

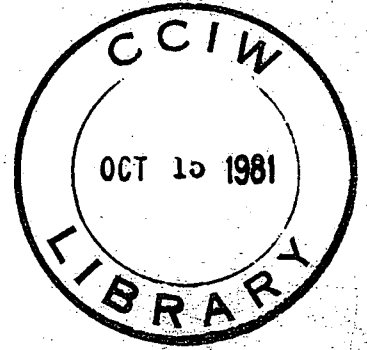


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UPPER GREAT LAKES WASTE LOADINGS TRENDS SIMULATION
MODEL: ECONOMIC PROJECTIONS, INDUSTRIAL-
MUNICIPAL WASTE TREATMENT - METHODOLOGY

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INTRODUCTION

The objective of Working Group A, Study Item IV, Upper Lakes Reference Group, was to provide a modelling framework within which future point-source waste loadings from economic and demographic activity could be projected. From a purely conceptual point of view, the task seemed clear, however, the process of empirically implementing these concepts proved to be an exceedingly difficult and oftentimes frustrating task.

The present report will concentrate on what emerged as the final product. Alternative modelling strategies that were significantly explored will be given some consideration as to content and reason for rejection. Other points of methodological importance will be covered, however, the virtue of brevity required that non-central issues be omitted.

THE ANALYTICAL FRAMEWORK

The original conception of the modelling framework favoured the adoption of the so-called 'systems dynamics' approach of Jay Forrester's World Dynamics and the Limits to Growth modelling efforts of the Club of Rome. The public controversy stirred up by these publications is well known, however, the subsequent research aimed at evaluating the scientific acceptability of such methods is not. The advantages of computer simulation are clearly recognized. Nevertheless, the model to be simulated must be

accurate if it is to have any meaning. This model accuracy is derived, in turn, from accurate assumptions about functional forms, data, and empirical validation. The bulk of the relevant criticism concerns the failure of these methods to meet any of these criteria.

In expanding the scope of potential methodologies, it became clearer that, in the context of the research problem at hand, the 'systems dynamics' approach was simply not flexible enough. Large, multi-dimensional data sets could not be handled. Also, the restrictions on functional form possibilities were found to be overly constraining and unworkable. Aside from these largely technical deficiencies, practical problems were also significant. Previous applications of 'systems dynamics' techniques used highly generalized and aggregate data. The Upper Lakes model required much more disaggregated information, both sectorally and spatially. To adequately capture the interrelationships of the national, provincial, and regional economies, as well as the dominance of the first, would have required a massive data collection and modelling effort if a complete 'systems dynamics' structure were to be constructed. While this was a possibility, the model that would have emerged would not have been of the 'structural' type, but rather of the recursive, 'reduced form' family. A further desire on the part of the modelling team was to provide for policy simulation capabilities and, technically, this requires a structural model. Unfortunately, the resources available for the Study Item were insufficient for such an undertaking. This situation prompted the decision to adopt an

already existing framework to provide the foundation for the economic projections and policy simulations. The need to consider separate industries in as fine a detail as possible narrowed the scope of available choice to one: CANDIDE. This model is the only one existing in Canada that provides any industrial detail as a part of the overall model structure. Under our general direction, INFORMETRICA Ltd. of Ottawa was contracted to provide economic projections to the year 2020 using their version of the CANDIDE model.

To provide measures of regional economic activity for the forecast horizon, an investigation of methodologies to link the regional economies to the national projection was undertaken. While several theoretical explanations for the spatial distribution of economic activity exist, in general, these theories are not empirically testable. Further, the smaller the geographic unit under examination, the less consistent, comprehensive, and analytically useful is the available data. The lack of sufficient data severely restricted the choice of linkage methodology. Problems with confidentiality provisions of the Statistics Act and project time constraints precluded the obtaining of time series data on regional economic activity. As a result, the only course of action open to the research team was to adopt information available in the 1971 Census of Population. This source provided a single year (1971) estimate of the spatial allocation of employment by certain industry groups consistent with the Standard Industrial Classification (SIC) and CANDIDE.

