and also noted a more compact sludge. A dairy industry contributes to the high influent phosphorus concentration. New London awaits funds to expand phosphorus treatment facilities.

Sources: Donahue & Associates, Sheboygan
Bob Martin, Director of Public Works
Ernie Schultz, STP operator

NORTH FOND DU LAC



[Treatment levels are based on data of Feb., July, Sept., 1973.]

Design flow: 0.40 MGD
Average flow: 0.457 MGD

Average influent total P: 6.7 mg/l as P; 25 lb/day P
Average effluent total P: 4.5 mg/l as P; 17 lb/day P

Treatment: PRIMARY
70-100 gpd liquid alum at primary tank.
Al:P ≅ 1.4:1 to 1.8:1

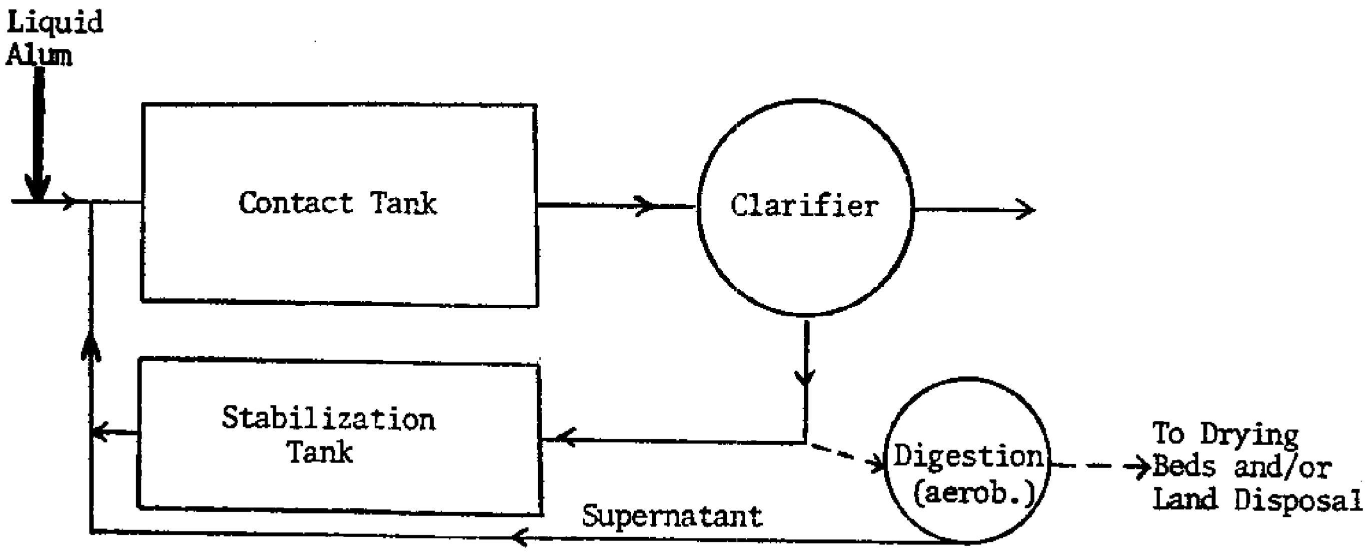
P Removal Efficiency: prior to chemical treatment -- 20% (assumed)
Al:P ≅ 1.4:1 -- 33%

	Cost	Annual Cost	¢/1000 gal.
Capital	$19,258	$1,652	0.99
Operating		2,101	1.26
Chemical		4,336	2.60
		$8,089	4.85¢/1000 gal. or $2.77/lb P removed

Comments: Engineers recommended Al:P = 2:1. No data from operator reports is shown here, but Mr. Rescka quoted 30-35% removal, confirmed by the state lab results.

Sources: Donahue & Associates, Sheboygan
Robert Hinn, STP Supt.
Truman LeMieux, city clerk
T. Rescka, STP operator

NORTH PARK S.D.



[Treatment levels are based on data from Nov. 1973-June 1974.]

Design flow: 0.90 MGD
Average flow: 1.439 MGD
Average flow exceeds design flow: 8 of 8 months

Average influent total P: 5.8 mg/l as P; 70 lb/day P
Average effluent total P: 0.48 mg/l as P; 6 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
110-120 gpd liquid alum at lift station (approximately 3/4 mile from plant); Al:P ≅ 0.8:1 to 1:1

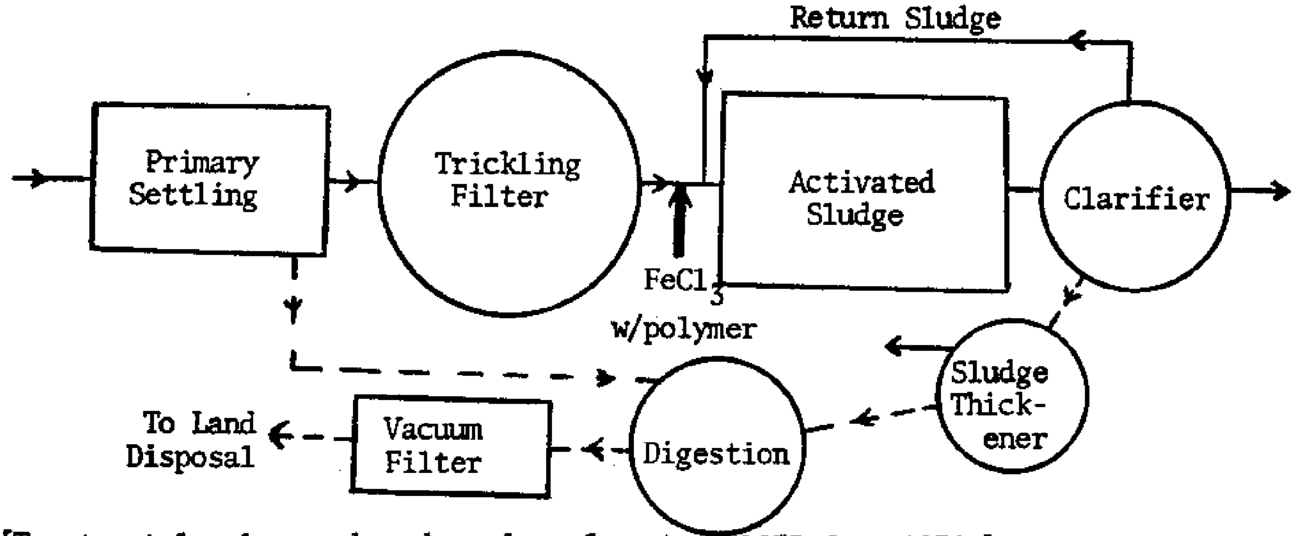
P Removal Efficiency: prior to chemical addition -- 11%
Al:P ≅ 0.8:1 -- 92%

	Cost	Annual Cost	¢/1000 gal.
Capital	$16,660	$ 1,430	0.27
Operating		4,206	0.80
Chemical		6,504	1.24
		$12,140	2.31¢/1000 gal. or $0.52/lb P removed

Comments: Chemical dose for liquid alum seems to be much less than that expected by the engineers (Al:P ≅ 2:1). Mr. Cruz noted increased sludge volume and better compaction and dewatering with alum addition.

Sources: Iverson & Associates, Elkhorn
George Cruz, STP Supt.

OCONTO



[Treatment levels are based on data from Aug. 1973-June 1974.]

Design flow: 3 MGD
Average flow: 1.396 MGD
Design flow not exceeded

Average influent total P: 4.6 mg/l as P; 54 lb/day P
Average effluent total P: 1.6 mg/l as P; 19 lb/day P

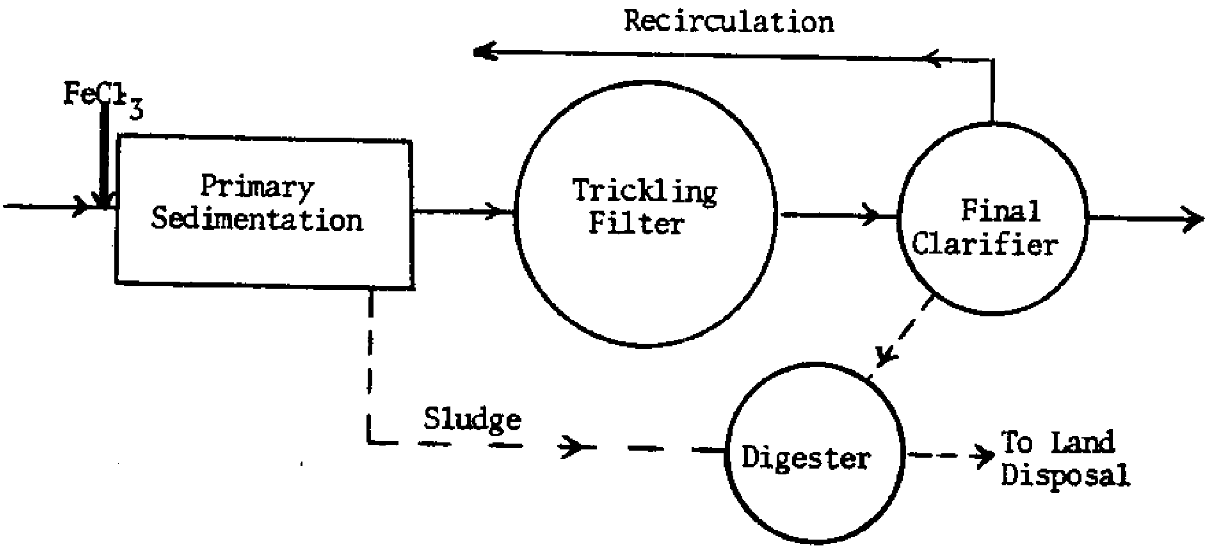
Treatment: CHEMICAL-BIOLOGICAL
50 mg/l $FeCl_3$ at day tank ahead of aeration; Fe:P ≅ 2:1 to 3:1
P Removal Efficiency: prior to chemical addition -- 25% (assumed)
Fe:P ≅ 2.5:1 -- 65%

	Cost	Annual Cost	¢/1000 gal.
Capital	$35,300	$ 3,332	0.30
Operating		10,531	2.07
Chemical--$FeCl_3$		10,869	2.13
--Polymer		4,818	0.94
		$29,550	5.44¢/1000 gal. or $2.31/lb P removed

Comments: The plant was recently upgraded--additions of aeration, sludge thickener, vacuum filter, and chemical treatment. Fe:P dose seems relatively high.

Sources: Foth & Van Dyke & Associates, Green Bay
John Viestenc, Utility Commission

OCONTO FALLS



[Treatment levels are based on data from May 1973-June 1974.]

Design flow: 0.160 MGD (max. 0.225 MGD)
Average flow: 0.206 MGD
Average flow exceeds design flow: 13 of 14 months
Average flow exceeds maximum design flow: 5 of 14 months

Average influent total P: 6.9 mg/l as P; 12 lb/day P
Average effluent total P: 1.7 mg/l as P; 3 lb/day P

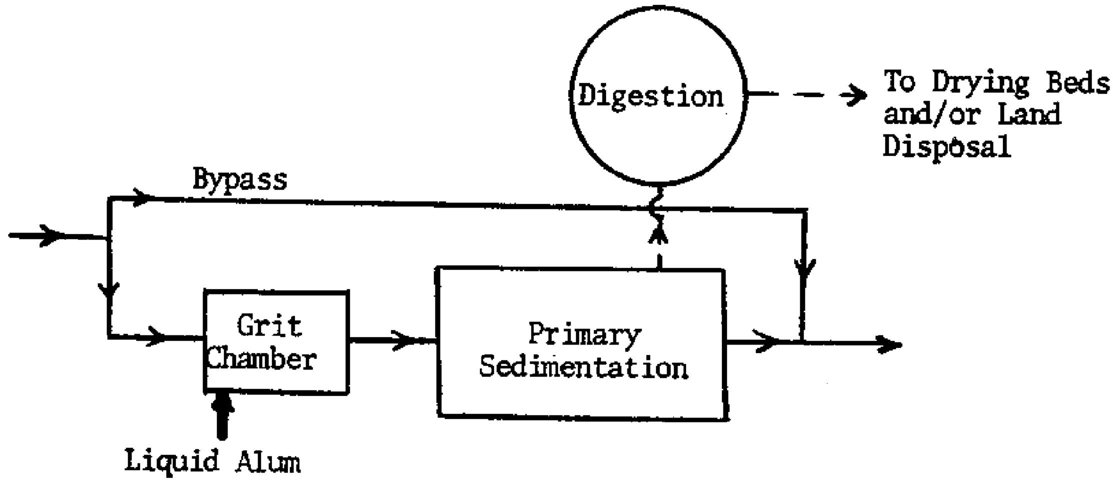
Treatment: PRIMARY
Approximately 25 gpd $FeCl_3$ (out of drums) at primaries;
Fe:P = 3:1

P Removal Efficiency: prior to chemical addition -- 20% (assumed)
Fe:P = 3:1 -- 75%

	Cost	Annual Cost	¢/1000 gal.
Capital	$340	$ 83	0.11
Operating		1,869	2.48
Chemical		6,844	9.10
		$8,796	11.69¢/1000 gal. or $2.68/lb P removed

Comments: A new combined treatment plant is planned for the future. Because of the character of the industrial wastes in the new plant, phosphorus may have to be added for efficient biological activity. The operator reported pump problems with ferric, but a large capital investment would be required for alum storage facilities.

Sources: Mr. John Turner
Mr. Ervin Peitersen



[Treatment levels are based on data from Oct. 1973-June 1974.]

Design flow: 12 MGD
Average flow: 10.947 MGD
Average flow exceeds design flow: 4 of 9 months

Average influent total P: 5.2 mg/l as P; 475 lb/day P
Average effluent total P: 1.73 mg/l as P; 158 lb/day P

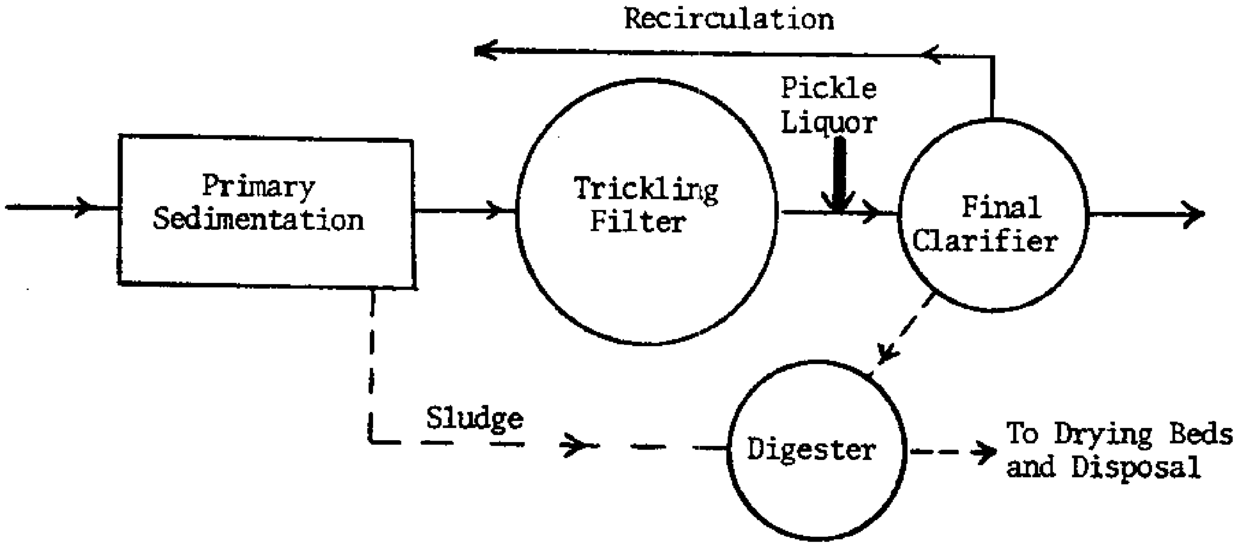
Treatment: PRIMARY
1300 gpd liquid alum at grit chamber; Al:P $\cong$ 1.3:1
P Removal Efficiency: prior to chemical addition -- 10%
Al:P $\cong$ 1.3:1 -- 67%

	Cost	Annual Cost	¢/1000 gal.
Capital	$35,000	$ 3,003	0.08
Operating		3,802	0.10
Chemical		69,182	1.73
Sludge Disposal		27,375	0.68
		$103,362	2.57¢/1000 gal. or $0.89/lb P removed

Comments: Digestion has been out of operation and raw sludge has been hauled. This is hauled under contract at 1.5¢/gal; Mr. Norwicki indicated that sludge was increased by 5000 gpd because of alum addition.

Sources: Donahue & Associates, Sheboygan
Leo Norwicki, STP Supt.

PESHTIGO



[Treatment levels are based on data from Feb. 1973-June 1974.]

Design flow: 0.40 MGD
Average flow: 0.495 MGD
Average flow exceeds design flow: 14 of 16 months

Average influent total P: 4.95 mg/l as P; 29 lb/day P
Average effluent total P: 1.75 mg/l as P; 7 lb/day P

Treatment: POST-BIOLOGICAL
Approximately 50 gpd $FeCl_3$ (from drums) ahead of final; Fe:P ≈ 2.5:1

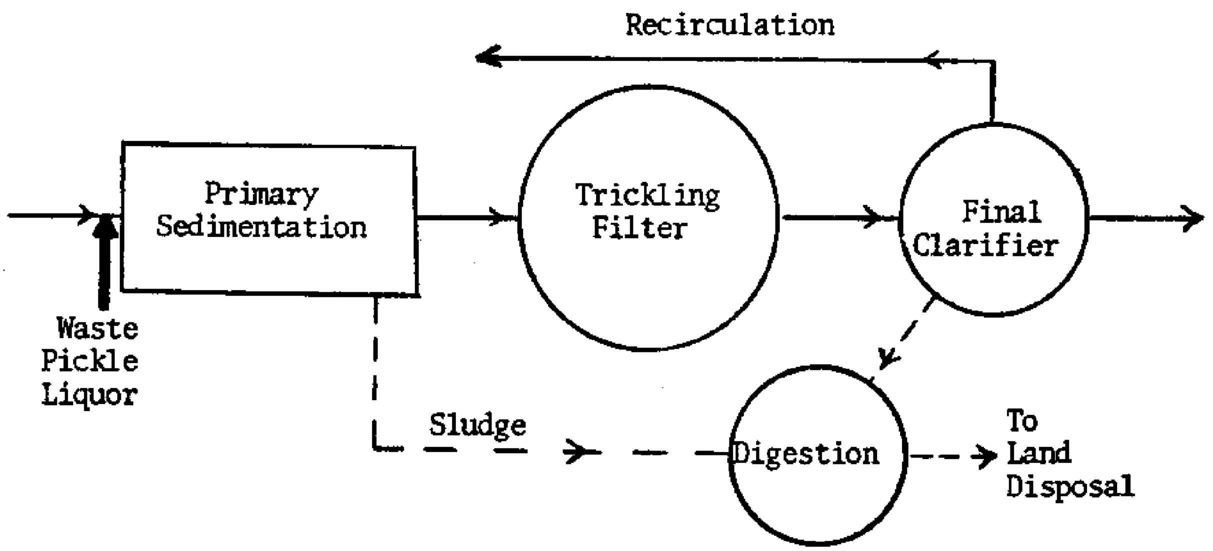
P Removal Efficiency: prior to chemical addition -- 20% (assumed)
Fe:P ≈ 2.5:1 -- 65%

	Annual Cost	¢/1000 gal.
Capital	$ 200	0.11
Operating	1,556	0.86
Chemical	15,878	8.79
	$17,634	9.76¢/1000 gal. or $2.20/lb P removed

Comments: New plant will incorporate an aerated lagoon system for combined treatment. 4-5 MGD plant may be operating near the critical nutrient level for the biological system. $FeCl_3$ with polymer is expected to be used for phosphorus removal.

Sources: Donahue & Associates, Sheboygan
Charles Bertrand, STP Supt.

PLYMOUTH



[Treatment levels are based on data from Nov. 1973-June 1974.]

Design flow: 0.6 MGD (Max. 1-1.3 MGD)
Average flow: 1.02 MGD
Average flow exceeds design flow: 8 of 8 months

Average influent total P: 9.4 mg/l as P; 80 lb/day P
Average effluent total P: 4.3 mg/l as P; 36 lb/day P

Treatment: PRIMARY
160 gpd waste pickle liquor ahead of primary tank; Fe:P $\cong$ 2.5:1

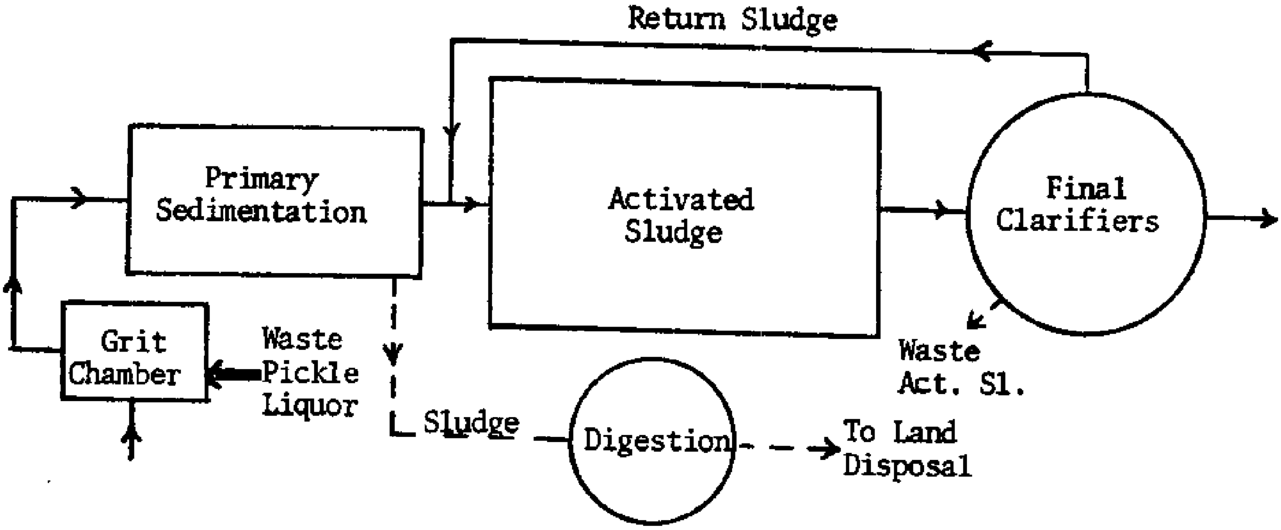
P Removal Efficiency: prior to chemical addition -- 4%
Fe:P $\cong$ 2.5:1 -- 54%

	Cost	Annual Cost	¢/1000 gal.
Capital	$17,610	$ 1,662	0.45
Operating		2,372	0.64
Chemical		10,218	2.74
		$14,252	3.83¢/1000 gal. or $0.89/lb P removed

Comments: It seems that alum was dosed at Al:P $\cong$ 1:1 with essentially the same average removal and cost as the present system. A dairy industry contributes to the waste load at the plant. The proposed new plant would be activated sludge with tertiary filtration.

Sources: Donahue & Associates, Sheboygan
Chet Harrison, STP Supt.
Dan Roder
John Hodge, Operator

PORT WASHINGTON



[Treatment levels are based on data from July 1973-June 1974.]

Design flow: 2.5 MGD (Max. 4.0 MGD)
Average flow: 1.495
Design flow was not exceeded.

Average influent total P: 10.7 mg/l as P; 133 lb/day P
Average effluent total P: 1.64 mg/l as P; 20 lb/day P

Treatment: PRIMARY
150-160 gpd waste pickle liquor at grit chamber; Fe:P $\cong$ 1.5:1

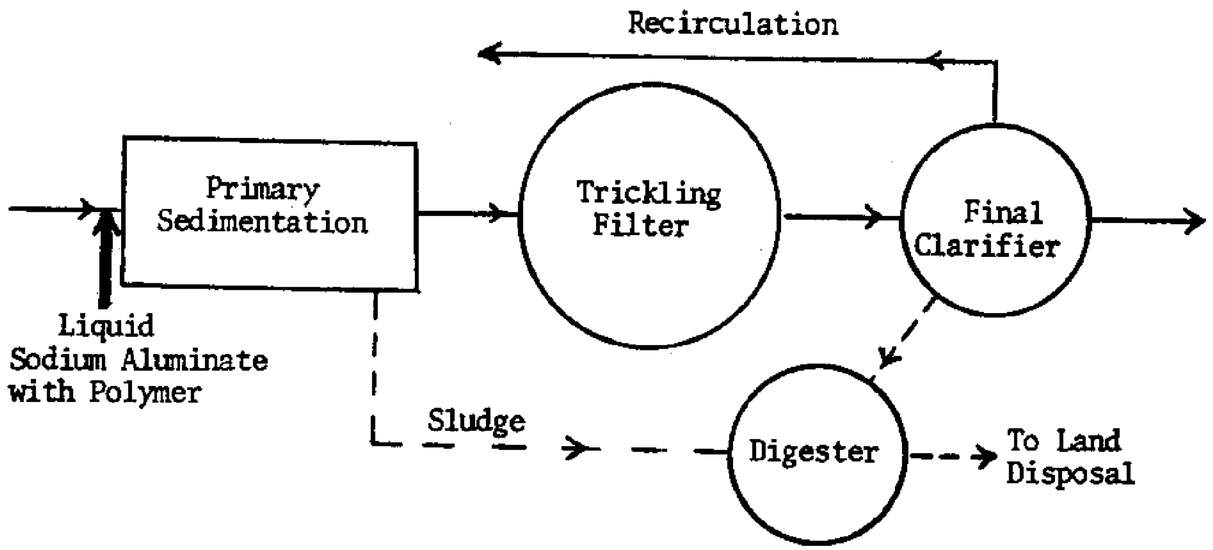
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Fe:P $\cong$ 1.5:1 -- 85%

	Cost	Annual Cost	¢/1000 gal.
Capital	$7,566	$ 714	0.13
Operating		1,726	0.32
Chemical		9,605	1.76
		$12,045	2.21¢/1000 gal. or $0.29/lb P removed

Comments: Originally, sodium aluminate addition was planned. Tank was fiberglassed to accommodate waste pickle liquor.

Sources: Donahue & Associates, Sheboygan
Ed Sauer, STP Supt.
Mr. Murphy, City Clerk

PORTAGE



[Treatment levels are based on data from Sept. 1973--assumed to be typical of plant performance.]

Design flow: 1.2 MGD
Average flow: 0.9 MGD

Average influent total P: 8.5 mg/1 as P; 64 lb/day P
Average effluent total P: 2.9 mg/1 as P; 22 lb/day P

Treatment: PRIMARY
64 gpd liquid sodium aluminate with polymer ahead of primary; Al:P $\cong$ 1.2:1

P Removal Efficiency: prior to chemical addition -- 21%
Al:P $\cong$ 1.2:1 with polymer -- 66%

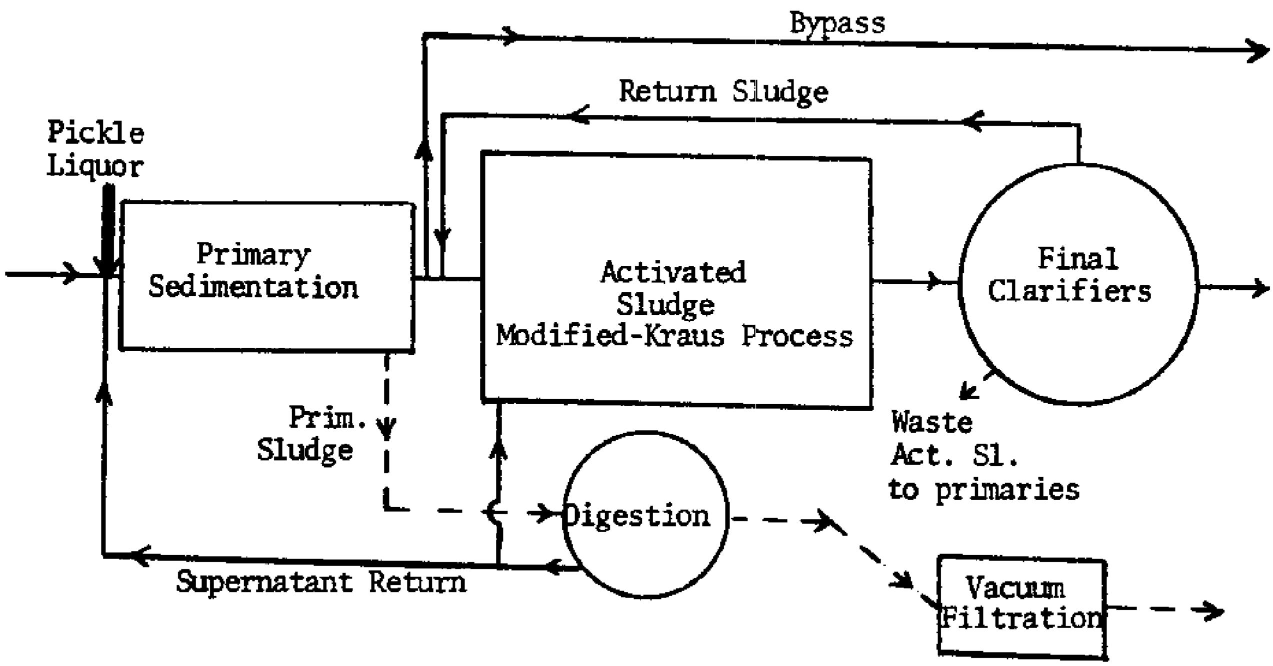
	Cost	Annual Cost	¢/1000 gal.
Capital	$5,000	$ 712	0.22
Operating		2,477	0.75
Chemical		21,424	6.52
		$24,613	7.49¢/1000 gal. or $1.60/lb P removed

Comments: Portage is located at the intersection of two major river systems:

	P Removal Required?
Fox River (Lake Michigan Basin)	YES
Wisconsin River (Mississippi River System)	NO

The present plant is located on the Fox River. Portage is waiting funds for a complete plant renovation.

Sources: General Engineering, Portage
Fred Hearder, Director of Public Works



[Treatment levels are based on data from June 1973-April 1974.]

Design flow: Primary--23 MGD
Secondary--12 MGD
Average flow: 23.854 MGD
Average flow exceeds design flow (Prim.): 6 of 11 months

Average influent total P: 4.4 mg/l as P; 875 lb/day P
Average effluent total P: 2.8 mg/l as P; 557 lb/day P

Treatment: PRIMARY
2000 gpd waste pickle liquor before primaries;
Approximately 12% Fe (Fe:P ≅ 2.5:1)

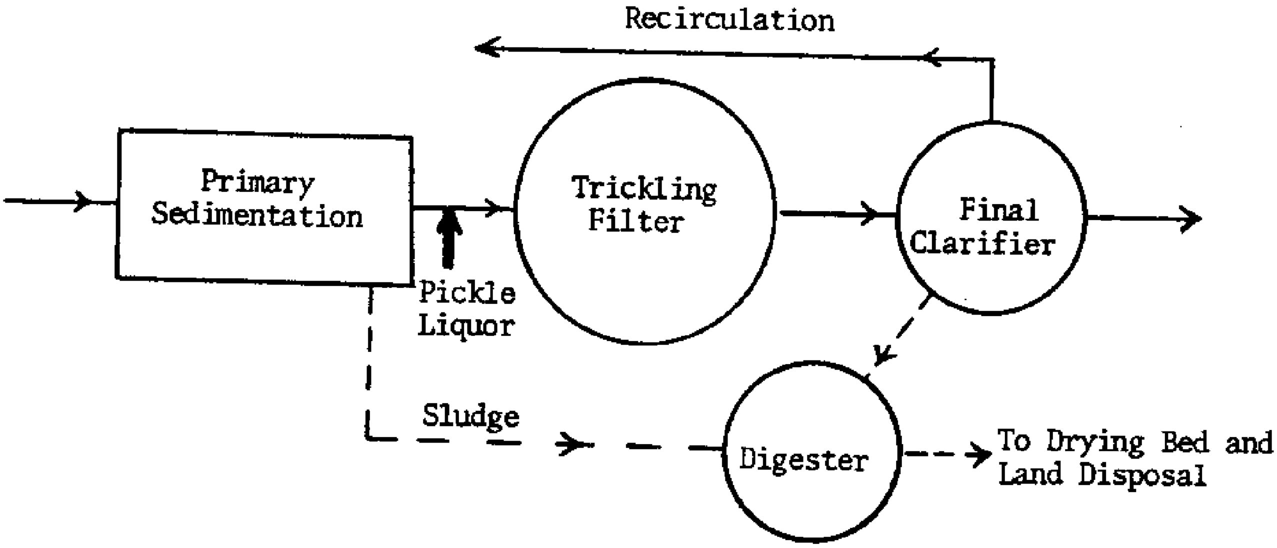
P Removal Efficiency: prior to chemical addition -- 8%
Fe:P ≅ 2.5:1 -- 36%

Approximate cost: 0.08¢/1000 gal. or $0.06/lb P removed.

Comments: Expecting construction soon to increase secondary treatment capacity to 30 MGD. For that part of the flow which undergoes secondary treatment, a 64% reduction in phosphorus is reported (Jan.-May 1974). This leaves a secondary effluent phosphorus concentration of 1.4 mg/l as P. Mr. Budrys noted that the return to the primary tanks prevents the overall phosphorus removal efficiency from being higher. $FeCl_3$ is used in conjunction with vacuum filtration.

Sources: Gary K. Coates, Engineer-Manager
Stan Budrys, STP Supt.

RIPON



[Treatment levels are based on data from Feb. 1974-June 1974.]

Design flow: 0.675 MGD (Avg.)
Average flow: 1.697 MGD
Average flow exceeded design flow: 5 of 5 months

Average influent total P: 5.9 mg/l as P; 84 lb/day P
Average effluent total P: 2.3 mg/l as P; 32 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
15 gph waste pickle liquor (approximately 10% Fe) ahead of trickling filter; Fe:P ≅ 4.5:1

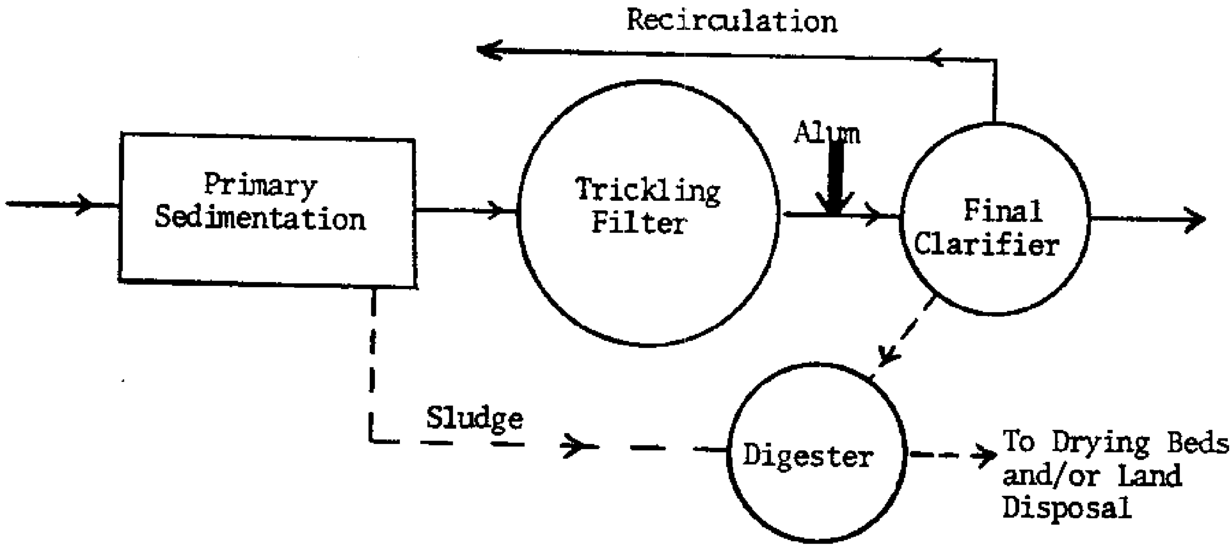
P Removal Efficiency: prior to chemical addition -- 20% (assumed)
Fe:P ≅ 4.5:1 -- 61%

	Cost	Annual Cost	¢/1000 gal.
Capital	$14,194	$ 1,340	0.22
Operating		1,282	0.21
Chemical		23,132	3.73
		$25,754	4.16¢/1000 gal. or $1.36/lb P removed

Comments: $FeCl_3$ was used at Ripon from March 1973-Dec. 1973 (Fe:P ≅ 2:1). Mr. Scheer noted that phosphorus removals were higher when a local industry's pickle plating waste reaches the plant. Mr. Scheer indicated that the trickling filter was badly overloaded. He also reported pump problems with $FeCl_3$ use. Increased sludge volume and % solids were noted with chemical addition. Reported pickle liquor dose seems high.

Sources: Donahue & Associates, Sheboygan
Claude Lee, City Engineer
Louis Scheer, STP Supt.

SHAWANO
(city)



[Treatment levels are based on data from April 1973-December 1973.]

Average flow: 1.0 MGD (estimate)

Average influent total P: 13.3 mg/l as P; 111 lb/day P
Average effluent total P: 9.8 mg/l as P; 82 lb/day P

Treatment: POST-BIOLOGICAL
100-200 lb/day dry alum ahead of finals; Al:P $\cong$ 0.5:1

P Removal Efficiency: prior to chemical addition -- 15%
Al:P $\cong$ 0.5:1 -- 26%

Approximate cost: 1.32¢/1000 gal. or $0.46/lb P removed

Comments: The above information pertains to the old plant of the city of Shawano. This plant will eventually be abandoned as the new Shawano Sanitary District plant becomes operational. The cost reported here involves the cost of the alum, mixer and feed equipment and estimated labor cost. After July 1, 1974, the alum was dosed at the primaries. The new plant will be 3 MGD activated sludge system employing the Zimpro wet air oxidation sludge processing. Cost estimates for phosphorus removal are as follows:

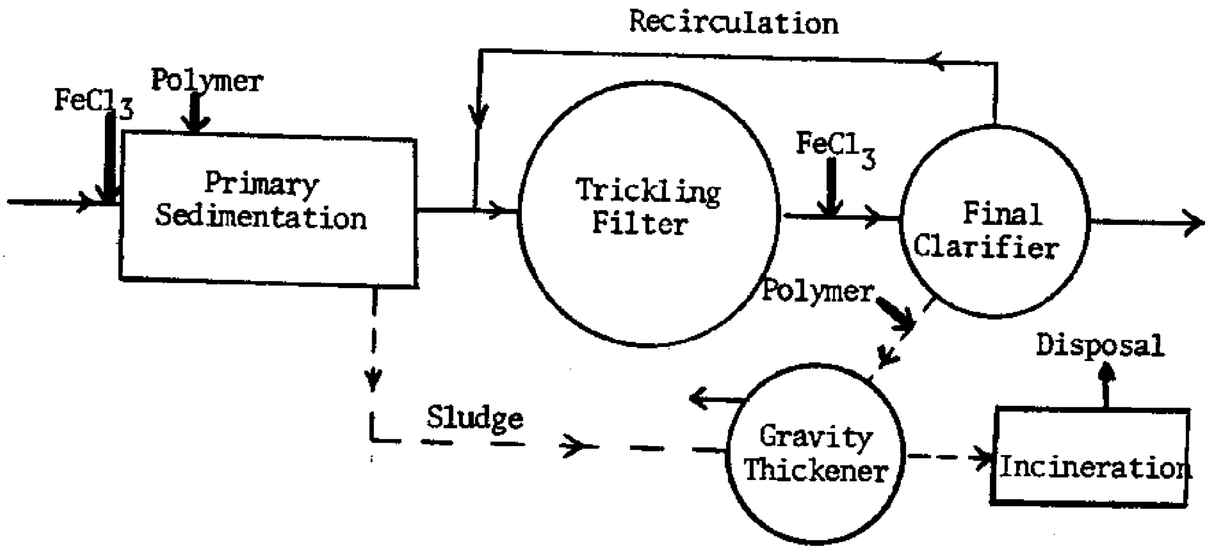
	Cost	Annual Cost	¢/1000 gal.
Capital	$15,984	$ 1,509	0.41
Operating		2,557	0.70
Chemical--$FeCl_3$		9,224	2.53
--Polymer		1,497	0.41
		$14,787	4.05¢/1000 gal.

Expected efficiency: Fe:P $\cong$ 1:1 with polymer -- 85%

1 MGD; 10.65 mg/l as P influent (89 lb/day P)
1.60 mg/l as P effluent (13 lb/day P)

Sources: Foth & Van Dyke & Associates, Green Bay; Mr. Nettnin, STP Supt.
Maurice Rott, Director of Public Works; Fritz Duebler

SHEBOYGAN



[Treatment levels are based on data from Sept. 1973-June 1974.]

Design flow: 16 MGD (Max. 22 MGD)
Average flow: 12.494 MGD
Design flow not exceeded during this period.

Average influent total P: 6.0 mg/l as P; 625 lb/day P
Average effluent total P: 3.6 mg/l as P; 375 lb/day P

Treatment: PRIMARY/POST-BIOLOGICAL
12 gph $FeCl_3$ with polyer at primaries; 24 gph $FeCl_3$ ahead of finals; Polymer ahead of sludge thickener; Fe:P $\cong$ 1.8:1 to 2:1

P Removal Efficiency: prior to chemical addition -- 20% (estimate)
Fe:P $\cong$ 1.8:1 -- 40%

	Cost	Annual Cost	¢/1000 gal.
Capital	$8,641	$ 1,230	0.03
Operating		2,038	0.04
Chemical--$FeCl_3$		169,192	3.71
--Polymer		9,636	0.21
Additional Sludge Cost		56,933	1.25
		$239,029	5.24¢/1000 gal. or $2.62/lb P removed

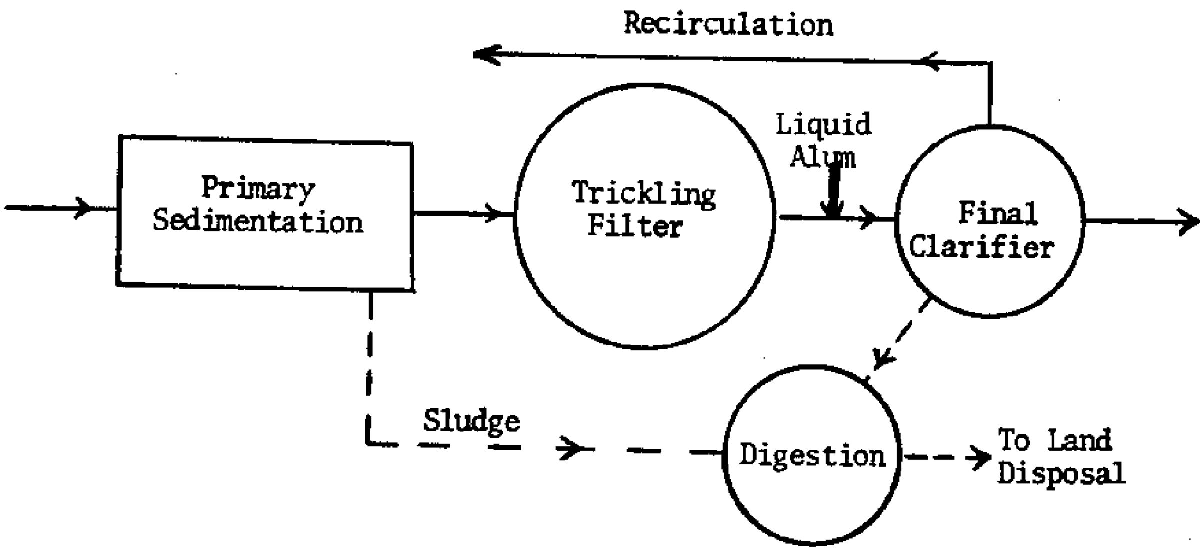
Comments: Capital investment for phosphorus removal facilities has been kept low. A new plant is planned, which will serve as regional treatment for the Sheboygan area. Mr. Stuebe noted that he could get 85% removal at about 50 gph $FeCl_3$, but the sludge system could not handle the load. Even at the present dosages, polymer addition at the thickener is very important for adequate performance.

SHEBOYGAN (Cont.)

Mr. Stuebe reported that BOD and solids removals were better with the addition of $FeCl_3$, but the incineration process was off because of the chemical nature of the sludge. Sludge costs indicated above consist of extra fuel required for incineration because of chemical addition; and extra hauling to disposal. Recirculation to the trickling filters has not caused any problems. A tanning industry contributes to the waste load at the plant.

Sources: Donahue & Associates, Sheboygan
Bill Stuebe, STP Supt.

SHEBOYGAN FALLS



[Treatment levels are based on data from Aug. 1973-June 1974.]

Design flow: 0.51 MGD (avg.)
Average flow: 0.78 MGD
Average flow exceeds design flow: 11 of 11 months.

Average influent total P: 9.2 mg/l as P; 60 lb/day P
Average effluent total P: 3.3 mg/l as P; 21 lb/day P

Treatment: POST-BIOLOGICAL
130 gpd liquid alum ahead of finals; Al:P ≅ 1:1

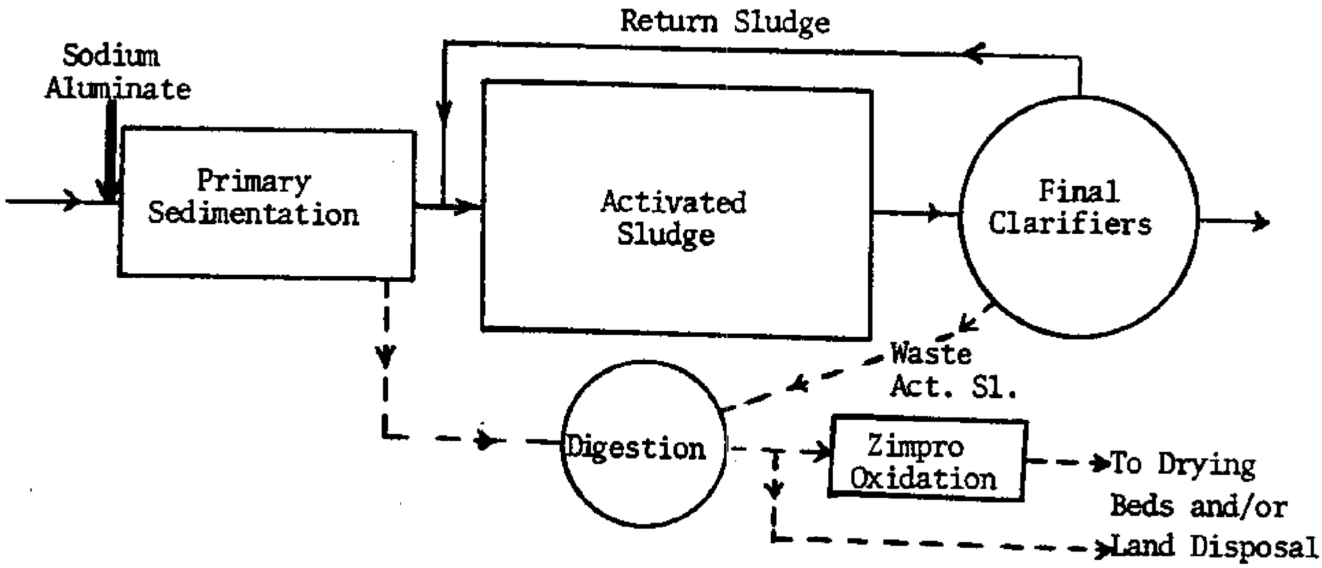
P Removal Efficiency: prior to chemical addition -- 18% (estimate)
Al:P ≅ 1:1 -- 64%

	Cost	Annual Cost	¢/1000 gal.
Capital	$12,600	$ 1,189	0.42
Operating		3,945	1.38
Chemical		7,450	2.62
		$12,584	4.42¢/1000 gal. or $0.88/lb P removed

Comments: Mr. Birsch indicated that he had tried dosing as high as 200-300 gpd alum and achieved 84% P removal, but he noted that the sludge system at the plant became badly overloaded. He also tried to dose alum ahead of the trickling filter, but the filter clogged. Mr. Birsch also reported an occasional pH problem caused by wastes from a local tanning industry. The city had its own plans drawn up for a new plant, but were told to go regional--proposed Sheboygan regional system.

Sources: Donahue & Associates, Sheboygan
Jerry Birsch, STP Supt.
City Clerk

SOUTH MILWAUKEE



[Treatment levels are based on data from Dec. 1973-June 1974.]

Design flow: 6 MGD (max. 12 MGD)
Average flow: 3.96 MGD
Design flow not exceeded.

Average influent total P: 4.0 mg/l as P; 132 lb/day P
Average effluent total P: 0.88 mg/l as P; 29 lb/day P

Treatment: PRIMARY
500-600 lb/day dry sodium aluminate feed ahead of primaries; Al:P ≅ 1:1

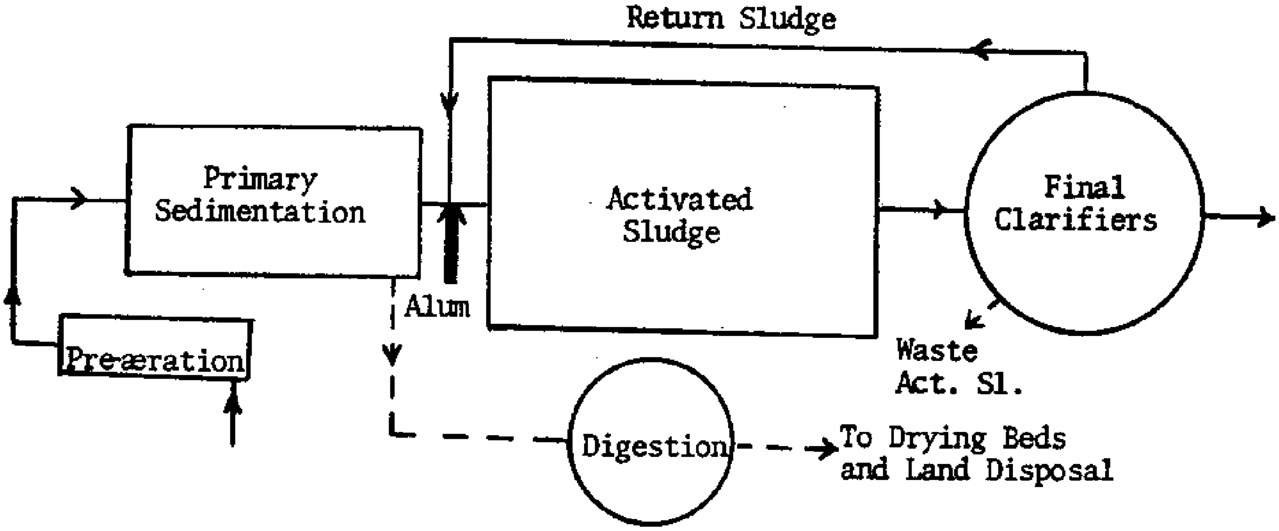
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1:1 -- 78%

	Cost	Annual Cost	¢/1000 gal.
Capital	$8,400	$ 793	0.05
Operating		1,734	0.12
Chemical		35,382	2.45
		$37,909	2.62¢/1000 gal. or $1.01/lb P removed

Comments: Mr. Martinek indicated that he would like to switch to liquid chemical feed. A tanning industry contributes to the waste load at the plant.

Sources: Nicholson Engr., South Milwaukee
John Martinek, STP Supt.

STURGEON BAY



[Treatment levels are based on personal interviews, which supplement the data.]

Design flow: 1.25 MGD (Maximum approximately 1.5 MGD)
Average flow: 1.68 MGD

Average influent total P: 6.4 mg/l as P; 90 lb/day P
Average effluent total P: 0.6 mg/l as P; 8 lb/day P

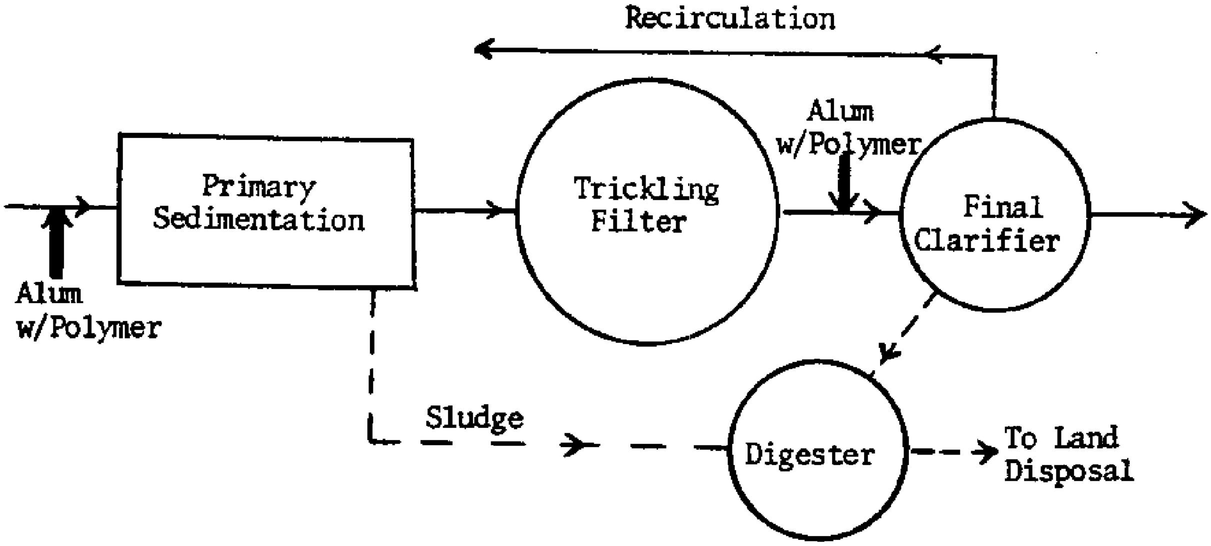
Treatment: CHEMICAL-BIOLOGICAL
350 gpd liquid alum ahead of aeration; Al:P ≅ 2:1

P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 2:1 -- 91%

	Cost	Annual Cost	¢/1000 gal.
Capital	$98,000	$ 8,409	1.37
Operating		10,869	1.77
Chemical		19,316	3.15
		$38,594	6.29¢/1000 gal. or $1.29/lb P removed

Comments: The plant is reported to be overloaded hydraulically. Mr. Bodwin noted a denser sludge and increased volume with chemical addition. Costs seem relatively high.

Sources: McMahon & Associates, Menasha
William Bodwin, STP Supt.



[Treatment was initiated in July 1974; treatment levels are based on personal interviews with Chris Szot.]

Design flow: 0.4
Average flow: 0.522
Average influent total P: 9.6 mg/l; 42 lb/day P

Treatment: PRIMARY/POST-BIOLOGICAL
Al:P $\cong$ 1.5:1 with polymer

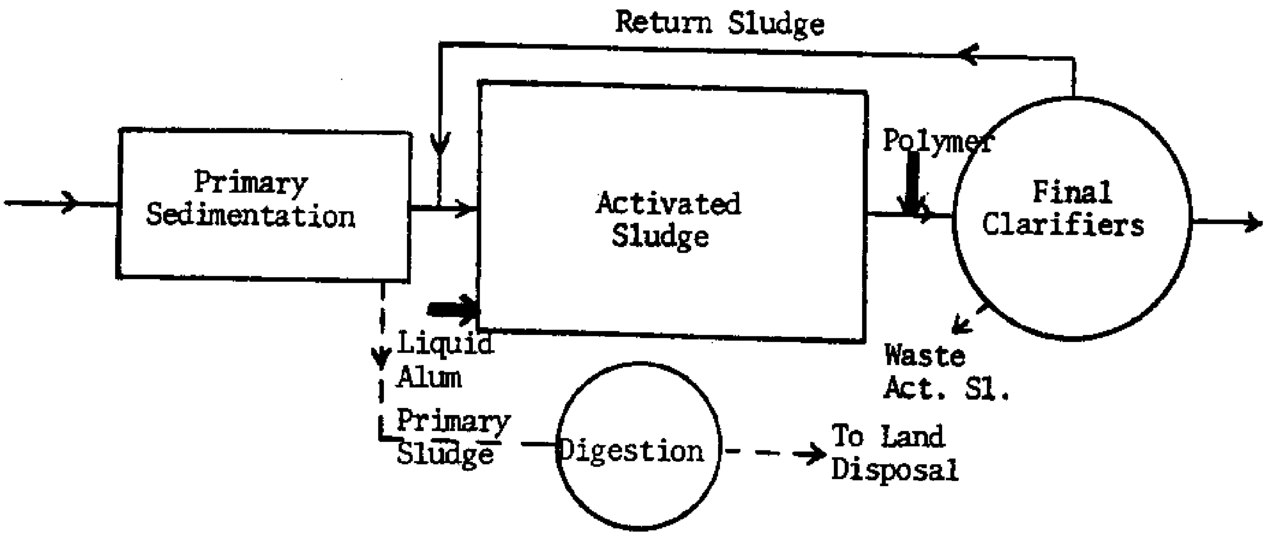
P Removal Efficiency: prior to chemical addition -- 22%
expected performance -- 85%
(Effluent P $\cong$ 1.44 mg/l as P)

	Cost	Annual Cost	¢/1000 gal.
Capital	$12,970	$ 1,224	0.64
Operating		2,142	1.12
Chemical		7,949	4.17
		$11,315	5.93¢/1000 gal. or $0.82/lb P removed

Comments: The plant is overloaded, but polymer addition aids settling and has worked well. Mr. Szot noted that over-dosing the alum caused problems at the plant.

Sources: Chris Szot, Engr.
John Schneider

THIENSVILLE



[Treatment levels are based on state lab data with monthly average flows for March 1973-May 1973.]

Design flow: 0.345 MGD (avg.)
Average flow: 1.12 MGD

Average influent total P: 4.4 mg/l as P; 41 lb/day P
Average effluent total P: 0.2 mg/l as P; 2 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
Liquid alum at aeration and polymer ahead of finals; Al:P ≅ 2:1

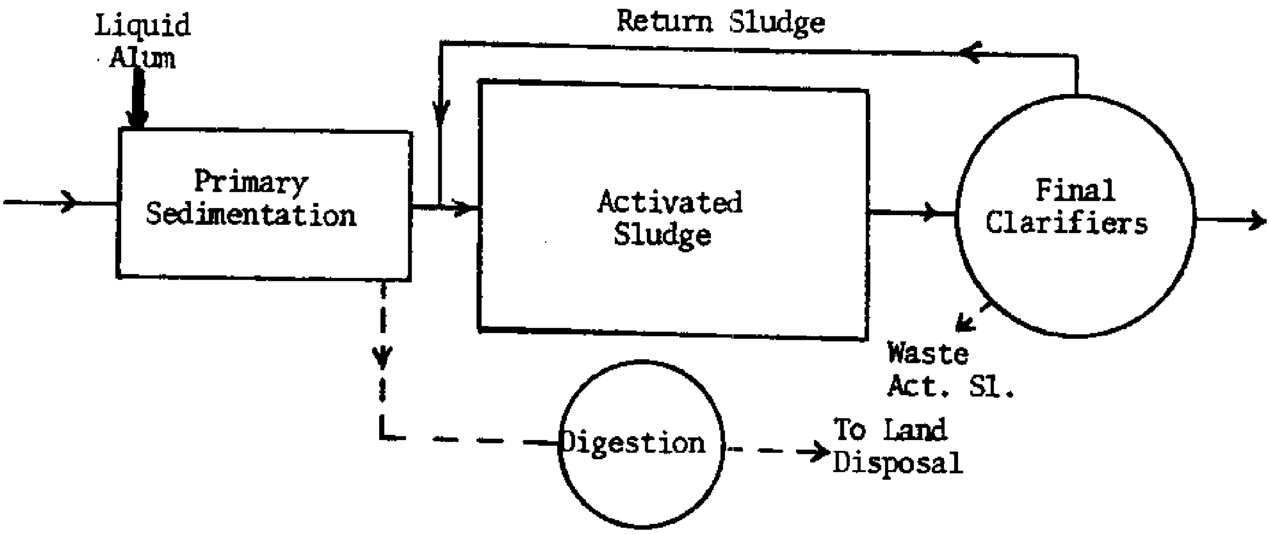
P Removal Efficiency: prior to chemical addition -- 33%
Al:P ≅ 2:1 with polymer -- 95%

	Cost	Annual Cost	¢/1000 gal.
Capital	$15,677	$ 1,480	0.36
Operating		7,331	1.79
Chemical (Alum)		10,910	2.67
Polymer		2,625	0.64
Additional Sludge Cost		2,064	0.50
		$24,410	5.96¢/1000 gal. or $1.71/lb P removed

Comments: Flows for March 1973-May 1973 may be somewhat higher than average, but the total phosphorus load in pounds generally remains constant. Mr. Laabs noted a considerable increase in sludge. He used enzyme treatment for several months at $400/mo., but then switched to hauling to land disposal. The cost of additional sludge handling because of chemical treatment is included here. Mr. Laabs noted that the area served is primarily residential.

Sources: Donahue & Associates, Sheboygan
Quintin Laabs, STP Supt.
James Laatsch

TWO RIVERS



[Treatment levels are based on data from Jan. 1974-June 1974.]