These estimates were used to allocate the national projections to the respective river basins or regions of the Upper Great Lakes. Implicit in this allocation mechanism is the assumption that the 1971 proportions remain constant throughout the projection horizon. While formally unrealistic, it was absolutely necessary, given the information and resources available to the project. Projections of economic activity based on the above methodology are available in three Social Sciences Division working papers: Estimates of Economic Activity in Regions of the Canadian Great Lakes Basin, Series A, Volumes I and II; and Series B. Part of the original research strategy was to have at least two different views of what Canada's economic structure might be in the future. This presented serious conceptual and practical problems that were recognized at the outset, however, attempts were made to articulate significant deviations from historical trends. Series A basically describes a continued trend in the relative growth of the service sector. Series B embodies the attempts to plot a different time path for Canada's economic future. Subsequent consideration of this alternative future resulted in the decision to use only one economic scenario (Series A) in the overall waste loadings projection model. This decision was based on the following.

First, it very quickly emerged that an articulation of a radically different future was a major task in itself and, given the constraints facing the project, not possible. The almost pure speculative nature of such a scenario and the revolutionary social and institutional changes implicit in it present formidable obstacles to such an effort.

Second, an alternative scenario was produced (Series B) and, within the simulation limits of the overall project and the CANDIDE model, it did represent a different economic outlook. However, the need to portray the economy operating at or near 'potential' obscured the major differences in the two scenarios. Also, the level of aggregation in CANDIDE, while fairly detailed compared to other feasible methods, was not sufficient to allow the emergence of differences in the economic outlook that were operationally meaningful in the ultimate purpose of simulating future waste loadings. Specifically, the regional economic inputs to the industrial waste loading calculations were not sufficiently different to warrant the expenditure of resources.

As noted above, the two scenarios are discussed and documented separately, and reference to these reports will illustrate the above comments more elaborately.

Although, for the various reasons cited above, it was not possible to model fundamental socio-economic changes explicitly, the overall project devoted a substantial amount of resources to more 'think-tank' type of futures conceptualization. Information drawn from this report (Social, Institutional, and Technological Trends and Synergisms Affecting Water Resources Quality in the Great Lakes Basin), by L. D'Amore, and from other sources, will provide opportunities to exercise judgemental overrides on the basic socio-economic inputs of the overall model. It is, in this sense, that the model displays its simulation capability.

DEMOGRAPHIC CONSIDERATIONS

As a part of the overall CANDIDE model certain demographic phenomena such as participation rates, labour force and employment, are generated endogenously. That is, they are explained by the model. Unfortunately, available versions of CANDIDE have not yet endogenized the source population itself. Therefore, population estimates for Canada are an exogenous variable, supplied from outside the model.

For the Upper Great Lakes regions under study, three possible treatments of population were available. First, a separate demographic projection model could be produced. Second, available population projections completed by the Ontario government could be adapted for use. Third, an attempt could be made to regionalize the population projections inherent in the CANDIDE projections, through the use of a crude economic-demographic linkage.

Neither the first nor third options proved to be entirely satisfactory. The Ontario Ministry of the Environment (MOE) utilized the Ontario government projections to estimate the future population for the regions in question. In the final analysis, the MOE estimates were chosen because they were generated by the most plausible and reliable methodology available to this project. Attempts were made to acquire more recent projections from the responsible department in the Ontario government, however, these proved to be unsuccessful. To allow for deviations from these estimates, simulation capabilities enable alternative scenarios based on informed judgement to be modelled. Significantly,

the overall model lacks economic and demographic interactions, and is therefore somewhat deficient in this matter. However, state-of-the-art modelling of these linkages is still fairly primitive and would be a major research task in itself for a multi-regional model like the present one. This lack of internal consistency between population and economic activity should be kept in mind when simulations of alternative scenarios are being undertaken.

INDUSTRIAL-MUNICIPAL WATER POLLUTION CONTROL INVESTMENT

In addition to forecasting future waste loadings, this Study Item was required to investigate and provide for the estimation of future spending requirements for water pollution control. The two categories of abatement spending covered in this analysis were industrial and municipal wastewater treatment. Each of these will be discussed in turn.

Industrial Treatment

To understand the rationale underlying the specification of this sector, a brief overview of industrial water pollution should prove valuable. Many industries use water directly in the production process. While some water is actually consumed, through evaporation for example, most is returned to its original source. However, during the production process many substances are added, either as required elements, or as by-products. Therefore, the water that is returned is generally in a state highly different than prior to use, containing differing concentrations of various substances or 'pollutants'.

The function of pollution abatement may be viewed in a two-fold way. It can act on the production process itself, by changing it. While not always primarily related to a desire to decrease pollution, indirectly, by lessening the amounts of pollutants generated and returned to the stream, that objective is accomplished. Also, through various methods, the pollutants can be partially or wholly removed after the production process, but before the water is returned to its source. This is commonly referred to as "end-of-the-pipe" treatment. The concern for the environment has prompted efforts in both of these directions.