Design flow: 3.29 MGD
Average flow: 2.779 MGD

Average influent total P: 5.7 mg/l as P; 132 lb/day P
Average effluent total P: 2.4 mg/l as P; 56 lb/day P

Treatment: PRIMARY
576 gpd liquid alum at primaries; Al:P $\approx$ 2:1

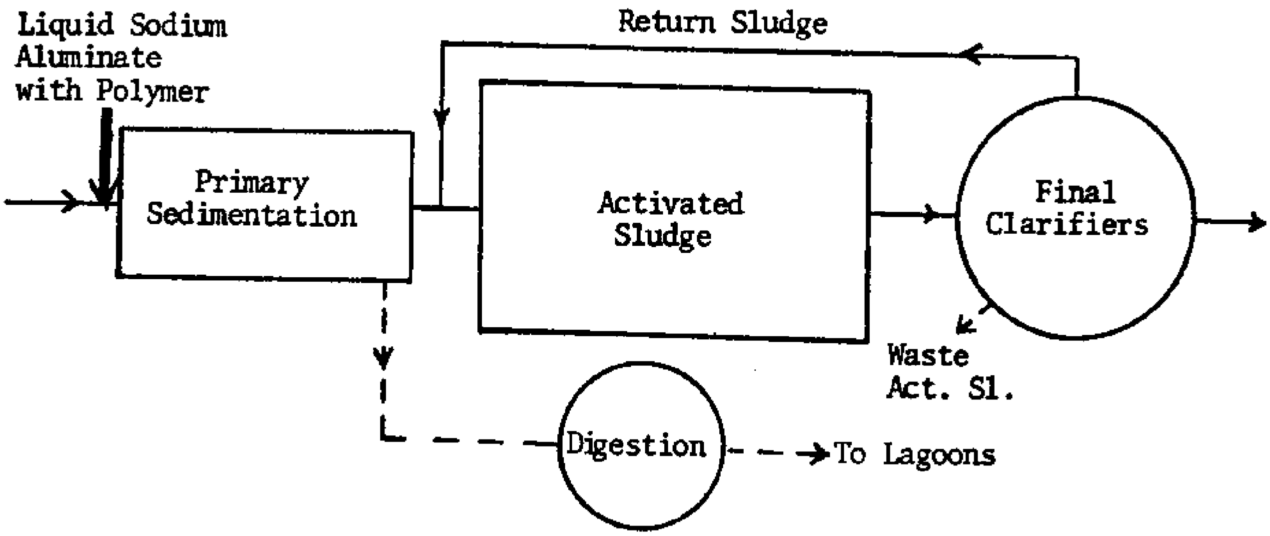
P Removal Efficiency: prior to chemical addition -- 45%
Al:P $\approx$ 2:1 -- 58%

	Cost	Annual Cost	¢/1000 gal.
Capital	$10,000	$ 945	0.09
Operating		1,180	0.12
Chemical		32,356	3.20
		$34,481	3.41¢/1000 gal. or $1.24/lb P removed

Comments: Two Rivers reported difficulties because of highly variable flows and industrial wastes. They are now waiting funds for a new 7-9 MGD plant.

Sources: Black & Veatch Engr., Kansas City, MO
Don Deprey, STP Supt.
Ray Schultz

UNION GROVE



[Treatment levels are based on data from Jan. 1973; Union Grove added chemicals for phosphorus removal from Nov. 1972-Mar. 1973. They had equipment problems and have not been back on line.]

Design flow: 0.360 MGD
Average flow: 0.512 MGD

Average influent total P: 8.5 mg/l as P; 36 lb/day P
Average effluent total P: 1.31 mg/l as P; 6 lb/day P

Treatment: PRIMARY
Liquid sodium aluminate with polymer at primary tanks; Al:P ≅ 1:1

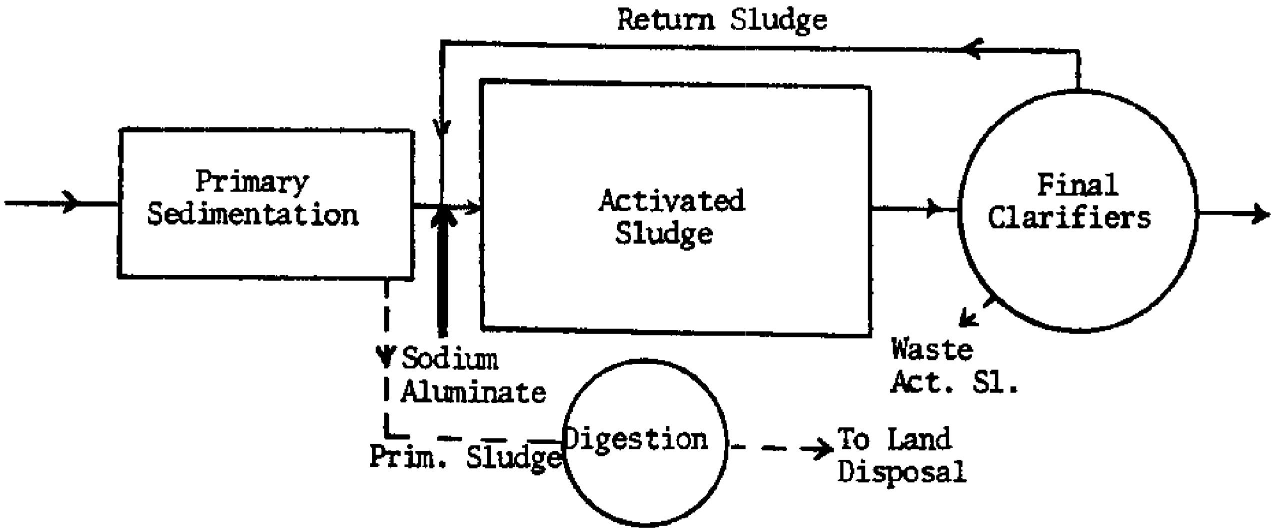
P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Al:P ≅ 1:1 with polymer -- 85%

	Cost	Annual Cost	¢/1000 gal.
Capital	$2,000	$ 285	0.15
Operating		3,650	1.95
Chemical		9,125	4.88
		$13,060	6.98¢/1000 gal. or $1.19/lb P removed

Comments: Union Grove is waiting funds for a new activated sludge plant.

Sources: Robers & Boyd, Engineers, Burlington
Russell Alschweiger, Director of Public Works

WAUPACA



[Treatment levels are based on all data reported from Jan. 1973-June 1974; Mr. Sorensen indicated that these phosphorus concentrations are recorded as PO_4 not as P.]

Design flow: 1.25 MGD
Average flow: 0.799 MGD
Design flow not exceeded.

Average influent total P: 5.0 mg/l as P; 33 lb/day P
Average effluent total P: 0.9 mg/l as P; 6 lb/day P

Treatment: PRIMARY/CHEMICAL-BIOLOGICAL (see comments below)
48 gpd liquid sodium aluminate--Al:P ≅ 1.8:1 (see comments below)

P Removal Efficiency: prior to chemical addition -- 40%
Al:P ≅ 1.8:1 -- 82%

	Cost	Annual Cost	¢/1000 gal.
Capital	$2,425	$ 345	0.12
Operating		2,195	0.75
Chemical		11,448	3.92
Polymer		1,121	0.38
		$15,109	5.17¢/1000 gal. or $1.53/lb P removed

Comments: Sodium aluminate addition was initially at primaries. As of Jan. 1974, it was dosed at the aeration tanks with seemingly improved results.

Treatment	Flow (MGD)	Influent mg/l P	Effluent mg/l P	% P Removal
PRIMARY	0.74	5.7	1.05	82
CHEM-BIOLOG	0.93	3.7	0.60	84

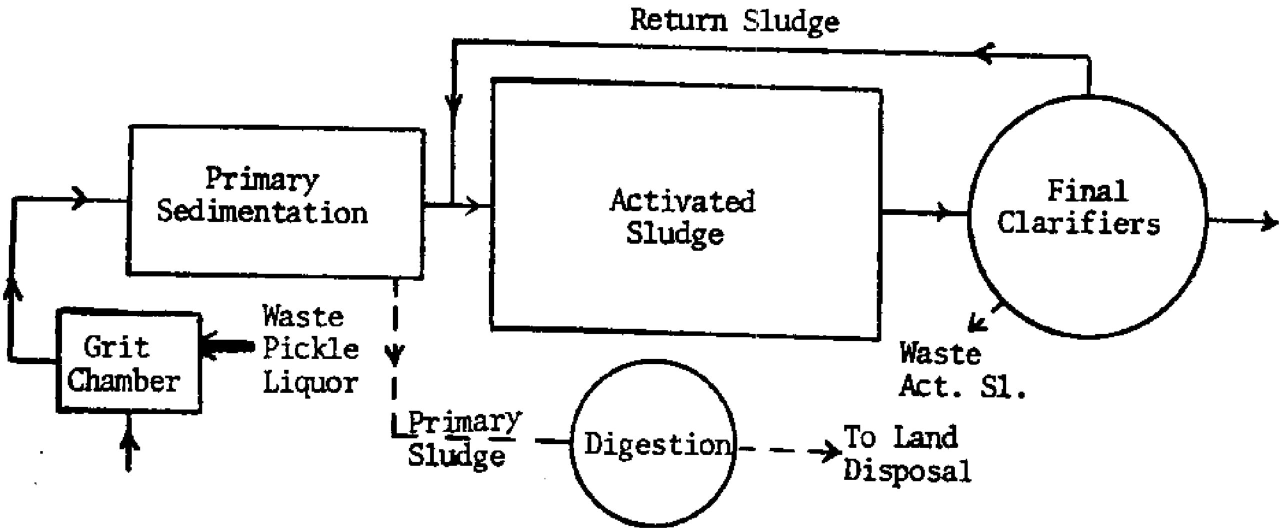
Mr. Sorensen noted that addition at primaries caused higher primary BOD and solids removals and decreased the efficiency of the biological

WAUPACA (Cont.)

system. Waupaca awaits funds for full-scale chemical feed facilities. Presently, polymer is added for only part of the year. Mr. Sorenson also indicated that he had some problems with the chemical feed pumps.

Sources: Mr. Gene Sorensen, STP Supt.

WEST BEND



[Treatment levels are based on data from May 1973-May 1974.]

Design flow: 2.5 MGD (avg.)
Average flow: 4.094 MGD
Average flow exceeds design flow: 13 of 13 months

Average influent total P: 7.51 mg/l as P; 256 lb/day P
Average effluent total P: 1.34 mg/l as P; 46 lb/day P

Treatment: PRIMARY
336 gpd waste pickle liquor at grit chamber;
(10-12% Fe) Fe:P ≅ 1.5:1

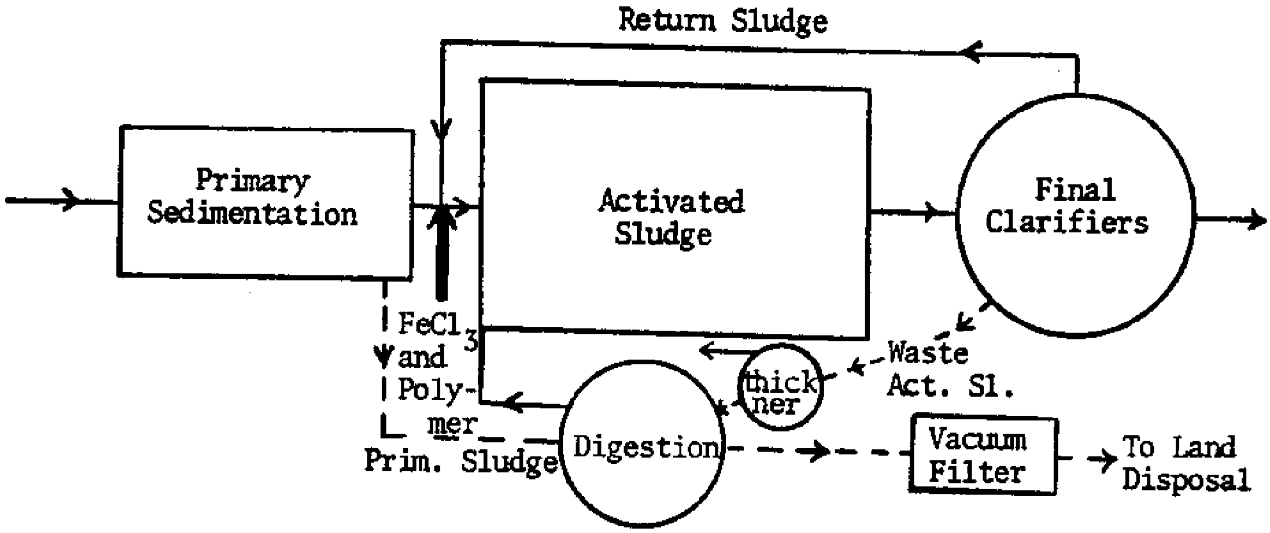
P Removal Efficiency: prior to chemical addition -- 46%
Fe:P ≅ 1.5:1 -- 82%

	Cost	Annual Cost	¢/1000 gal.
Capital	$23,438	$ 2,212	0.15
Operating		3,771	0.25
Chemical		19,622	1.31
		$25,645	1.71¢/1000 gal. or $0.33/lb P removed

Comments: Addition of waste pickle liquor ahead of aeration was tried, but Mr. Becker decided on primary addition. Mr. Becker indicated that, with pickle liquor addition, he was pumping the same volume of sludge, but the % solids was higher. The plant is generally overloaded, but still provides good treatment. West Bend is waiting funds for a major plant remodeling.

Sources: Donahue & Associates, Sheboygan
Mike Becker, STP Supt.

WEYAUWEGA



[Treatment levels and cost information and estimates are based on information from engineering reports and personal interviews.]

Design flow: 0.51 MGD
Average flow: 0.35 MGD

Average influent total P: 11 mg/l as P; 32 lb/day P
Expected effluent total P: 1.65 mg/l as P; 5 lb/day P

Treatment: CHEMICAL-BIOLOGICAL
$FeCl_3$ with polymer ahead of aeration; estimated Fe:P $\cong$ 1.2:1

P Removal Efficiency: prior to chemical addition -- 30% (assumed)
Fe:P $\cong$ 1.2:1 with polymer -- 85%

Estimated annual cost: $7,848 (6.13¢/1000 gal. or $0.80/lb P removed)

Comments: The plant has just undergone complete renovation and is on line since February 1974. The upgrading included the addition of mechanical aeration, additional clarifier capacity, vacuum filtration, and chemical feed facilities. No phosphorus removal data is reported here. Weyauwega went on line for phosphorus removal at the old plant as of February 1973 with $FeCl_3$ addition out of drums. An estimated 50-60% removal was obtained with this system.

Sources: Foth & Van Dyke & Associates, Green Bay
Mr. Minton, STP Supt.
Mr. Cal Cheet, City Clerk

APPENDIX B

Plant Data

Data sheets indicating monthly average flows, phosphorus levels, and removal percentages for each plant are included. Where Wisconsin State Hygiene Laboratory data is reported, corresponding flows are monthly average flows as reported in the monthly operator reports. Where phosphorus levels are those reported by individual operators, flows are either monthly average flows or, when available, the average flow for those days of the month when phosphorus analyses were run. The frequency of phosphorus tests ranges from one a month to daily evaluations. The phosphorus test, as prescribed in Standard Methods (28), has generally not been well received by operators. Thus, consistent and accurate data has sometimes not been available, especially for the early months of treatment. The data from the State Lab's analysis provide an important check on phosphorus levels, and in some cases, the only consistent information available.

A related problem is that samples analyzed at the State Lab may be grab samples only, and not 24 hour composites as requested. Thus, phosphorus levels and removals may not be typical of plant performance. Soluble phosphorus data is also reported on State Lab samples. Samples were not preserved in any way and the time lag between sampling and testing may be one or two weeks. According to technicians at the water chemistry lab, the soluble phosphorus concentration would change considerably under these conditions. Melkersson (6) states that evaluations should be based on unfiltered samples, because filtered samples may provide exaggerated phosphorus removal performance and may not show carry-over of metal ions. Also, since the removal order is based on total phosphorus regardless of form, and since the scope of this report does not permit any further examination of treatment specifics for 53 plants, the soluble phosphorus data is not analyzed any further in this paper.

Another significant problem is the lack of consistent and uniform reporting of phosphorus concentrations. Concentrations are reported in mg/l as PO_4 and in mg/l as P, a difference of a factor of three. The basis is not noted on the standard forms and is generally not reported. All State Lab data is reported in mg/l as P. All data from operator reports is listed as it is reported and corrected to mg/l as P only as specifically noted, based on consultation with the appropriate sources. Major process changes and phosphorus treatment modifications and corresponding approximate dates are listed below the data.

ALGOMA

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.745			8.0	4.6	42
Mar.	0.807	3.0	0.01	8.0	1.0	88
Apr.	1.190	1.5	0.06	3.7	0.5	86
May	1.550	2.3	0.03	4.3	0.4	91
June	1.352	2.6	0.32	5.7	0.3	95
July	0.675	3.4	0.06	4.8	0.3	92
Aug.	0.590	3.6	0.06	7.0	0.5	93
Sept.	0.468			7.15	0.97	86
Oct.	0.645			7.2	0.14	98
Nov.	0.633			7.2	0.16	98
Dec.	0.727			5.52	0.26	95
Jan. 1974	0.646			5.0	0.96	81
Feb.	0.536			5.6	0.63	89
Mar.	0.688			5.6	0.76	86
Apr.	0.896			6.0	0.88	85
May	0.832			6.9	1.18	83
June	1.022			7.5	1.61	78

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for removal of phosphorus; $FeCl_3$ plus polymer added at aerated grit chamber; Doses seem to range from 70-100 gpd ferric with maximum removals in the 150-160 gpd range.

APPLETON

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	13.01			11.5	3.0	74
Mar.	16.37	3.0	2.0	11.3	4.0	65
Apr.	16.82	1.3	1.3	3.3	2.2	33
May	17.07	4.0	1.7	7.5	2.4	68
June	14.05	2.8	3.1	9.5	3.8	60
July	12.19	5.8	1.5	10.1	2.3	77
Aug.	12.66	5.0	3.5	10.5	4.2	60
Sept.	12.36	4.5	1.9	5.8	2.9	50
Oct.	13.85			10.03	2.8	72
Nov.	13.51			12.51	2.97	76
Dec.	13.38			13.27	3.19	76
Jan. 1974	12.77			15.51	3.17	80
Feb.	12.64			12.5	2.96	76
Mar.	15.11			10.76	0.99	91
Apr.	16.97			8.33	1.23	85
May	16.04			11.24	1.8	84
June	16.71			9.74	2.26	77

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ at 15-20 gal/mg dosed at grit chamber; Polymer added before primary tanks.

Oct. or
Nov. 1973--Complete full scale phosphorus treatment facilities on line.

Mar. 1974--Apparently started dosing higher, as evidenced by improved effluent concentrations; 50 gal/mg $FeCl_3$ at grit chamber; Polymer added to line to primaries.

June 1974--Experimented with additional points of application; Dosed 4 gph $FeCl_3$ to aeration effluent.

1975 or
1976--Construction to double plant capacity.

BERLIN

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.321			5.4	2.8	48
Mar.	1.853	0.60	0.18	1.8	0.9	50
Apr.	1.921	1.00	0.50	3.0	1.0	67
May	1.953	2.5	1.60	3.5	2.0	43
June	1.620	3.1	2.4	4.3	3.0	30
July	1.198	4.0	1.5	5.0	1.6	68
Aug.						
Sept.	1.070	4.0	3.8	6.5	4.0	38
Oct.						
Nov.						
Dec.		1.8	2.0	5.5	3.4	38
Jan. 1974		2.9	0.11	6.6	2.3	65
Feb.						
Mar.	2.403			4.5	3.75	17
Apr.	1.505			3.51	2.22	37
May	1.445			4.4	2.5	44
June	1.459			3.38	1.9	43

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Dosing $FeCl_3$ w/polymer before primary settling tanks.

May 1974--Switched to liquid alum (Al: $P \cong 1.3 : 1$) before primaries.

--Waiting funds for new plant.

BUTTE DES MORTS U.D.
Town of Grand Chute
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.580					
Mar.	1.006					
Apr.	1.328					
May						
June	1.151					
July						
Aug.						
Sept.	0.723					
Oct.						
Nov.						
Dec.						
Jan. 1974						
Feb.						
- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
Mar.	0.534			19	4.	79
Apr.	0.900			5.8	0.75	87
May	0.649			6.2	0.58	91
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Liquid alum doses range from 3 to 7 gph; No polymer.

July-
Aug. 1973--P treatment down because of equipment failure; (1 1/2 months).

--Plans are to upgrade sludge system, but a tie to a regional system of sewage treatment is being proposed.

CEDARBURG

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.699			5.4	4.0	26
Mar.	2.390	0.8	1.0	6.6	1.7	74
Apr.	3.115	0.55	0.85	2.9	1.8	38
May	2.885	1.1	1.4	3.6	1.5	58
June	2.003	3.9	1.4	6.2	1.7	72
July	1.364	4.5	2.0	6.8	2.4	65
Aug.						
Sept.	1.292			10.97	2.1	81
Oct.	1.396			10.45	2.5	76
Nov.	1.520			7.6	2.45	68
Dec.	1.856			6.6	2.5	62
Jan. 1974	1.689			6.2	2.7	56
Feb.	1.797			7.4	4.0	46
Mar.	2.854			4.4	1.7	61
Apr.	2.691			4.5	1.7	62
May	2.297			5.4	1.76	67
June	2.013			4.7	1.2	74

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Dosed lime at 258 lb/day.

June 1973--Switched to feeding dry alum at 500 lb/day.

June 1974--Experimented with waste pickle liquor addition.

July 1974--Experimenting with sodium aluminate-polymer combination; Reported dosing 300 lb/day sodium aluminate.

--Plan to switch to liquid chemical feed.

CHILTON

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.614			17.4	4.0	77
Mar.		9.3	0.38	23.5	2.0	91
Apr.		1.8	0.28	3.8	0.94	75
May		19.6	0.06	38.8	1.5	96
June		15.5	0.55	28.0	2.8	90
July	0.405	38.6	0.48	52.0	1.4	97
Aug.	0.449	3.3	0.16	5.7	1.1	81
Sept.	0.423	3.6	0.05	7.8	0.6	92
Oct.	0.464			19.6	3.5	82
Nov.	0.488			15.7	1.7	89
Dec.	0.498			32.0	2.2	93
Jan. 1974	0.460			15.6	2.1	86
Feb.	0.427			21.9	3.3	85
Mar.	0.533			20.1	1.0	95
Apr.	0.680			13.4	1.4	90
May	0.550			28.1	4.4	84
June	0.485			33.1	3.6	89

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Feb. 1973--Initiated treatment for phosphorus removal; 200 gpd liquid alum added to return sludge line; Polymer used.

May 1974--Discontinued polymer addition temporarily; Resolving sludge overload problem.

CLINTONVILLE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.908			11.5	3.0	74
Mar.	1.136	2.5	1.7	6.4	2.5	61
Apr.	1.255	2.8	2.1	5.5	2.8	49
May	1.288	3.6	1.4	6.2	1.9	69
June	1.298	1.5	0.25	3.0	0.58	81
July	1.136	1.4	2.2	2.8	2.5	11
Aug.	0.960			5.8	1.2	79
Sept.	0.744	6.0	2.0	7.0	5.3	24
Oct.		6.5	4.1	11.0	4.3	61
Nov.		2.9	2.5	6.5	3.3	49
Dec.		4.4	3.6	10.5	5.0	52
Jan. 1974		3.4	4.0	5.1	4.2	18
Feb.						
Mar.	0.733			5.3	4.6	13
Apr.	1.077			4.87	0.63	87
May	1.090			4.1	0.77	81
June	1.008			5.85	0.7	88

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Dosing 400 lb/day alum; Interim facilities only.

Apr. 1974--Full scale phosphorus treatment facilities on line; Dosing liquid alum at 80 gpd before aeration tank and polymer before finals.

DE PERE
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	2.397			10.5	9.8	7
Mar.	2.910	4.7	0.3	8.0	1.8	78
Apr.	2.950	3.0	0.13	3.7	1.3	65
May	2.920	4.3	1.3	5.6	2.3	59
June	2.855	1.1	0.3	4.3	0.75	82
July	2.923	1.5	0.2	11.0	1.1	90
Aug.	2.910					
Sept.	2.510	6.2	0.12	8.5	2.3	73
Oct.		9.3	1.2	12.6	2.8	78
Nov.		4.4	0.15	13.	2.8	78
Dec.		8.3	0.34	12.	1.8	85
Jan. 1974	2.310			7.8	1.5	81
Feb.	2.621			7.5	1.78	76
Mar.	2.694			5.72	1.38	76
Apr.	2.572			4.67	0.49	90
May	2.670			6.32	1.35	79
June	2.754			6.12	1.19	80

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Feb. 1973--Initiated treatment for phosphorus removal; Dosing liquid alum at 450 gpd.

June 1973--Experimented with alum-sodium aluminate-polymer combination.

July 1973--Liquid alum at 400-450 gpd. plus polymer ahead of final clarifiers.

Fall 1974--Possibly start construction on major plant upgrading; see discussion.

FOND DU LAC

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				12.0	10.0	17
Mar.		0.8	2.7	3.0	3.7	
Apr.		6.7	3.4	11.4	5.0	56
May		4.3	4.2	8.0	6.4	20
June	6.835	8.8	8.5	11.5	10.5	9
July	5.317	7.3	7.0	18.8	8.5	55
Aug.	5.893					
Sept.	5.608	3.0	0.35	8.6	14.4	
Oct.	6.285			7.0	3.2	54
Nov.	5.676			7.3	3.2	56
Dec.	5.827			9.6	3.5	64
Jan. 1974	6.205			7.7	2.7	65
Feb.	6.398			6.7	2.2	67
Mar.	7.261			5.0	3.0	40
Apr.	8.321			5.3	2.5	53
May	7.143			6.5	3.9	40
June	6.966			7.0	4.3	39

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Sept. 14, 1973--Initiated treatment for phosphorus removal; But system not fully operational till Oct. 15; Liquid alum dosed ahead of finals at approximately 1500 gpd.

Jan. 1977--Major upgrading possibly operational; Pure oxygen aeration system planned; (11 MGD plant).

GERMANTOWN

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.748			14.0	6.0	57
Mar.	0.847	6.6	5.5	11.0	7.4	33
Apr.	1.003	1.6	2.8	5.5	3.5	36
May	0.957	15.9	5.9	30.0	14.0	53
June	0.777	6.3	5.7	13.6	6.7	51
July	0.566	8.5	10.8	13.8	12.6	9
Aug.	0.522					
Sept.	0.525	12.8	8.1	18.0	9.5	47
Oct.		3.8	9.3	7.5	9.8	
Nov.		2.9	6.0	6.5	6.8	
Dec.		1.8	2.1	4.6	2.6	43
Jan. 1974		6.5	3.8	11.6	4.7	59
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Aug. 1974--No phosphorus treatment to date.

GRAFTON

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.237			12.4	3.2	74
Mar.	1.541	4.7	1.9	13.6	3.4	75
Apr.	1.709	0.95	0.86	9.0	1.9	79
May	1.460	7.6	1.6	13.8	2.8	80
June	1.107	12.0	1.1	13.4	1.6	88
July	0.901	10.5	4.2	15.8	4.4	72
Aug.	0.888	2.3	7.3	14.8	14.3	3
Sept.	0.839	18.0	4.5	22.5	5.0	78
Oct.		21.5	0.4	21.5	5.25	76
Nov.		11.4	1.9	17.0	3.0	82
Dec.		11.0	1.1	13.5	1.7	87
Jan. 1974	1.028			12.42	1.54	88
Feb.	1.000			17.25	1.39	92
Mar.	1.465			15.76	1.92	88
Apr.	1.480			12.12	1.44	88
May	1.375			18.25	1.86	90
June	1.140			18.85	1.35	93

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Liquid alum with polymer; Alum dosage averages 200 gpd; Doses were varied in early months of treatment.

GREEN BAY

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				8.6	8.4	2
Mar.		3.0	1.0	7.5	6.0	20
Apr.		0.9	0.54	3.4	2.3	32
May		2.8	0.13	5.8	3.1	46
June		2.3	0.23	4.3	2.8	35
July	19.880	3.2	0.15	5.8	1.8	70
Aug.						
Sept.		4.5	2.5	7.5	5.5	27
Oct.		3.8	3.8	7.8	7.8	0
Nov.		4.0	1.3	7.0	1.3	81
Dec.		1.3	0.88	8.0	4.3	46
Jan. 1974		3.0	0.28	6.8	3.3	51
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum dose varied: June 1973-1600 gpd-35% and July 1973-2900 gpd-70%.

Sept. 1973--Tried $FeCl_3$ but had problems with plugging.

Nov. 1973--Went back to liquid alum ahead of finals at 2200 gpd.

Mar. 1975--Expect new plant to be on line; Currently under construction; Combined treatment with activated sludge system.

KAUKAUNA

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.179			10.0	6.8	32
Mar.	2.789	0.96	1.40	2.3	1.8	22
Apr.	2.931	1.8	0.14	3.3	0.47	86
May	3.160	3.1	0.07	4.6	0.70	85
June	1.233	3.0	0.04	4.8	0.32	93
July	1.463	5.3	0.63	7.0	0.20	97
Aug.	1.610					
- - -		- - -	- - -	- - -	- - -	- - -
Sept.	1.695			11.1	1.45	87
Oct.	1.523			10.4	1.0	90
Nov.	1.506			10.5	0.55	95
Dec.	1.697			6.6	0.6	91
Jan. 1974	1.644			11.68	1.46	88
Feb.	1.504			12.6	1.4	89
Mar.	2.266			8.8	1.57	82
Apr.	2.992			6.89	0.76	89
May	2.601			8.71	1.39	84
June	2.684			9.5	1.36	86

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 22, 1973--Initiated treatment for phosphorus removal; Dosing liquid alum ahead of final clarifiers.

--Expecting bids to go out in 1975 on plant additions to facilitate regional treatment; New plant will provide flow capacities of 5.3-7.3 MGD (avg.) and 16-19 MGD (max).

KENOSHA

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	20.557			5.0	3.8	24
Mar.	20.590	1.0	0.34	3.0	0.9	70
Apr.	24.970	1.6	2.50	3.4	3.5	
May	23.920	1.7	0.55	2.8	1.4	50
June	23.650	1.9	1.30	8.8	1.8	80
July	20.160	2.0	0.75	4.0	1.1	72
Aug.	19.162					
Sept.		0.9	0.08	5.3	0.35	93
Oct.		2.1	0.09	7.7	0.75	91
Nov.		1.5	0.10	2.5	0.62	75
Dec.		4.5	0.25	5.0	1.30	74
Jan. 1974		3.1	0.04	7.8	0.90	88
Feb.						
Mar.						
Apr.						
May	25.389			3.6	1.8	50
June	27.582			4.0	0.9	78

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 19, 1973--Initiated treatment for phosphorus removal; 1500-2000 gpd waste pickle liquor ahead of aeration; Noted problems with feed system until June 1974.

Sept. 1973--Tried dosing a polymer in combination with pickle liquor.

Oct. 1973--Discontinued polymer feed.

June 1974--Noted as first month that pickle liquor feed system worked well.

--New 40 MGD plant being planned.

KEWASKUM

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.						
Apr.						
- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
May	0.915			16.0	5.0	69
June	0.626			14.5	3.25	78
July	0.370			18.0	2.6	85
Aug.	0.477			23.5	3.5	85
Sept.	0.498			22.1	4.0	82
Oct.	0.476			13.1	2.8	80
Nov.	0.522			15.4	3.9	75
Dec.	0.592			10.3	2.1	80
Jan. 1974	0.265			33.4	3.6	89
Feb.	0.162			23.3	5.0	79
Mar.	0.631			16.1	8.1	50
Apr.						
May	0.366			17.3	8.9	49
June	0.225			18.0	11.6	36

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

May 15, 1973--Initiated treatment for phosphorus removal; 6 gph liquid alum added at pre-aeration.

Sept. 1974--Full scale phosphorus treatment facilities expected to be operational.