The problem addressed here is to determine what the cost of these abatement options has been in the past and what it is likely to be in the future, given various objectives concerning allowable pollution levels of water returned to the stream. While this Reference Group concentrated on approximately 30 major pollutants, there are thousands of substances existing in trace amounts in water resources, and thousands more being created every year. To compound the problem further, treatment methods are often pollutant specific, in the sense that they concentrate on one substance, leaving the others as before. There are exceptions of course, however, no one method will remove all undesirable materials. A great deal of effort has been expended in the United States considering pollution abatement costs. Unfortunately, no comparable studies have been carried out in Canada. In addition, the legislative objectives guiding pollution abatement in both countries are generally concerned with achieving a given level of water quality. This objective is a very nebulous one in that water quality and quantity

are inextricably tied, and a given level of water quality cannot be used to infer the extent to which pollutants are removed before the water is returned to the stream. Also the water quality, quantity relationship is only one of many factors affecting a given quality outcome.

Reference to specific studies examining the relationships between specific pollutant removal levels, and costs of this removal, provided some information. These studies were either too general or too specific to be of much use in a comprehensive framework. The sheer volume of technical and engineering information available quickly grew to unmanageable proportions. The only reasonable cost data available in a usable form was related to the SIC industry group classes. This data was collected by the Ontario Ministry of the Environment and covered approvals processed by the Ministry. It did not represent actual outlays, and was for capital costs only, containing no allowance for interest, depreciation, operating and maintenance costs. In addition, no relationship between these capital outlays and the level of treatment they achieved was available or could be reasonably inferred. The 1971 Census of Manufactures included a question concerning water pollution abatement investment. However, this effort was ill-conceived and resulted in inconsistent and unusable estimates.

Without detailed information with which to estimate a relationship between capital expenditures and pollutant removal levels, recourse was made to available micro studies and other a priori information for modelling purposes. These sources indicated the general form of the functional relationship between treatment levels and capital costs to be a non-linear one.

Rather than assuming a totally non-linear curve, one that was linear over a certain portion of its length and then became exponentially non-linear was chosen. This treatment is consistent with the generally accepted view that the marginal cost of increasing pollutant removal levels increases very rapidly as 100 percent removal is approached. To simplify, it was assumed that lower treatment levels could be achieved at constant marginal costs.

Having specified the general shape of the cost curve, the parameters involved were made simulation variables. As a point of departure, marginal costs were assumed constant to 90 percent removal and exponential beyond. The power of the exponent was also made a simulation variable as was the current level of each industry's treatment.

The Economic Model

Once the functional form and its parameters had been chosen, the augments of the function remained to be specified. The scarcity of data severely limited the range of choice. A simple economic framework consisting of a capital-output model of investment was chosen. To empirically estimate this model, one needs a time series of capital stocks and a time series of post-treatment waste production. Completely satisfactory figures on the former and any figures on the latter were not available. To overcome the first problem, it was decided that, as a first approximation, the MOE approvals figures could serve as a series of gross investment flows. These flows were then transformed by conventional techniques into a capital stock series using a 5 percent depreciation rate. The only consistent figures on waste flows related to 1973.

Therefore, the pollution capital stock calculated for that year was related to industry output in the same year to form a pollution capital to output ratio. It was further assumed that this ratio was the desired and actual one required to achieve the given level of pollution loadings per unit of output as measured in 1973. This assumption implies that full capacity utilization of the stock of pollution capital is realized in every time period.

In summary, the following assumptions characterize the investment equation specifications:

- (1) that investment is determined by a capital-output model;
- (2) that desired and actual capital stocks are equal, implying instantaneous adjustment and no investment lags;
- (3) that desired stocks, and therefore net investment, respond identically to both output changes and treatment level changes; and
- (4) beyond the point of increasing marginal cost (for example, 90 percent removal), the stock requirements increase exponentially.

Investment flows were differentiated into two types: one characterizing a first approximation to maintaining the baseline or 1973 treatment levels, and the other designed to provide simulation capabilities for investigating different assumption sets concerning the specification of future water quality

and effluent discharge regulations. These equations are now presented in turn.