KEWAUNEE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.309			9.0	5.6	38
Mar.	0.383	1.7	2.3	6.3	4.7	25
Apr.	0.447	2.0	0.6	11.0	0.6	94
May	0.553	2.1	0.72	7.0	2.6	63
June	0.554	4.9	1.9	5.9	3.2	46
July	0.423	3.8	2.1	6.0	3.2	47
Aug.	0.424					
Sept.	0.395	4.0	0.12	6.0	0.3	95
Oct.		4.0	0.38	7.5	2.6	65
Nov.		2.1	0.16	6.8	1.2	82
Dec.		0.95	0.22	9.1	2.0	78
Jan. 1974		2.9	0.14	7.5	2.5	67
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Feb.						
Mar.						
Apr.						
May						
June	0.484			28.67	1.5	95

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Apr. 1973--Initiated treatment for phosphorus removal; Temporarily dosing $FeCl_3$--drum lots; 25-30 gpd.

Sept. 1973--Switch to feeding liquid alum ahead of primary tanks; Doses range from 3-5 gph.

--Expecting construction by 1975 to double present plant capacity.

KIEL

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				59.6	20	66
Mar.		4.6	3.4	17.5	26	
Apr.		7.5	10.3	10.5	13	
May	1.004	12.2	0.18	15.0	1.4	91
June		17.0	2.6	18.8	3.3	82
July		26.0	7.0	28.5	8.5	70
Aug.						
Sept.		16.6	2.6	17.6	5.3	70
Oct.		9.5	0.85	13.6	1.5	89
Nov.		30.0	2.1	31.5	9.5	70
Dec.		11.3	2.5	16.4	8.0	51
Jan. 1974		14.1	2.8	16.6	5.8	65
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum added before finals.

--Expansion planned, but no dates reported at this time.

KIMBERLY

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.540			11.0	9.6	13
Mar.	0.588	1.3	0.75	4.3	5.6	
Apr.	0.612	3.0	0.02	7.3	0.42	94
May	0.620	2.2	0.08	4.9	0.45	91
June	0.542	10.3	0.23	13.0	1.3	90
July	0.475	8.0	0.02	9.8	0.55	94
Aug.	0.476					
Sept.	0.452	7.7	0.01	10.0	1.7	83
Oct.		6.0	0.03	12.0	1.2	90
Nov.	0.545	6.5	0.05	9.2	2.8	70
Dec.	0.572	5.8	0.60	8.1	1.7	79
Jan. 1974	0.544	5.5	0.04	9.6	2.4	75
Feb.	0.506			21.2	2.6	88
Mar.	0.600			19.9	2.3	88
Apr.	0.578			18.0	1.43	92
May	0.600			23.1	2.4	90
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Apr. 1973--Initiated treatment for phosphorus removal; Average dose is 160 gpd liquid alum.

Jan. 1974--Alum feed line froze.

--Eventually scheduled to be linked to Kaukauna regional plant.

KOHLER

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
		- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
Mar.	0.456			12.0	3.0	75
Apr.	0.452			11.0	1.7	85
May	0.441			14.0	2.0	86
June	0.362			17.0	2.0	88
July	0.257			15.0	1.96	87
Aug.	0.284			17.0	5.0	71
Sept.	0.268			14.5	2.5	83
Oct.	0.164			6.75	1.25	81
Nov.	0.655			7.8	1.0	87
Dec.	0.269			7.0	1.84	74
Jan. 1974	0.462			2.3	1.02	55
Feb.	0.387			5.3	1.2	78
Mar.	0.668			2.8	0.62	78
Apr.	0.967			3.24	0.88	73
May	0.691			3.23	0.56	81
June	0.717			2.41	0.30	88

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum added at aeration tanks.

--Expect to be linked to proposed Sheboygan regional system.

LITTLE CHUTE
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.040					
Mar.	1.206					
Apr.	1.143					
May	1.168					
June	0.745					
July	0.504					
Aug.	0.538					
Sept.	0.522					
Oct.						
Nov.						
Dec.						
Jan. 1974						
Feb.						
		- - - -	- - - -	- - - -	- - - -	- - - -
Mar.	0.769			6.0	0.75	88
Apr.	0.634			5.06	0.96	81
May	0.757			6.21	0.46	93
June	0.768			6.4	0.74	88

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

May 1973--Initiated treatment for phosphorus removal; Dosing liquid alum at 140 gpd to pre-aeration.

--Eventually scheduled to be linked to Kaukauna regional plant.

MARINETTE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	3.000			12.0	3.2	73
Mar.	4.500	0.08	0.18	5.0	2.5	50
Apr.	4.800	0.07	0.10	3.9	0.75	81
May	5.400	0.60	0.09	11.0	0.11	99
June	5.530	0.60	0.45	2.6	0.60	77
July	4.190	0.40	1.30	9.8	1.6	84
Aug.	3.260					
Sept.	2.650	1.50	1.4	12.8	1.8	86
Oct.		1.80	0.75	4.5	1.25	72
Nov.		0.29	0.17	4.3	1.10	74
Dec.		1.30	0.45	5.0	2.0	60
Jan. 1974	2.532			3.42	0.74	78
Feb.	2.386			2.94	0.57	81
Mar.	3.018			2.60	0.34	87
Apr.	3.977			2.87	0.36	87
May	4.035			2.65	0.42	84
June	4.343			2.40	0.54	78

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ at 1 mg/l; polymer 0.1 mg/l

Apr. 1973--$FeCl_3$ dose increased to approximately 8 mg/l (50-75 gpd).

MANITOWOC

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				20.0	12.6	37
Mar.		3.2	3.0	5.6	4.6	18
Apr.		3.8	3.6	9.0	6.0	33
May		2.0	0.35	5.7	4.0	30
June		0.6	0.07	5.8	2.9	50
July	8.700	4.8	3.3	9.3	5.3	43
Aug.	8.845					
Sept.	8.997	4.5	0.95	8.0	2.1	74
Oct.		4.3	0.13	10.0	2.6	74
Nov.		3.5	0.06	7.3	0.18	98
Dec.	8.730	2.4	0.25	7.0	2.3	67
Jan. 1974	10.010			8.67	4.23	50
Feb.	9.344			8.2	3.9	52
Mar.	11.784			8.9	4.0	55
Apr.	12.680			8.1	3.5	63
May	11.33			15.9	4.5	72
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

May 1973--Initiated treatment for phosphorus removal; Dosing liquid alum (1440 gpd).

July 25, 1973--New chemical feed equipment started up; includes addition of polymer.

Sept. 1973--Switched to $FeCl_3$; dosing at 576 gpd average; with polymer.

Nov. 1973--Experimented with alum-sod. aluminate-polymer combination.

Dec. 1973--Liq. alum at about 2000 gpd.

Feb. 1974--$FeCl_3$ ~~(576 gpd)~~ plus polymer.

--Hoping for construction to begin soon on doubling present capacity.

MENASHA S.D. 4 (EAST)

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				15.0	6.0	60
Mar.	1.000	0.55	1.60	2.5	0.2	92
Apr.	1.100	2.4	2.10	7.3	4.5	38
May	1.180	1.9	0.03	6.1	2.5	59
June	0.682	5.8	0.09	10.3	0.5	95
July	0.502	7.8	0.06	11.0	0.85	92
Aug.	0.473					
Sept.	0.440					
Oct.		1.8	0.9	6.5	2.4	63
Nov.		0.08	0.28	8.8	1.3	85
Dec.		1.8	0.6	6.8	13.9	
Jan. 1974	0.519			13.5	3.0	78
Feb.	0.601			11.5	4.0	65
Mar.						
Apr.						
May						
June	0.771			15.0	3.0	80

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

June 15, 1973--Initiated treatment for phosphorus removal; Dosing liquid alum at 450 ml/min.

Oct. 1973--Dosing liquid alum at 270 ml/min.

--Expect to upgrade chemical feed equipment soon.

June 1976--Will be expected to remove phosphorus at west plant.

MENOMONEE FALLS I

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Total P (mg/1)	T.F. Effluent Total P (mg/1)	A.S. Effluent Total P (mg/1)	T.F. % P Removal	A.S. % P Removal
Aug. 1973	1.500	10.0	10.0	10.0	0	0
Sept.	1.500	10.0	10.0	10.0	0	0
May 1974	1.865	7.17	3.5	1.0	51	86
June	1.720	8.88	6.8	2.3	24	74
			MENOMONEE FALLS II			
Aug. 1973	0.644	10.0		10.0		0
Sept.	0.688	10.0		10.0		0
June 1974	0.977	9.33		2.44		74

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Nov. 1973--Initiated treatment for phosphorus removal; Waste pickle liquor at 145 gpd.

--Eventual hook up to Milwaukee Metropolitan system.

MILWAUKEE - JONES ISLAND

	Flow (MGD) WEST	Flow (MGD) EAST	Influent Total P (mg/l as P)	Effluent Total P (mg/l as P) WEST	Effluent Total P (mg/l as P) EAST	P Removal Efficiency % WEST	P Removal Efficiency % EAST
Jan. 1973	66	93.3	7.3	1.21	0.39	83	95
Feb.	64	94.4	7.2	2.02	0.78	72	89
Mar.	74.3	99	5.9	2.1	1.0	64	83
Apr.	81.1	107.1	4.5	0.47	0.28	90	94
May	76.1	96.1	5.0	0.76	0.76	85	85
June	73.6	91.5	4.9	0.61	0.64	88	87
July	71.2	91.3		EQUIPMENT DOWN			
Aug.	70.7	95.7					
Sept.							
Oct.							
Nov.	57.4	77.3	6.8	0.3	0.18	96	97
Dec.	58.1	80.7	5.3	0.47	0.19	91	96
Jan. 1974	57.4	79.6	6.1	0.55	0.3	92	95
Feb.	58.4	81.2	5.6	0.62	0.47	89	92
Mar.	72.4	97.9	4.7	0.69	0.38	85	92
Apr.	70.6	96.8	5.0	0.46	0.25	91	95
May	70.5	95.5	5.5	0.44	0.28	92	95
June	73.4	97.1	4.9	0.43	0.3	91	94

NOTE: The data above is from monthly operator reports to the DNR.

MILWAUKEE - JONES ISLAND
(East Plant)

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				6.8	0.9	87
Mar.		0.65	0.02	5.6	0.32	94
Apr.		0.08	0.02	2.6	0.11	96
May		1.00	0.05	3.8	0.25	93
June		3.00	2.30	6.3	4.1	35
July		2.30	1.90	10.0	5.3	47
Aug.						
Sept.		0.50	0.08	5.3	0.23	96
Oct.						
Nov.		0.90	0.09	4.2	0.38	91
Dec.		1.50	0.45	5.5	0.45	92
Jan. 1974						
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

See Discussion.

MILWAUKEE SOUTH SHORE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				12.5	6.0	52
Mar.	32.2	0.60	0.65	6.3	2.0	68
Apr.	83.3	0.40	0.25	5.6	2.2	61
May	69.3	0.90	0.80	4.2	3.0	28
June		0.58	0.04	4.0	0.17	96
July	42.4	0.65	0.05	4.3	0.26	94
Aug.						
Sept.	50.0	3.60	2.20	8.5	4.9	42
Oct.		0.70	0.04	5.3	0.19	96
Nov.		1.10	1.00	8.0	3.75	53
Dec.		1.4	1.3	7.0	3.4	51
Jan. 1974		1.0	0.6	6.8	3.4	50
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

--Have been adding waste pickle liquor prior to Jan. 1973 to neutralize highly alkaline industrial waste.

--Expect to be on line by Jan. 1975 with full scale phosphorus treatment.

NEENAH-MENASHA

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.	15.00			4.0	0.4	90
Mar.	13.00					
Apr.	21.00			2.2	0.34	84
May	23.00			1.9	0.47	75
June	17.00			3.8	0.58	85
July	12.00			1.3	0.23	82
Aug.	13.00			3.1	1.6	48
Sept.	12.00			3.6	2.1	42
Oct.	13.00			4.1	2.1	49
Nov.	13.00			3.7	1.3	65
Dec.	12.60			3.3	1.9	42
Jan. 1974	12.43			3.9	0.9	77
Feb.	11.65			3.2	0.7	78
Mar.	14.19			3.7	0.7	81
Apr.	17.47			2.7	0.8	70
May	13.30			3.0	1.2	60
June	14.84			4.0	1.2	70

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

No phosphorus treatment to date.

NEW HOLSTEIN
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.						
Apr.						
May	0.486			20.0	5.0	75
June	0.488			20.0	6.0	70
July	0.431			20.0	6.0	70
Aug.	0.410			18.0	6.0	67
Sept.	0.394			18.0	6.0	67
Oct.						
Nov.						
Dec.						
Jan. 1974						
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Feb. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ at 25 gpd.

May 1974--New plant on line; Liquid alum plus polymer added at final clarifiers; No tests for phosphorus at new plant to date.

NEW LONDON
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				14.6	11.5	21
Mar.	1.500	6.8	2.0	14.2	3.0	79
Apr.	1.600	2.8	0.05	6.2	1.6	74
May	1.300	7.0	1.80	10.5	3.3	68
June	1.200	9.8	2.5	13.6	2.6	81
July	0.748	12.8	8.1	15.5	9.3	40
Aug.						
Sept.	0.500	10.5	0.38	12.0	2.1	82
Oct.		7.8	5.0	11.8	5.6	53
Nov.		15.0	0.55	20.0	2.3	88
Dec.	0.527			17.6	1.6	91
Jan. 1974	0.563			19.2	8.3	57
Feb.	0.515			16.9	4.6	73
Mar.	0.946			13.7	2.4	82
Apr.	1.114			18.7	3.6	81
May	0.784			18.0	2.5	86
June	1.076			14.0	1.1	92

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum at final clarifiers.

--Major plant upgrading including additions to chemical feed operation planned, but not expected to go on line before 1980.

NORTH FOND DU LAC
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.53			6.5	5.0	23
Mar.	0.86					
Apr.	0.85	0.53	0.56	1.9	2.3	
May	0.78					
June						
July	0.44	3.3	0.75	7.0	3.6	48
Aug.						
Sept.	0.40	3.2	2.9	6.5	5.0	23
Oct.		3.3	1.7	6.2	4.8	23
Nov.		1.3	0.72	6.6	4.0	39
Dec.						
Jan. 1974						
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Feb. 1973--Initiated treatment for phosphorus removal; Liquid alum added ahead of primary tanks.

--Regional treatment planned for Fond du Lac area in the future (possibly 3-5 years).

NORTH PARK S.D.
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.						
Apr.						
May						
June	1.010			5.3	4.7	11
July	0.823			5.7	0.8	86
Aug.	0.721			5.0	0.78	84
Sept.	0.824			5.4	0.83	85
Oct.	1.000			5.8	0.83	86
Nov.	1.162			5.07	0.14	97
Dec.	1.599			5.62	0.36	94
Jan. 1974	1.353			5.5	0.36	93
Feb.	1.315			6.3	0.65	90
Mar.	1.629			6.1	0.68	89
Apr.	1.679			5.76	0.53	91
May	1.564			5.88	0.53	91
June	1.209			5.87	0.56	90

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

July 1973--Initiated treatment for phosphorus removal; Powdered alum addition.

Nov. 1973--Switched to liquid alum feed at lift station approximately 110-120 gpd.

--Bids have been let on construction to double present plant capacity; Waiting construction.

OCONTO

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				3.2	0.6	81
Mar.	1.833	0.12	0.03	2.9	0.3	90
Apr.	1.924	0.23	0.06	1.8	0.5	73
May	2.260	0.19	0.05	2.5	0.42	83
June						
July	1.310	0.36	0.12	3.1	0.3	90
- - -	- - -	- - -	- - -	- - -	- - -	- - -
Aug.	1.632			6.2	1.7	73
Sept.	1.030			6.3	1.7	73
Oct.	1.117			5.0	1.7	66
Nov.	1.298			5.0	1.8	64
Dec.	0.997			4.2	1.8	57
Jan. 1974	0.832			3.3	1.6	52
Feb.	0.776			4.8	1.7	65
Mar.	1.493			3.4	1.5	56
Apr.	2.133			3.4	1.6	53
May	2.154			5.5	1.1	80
June	1.897			3.3	1.1	67

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ plus polymer.

OCONTO FALLS

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.						
Apr.						
May	0.400			4.6	2.1	54
June	0.124			5.0	0.7	86
July	0.208			8.3	1.4	84
Aug.	0.209			8.1	1.2	85
Sept.	0.190			7.3	1.15	84
Oct.	0.175			8.7	1.3	85
Nov.	0.188			8.5	2.6	69
Dec.	0.183			7.8	1.8	77
Jan. 1974	0.188			6.0	1.0	83
Feb.	0.191			7.3	2.6	64
Mar.	0.233			6.0	1.7	72
Apr.	0.308			5.8	2.3	60
May	0.251			5.8	1.8	69
June	0.238			7.1	2.2	69

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ out of drums before primary tanks.

-- Waiting funds for new plant--combined treatment.

OSHKOSH

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				8.5	6.8	20
Mar.	15.750	0.50	0.06	1.8	1.3	28
Apr.		0.15	0.02	2.5	1.5	40
May	16.142	1.00	0.10	2.8	1.3	54
June	12.605	2.90	0.02	4.5	1.3	71
July		0.75	0.22	6.0	1.4	77
Aug.						
Sept.	9.650	4.00	0.20	6.8	1.4	79
Oct.	9.093			6.7	2.1	68
Nov.	9.094			7.1	1.8	74
Dec.	8.940			6.1	2.7	56
Jan. 1974	9.010			5.8	1.7	71
Feb.	9.040			5.6	2.0	64
Mar.	12.600			4.3	2.0	53
Apr.	14.489			3.4	1.0	71
May	13.704			3.9	1.2	69
June	12.557			3.9	1.04	73

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum addition (temporary chemical feed facilities).

July 1973--Chemical feed equipment operational.

Mar. 1975--New plant scheduled to be on line; Activated sludge system with vacuum filtration and zimpro sludge processing (40 MGD plant); Liquid alum plus polymer addition is planned for phosphorus removal.

PESHTIGO
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent PO_4 (mg/1)	Effluent PO_4 (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
- - -	- - -	- - -	- - -	- - -	- - -	- - -
Feb.	0.537	12.5	7.4	4.1	2.4	41
Mar.	0.548	15.25	5.25	5.0	1.7	66
Apr.	0.602	16.0	5.5	5.2	1.8	66
May	0.569	15.0	4.33	4.9	1.4	71
June	0.513	14.75	4.25	4.8	1.4	71
July	0.652	16.0	5.0	5.2	1.6	69
Aug.	0.545	16.0	5.0	5.2	1.6	69
Sept.	0.380					
Oct.						
Nov.	0.406	16.0	5.0	5.2	1.6	69
Dec.	0.415	16.0	5.0	5.2	1.6	69
Jan. 1974	0.464	16.0	5.0	5.2	1.6	69
Feb.	0.451	15.0	6.0	4.9	2.0	60
Mar.	0.415	14.0	5.0	4.6	1.6	64
Apr.	0.368	15.0	6.0	4.9	2.0	60
May	0.480	15.0	6.0	4.9	2.0	60
June	0.451	15.0	6.0	4.9	2.0	60

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; $FeCl_3$ from drums dosed at 30-50 gpd.

Oct. 1974--New plant expected to be on line; 4-5 MGD plant with combined treatment; Expecting to use $FeCl_3$ with polymer.

PLYMOUTH

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.	1.300	0.08	1.80	4.7	4.5	4
Apr.						
May	1.210	1.5	2.5	7.0	3.8	46
June	1.200	1.3	2.4	8.0	4.2	48
July	1.000	1.5	2.8	6.3	3.8	40
Aug.	1.038			12.0	4.5	62
Sept.	0.966			9.5	3.0	68
Oct.	1.002			10.0	4.0	60
Nov.	0.928			11.2	3.5	70
Dec.	1.100			12.0	4.0	67
Jan. 1974	0.915			11.0	4.0	64
Feb.	0.994			10.75	4.5	58
Mar.	1.015			8.5	4.5	47
Apr.	1.138			6.5	4.5	31
May	1.298			7.2	4.8	33
June	0.775			8.0	4.75	41

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum ahead of primaries at 170 gpd.

Nov. 1973--Switched to waste pickle liquor addition (approximately 160 gpd).

--Waiting funds for proposed new plant.

PORT WASHINGTON
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.736			8.4	4.5	46
Mar.	1.820	3.80	0.25	8.8	1.0	89
Apr.	2.340	0.40	0.33	3.6	0.92	74
May	2.162	0.29	0.27	6.4	0.65	90
June	1.535	2.0	0.2	7.8	1.1	86
July	1.082			11.96	1.18	90
Aug.						
Sept.	1.140			9.07	1.3	86
Oct.	1.333			11.1	1.71	85
Nov.	1.204			10.4	1.6	85
Dec.	1.592			10.06	1.6	84
Jan. 1974	1.332			10.5	1.44	86
Feb.	1.248			10.2	1.33	87
Mar.	1.935			9.96	1.83	82
Apr.	1.962			10.42	2.06	80
May	1.884			12.04	1.96	84
June	1.735			12.14	2.51	83

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Nov. 1972--New plant on line; (2.5 MGD A.S.).

Jan. 1973--Initiated treatment for phosphorus removal; 100 gpd waste pickle liquor.

May 1973--Increased average dose of P.L. to 150-160 gpd.

PORTAGE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				7.6	7.4	3
Mar.		4.8	5.0	9.0	5.0	44
Apr.	0.70	2.5	3.8	7.4	5.3	28
May	0.65	5.2	5.0	8.0	6.5	19
June	0.50	7.0	6.1	8.5	7.5	12
July		7.9	6.3	9.6	8.0	17
Aug.						
Sept.	0.90	4.5	0.35	8.5	2.9	66
Oct.		6.0	2.4	12.1	6.3	48
Nov.		4.3	1.3	10.0	5.9	41
Dec.		6.0	0.75	12.0	4.9	59
Jan. 1974		3.8	0.03	12.8	3.9	70
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

August 20, 1973--Initiated treatment for phosphorus removal; Sodium aluminate plus polymer.

Nov. 1973--Temporary facilities for chemical feed complete.

--Waiting complete plant renovation.

RACINE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	19.00			5.5	5.6	
Mar.	24.85	1.8	1.90	4.5	3.7	18
Apr.	29.60	1.2	0.01	3.6	1.6	56
May	28.90	2.3	0.04	5.0	2.6	48
June	26.00			4.6	2.2	52
July	23.70			4.2	2.19	48
Aug.	21.90			4.4	2.81	36
Sept.	22.00			5.0	2.16	57
Oct.	26.30			4.8	2.9	40
Nov.	20.75			4.9	2.65	46
Dec.	23.90			4.46	3.56	20
Jan. 1974	22.48			4.62	3.46	25
Feb.	22.66			3.86	2.93	24
Mar.	26.84			3.49	3.25	7
Apr.	25.86			3.77	2.85	24
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

1968--New 12 MGD secondary treatment on line.

March 14, 1973--Initiated treatment for phosphorus removal; Waste pickle liquor added ahead of primaries at 2000 gpd; (12-14% Fe).

1974-1975--Construction to begin to increase secondary treatment capacity to accommodate 30 MGD average flow.

RIPON

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				7.0	3.2	54
Mar.	2.210	0.60	0.6	5.3	2.4	55
Apr.						
May	1.125	0.02	0.18	1.0	2.0	
June	2.080	2.0	0.35	6.3	2.1	67
July	1.540	1.2	0.35	5.3	1.4	74
Aug.						
Sept.	1.630	1.3	0.23	6.0	1.1	82
Oct.		2.5	0.14	6.8	1.2	82
Nov.		2.0	0.30	6.0	1.1	82
Dec.		4.9	0.10	9.5	1.0	89
Jan. 1974		1.5	0.05	6.0	1.4	77
Feb.	1.371			2.19	0.58	74
Mar.	1.625			6.3	2.1	67
Apr.	1.724			5.32	1.72	68
May	1.892			4.8	1.7	65
June	1.872			10.9	5.3	51

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Chemical feed pump problems in early months of treatment; $FeCl_3$ added ahead of trickling filter.

Jan. 1974--Switched to waste pickle liquor before T.F. at approximately 15 gph (10-12% Fe).

--Plans for a new plant are up for state and EPA approval.

SHAWANO

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.				14.0	11.6	17
Mar.		2.8	2.4	6.9	6.0	13
Apr.		17.5	9.5	18.5	12.0	35
May		4.0	2.4	7.0	5.3	24
June		5.6	6.6	9.5	8.6	9
July		6.0	7.3	10.0	8.5	15
Aug.						
Sept.		10.2	7.6	13.0	9.0	31
Oct.		11.0	7.9	17.5	10.0	43
Nov.		6.0	7.2	11.8	9.4	20
Dec.		15.0	11.3	19.4	15.4	21
Jan. 1974		5.1	8.1	9.6	11.6	
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Feb.						
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Apr. 1973--Initiated treatment for phosphorus removal; Powdered alum at final clarifiers (100 lb/day).

July 1974--Dosing powdered alum at primary tanks; dose maintained at 100 lb/day.

1975 or
1976--New plant expected to be operational; (Shawano S.D.--3 MGD Act. Sludge plant).

SHEBOYGAN

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	11.450			8.0	5.3	34
Mar.	15.120	3.0	1.10	7.0	5.0	28
Apr.	15.680	1.5	0.85	5.4	2.9	46
May	17.360	2.0	1.20	6.3	3.8	40
June	16.400	1.1	1.20	4.8	3.2	33
July	13.400	1.4	1.60	5.2	3.4	35
- - -	- - -	- - -	- - -	- - -	- - -	- - -
Aug.						
Sept.	11.250			6.5	3.22	50
Oct.	11.272			7.5	4.64	38
Nov.	10.900			6.9	4.49	35
Dec.	11.762			5.22	3.73	29
Jan. 1974	11.135					
Feb.	9.921			7.29	3.6	51
Mar.	13.840			5.63	3.45	39
Apr.	15.050			4.72	2.76	42
May	12.690			5.66	3.77	33
June	15.760			4.58	2.53	45

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Varying doses of $FeCl_3$ with polymer (12-20 gph).

July 1973--Experimented with liquid alum, with and without polymer.

Oct. 1973--$FeCl_3$ plus polymer at primary tanks; $FeCl_3$ at wet well ahead of finals; also polymer addition ahead of sludge thickener.

--Plans to construct Act. Sludge plant to provide regional treatment serving the Sheboygan area.

SHEBOYGAN FALLS

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	1.053			10.6	2.5	76
Mar.		8.3	1.9	11.3	3.8	66
Apr.	1.070	3.5	0.74	9.0	3.8	58
May	1.110	5.6	0.7	8.6	3.1	64
June	0.736	3.8	1.4	8.4	2.8	67
July	0.515	7.4	2.5	9.6	3.3	66
Aug.	0.543			10.7	3.4	68
Sept.	0.542			9.5	3.1	67
Oct.	0.652			11.0	2.8	75
Nov.	0.677			10.1	3.0	70
Dec.	0.877			10.34	3.5	66
Jan. 1974	0.758			11.1	4.0	64
Feb.	0.673			9.9	4.5	55
Mar.	1.030			6.6	2.9	56
Apr.	1.180			5.8	2.9	50
May	0.811			7.8	3.0	62
June	0.834			7.9	2.9	63

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Feb. 1973--Initiated treatment for phosphorus removal; Liquid alum at 130 gpd.

--Sheboygan Falls had its own plans drawn up for a new plant, but was told to go regional (proposed Sheboygan Regional system).

SOUTH MILWAUKEE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
'eb.	2.895			8.0	4.0	50
Mar.	3.750	1.5	2.00	5.6	3.2	43
Apr.	5.090	1.3	0.95	3.7	1.7	54
May	4.090	2.5	2.20	4.0	2.5	38
June	3.550	2.3	3.1	4.3	3.4	21
July	2.760			20.0	15.0	25
Aug.	2.840			21.0	14.0	33
Sept.						
Oct.	2.830			5.1	1.2	76
Nov.	2.662			15.0	3.0	80
Dec.	3.350			4.5	1.1	76
Jan. 1974	3.124			5.1	1.1	78
Feb.	2.964			4.7	0.9	81
Mar.	5.110			3.79	0.84	78
Apr.	4.750			3.33	0.66	80
May	4.595			3.54	0.82	77
June	3.830			3.18	0.73	77

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Sept. 1972--New plant on line; Old plant was primary treatment only; Began using lime for phosphorus removal.

Feb. 1973--Switched to feeding dry alum (approximately 400 lb/day).

Sept. 1973--Increased alum dose to 2000-4000 lb/day.

Dec. 1973--Switched to sodium aluminate (500-600 lb/day).

--Mr. Martinek expressed the desire to try liquid feed.

STURGEON BAY
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973						
Feb.				5.5	1.4	74
Mar.	1.930	3.5	1.0	6.5	2.8	57
Apr.	1.850	0.55	0.50	2.4	1.6	33
May	2.053	0.75	0.50	2.0	1.0	50
June	2.036	2.0	0.65	3.5	1.6	54
July	1.688	1.8	0.05	11.8	0.4	97
Aug.						
Sept.	1.000	1.8	0.05	8.8	0.55	94
Oct.		1.0	0.06	7.5	0.28	96
Nov.		1.1	0.08	10.8	0.56	95
Dec.		0.90	0.04	8.0	0.7	91
Jan. 1974		0.18	0.06	29.2	3.7	87
Feb.	1.114			50.0	3.6	93
Mar.	1.630			4.02	2.43	40
Apr.	1.674			6.9	2.7	61
May	1.631			17.9	2.0	89
June	1.728			21.8	1.6	93

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; Temporary system--dosing powdered alum at 100 lb/day.

July 1973--Full-scale chemical feed equipment on line; Liquid alum at 320-350 gpd ahead of aeration with polymer feed.

May 1974--Discontinued polymer use.

STURTEVANT
PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.						
Mar.						
Apr.						
May						
June						
- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
July	0.507			29.0	15.0	48
Aug.	0.463			33.0	28.0	15
Sept.	0.469			36.4	31.0	15
Oct.	0.536			16.0	23.0	
Nov.	0.554			29.0	28.0	3
Dec.	0.572			35.0	22.0	37
Jan. 1974						
Feb.	0.554			8.8	4.6	48
Mar.						
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

July 1974--Initiated treatment for phosphorus removal; Liquid alum plus polymer, both ahead of primary tanks and ahead of final clarifiers.

THIENSVILLE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	0.60			5.2	3.5	33
Mar.	1.05	0.10	0.05	7.0	0.3	96
Apr.	1.15	0.55	0.02	2.3	0.14	94
May	1.15	0.04	0.002	3.8	0.06	98
June		0.035	0.005	8.8	0.08	99
July		0.170	0.006	9.0	0.22	98
Aug.						
Sept.		4.0	0.016	6.0	0.18	97
Oct.		2.0	0.02	3.5	0.03	91
Nov.		2.2	0.03	4.0	0.22	94
Dec.		1.8	0.02	4.2	0.26	94
Jan. 1974		1.3	0.01	4.9	0.08	98
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Feb.						
Mar.				4.3	0.2	95
Apr.						
May						
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum plus polymer addition.

--Probably expected to hook up with Milwaukee Metropolitan system in the future.