Baseline Scenario Investment

This is the investment required to maintain, at a constant, the base year (1973) level of treatment. In the present framework this implies that the pollution capital stock to industry output ratio must remain constant. This means that the stock of pollution capital must grow by the same proportion as output. Following the assumption set noted above, and allowing for depreciation of the last periods' stock of capital, the expressions outlining investment in the baseline scenario are:

$$ITMIO1_t = STOCK1_{t-1} * \frac{RDP_t}{RDP_{t-1}} + DEP * STOCK1_{t-1} - STOCK1_{t-1} \quad (1)$$

$$STOCK1_t = STOCK1_{t-1} + ITMIO1_t - DEP * STOCK1_{t-1} \quad (2)$$

Where;

$ITMIO1_t$ = Baseline capital investment in industrial treatment in year t.

$STOCK1_t$ = Baseline stock of industrial pollution capital at end of year t.

RDP_t = Real domestic product in year t.

DEP = Rate of economic depreciation.

It is important to note that equations (1) and (2) and all other such equations that follow (both industrial and municipal) also have industry and region dimensions. To simplify the exposition, these were omitted.

Increased Treatment Scenario Investment

For these simulation generated scenarios, it is assumed that up to a certain level of treatment, 90 percent for example, the capital stock to output ratio must increase in the same proportion as the desired treatment level increase. For example, to increase the removal of a certain pollutant by 10 percent, say from 40 percent removal level to a 50 percent level, the stock of pollution capital would have to rise by 10 percent, given no change in output. This means that the pollution capital to output ratio would rise by 10 percent.

Above the 90 percent treatment level, some easily represented functional form was required to depict the generally acknowledged rapid rise in incremental capital costs and, therefore, required capital stocks. (See, for example, Kneese and Shultze: Pollution, Prices, and Public Policy, Brookings Institution, 1975, especially pp. 18-22.) For this purpose, the exponential function $y=e^{ax}$ was chosen.

In general, the investment flows needed to satisfy any increased removal decision would be equal to the normal or baseline investment, plus that amount required to increase the pollution capital to output ratio by the necessary amount. It is important to understand the one-shot nature of each treatment policy decision. The policy augmented stock in the current year becomes the lagged stock the next year, grows proportionally with output, and is replaced as it is depreciated, however, at a higher absolute level than it would have been in the absence of the policy change. For example, if in

a given year, the desired treatment level is increased by 20 percent (remaining below the 90 percent level), the stock of pollution capital must increase by 20 percent, with everything else constant. This increase is a one-shot event. Once the stock is increased by 20 percent, it is maintained at this relative level naturally, through our investment equation specifications. The only time it needs such an increase again is if treatment levels are increased by another policy change. The expressions for investment, in the presence of policy changes, are the following:

$$\begin{aligned} \text{ITMI03}_t = & \left[1 + (\text{DESTRL} - \text{BASTRL}) \right] * \text{STOCK3}_{t-1} * \frac{\text{RDP}_t}{\text{RDP}_{t-1}} \\ & + \text{DEP} * \text{STOCK3}_{t-1} - \text{STOCK3}_{t-1} \end{aligned} \quad (3)$$

$$\text{STOCK3}_t = \text{STOCK3}_{t-1} + \text{ITMI03}_t - \text{DEP} * \text{STOCK3}_{t-1} \quad (4)$$

Where:

ITMI03_t = Policy affected capital investment in industrial investment
in year t

STOCK3_t = Policy affected stock of industrial pollution capital in
year t

DESTRL = Desired treatment level (simulation variable)

BASTRL = Baseline (1973) treatment level (simulation variable).

All other notation is defined in the variable list of equations

(1) and (2). Also note that the expression $\left[1 + (\text{DESTRL} - \text{BASTRL}) \right]$ is greater than one only in the years of policy change. If an increase of 10 percent points in treatment levels was desired, this expression would

equal 1.10, only in the year that the increase was implemented. For that year, NET INVESTMENT is 10 percent higher than it otherwise would have been. Therefore, the pollution capital stock to output ratio is 10 percent higher, which is the result we want and consistent with our assumptions.

Separating Baseline from Policy
Affected Investment Expenditure

Since ITMI03 also contains ITMI01, double counting is possible unless measures are taken to separate them. To do this properly, both ITMI01 and ITMI03 are calculated for each projection. The expression for ITMI03 has been designed to enable the policy change term, $1 + (\text{DESTRL} - \text{BASTRL})$, to equal one for all years except those of treatment level changes.