TWO RIVERS

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	2.440			12.5	4.8	62
Mar.	2.585	3.3	1.5	10.4	6.5	38
Apr.	2.610	1.5	1.3	7.6	5.6	26
May	2.748	0.85	0.27	2.2	4.7	
June	2.880	1.3	0.48	9.7	7.4	24
July	2.700	4.0	0.32	7.4	4.6	38
Aug.	2.810					
Sept.	2.522	0.33	0.04	6.9	6.9	0
Oct.	2.732	0.75	0.40	8.75	5.25	40
Nov.	2.560	0.02	0.18	13.4	4.8	64
Dec.	2.825	0.60	0.05	7.8	6.1	22
Jan. 1974	2.679			7.8	4.3	45
Feb.	2.525			7.1	1.9	73
Mar.	2.854			5.5	2.3	58
Apr.	2.809			1.7	0.16	91
May	2.912			7.95	3.16	60
June	2.896			4.3	2.4	44

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

April 18, 1973--Initiated treatment for phosphorus removal.

--Waiting funds for new 7-9 MGD plant.

UNION GROVE

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973	0.512			26	4	85
Feb.	0.466					
Mar.	0.604					
Apr.	0.671					
May	0.618					
June						
July	0.418					
Aug.	0.386					
Sept.	0.427					
Oct.	0.476					
Nov.	0.496					
Dec.	0.547					
Jan. 1974	0.545					
Feb.	0.584					
Mar.	0.651					
Apr.	0.628					
May	0.618					
June	0.529					

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Nov. 1972--Initiated treatment for phosphorus removal; Liquid sodium aluminate plus polymer ahead of primaries.

Mar. 1973--Discontinued chemical treatment; Waiting funds for new plant.

WAUPACA

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/l)	Effluent Soluble P (mg/l)	Influent Total P (mg/l)	Effluent Total P (mg/l)	Total P Removal Efficiency %
Jan. 1973	0.568			18.0	2.0	89
Feb.	0.703			21.0	2.7	87
Mar.						
Apr.						
May						
June	1.070			16.0	2.0	88
July						
Aug.	0.927			9.0	1.0	89
Sept.	0.528			27.0	9.5	65
Oct.						
Nov.						
Dec.	0.620			13.0	2.1	84
Jan. 1974						
Feb.						
Mar.	0.908			9.4	1.8	81
Apr.						
May	0.941			11.4	1.8	84
June	0.929			13.0	1.8	86

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND
PHOSPHORUS TREATMENT MODIFICATIONS

Jan. 1973--Initiated treatment for phosphorus removal; 48 gpd liquid sodium aluminate ahead of primary tanks.

Jan. 1974--48 gpd sodium aluminate at head of aeration tanks.

--Waiting funds on chemical feed equipment; (Throughout the period of treatment, have been adding polymer only from spring to late fall).

WEST BEND

PHOSPHORUS REMOVAL EFFICIENCIES

	Flow (MGD)	Influent Soluble P (mg/1)	Effluent Soluble P (mg/1)	Influent Total P (mg/1)	Effluent Total P (mg/1)	Total P Removal Efficiency %
Jan. 1973						
Feb.	3.116			7.4	4.0	46
Mar.	3.67	3.6	0.37	7.8	2.0	74
Apr.	3.920			7.9	1.2	85
May	4.290			6.5	1.5	77
June	3.940			6.4	1.1	83
July	3.200			5.8	0.4	93
Aug.	3.469			5.6	1.4	75
Sept.	3.260			9.43	1.53	89
Oct.	3.320			8.94	1.44	84
Nov.	4.050			9.1	1.5	84
Dec.	3.910			7.69	0.98	87
Jan. 1974	4.320			7.95	1.03	87
Feb.	4.235			7.21	1.12	84
Mar.	5.225			6.79	1.18	83
Apr.	5.200			8.2	1.43	83
May	4.800			8.04	1.66	79
June						

NOTE: The data above the dashed line are from the State Lab's analysis; the remainder is from individual operator reports to the DNR.

PLANT PROCESS CHANGES AND PHOSPHORUS TREATMENT MODIFICATIONS

Mar. 1973--Initiated treatment for phosphorus removal; Liquid alum addition.

May 1973--Switched to waste pickle liquor addition; (336 gpd at grit chamber).

--Waiting funds for major plant upgrading.

APPENDIX C

Treatment-Cost Alternatives

Treatment-cost alternatives used as the data base for the computer analysis are illustrated graphically in this appendix. The alternatives are discrete points and the line drawn thru the points is only representative of the straight line relation on the semi-log plot. Treatment alternatives based on actual data are specifically designated. The treatment required at the maximum removal alternatives is indicated.

Also included is a comparison with alternatives developed by Fait (1). The study by Fait was a predictive one with a variety of treatment alternatives postulated for each city, e.g. primary ferric addition, combined alum addition, or lime treatment. Thus only those alternatives which are comparable are included here. The cost is adjusted according to the ratio of the appropriate sewage treatment plant construction cost indices (30). Treatment levels applied by Fait (1), excluding lime addition and microscreening, are:

	PRIMARY	CHEM-BIOLOG.
Fe:P = 1.5:1	70%	80%
2:1	80%	90%
Al:P = 1.2:1	--	80%
1.4:1	--	90%

Alternatives did not include any estimates for pickle liquor addition which are difficult to predict because of the variety of sources and costs. Other differences in the cost levels of alternatives listed by Fait (1) and those reported here can be explained by: the temporary facilities currently on line at many plants, the inclusion of maintenance labor at small plants by Fait (1) which would result in a difference of approximately 1.4¢/1000 gal. at 1 MGD plants (with less if any relative difference at larger plants), and specific treatment conditions or problems encountered in implementation.

The prediction of phosphorus treatment performance and costs without pilot plant tests or even jar tests is very difficult and highly speculative. Melkersson (6) emphasized the importance of pilot plant tests in determining chemicals and application points for efficient phosphorus removal.

Examples of the treatment-cost alternative determination for three of the cities follows.

(i) Sturgeon Bay

Several actual levels of treatment are available at Sturgeon Bay. Before full-scale chemical feed facilities were on line, Sturgeon Bay dosed at Al:P $\cong$ 0.5:1 to get 55% removal. The current level of treatment is 91% removal at Al:P $\cong$ 2:1 and an effluent concentration of 0.6 mg/l as P. Polymer had been used for a period of time with proven effectiveness at Al:P $\cong$ 2:1 and 95 % removal with an effluent concentration of approximately 0.3 mg/l as P. After these known levels are plotted, a line is drawn approximately to fit the known data. Supplemental points are chosen to provide a range of treatment alternatives. The points chosen here are at 75% and 85% removal. The assumed level of treatment without chemical addition is also plotted at the fixed cost of the chemical feed facilities. No particular problems with hydraulic or sludge overloads is indicated at current operating levels.

(ii) Marinette

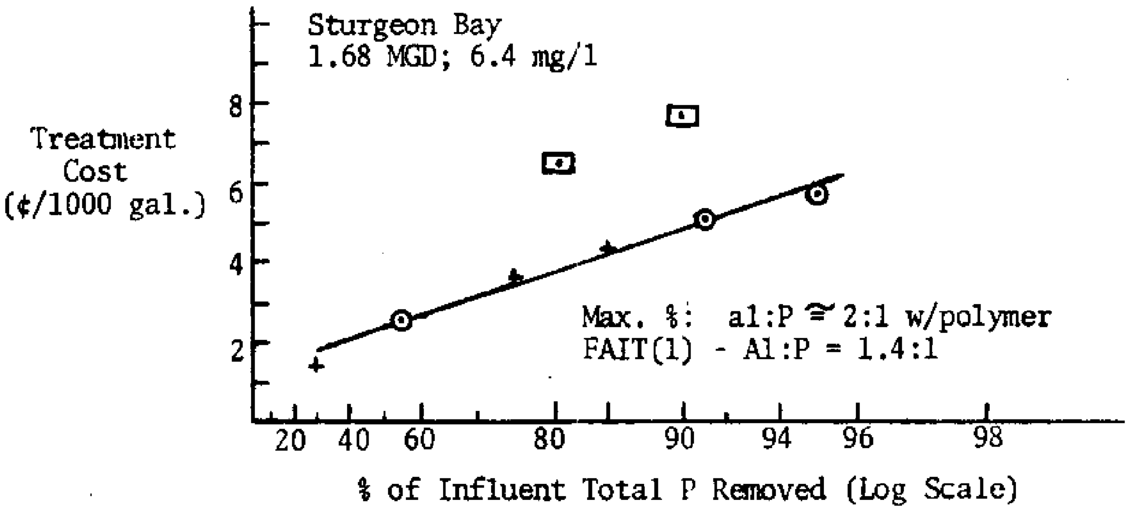
The level of treatment at Marinette is 82% at Fe:P $\cong$ 1:1 with polymer, with a resulting effluent concentration of 0.5 mg/l as P. No particular hydraulic or sludge problems are noted, and with this generally efficient plant a chemical dose of Fe:P $\cong$ 1.5:1 should present no particular problems and provide the capability to attain approximately 0.2 mg/l as P in the effluent. In this example the low effluent concentration at the maximum removal alternative makes the realization of this treatment level a speculative one. But the low influent concentration of 2.8 mg/l as P, the relatively low Fe:P ratio required for achieving an effluent concentration of 0.5 mg/l as P, and the effective use of polymer provide reasons why the low level of residual phosphorus could be reached.

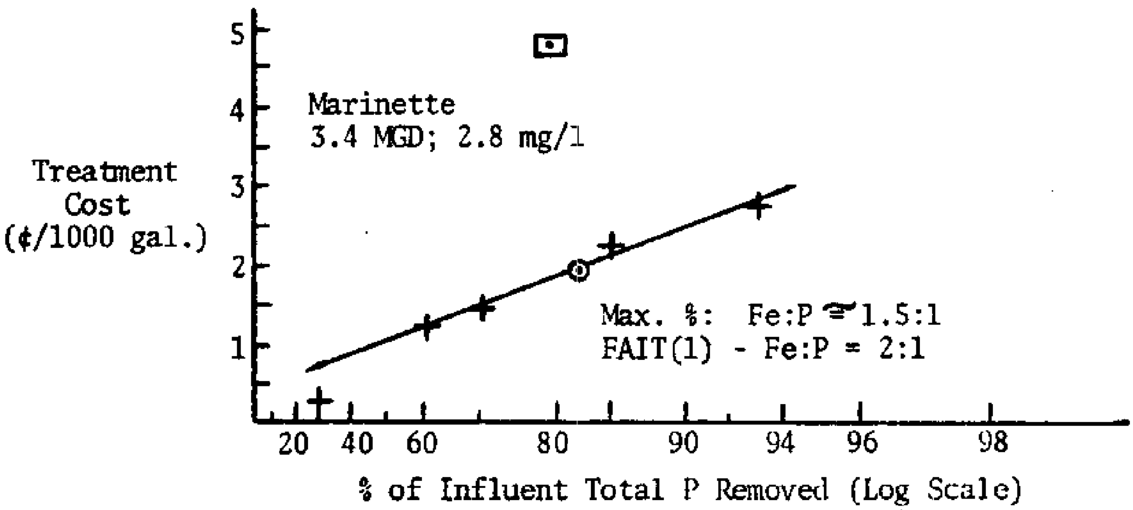
(iii) Sheboygan

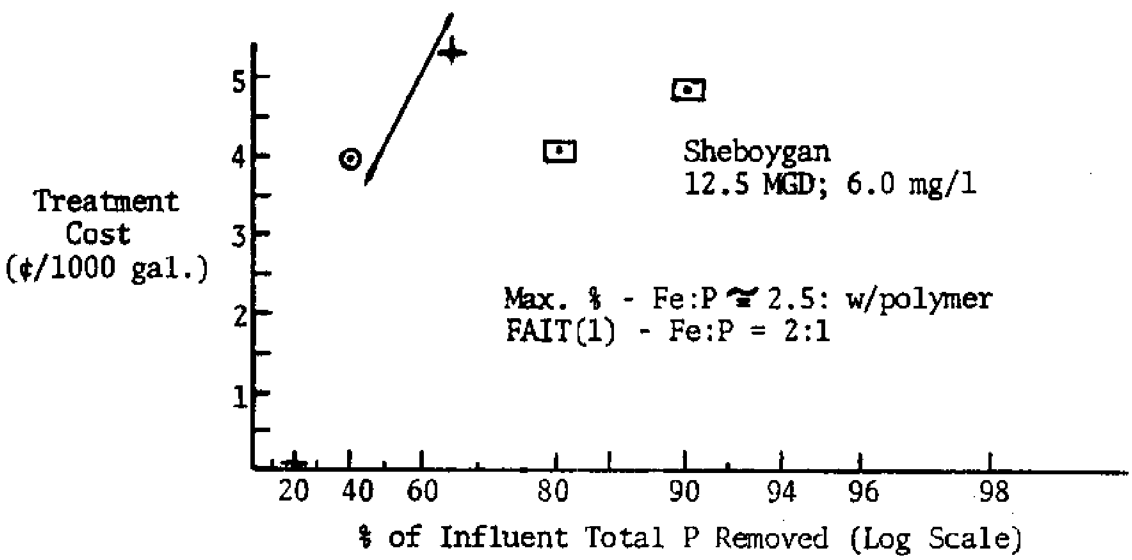
Under chemical doses required to obtain approximately 85% removal, the sludge handling and disposal system becomes badly overloaded. Investment is kept low because of the planned regional plant at Sheboygan. The average level of treatment is 40% removal at Fe:P ≅ 1.8:1 with polymer. An estimated 20% removal is obtained with no chemical treatment. Mr. Stuebe indicated that he would increase the dose somewhat to get a higher average removal, but noted that 60-65% was the maximum removal possible under current plant conditions. It is assumed that a dose of Fe:P ≅ 2.5:1 will be adequate to maintain a 65% removal level.

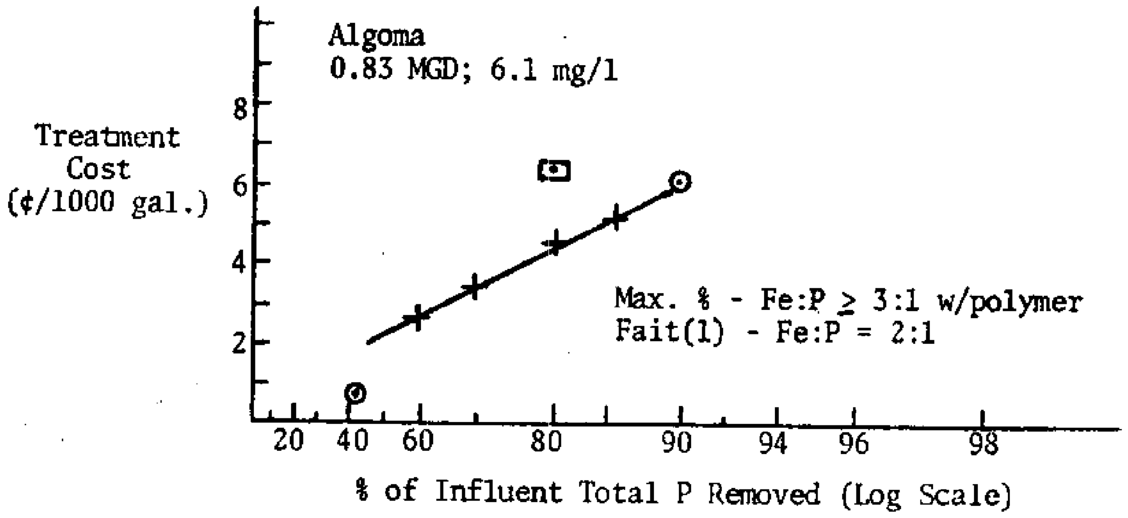
Key to Symbols and Abbreviations Used in Appendix C

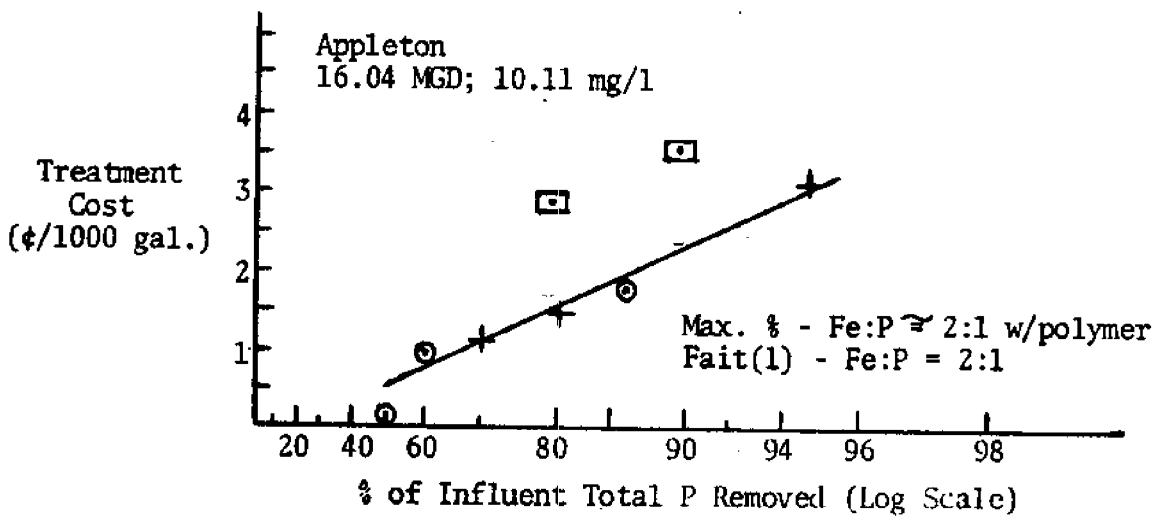
⊙	Alternatives based on actual treatment levels
+	Calculated or estimated treatment levels used as alternatives
●	Estimated treatment levels used as alternatives for computer runs when new plants are on line or treatment problems are resolved.
⊡	Alternatives listed by Fait (1)
———	Line representative of treatment-cost relationship
-----	Estimated treatment-cost relationship when new plants are on line or treatment problems are resolved
NP	Refers to alternatives when new plant is operational
P.L.	Refers to waste pickle liquor addition for phosphorus removal; Fait (1) did not use pickle liquor as a treatment alternative.

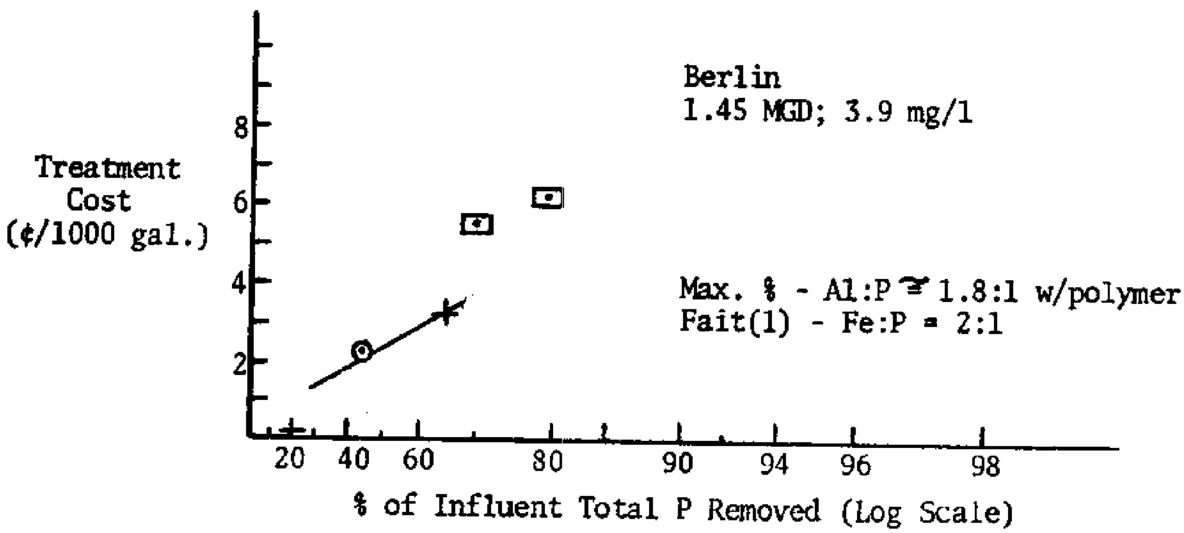

Sturgeon Bay
1.68 MGD; 6.4 mg/1
Treatment Cost (¢/1000 gal.)
8
6
4
2
Max. %: al:P ≅ 2:1 w/polymer
FAIT(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

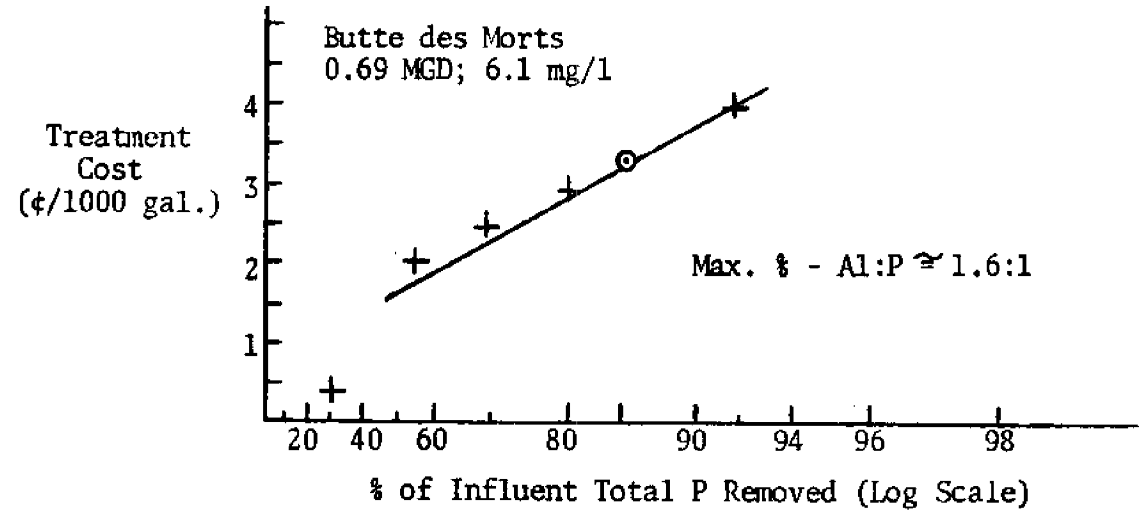

5
4
3
2
1
Marinette
3.4 MGD; 2.8 mg/1
Treatment Cost (¢/1000 gal.)
Max. %: Fe:P ≅ 1.5:1
FAIT(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

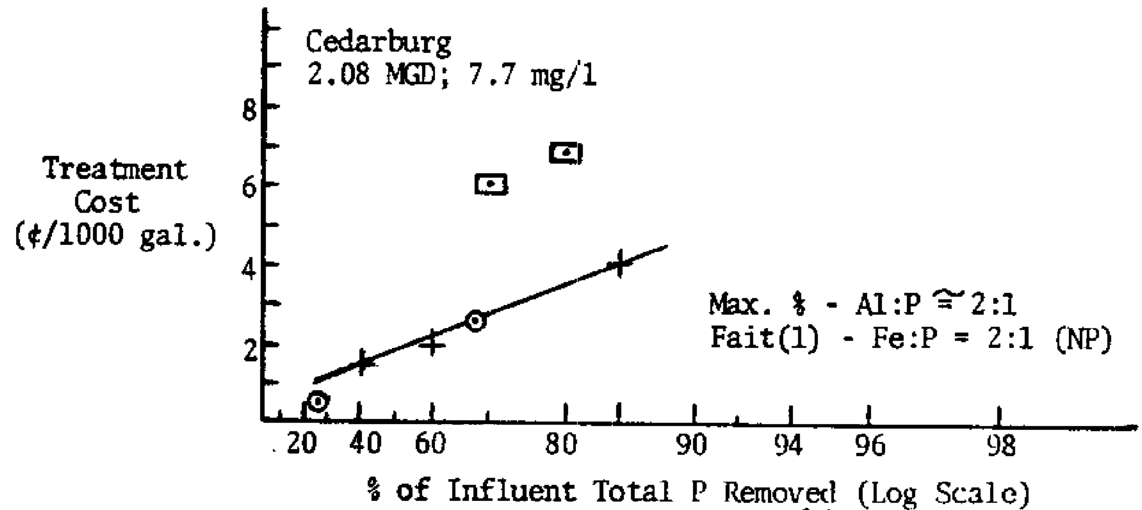

5
4
3
2
1
Sheboygan
12.5 MGD; 6.0 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 2.5: w/polymer
FAIT(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

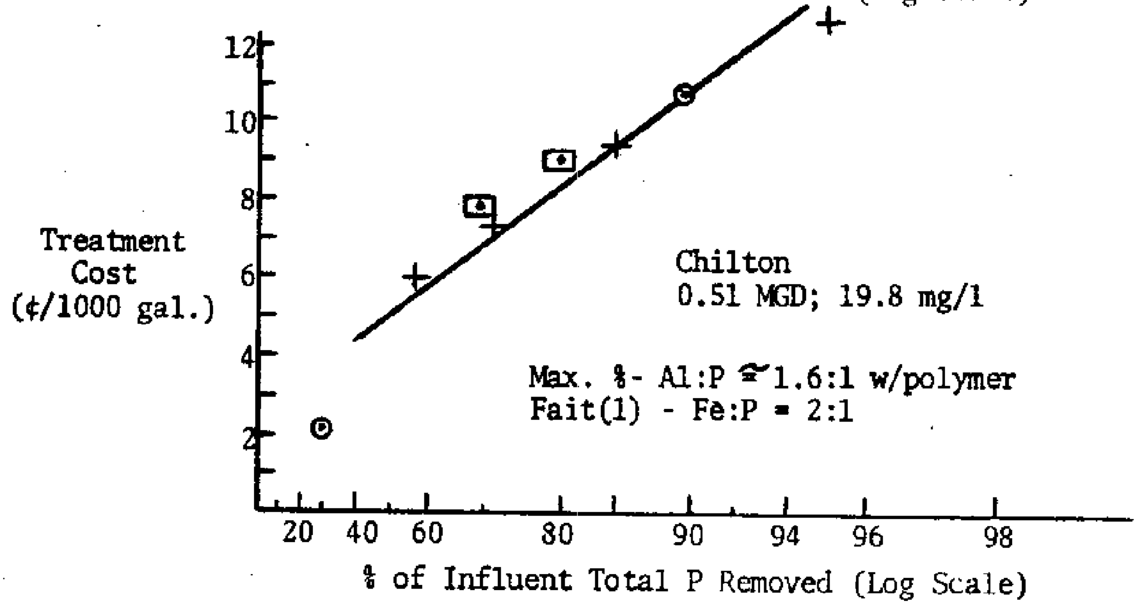

Algoma
0.83 MGD; 6.1 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≥ 3:1 w/polymer
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

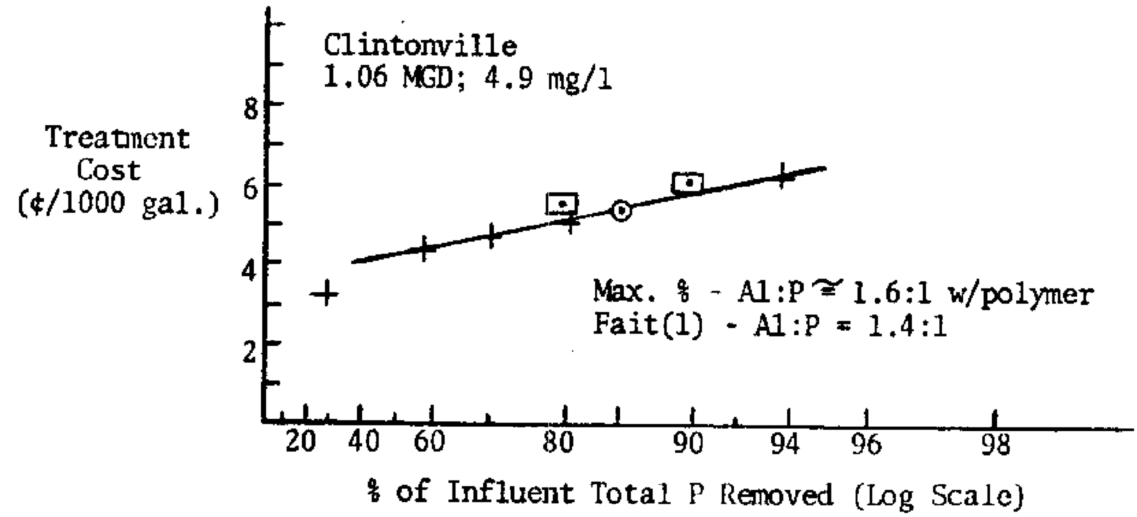

Appleton
16.04 MGD; 10.11 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 2:1 w/polymer
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

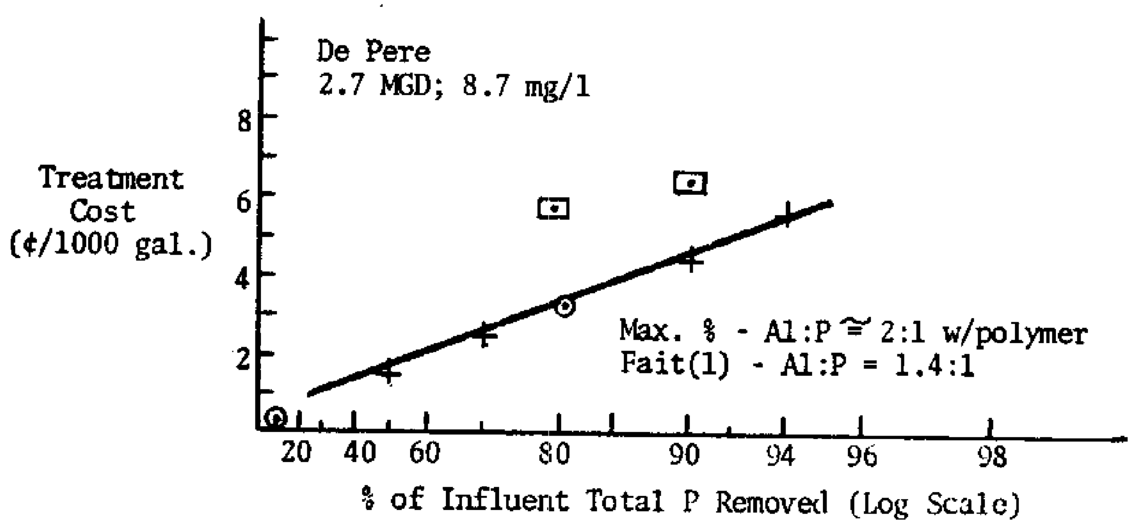

Berlin
1.45 MGD; 3.9 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1.8:1 w/polymer
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

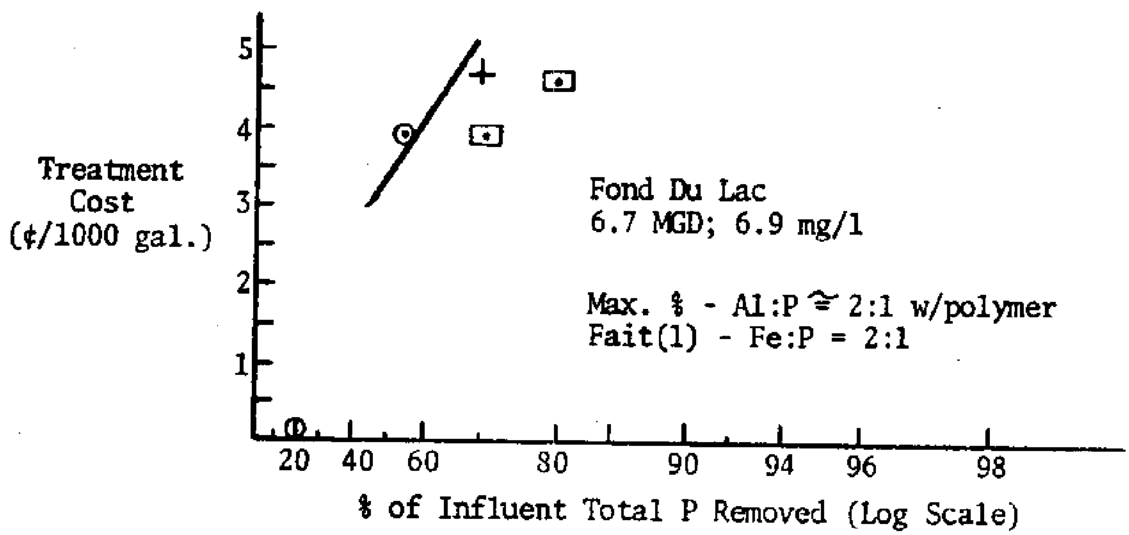

Butte des Morts
0.69 MGD; 6.1 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1.6:1
% of Influent Total P Removed (Log Scale)
1
2
3
4
20
40
60
80
90
94
96
98

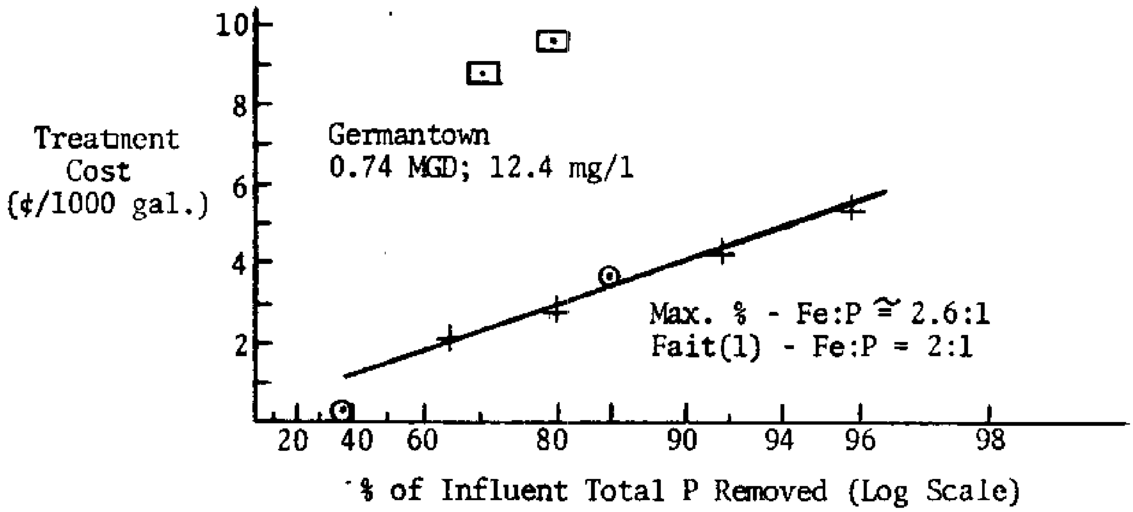

Cedarburg
2.08 MGD; 7.7 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2:1
Fait(1) - Fe:P = 2:1 (NP)
% of Influent Total P Removed (Log Scale)
2
4
6
8
20
40
60
80
90
94
96
98

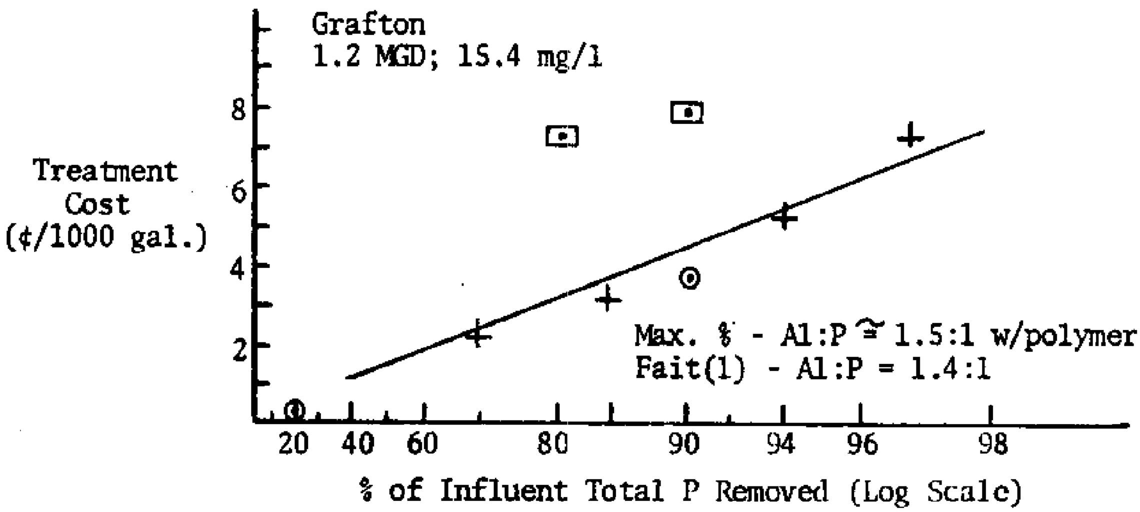

Chilton
0.51 MGD; 19.8 mg/1
Treatment Cost (¢/1000 gal.)
Max. %- Al:P ≅ 1.6:1 w/polymer
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)
2
4
6
8
10
12
20
40
60
80
90
94
96
98

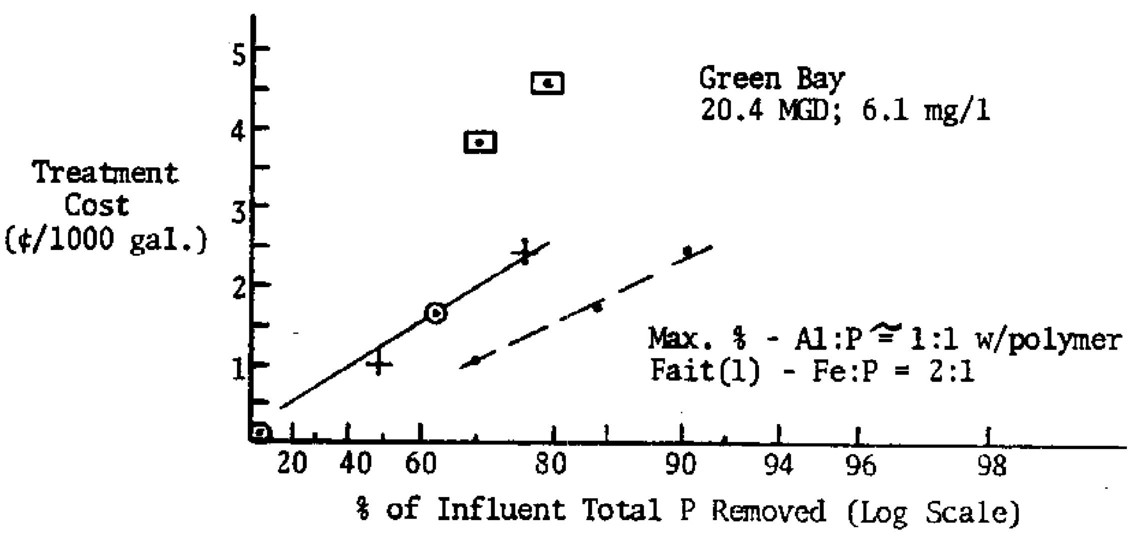

Clintonville
1.06 MGD; 4.9 mg/1
Treatment Cost (¢/1000 gal.)
2
4
6
8
Max. % - Al:P ≅ 1.6:1 w/polymer
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

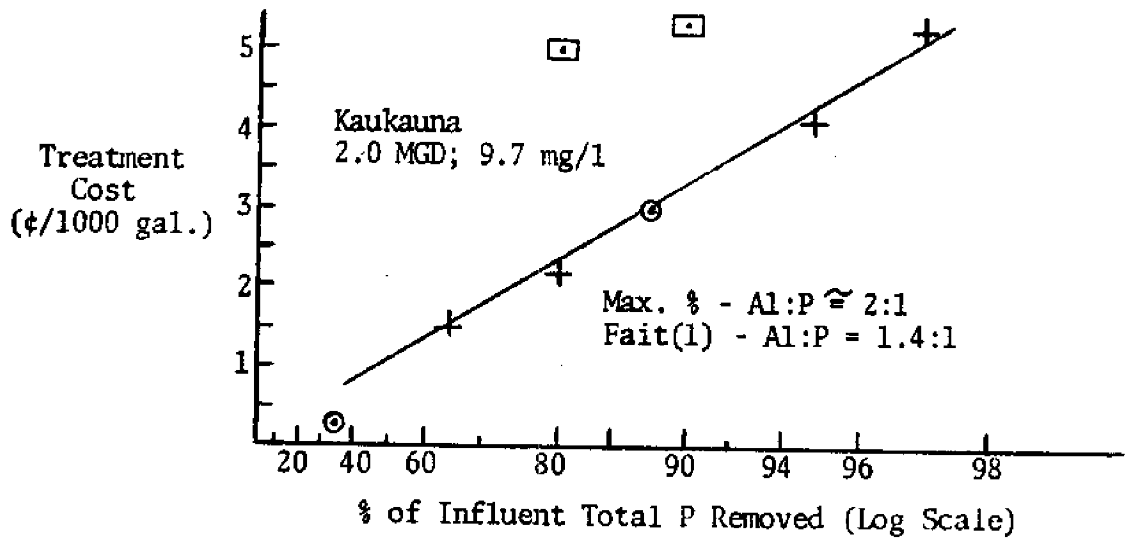

De Pere
2.7 MGD; 8.7 mg/1
Treatment Cost (¢/1000 gal.)
2
4
6
8
Max. % - Al:P ≅ 2:1 w/polymer
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

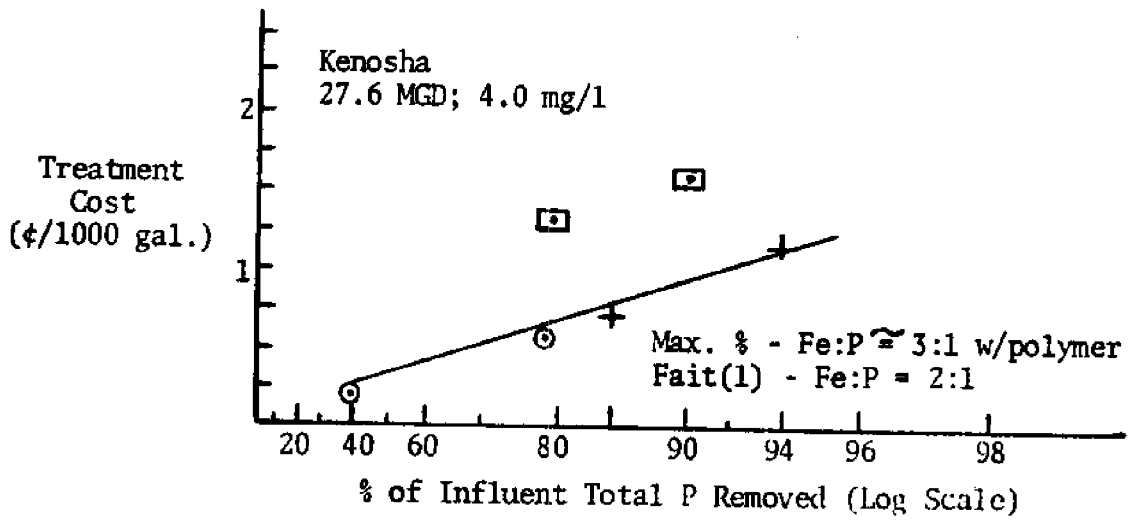

Treatment Cost (¢/1000 gal.)
1
2
3
4
5
Fond Du Lac
6.7 MGD; 6.9 mg/1
Max. % - Al:P ≅ 2:1 w/polymer
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

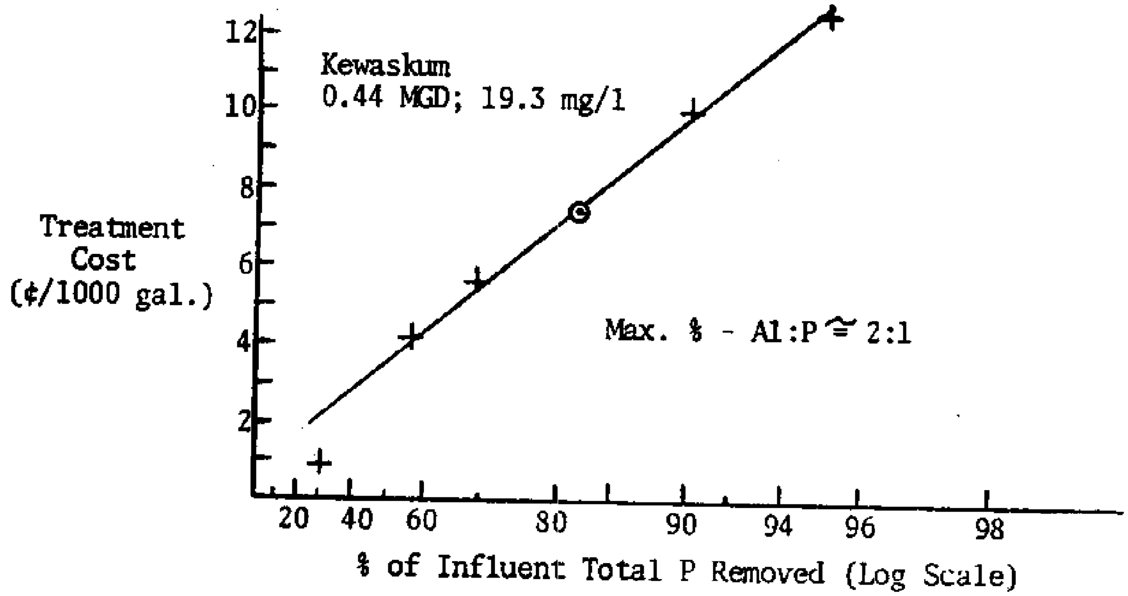

Treatment Cost (¢/1000 gal.)
10
8
6
4
2
Germantown
0.74 MGD; 12.4 mg/l
Max. % - Fe:P ≅ 2.6:1
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

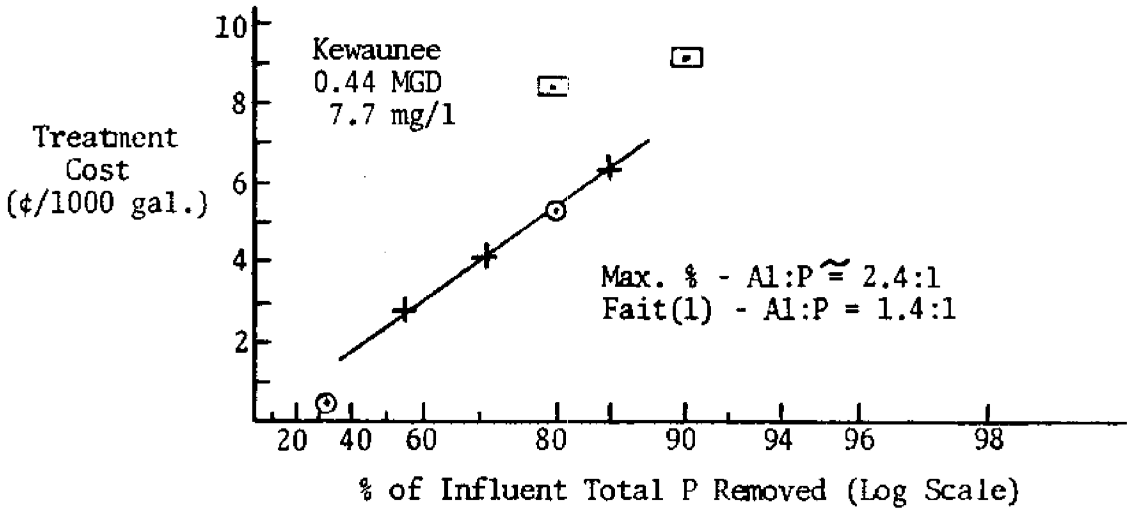

Grafton
1.2 MGD; 15.4 mg/l
Treatment Cost (¢/1000 gal.)
8
6
4
2
Max. % - Al:P ≅ 1.5:1 w/polymer
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

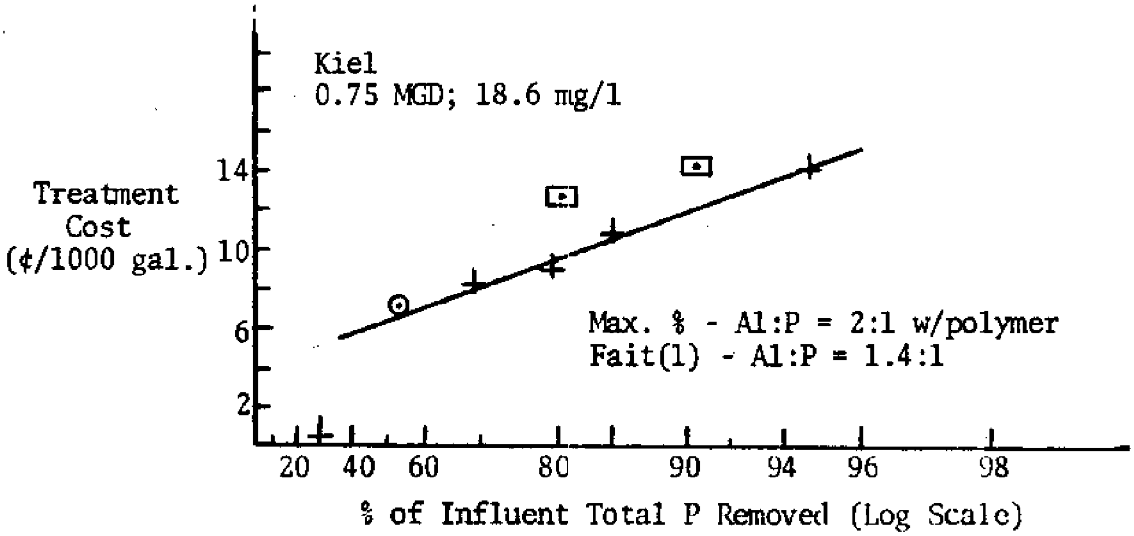

Treatment Cost (¢/1000 gal.)
5
4
3
2
1
Green Bay
20.4 MGD; 6.1 mg/l
Max. % - Al:P ≅ 1:1 w/polymer
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

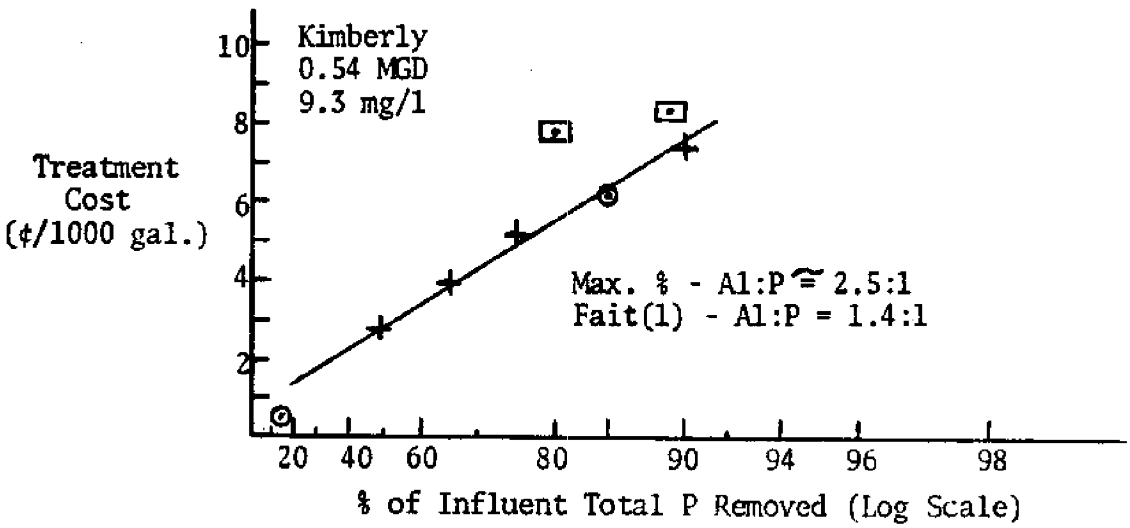

Treatment Cost (¢/1000 gal.)
5
4
3
2
1
Kaukauna
2.0 MGD; 9.7 mg/1
Max. % - Al:P ≅ 2:1
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

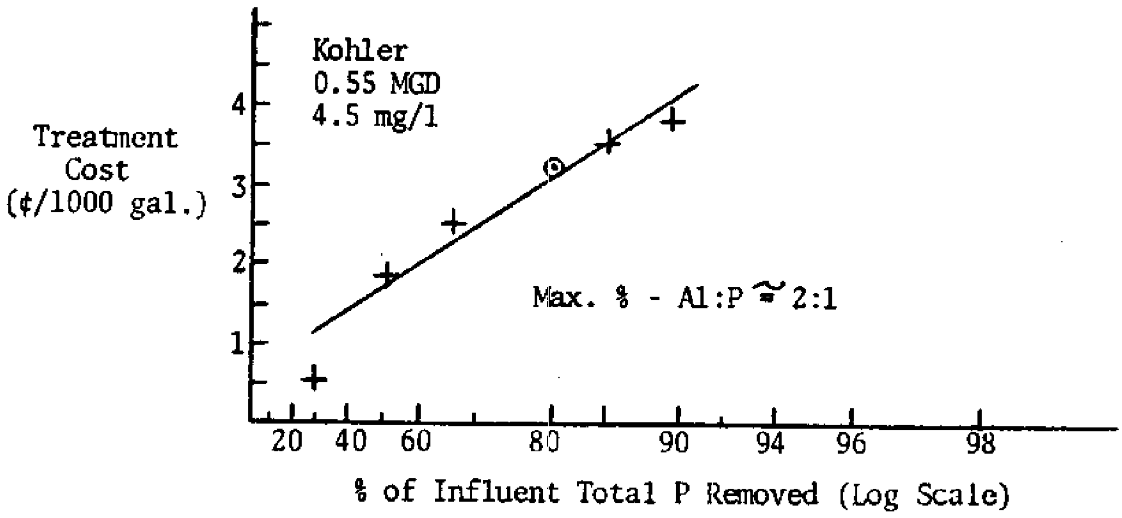

Treatment Cost (¢/1000 gal.)
2
1
Kenosha
27.6 MGD; 4.0 mg/1
Max. % - Fe:P ≅ 3:1 w/polymer
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

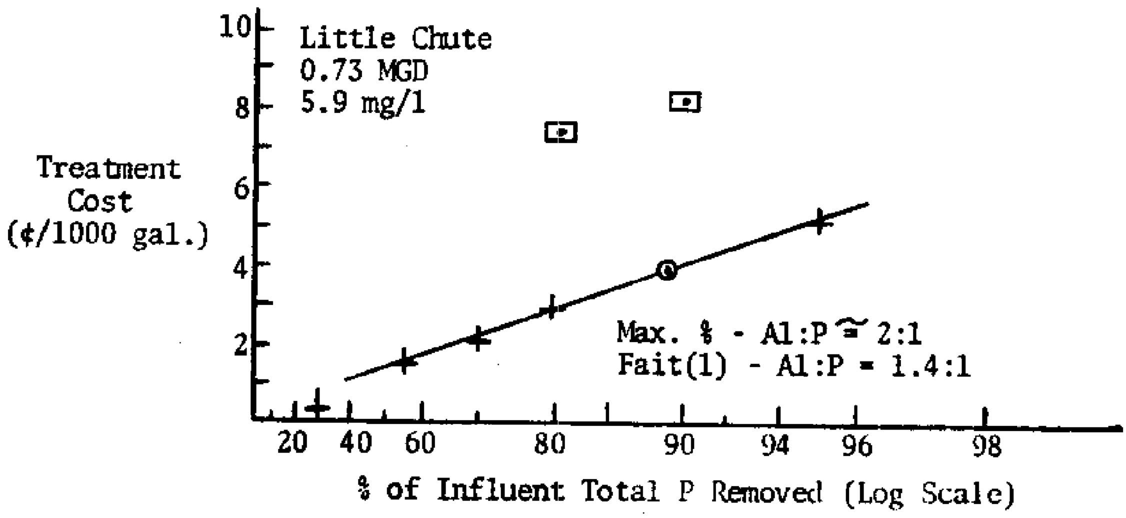

Treatment Cost (¢/1000 gal.)
12
10
8
6
4
2
Kewaskum
0.44 MGD; 19.3 mg/1
Max. % - Al:P ≅ 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

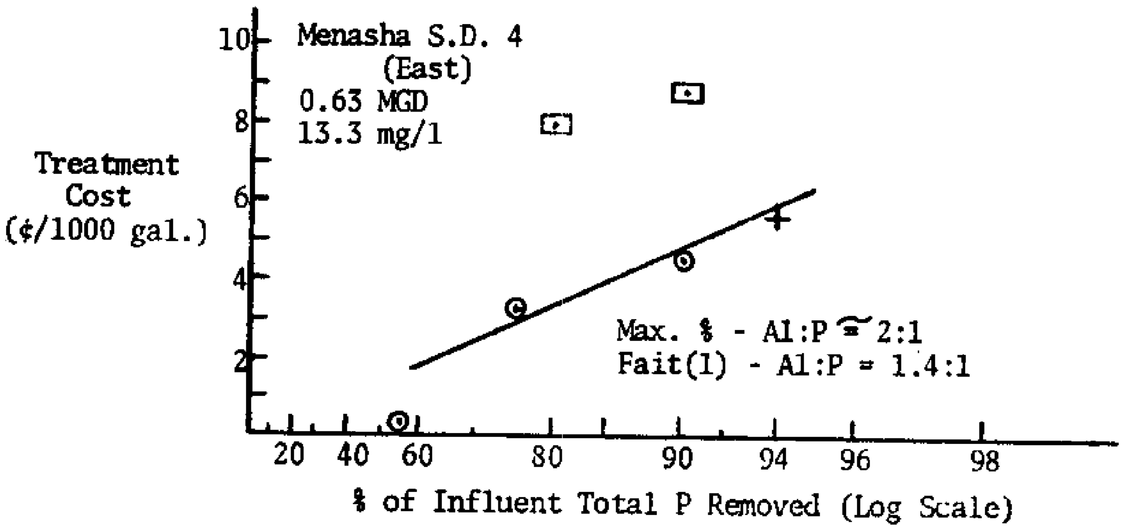

Kewaunee
0.44 MGD
7.7 mg/1
Treatment Cost (¢/1000 gal.)
10
8
6
4
2
Max. % - Al:P ≅ 2.4:1
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

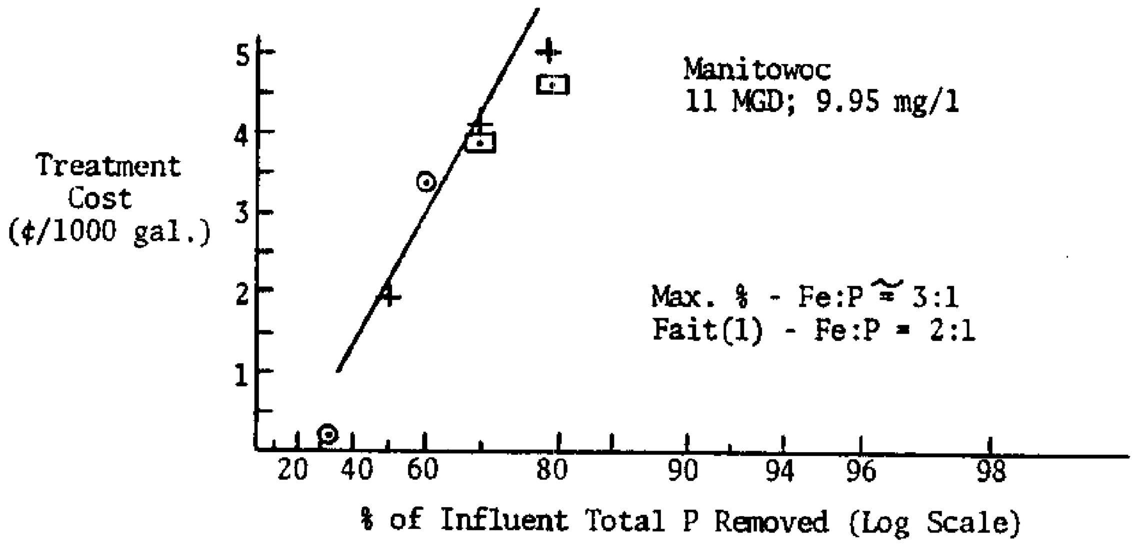

Kiel
0.75 MGD; 18.6 mg/1
Treatment Cost (¢/1000 gal.)
14
10
6
2
Max. % - Al:P = 2:1 w/polymer
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

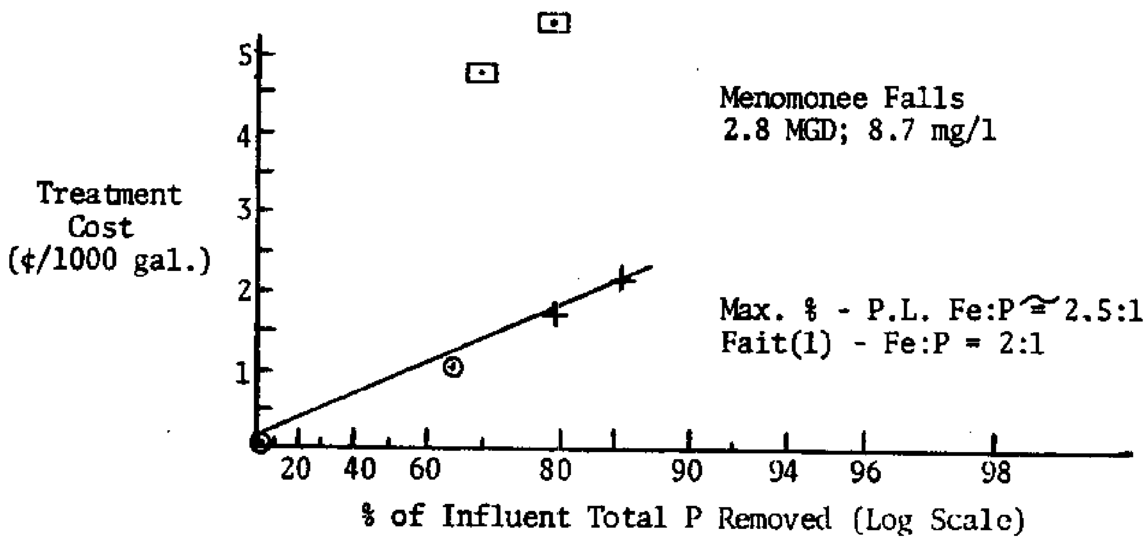

Kimberly
0.54 MGD
9.3 mg/1
Treatment Cost (¢/1000 gal.)
10
8
6
4
2
Max. % - Al:P ≅ 2.5:1
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