Also modelled is a separate sector for baseline investment, with its own base year stock variable and subsequent stock levels. The calculation of ITMI01 is then subtracted from ITMI03, to give the policy induced investment flows. To allow for the single year policy effect, the expression (3) above for ITMI03 can be rewritten as:

$$\begin{aligned} \text{ITMI03}_t = & (\text{DESTRL} - \text{BASTRL}) * \text{STOCK3}_{t-1} * \frac{\text{RDP}_t}{\text{RDP}_{t-1}} + \text{STOCK3}_{t-1} * \frac{\text{RDP}_t}{\text{RDP}_{t-1}} \\ & + \text{DEP} * \text{STOCK3}_{t-1} - \text{STOCK3}_{t-1} \end{aligned} \quad (5)$$

with allowance made in the first term on the right hand side of (5), for the single year nature of such a shock. When this term does equal zero, the whole expression collapses to equation (1) above for ITMI01. The complicating factor that requires computation of both of them is the one-shot nature of the stock change, and the continued effects of this higher stock on

future investment flows. In fact, after the policy change, equation (4) is just equation (1), only with a higher stock value driving the investment expenditure.

For the case where desired treatment levels exceeds 90 percent removal, the simple proportional expression is replaced with one like the following:

$$e^{.5 (DESTRL - .90)} 100$$

with allowance once again for its non-zero value existing only in years of policy change. The 90 percent value, used as the critical one in this example, is also programmed for simulation. If a user wishes to substitute a different value, it is very simple.

Further Considerations

The necessity to specify the form and parameters of the above investment equations, 'a priori', in effect making these equations simple accounting identities, presents further conceptual problems in addition to those noted. While pollution abatement often takes the form of end-of-pipe treatment, it is also accomplished through process changes as noted earlier. However, expenditures undertaken for process changes are not easily identifiable as pollution abatement oriented. In fact, these expenditures might plausibly be related to a desire to economize on a production input that has become relatively expensive, or perhaps even redundant, due to technical progress, and not because of the input's detrimental impact on water quality. Despite this lack of clear distinction, some efforts at measuring such process change abatement are undertaken in the United States.

Modelling such expenditure is another matter however. This class of spending is, therefore, not examined here. The estimates generated by the present equations are based on a separable stock of capital purchased solely for pollution abatement purposes.

Nevertheless, the impact of technical progress on the demand for pollution abatement capital needs to be recognized and accounted for. In this simple model, the demand for pollution control capital is in a one-to-one relationship with real domestic product. Note, however, that technological change allows more output to be produced with the same quantity of inputs. To the extent that water is considered like any other input, this may lead to a decrease in the amount of water used per unit of output. Unfortunately, it is not clear that the historical treatment of water as a common property resource has sufficiently changed so that water now enters production functions in the same way that the other inputs do; as a scarce resource whose relative price reflects that scarcity. As long as the real resource cost of water fails to reflect this scarcity, technological change may contain an inherent bias towards the use of the underpriced resource.

Further, the need for pollution abatement equipment depends not only on the quantity of water used, but also on the quality of this water after use. To further complicate matters, the present legislative process responsible for water quality guidelines and regulations considers the quality of the receiving stream as an important governing factor. In the production process itself, the development of cleaner technologies will influence the need for abatement measures. The possible need to economize on

certain polluting substances or methods may result in a relative decline in environmental damage.

The number of possibilities and their combinations presents a formidable question, with no simple answer. The above discussion has only tried to point out a few of the more noticeable ones.

The effects of technical change will also influence the production of pollution abatement equipment itself. It seems clear that some progress will be made in this direction. It is also clear that innovation giving rise to technical progress requires, and is directly related to, an economic incentive. Those fields of endeavour with the highest expected payoff naturally receive the most research effort. This incentive is equated to the private rate of return, notwithstanding government efforts to give the social rate of return equal importance. To date, these efforts have had limited success, with public institutions and public sponsored programs undertaking the greatest part of such research. Even the required direction of future research becomes clouded when commercial applications of what we already know are delayed and fought. As long as environmental management does not share equal economic status with other activities, the long-run prospects for technical progress in this area seem to indicate an advance that will be less than that which prevails in the economy as a whole.

Finally, the behaviour of pollution abatement capital costs as firm output (or plant scale) increases requires consideration. Theoretically, these costs could increase, decrease, or remain constant.

An adequate assessment of this relationship is beyond this research effort, so for simplicity, the scale factor was assumed to reflect constant costs.

Final Model Choice

In order to provide at least a minimum consideration of the effects of technical progress on water use and treatment, provision was made in the final capital cost algorithm for judgement. To accomplish this, two simulation variables were added. One reflected possible changes in water use patterns and average waste loadings. While not entirely unambiguous, neither is the phenomenon that is being measured. This variable affected the relationship between the pollution capital stock and output. Specifically, the stock-output relationship in equations (1) and (3) was modified to account for possible changes in water use and waste loads. This consideration resulted in a new expression for (1) and (3), as follows:

$$ITMI01 = STOCK1_{t-1} * \left(\frac{RDP_t}{RDP_{t-1}} - CHWFAC \right) + DEP * STOCK1_{t-1} - STOCK1_{t-1} \quad (6)$$

where the simulation variable CHWFAC represents an annual percentage fall (rise) in average water use and/or average waste load. This annual value is obtained by interpolating a decoy (growth) rate between the two end points of the forecast horizon. The base year represents the value one hundred, and the other end point takes the simulation value, be it lower or higher than the base year value. The same variable is inserted into equation (3) for ITMI03 in the identical place.

The second simulation variable attempts to capture the changing efficiency of capital investment. Here, this is represented by lowering (raising) the required expenditure by a suitable percentage factor. To accomplish this, the right-hand side of (6), with the exception of the last term, $STOCK1_{t-1}$, is

multiplied by the variable EFF\$01. For example, if capital is assumed to grow in efficiency by two percent per year, the value of EFF\$01 would be .98.

As noted, it is realized that this method of treating technical progress is not very sophisticated. However, it is necessary to consider this phenomenon somehow, and the approach taken here at least captures the basic essence of the problem.

Municipal Treatment

Introduction

The modelling of municipal waste-water systems was facilitated by the relative simplicity of understanding and a relatively well developed, understood, and standard technology. While there is still a great deal of progress to be made in this area, enough is known to make possible a fairly simple and accurate representation of the real world. The model of investment spending developed here focused only on the provision of residential waste treatment plants, and did not consider accompanying expenditure on sewage collection and outlays on drainage systems (storm sewers). Nor was provision for treatment of industrial waste flows considered. These omissions were not dismissed lightly since they form a substantial, if not major, portion of outlays on overall sewage treatment. However, the lack of essential information at the appropriate time led to the decision to proceed with what was available. If it is desired in the future, these shortcomings could be considered and rectified to whatever extent possible. In the interim, it is

possible to use a judgemental rule of thumb concerning the relation between sewage treatment plants and the other capital outlays mentioned. The industrial waste flow problem is not so simple, and will simply have to be kept in mind. One further caveat concerns the omission of operating and maintenance costs associated with municipal sewage systems. Again, problems of data availability, comparability, and reliability, as well as timeliness, prompted the foregoing of this cost consideration.

The Conceptual Model

In the real world, the construction (supply) of sewage treatment plants is carried out in discrete, 'lumpy' steps and is usually of sufficient size to provide services for estimated demands of twenty years or more into the future. While, for the urban population at least, sewage collection systems are now a prerequisite for new development, the matching of sewage treatment capacity (supply) with the demand for that capacity is not always accomplished. At a given point in time, some areas might have excess capacity, while others have a substantial portion of their waste-water returned to nature with no form of treatment whatsoever. Fiscal constraints and different government priorities and plans are among several factors determining the actual outlays made for sewage treatment plants. Further, some municipal plants treat industrial waste. As noted, these future needs were not considered here. Rather, the present approach concentrated on the urban residential population.

These problems, associated with attempting to predict the time path of actual outlays on treatment plants, suggested that an alternative tact might be easier and more fruitful. Therefore, sewage treatment expenditures are estimated on an annual basis and are required amounts, dependent on the assumed values of the variables that (in this model) determine sewage treatment requirements.

The set of equations determining required capital outlays on sewage treatment systems are simple, straightforward accounting relations. Current institutional and technological considerations governing the design and configuration of treatment plants have a long history and are relatively rigid in application. Plant capacity is invariably specified in terms of the number of gallons of waste-water that can be processed each day. For the purposes of this study, the only other significant design specification concerns the extent to which the waste-water is processed. These specifications are commonly grouped into three categories: primary, secondary, and tertiary or advanced. Note that these categories do not designate unique methods of treatment. As one advances from primary to tertiary methods, there is an increasing number of technological configurations or sophistications within each method type. While the primary and secondary methods used in the study basin and considered for modelling purposes presented few problems, tertiary methods encompassed a fairly wide array of technical choice.

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