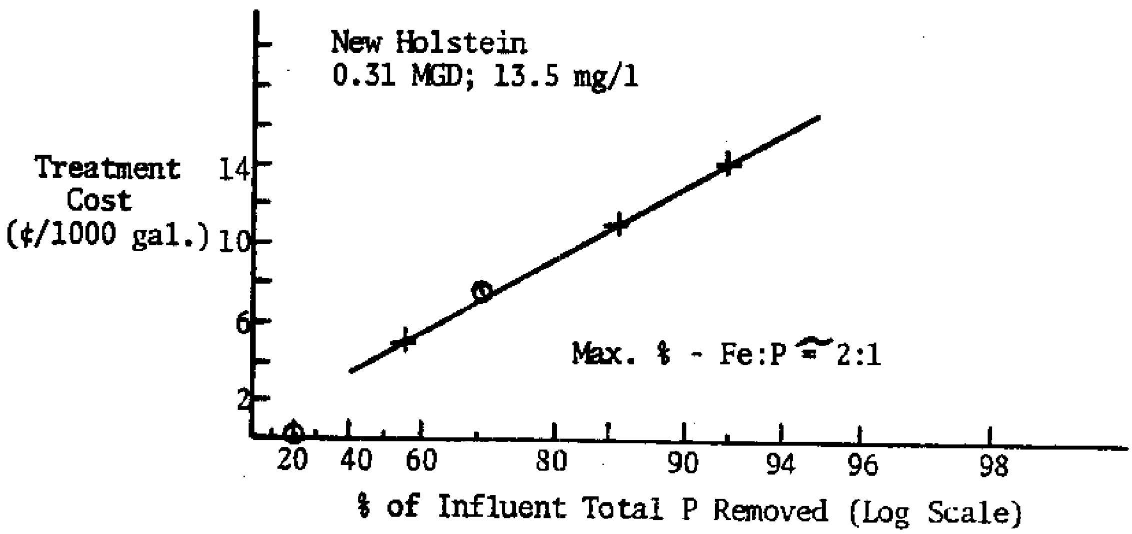

Kohler
0.55 MGD
4.5 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2:1
% of Influent Total P Removed (Log Scale)

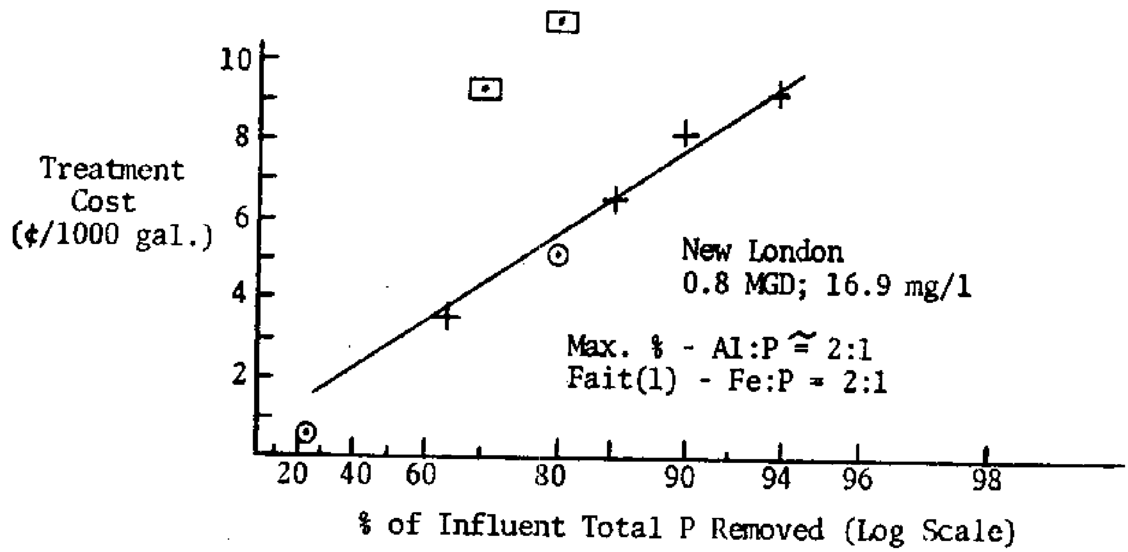

Little Chute
0.73 MGD
5.9 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2:1
Fait(1) - Al:P = 1.4:1
% of Influent Total P Removed (Log Scale)

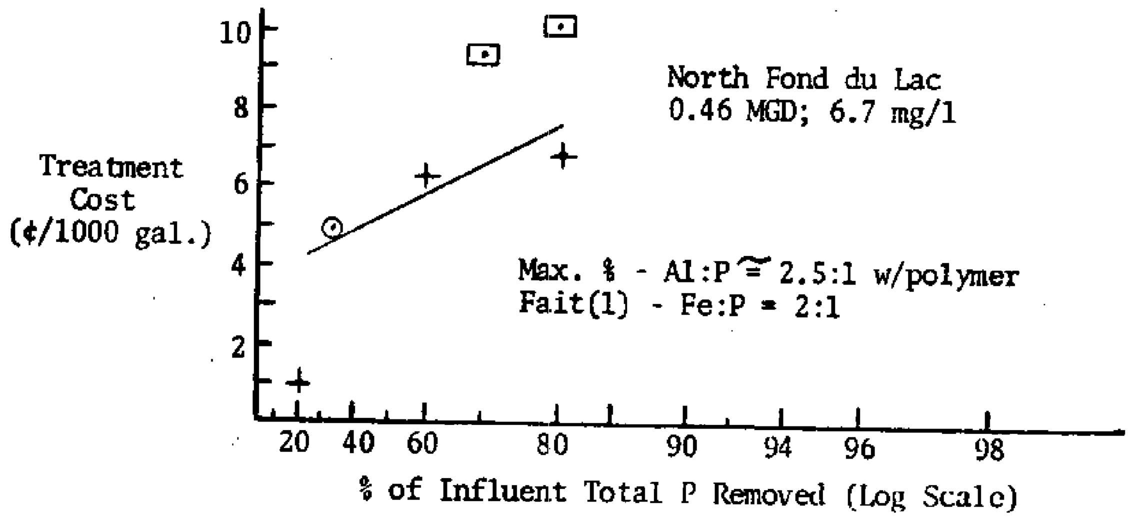

Menasha S.D. 4 (East)
0.63 MGD
13.3 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2:1
Fait(1) - Al:P = 1.4:1
% of Influent Total P Removed (Log Scale)

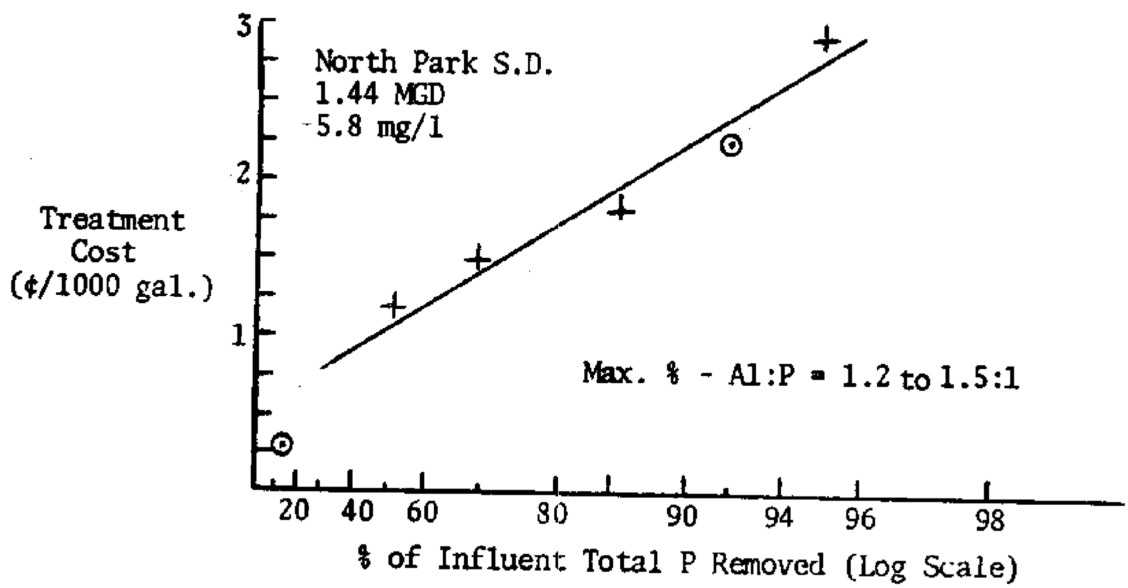

Manitowoc
11 MGD; 9.95 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 3:1
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

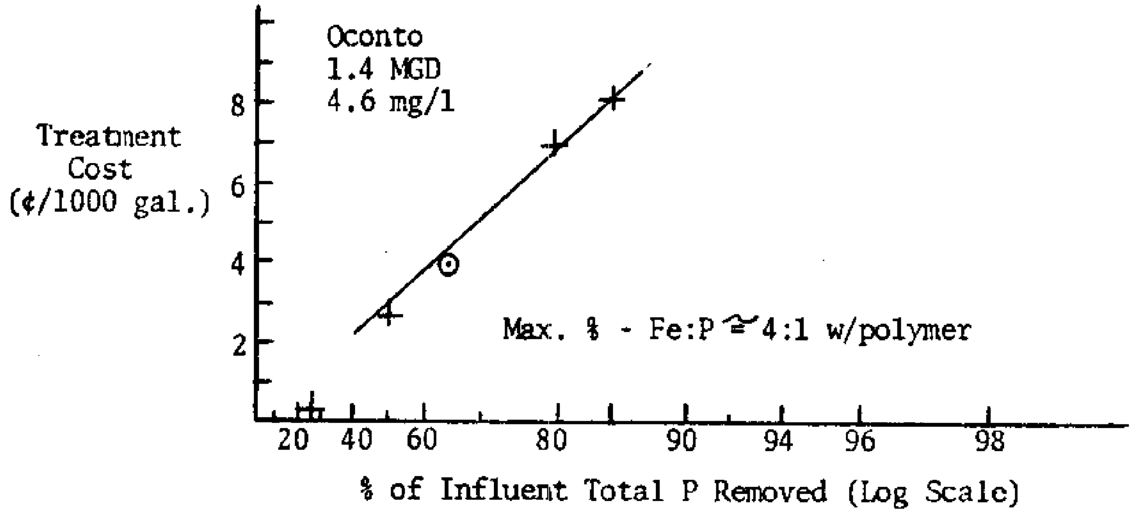

Menomonee Falls
2.8 MGD; 8.7 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - P.L. Fe:P ≅ 2.5:1
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

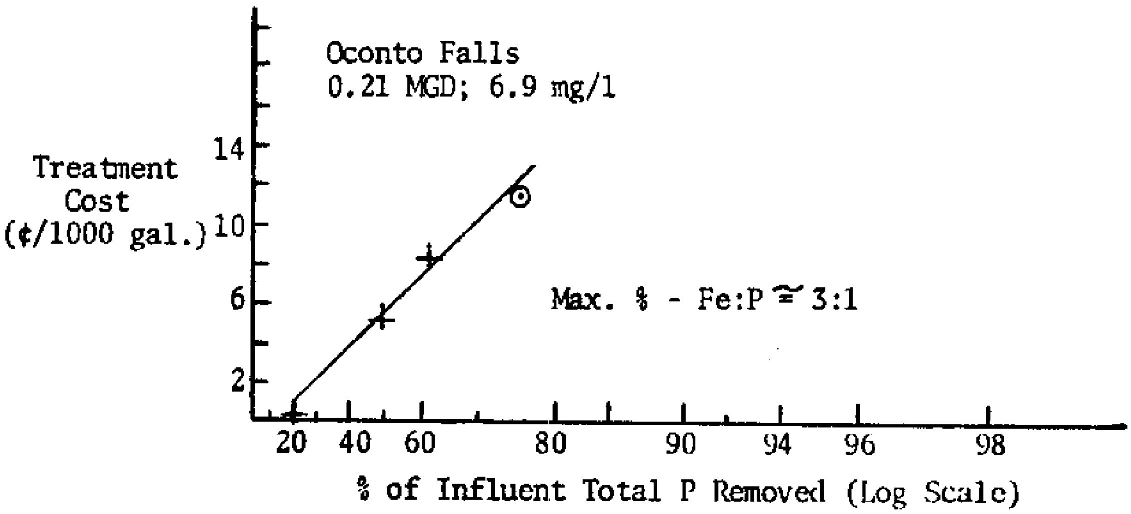

New Holstein
0.31 MGD; 13.5 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 2:1
% of Influent Total P Removed (Log Scale)

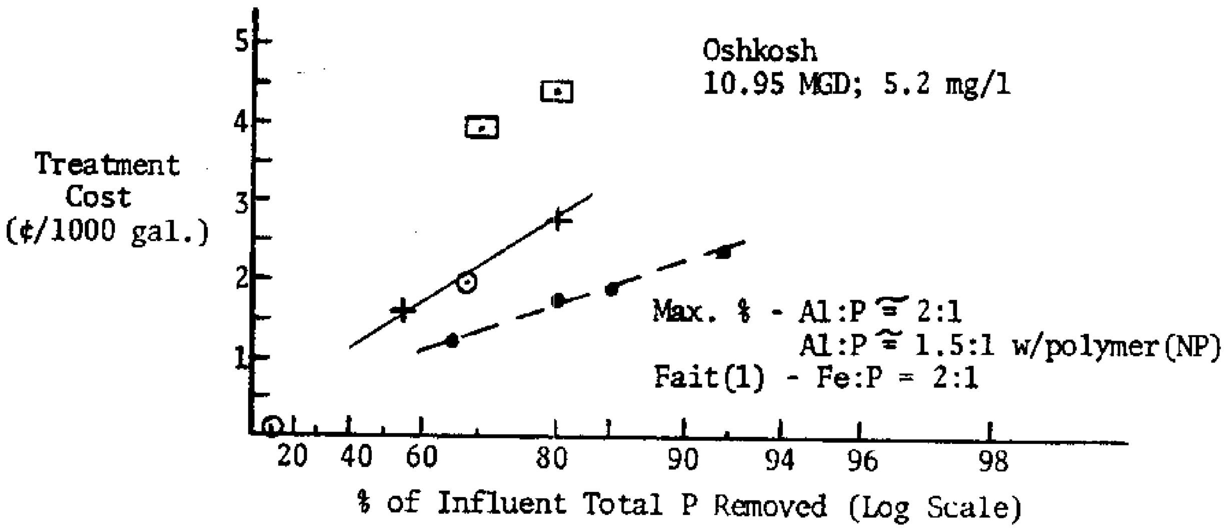

Treatment
Cost
(¢/1000 gal.)
10
8
6
4
2
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)
New London
0.8 MGD; 16.9 mg/l
Max. % - Al:P ≅ 2:1
Fait(1) - Fe:P = 2:1

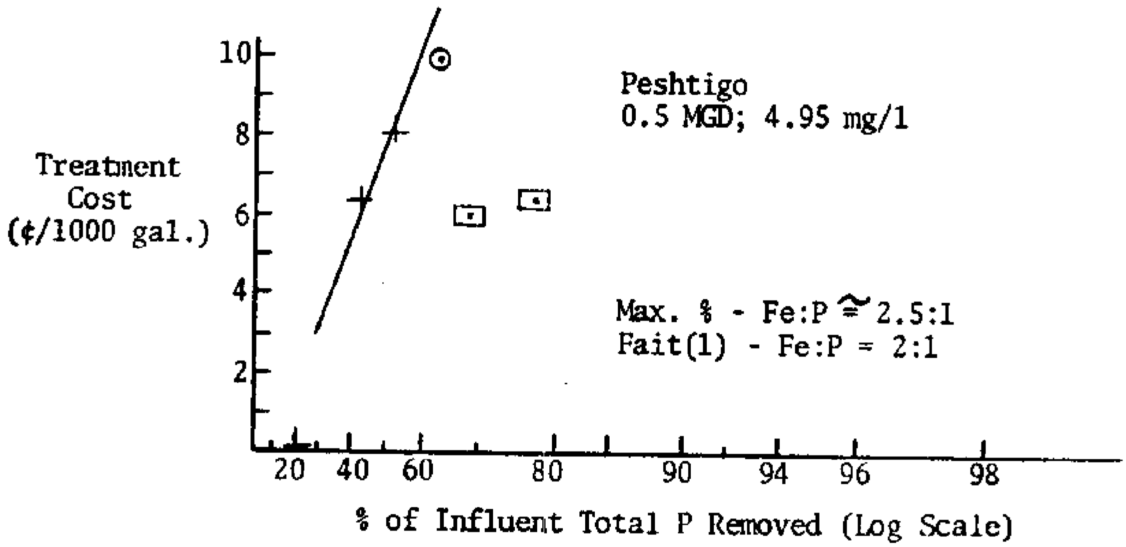

Treatment
Cost
(¢/1000 gal.)
10
8
6
4
2
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)
North Fond du Lac
0.46 MGD; 6.7 mg/l
Max. % - Al:P ≅ 2.5:1 w/polymer
Fait(1) - Fe:P = 2:1

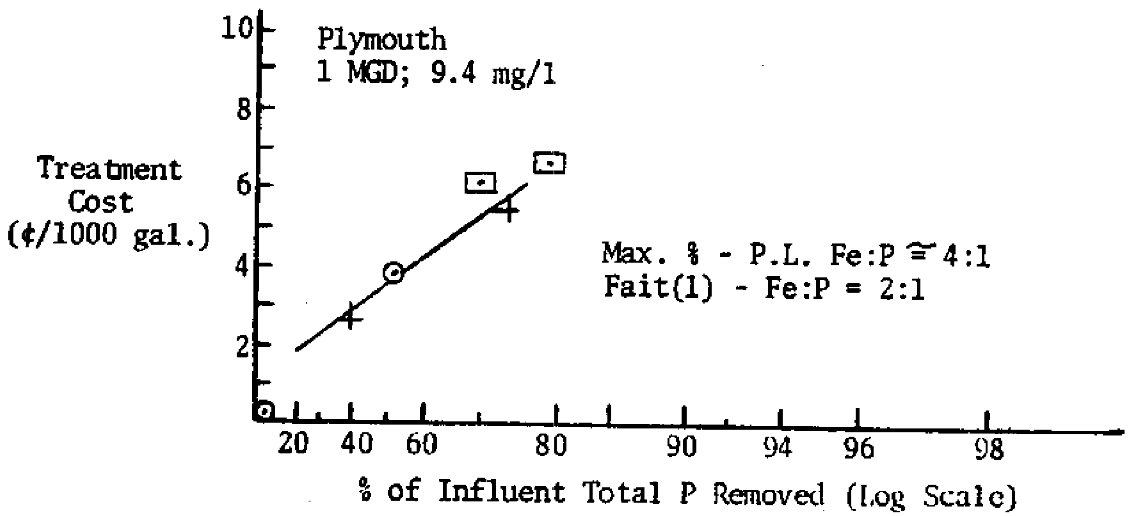

Treatment
Cost
(¢/1000 gal.)
3
2
1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)
North Park S.D.
1.44 MGD
5.8 mg/l
Max. % - Al:P = 1.2 to 1.5:1

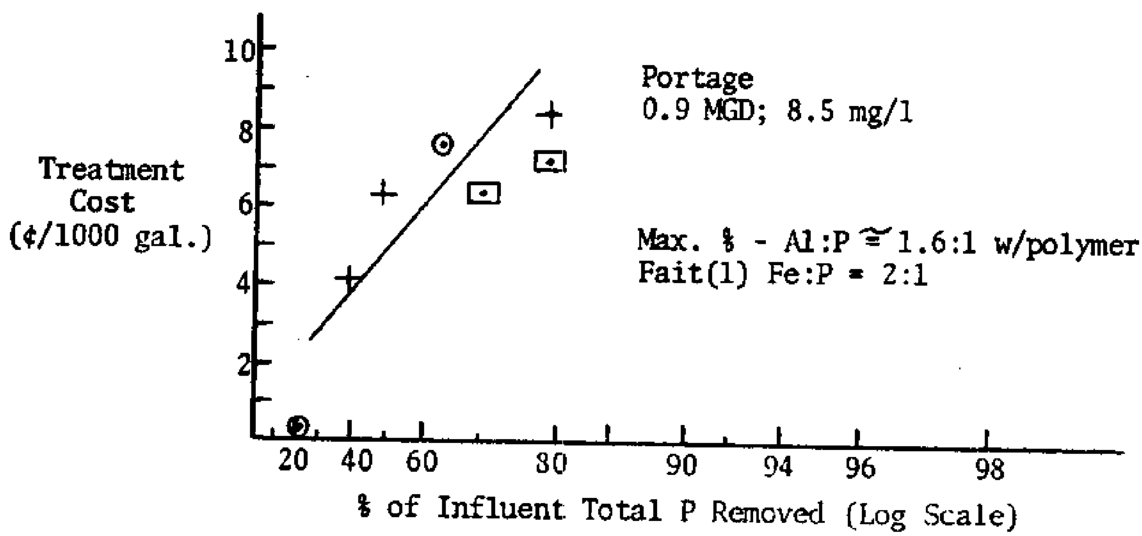

Oconto
1.4 MGD
4.6 mg/1
Treatment
Cost
(¢/1000 gal.)
8
6
4
2
Max. % - Fe:P ≅ 4:1 w/polymer
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

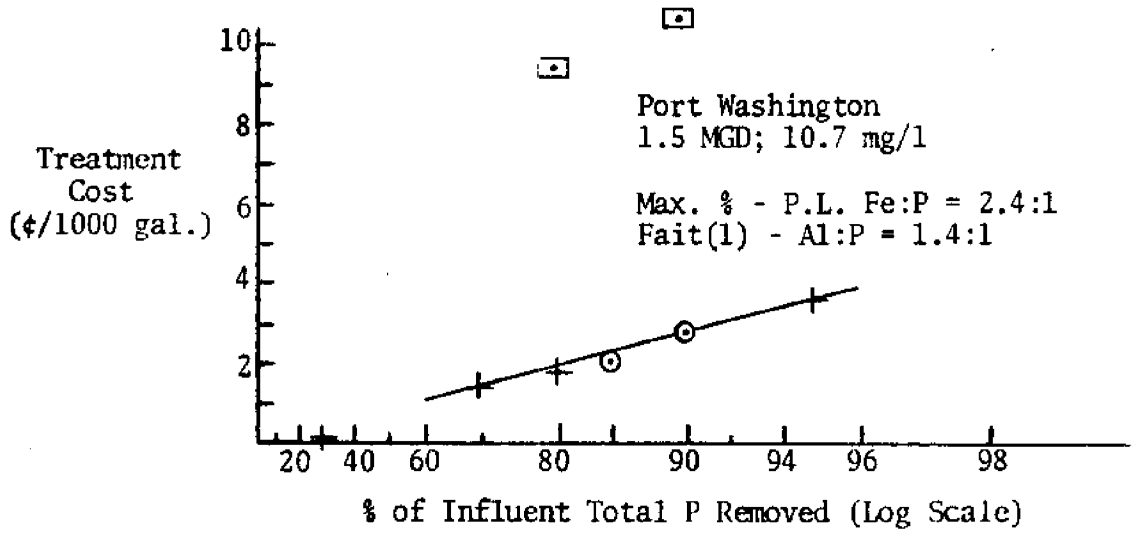

Oconto Falls
0.21 MGD; 6.9 mg/1
Treatment
Cost
(¢/1000 gal.)
14
10
6
2
Max. % - Fe:P ≅ 3:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

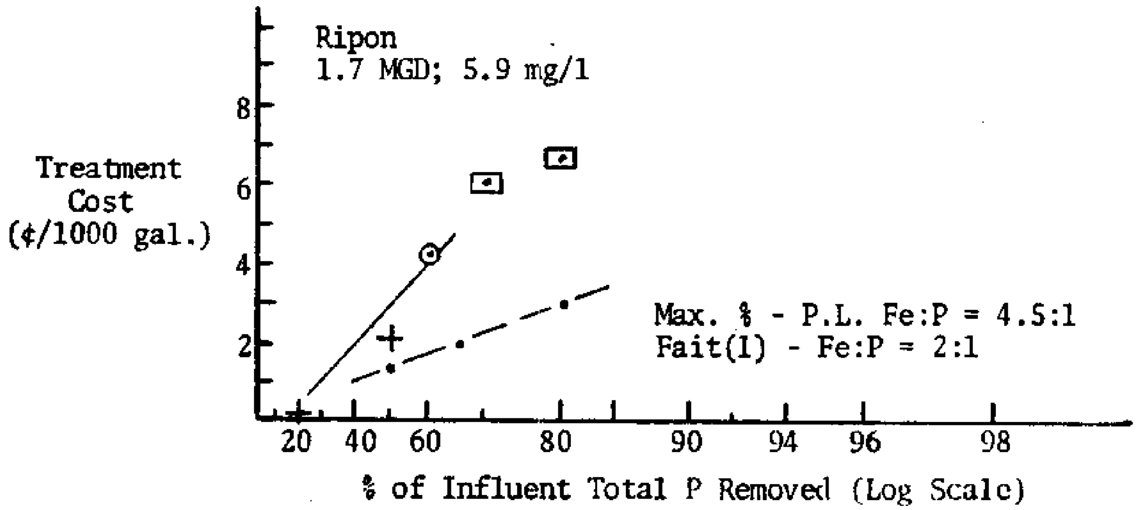

Oshkosh
10.95 MGD; 5.2 mg/1
Treatment
Cost
(¢/1000 gal.)
5
4
3
2
1
Max. % - Al:P ≅ 2:1
Al:P ≅ 1.5:1 w/polymer(NP)
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

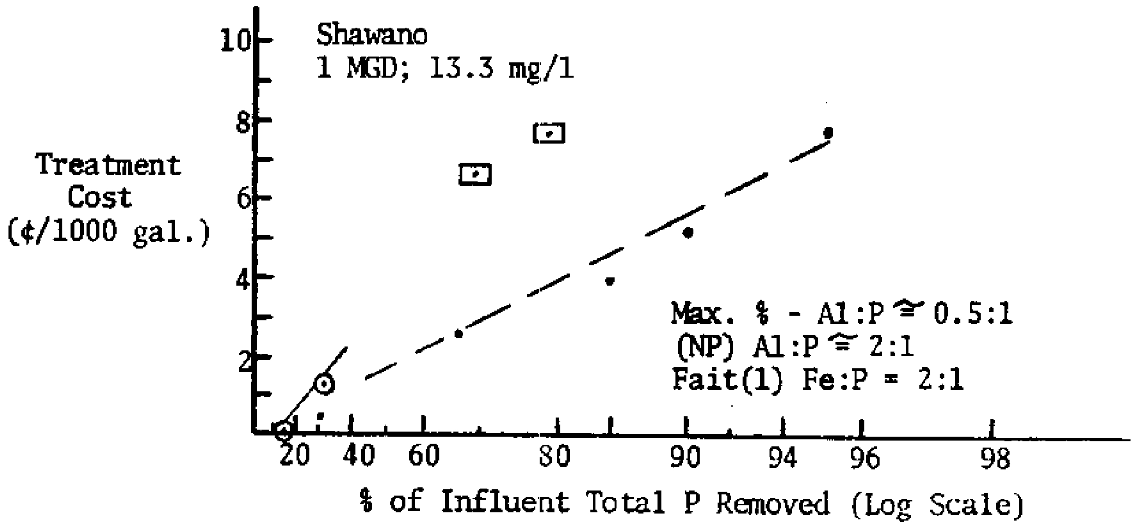

Peshtigo
0.5 MGD; 4.95 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 2.5:1
Fait(1) - Fe:P = 2:1
10
8
6
4
2
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

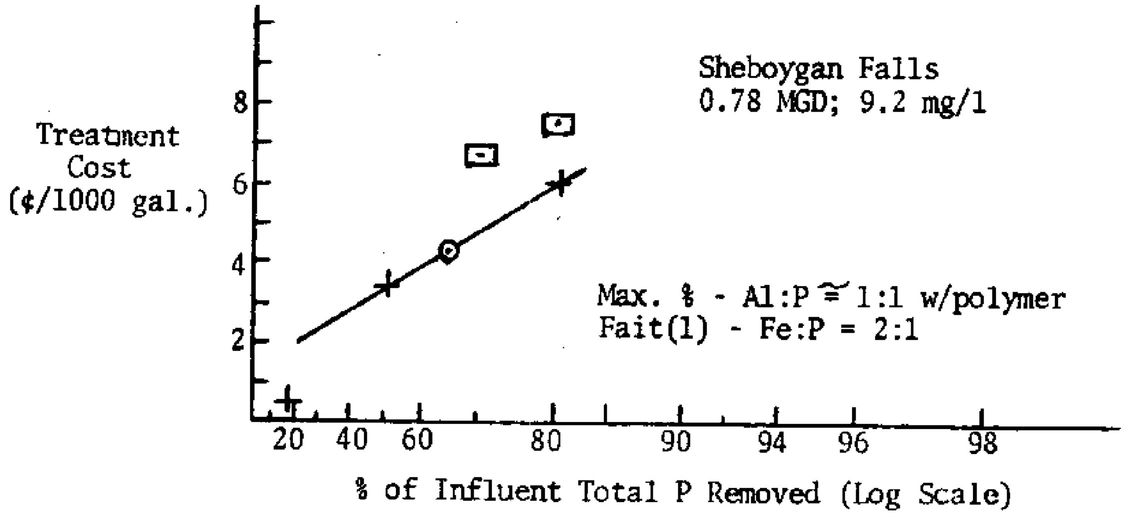

Plymouth
1 MGD; 9.4 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - P.L. Fe:P ≅ 4:1
Fait(1) - Fe:P = 2:1
10
8
6
4
2
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)


Portage
0.9 MGD; 8.5 mg/l
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1.6:1 w/polymer
Fait(1) Fe:P = 2:1
10
8
6
4
2
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

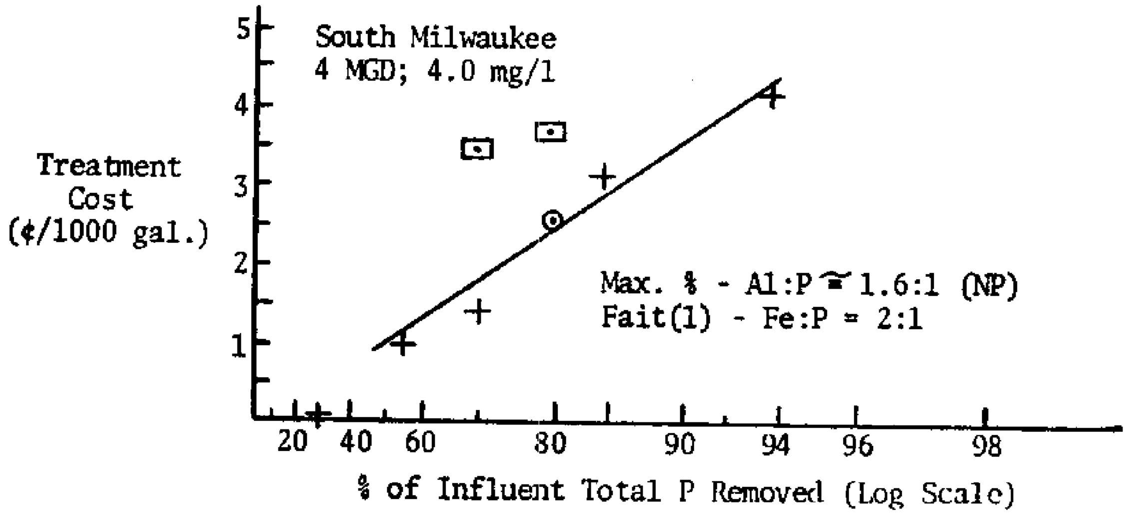

Treatment Cost (¢/1000 gal.)
10
8
6
4
2
Port Washington
1.5 MGD; 10.7 mg/1
Max. % - P.L. Fe:P = 2.4:1
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)


Ripon
1.7 MGD; 5.9 mg/1
Treatment Cost (¢/1000 gal.)
8
6
4
2
Max. % - P.L. Fe:P = 4.5:1
Fait(1) - Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

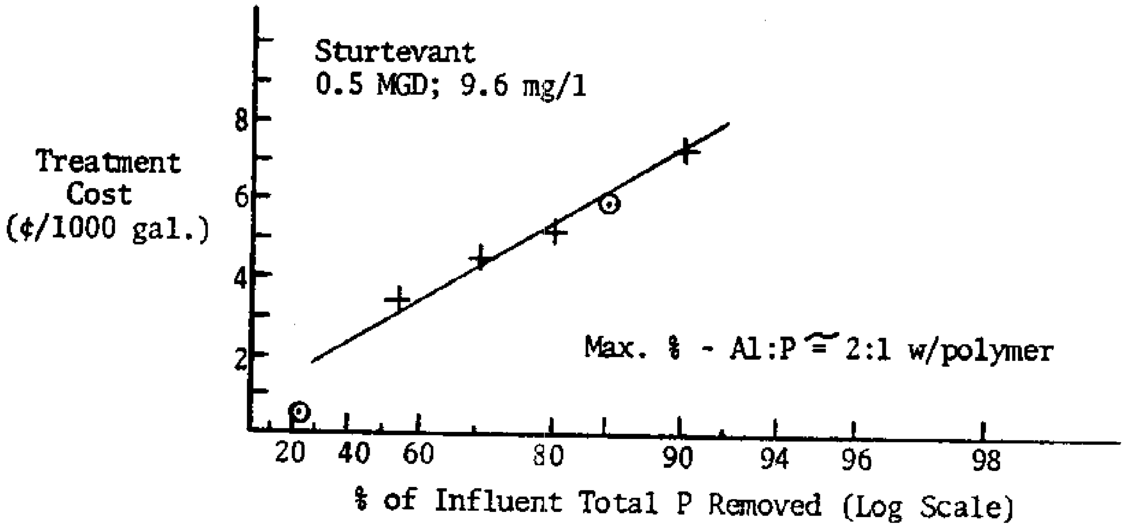

Shawano
1 MGD; 13.3 mg/1
Treatment Cost (¢/1000 gal.)
10
8
6
4
2
Max. % - Al:P ≅ 0.5:1
(NP) Al:P ≅ 2:1
Fait(1) Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)



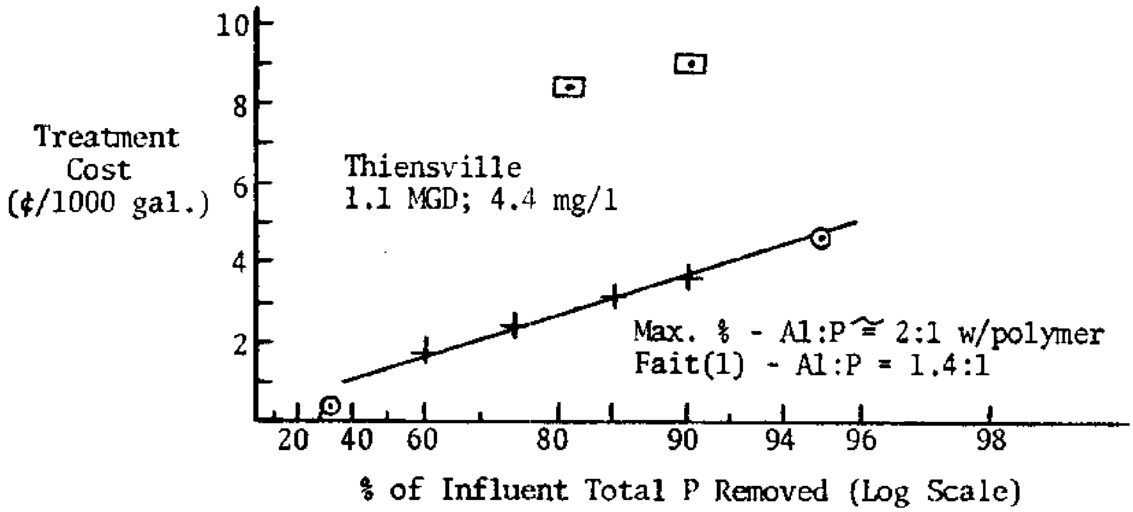
Sheboygan Falls
0.78 MGD; 9.2 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1:1 w/polymer
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

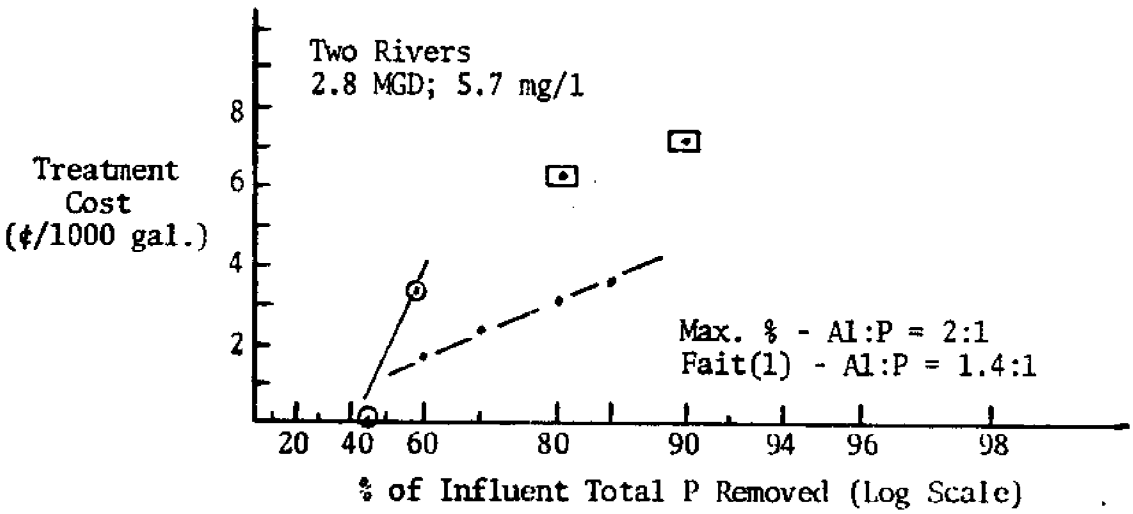


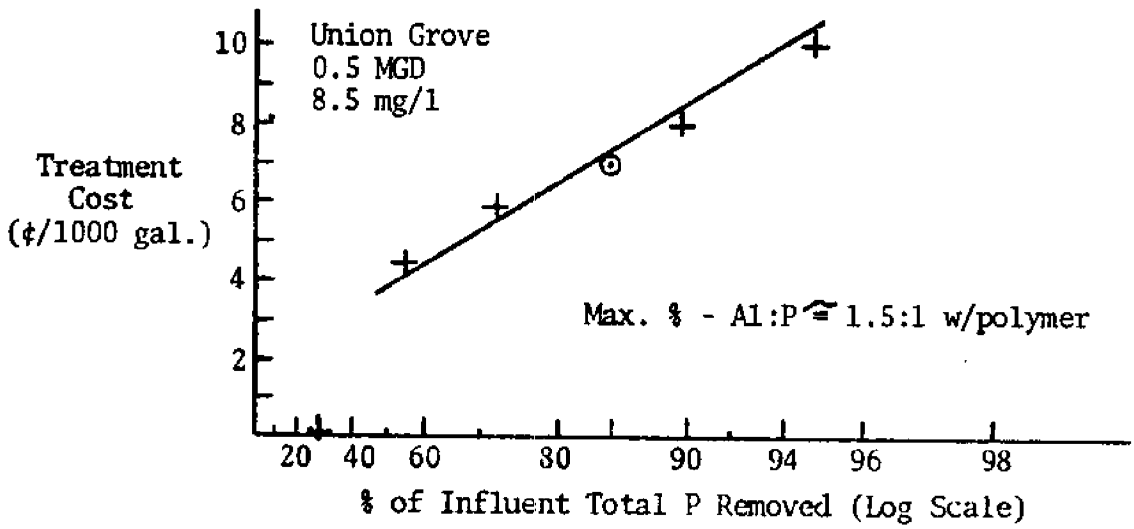
South Milwaukee
4 MGD; 4.0 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1.6:1 (NP)
Fait(1) - Fe:P = 2:1
% of Influent Total P Removed (Log Scale)

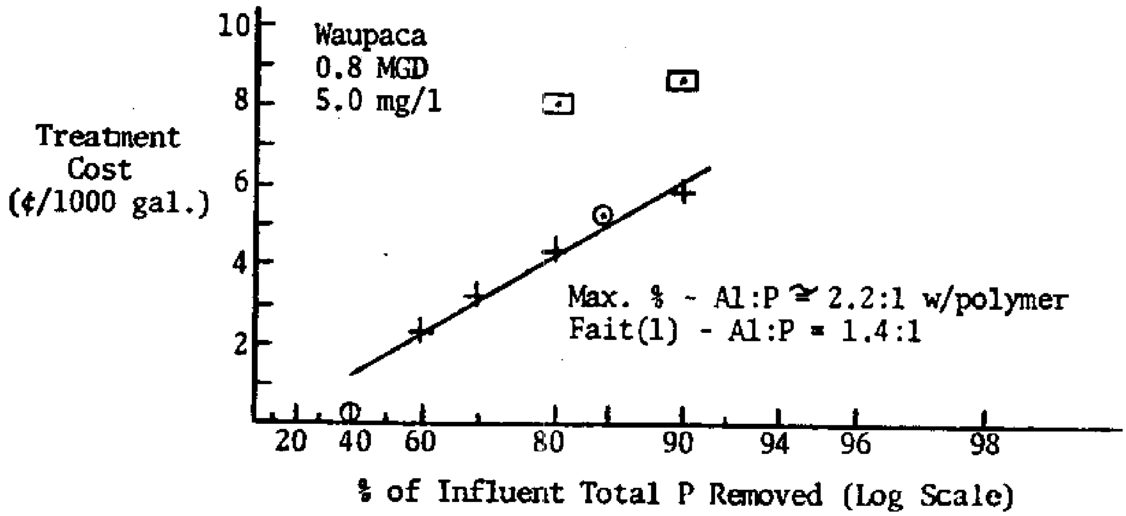


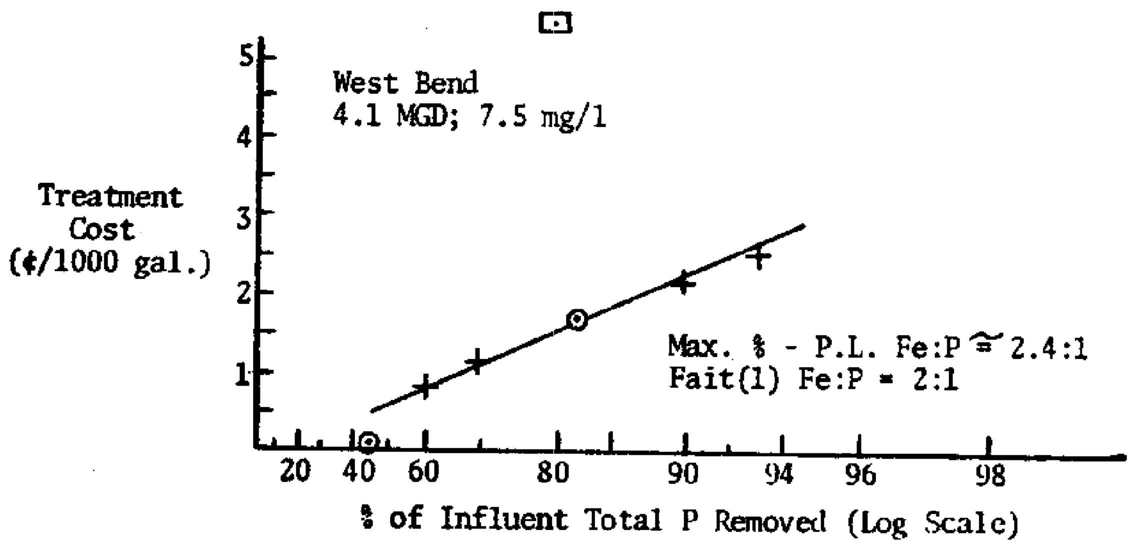
Sturtevant
0.5 MGD; 9.6 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2:1 w/polymer
% of Influent Total P Removed (Log Scale)

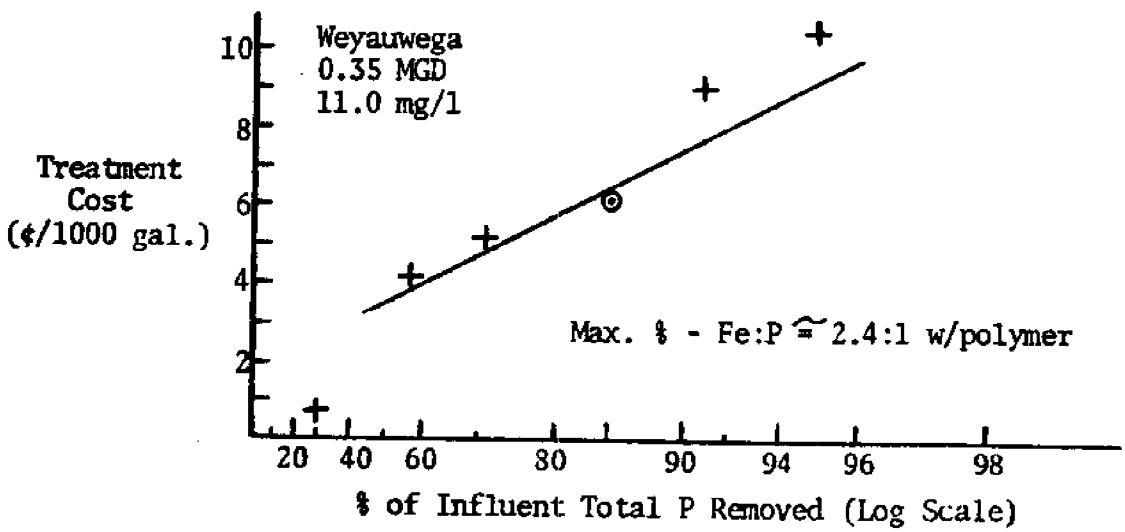

Treatment Cost (¢/1000 gal.)
Thiensville
1.1 MGD; 4.4 mg/1
Max. % - Al:P ≅ 2:1 w/polymer
Fait(1) - Al:P = 1.4:1
% of Influent Total P Removed (Log Scale)


Two Rivers
2.8 MGD; 5.7 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P = 2:1
Fait(1) - Al:P = 1.4:1
% of Influent Total P Removed (Log Scale)


Union Grove
0.5 MGD
8.5 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 1.5:1 w/polymer
% of Influent Total P Removed (Log Scale)


Waupaca
0.8 MGD
5.0 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Al:P ≅ 2.2:1 w/polymer
Fait(1) - Al:P = 1.4:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)


West Bend
4.1 MGD; 7.5 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - P.L. Fe:P ≅ 2.4:1
Fait(1) Fe:P = 2:1
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)


Weyauwega
0.35 MGD
11.0 mg/1
Treatment Cost (¢/1000 gal.)
Max. % - Fe:P ≅ 2.4:1 w/polymer
20 40 60 80 90 94 96 98
% of Influent Total P Removed (Log Scale)

The alternatives at the five remaining plants are as follows:

	MGD	Influent mg/1 P	Removal %	¢/1000 gal.
Holland S.D.	0.144	46	50	0
Neenah-Menasha	13.4	3.5	62	0
Milwaukee-Jones Island	160	5.6	50	0
			89	0.02
Milwaukee SS	55.4	6.6	59	0
	w/full scale phosphorus treatment:		95	0.33
Racine	23.8	4.4	8	0
			36	0.08
		with new plant:	30	0
			89	0.08

NOTE: Holland S.D. and Neenah-Menasha are not assigned alternative removal possibilities. The South-Shore and Jones Island plants at Milwaukee and the new Racine plant are provided only with minimum and maximum alternatives because of the assumed negligible costs of waste pickle liquor at these plants.

APPENDIX D

Initial Wisconsin DNR Phosphorus Removal Policy

State of Wisconsin
Department of Natural Resources
Manual Code 3403.1

SUBJECT: Policy on Phosphorus Removal From Effluent
(Adopted April 17, 1969)

PREAMBLE

Phosphorus is a key nutrient controlling fertility of natural waters. Small concentrations of phosphorus may stimulate the growth of blue-green algae and other organisms, making rivers and lakes unsuitable for recreation and increasing water purification costs. Where algae do not thrive, increased growth of floating and bottom-rooted weeds impedes stream flow and complicates other aspects of water management.

Sewage effluents often contribute large amounts of phosphorus to surface waters. Methods exist for substantial removal of phosphorus from sewage and industrial wastes.

POLICY

Prompt action to reverse the present over-fertilization of waters of Wisconsin and to enhance the quality of these waters for all useful purposes is essential.

It is the policy of the Natural Resources Board that:

1. The Department of Natural Resources may require any wastewater discharger--regardless of population, volume or type of waste discharged, or geographic location--to provide for removal of excess amounts of phosphorus where such discharges are causing, or may cause, over-fertilization of surface waters.

2. In conformance with recommendations of the Lake Michigan Enforcement Conference, the Department shall take the actions necessary to achieve an overall reduction of at least 80 percent of the phosphorus tributary to municipal and industrial waste treatment facilities located within the Lake Michigan drainage basin by December 31, 1972.

NATURAL RESOURCES BOARD POLICY

Date May 2, 1969

Distribution:

All Supervisory Personnel

LAKE MICHIGAN DRAINAGE BASIN

At the second session of the Lake Michigan Enforcement Conference, February 25, 1969, it was agreed by the conferees that each state would determine where phosphorus reduction is required, and an overall 80 percent reduction of total phosphorus from waste water effluents would be achieved within that state's portion of the Lake Michigan Basin by December 31, 1972.

The Natural Resources Board at its April meeting established a policy of phosphorus removal to the effect that the Department may require any waste water discharger to provide for removal of phosphorus where such discharges are causing or may cause over-fertilization. The Board also confirmed the intent of the state to comply with the recommendations of the Lake Michigan Conference in achieving an overall reduction of at least 80 percent of the phosphorus tributary to municipal and industrial treatment facilities.

The population distribution of municipalities in Wisconsin's section of the Lake Michigan Basin is shown in the following table:

Size	Cumulative No. of Sources*	Percent of Population
20,000+	11	83.0
10,000+	15	85.8
5,000+	33	92.0
2,500+	48	94.7
All	177*	100.0

*Does not include 54 small sewage treatment plants in the basin serving schools, institutions, trailer parks, industries and subdivisions.

Phosphorus removal costs for the smaller communities are disproportionately high, and we cannot reasonably expect to achieve consistently high treatment efficiencies. In addition, sources under 2,500 population amount to more than two-thirds the total number of discharges but represent only 5-6 percent of the total phosphorus potential from sewage. An overall phosphorus removal of 80 percent should be achieved if those municipalities with a population over 2,500 were to achieve a phosphorus reduction of 85 percent.

Some overall phosphorus removal is inherent in conventional treatment. Of the 51 sewage treatment plant composite influent and effluent samples investigated by the Division of Environmental Protection for total phosphorus in connection with the 1968 drainage basin surveys, 5 showed no change, 20 indicated negative removals, and the remaining 26 plants had various reductions. The combined average removals from all 51 plants amounted to 7.8 percent. With minor plant modifications and encouraging operational changes to enhance phosphorus removal, one might reasonably expect a 10 percent overall reduction.

There are other factors that need to be considered in phosphorus removal. Irrigation and other forms of soil absorption achieve very near a 100 percent removal. Data from sewage stabilization ponds indicate removals of as high as 90 percent during the summer months, probably by weed and algal uptake, but the removals after long ice coverage and septic conditions are not significant. Domestic sewage has a phosphorus concentration of about 10 mg/l and amounts to approximately 3.5 pounds per person per year. Industries such as milk, meat and vegetable processing have phosphorus concentrations comparable to domestic sewage.

This information is supplementary to that stated by the Natural Resources Board in its "Policy on Phosphorus Removal from Effluent," a copy of which is enclosed. In general, a 2,500 population or its phosphorus equivalent will be the key factor in determining whether a phosphorus removal facility will be required. However, such facilities may be required of smaller sources where a discharge causes or may cause over-fertilization of a surface water.

Additional guidance and technical assistance on phosphorus removal will be provided by the Bureau of Water Supply and Pollution Control.

APPENDIX E

Computer Documentation of the Dynamic Programming Model

```
      DIMENSION DEC(5),CST(5)
      DIMENSION PHOS(53)
      DIMENSION COST(53,6),MAX(53)
      DIMENSION MIN(53),PERCNT(12),LLOAD(12),IREM(12),REM(12)
      DIMENSION ARRAY(25000,2)
      COMMON/BIG/ARRAY
      DIMENSION FRACT(53,6)
      DIMENSION NAME(53,3)
      INTEGER ZERO
      INTEGER DECIDE(53,6)
      INTEGER NUMDEC(53)
C     INPUT ALL DECISIONS/COSTS
C     ACCUMULATE MAX TOTAL FEASIBLE INPUT AT EACH STAGE
C     ACCUMULATE LOAD TO BE REMOVED
C
C     READ NO. / PLANTS, NO. POLICIES, POLICY PERCENTAGES
C     MAXIMUM NO. POLICIES = 12
      READ 10,NPLANT,NP,(PERCNT(I),I=1,NP)
   10 FORMAT(2I2,12F4.3)
      LOAD=0
      ZERO=0
      ISTRT1=10001
      ISTRT2=1
      DO 100 I=1,NPLANT
C
C     READ TWO CARDS PER PLANT, GIVING:
C     1. INFLUENT FLOW (MGD)
C        TOTAL INFLUENT PHOSPHORUS CONCENTRATION(MG/L AS P)
C        CURRENT REMOVAL PERCENTAGE
C        ALTERNATE REMOVAL PERCENTAGES AND COSTS
C     2. PLANT NAME
      READ 20,FLOW,AMT,DZERO,(DEC(J),CST(J),J=1,5)
   20 FORMAT(F7.3,2X,F4.1,2X,F4.3,5(2X,F4.3,2X,F4.1))
       READ 22,CI
   22  FORMAT(F4.3)
      READ 988,(NAME(I,J),J=1,3)
  988 FORMAT(3A6)
      MAXDEC=0
      PHOS(I)=FLOW*AMT*8.34
      LOAD=LOAD+PHOS(I)+.5
      CURREN=PHOS(I)*DZERO/100.
      DECIDE(I,1)=CURREN+.5
      FRACT(I,1)=DZERO/100.
      ZERO=ZERO+CURREN+.5
      MIN(I)=ZERO
       COST(I,1)=CI*FLOW*10.
C
C     SET UP COST, DECISION (POUNDS), AND PERCENTAGE TABLES
      DO 30 J=1,5
      IDEC=DEC(J)*1000
      IF(IDEC.EQ.0) GO TO 35
      FRACT(I,J+1)=DEC(J)/100.
      DECIDE(I,J+1)=PHOS(I)*DEC(J)/100.+.5
      COST(I,J+1)=FLOW*CST(J)*10.
      IF(DECIDE(I,J+1).GT.MAXDEC) MAXDEC=DECIDE(I,J+1)
   30 CONTINUE
```

```
          J=6
   35     NUMDEC(I)=J
          NUMBER=J
          IF(I.EQ.1) MAX(I)=MAXDEC
          IF(I.GT.1) MAX(I)=MAX(I-1)+MAXDEC
C
C         PRINT TABLE ENTRIES FOR EACH PLANT
          PRINT 989,(NAME(I,J),J=1,3),DZERO,CURREN
  989 FORMAT(/1X,3A6,5X,'CURRENT REMOVAL PERCENTAGE ',F4.1,5X,
     X'CURRENT REMOVAL ',F6.2)
          PRINT 990,PHOS(I),LOAD,MAX(I),(DECIDE(I,J),COST(I,J),FRACT(I,J)
     X,J=1,NUMBER)
  990 FORMAT(' INFLUENT  P  ',F8.2,'  TOTAL LOAD',
     X' INCLUDING THIS STAGE ',I10,' MAXIMUM FEASIBLE INPUT ',
     X'TO THIS STAGE ',I8/
     X(20X,I6,'=REMOVAL',5X,F8.2,'=COST',5X,F4.3,'=PERCENTAGE'))
  100 CONTINUE
C
C         PRINT ACCUMULATED LOAD AND CURRENT REMOVALS
          PRINT 101,LOAD,ZERO
  101 FORMAT(' TOTAL LOAD=',I10,5X,'CURRENT REMOVALS=',I10)
C
C         PRINT POLICY PERCENTAGES AND ASSOCIATED POUNDAGE FIGURES
          PRINT 103,(PERCNT(I),I=1,NP)
  103 FORMAT('1POLICY PERCENTAGES:',12(2X,F4.3,3X))
          DO 105 K=1,NP
  105 LLOAD(K)=LOAD*PERCNT(K)+.5
          PRINT 107,(LLOAD(K),K=1,NP)
  107 FORMAT(' DAILY TOTAL POUNDS:',12(2X,I5,2X))
C
C         SET UP COSTS AND REMOVALS FOR STAGE ONE.
C         THERE ARE NO ASSOCIATED COSTS FOR STAGE 1
C
  155 NUMBER=NUMDEC(1)
          ISTAGE=1
          ICNT2=MAX(1)-MIN(1)+1
C
C         DO THE FOLLOWING FOR EACH INPUT TO STAGE 1
          DO 175 I=1,ICNT2
          INPUT=I+MIN(1)-1
C
C         DETERMINE LEAST DECISION WHICH COMPLETELY REMOVES INPUT
          DO 160 J=1,NUMBER
          IF(INPUT.LE.DECIDE(1,J)) GO TO 171
  160 CONTINUE
          PRINT 221
  221 FORMAT(' PROGRAM ERROR -- POSSIBLE INPUT TABLE IN ERROR')
          STOP
C         SAVE COST AND AMOUNT REMOVED FOR THIS DECISION
  171 ARRAY(ISTRT2+I-1,1)=COST(1,J)
          ARRAY(ISTRT2+I-1,2)=DECIDE(1,J)
  175 CONTINUE
          WRITE(21,994)(ARRAY(ISTRT2+I-1,1),ARRAY(ISTRT2+I-1,2),I=1,ICNT2)
  994 FORMAT(9(F8.2,F6.0))
C
C         TREAT STAGES 2 THRU N, SAVING ONLY OPTIMAL DECISIONS
          ISTAGE=1
```

```
  200 ITEMP=ISTRT1
      ISTRT1=ISTRT2
      ISTRT2=ITEMP
      ICNT1=ICNT2
      ISTAGE=ISTAGE+1
      ICNT2=MAX(ISTAGE)-MIN(ISTAGE)+1
C
C     DO THE FOLLOWING FOR EACH INPUT TO THE STAGE BEING CONSIDERED
      DO 217 I=1,ICNT2
  217 ARRAY(ISTRT2+I-1,1)=0
      NUMBER=NUMDEC(ISTAGE)
      DO 240 I=1,ICNT2
      DO 240 J=1,NUMBER
      ITRIAL=I+MIN(ISTAGE)-1-DECIDE(ISTAGE,J)
C
C     MAKE SURE RESIDUE CAN BE HANDLED FURTHER DOWN THE LINE
      IF(ITRIAL.GT.MAX(ISTAGE-1)) GO TO 240
      IF(ITRIAL.LT.MIN(ISTAGE-1)) GO TO 240
C     SAVE IMMEDIATE COST
      COST1=COST(ISTAGE,J)
      IPOINT=ITRIAL-MIN(ISTAGE-1)+ISTRT1
C     DETERMINE ASSOCIATED COST (OPTIMAL)
      COST2=COST1+ARRAY(IPOINT,1)
  230 ITEST=ARRAY(ISTRT2+I-1,1)
      IF(ITEST.EQ.0) GO TO 235
      ITEST=COST2-ARRAY(ISTRT2+I-1,1)
      IF(ITEST.GE.0) GO TO 240
C     SAVE TOTAL COST AND REMOVAL DECISION ONLY IF
C      TOTAL COST IS MINIMAL
  235 ARRAY(ISTRT2+I-1,1)=COST2
      ARRAY(ISTRT2+I-1,2)=DECIDE(ISTAGE,J)
  240 CONTINUE
      IF(ISTAGE.EQ.NPLANT) GO TO 260
      WRITE(21,994)(ARRAY(ISTRT2+I-1,1),ARRAY(ISTRT2+I-1,2),I=1,ICNT2)
      GO TO 200
C
C     BACKWARD TRACE
C     OUTPUT RESULTS
  260 DO 265 K=1,NP
      IPOINT=LLOAD(K)-MIN(ISTAGE)+ISTRT2
  265 REM(K)=ARRAY(IPOINT,1)
C
C     PRINT COSTS FOR SELECTED REMOVALS AT STAGE N
C     (TOTAL SYSTEM COSTS)
      PRINT 275,(REM(K),K=1,NP)
  275 FORMAT(' DAILY TOTAL COSTS :',12(1X,F8.2))
      PRINT 280
  280 FORMAT(/' REMOVAL DECISIONS AT EACH PLANT:')
  300 IF(ISTAGE.EQ.NPLANT) GO TO 304
C
C     DETERMINE NUMBER OF LOGICAL RECORDS WRITTEN ON
C     DRUM FOR STAGE CONSIDERED
      ICNT2=MAX(ISTAGE)-MIN(ISTAGE)+1
      IREC=ICNT2/9
      JREC=MOD(ICNT2,9)
      IF(JREC.NE.0) IREC=IREC+1
      DO 302 I=1,IREC
```

```
  302 BACKSPACE 21
      READ(21,994)(ARRAY(ISTRT2+I-1,1),ARRAY(ISTRT2+I-1,2),I=1,ICNT2)
      DO 303 I=1,IREC
  303 BACKSPACE 21
  304 DO 307 I=1,NP
      IPOINT=LLOAD(I)-MIN(ISTAGE)+ISTRT2
C     GET REMOVAL DECISION (LBS / DAY) FOR THIS POLICY
      IREM(I)=ARRAY(IPOINT,2)
      LLOAD(I)=LLOAD(I)-IREM(I)
      NUMBER=NUMDEC(ISTAGE)
C     DETERMINE PERCENTAGE DECISION FOR THIS REMOVAL
      DO 305 J=1,NUMBER
      IF(IREM(I).EQ.DECIDE(ISTAGE,J)) GO TO 307
  305 CONTINUE
      PRINT 221
      STOP
  307 REM(I)=FRACT(ISTAGE,J)
C
C     PRINT POLICY PERCENTAGES AT THIS PLANT
      PRINT 310,(NAME(ISTAGE,J),J=1,3),(REM(J),J=1,NP)
  310 FORMAT(1X,3A6,1X,12(2X,F4.3,3X))
      IF(ISTAGE.EQ.1) STOP
      ISTAGE=ISTAGE-1
      GO TO 300
      END
```