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RESOURCE RECOVERY MODELS FOR REGIONAL PLANNING AND POLICY EVALUATION

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ABSTRACT

MITRE has designed and developed several models for regional resource recovery planning. These models have been applied in several planning and policy evaluation programs, and, from this work, insights have been gained into the economics of regionalization in resource recovery planning. The models and application programs are described, and the insights are discussed.

INTRODUCTION

In this paper, we shall describe models for regional resource recovery planning, and their application programs. From this work, we have gained many insights into the economics of regionalization; but given the early stage of our work, and the crude state of our data, these insights are not answers, but rather questions to be asked, and suggestions for further investigation.

BACKGROUND

In resource recovery, there is an economic push towards regional solutions -- to take advantage of the substantial economies of scale in processing. But regionalization in turn generates two problems:

- a complexity in system design (see Figure 1)
- a difficulty in achieving a consensus among the large number of autonomous decision-makers in a large region.

The planning model is intended to help with both problems:

- by sorting out the many locational, process selection, and transportation link selection issues, and identifying a minimum-cost solution; and

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ECONOMIC ELEMENTS OF A REGIONAL RESOURCE RECOVERY SYSTEM

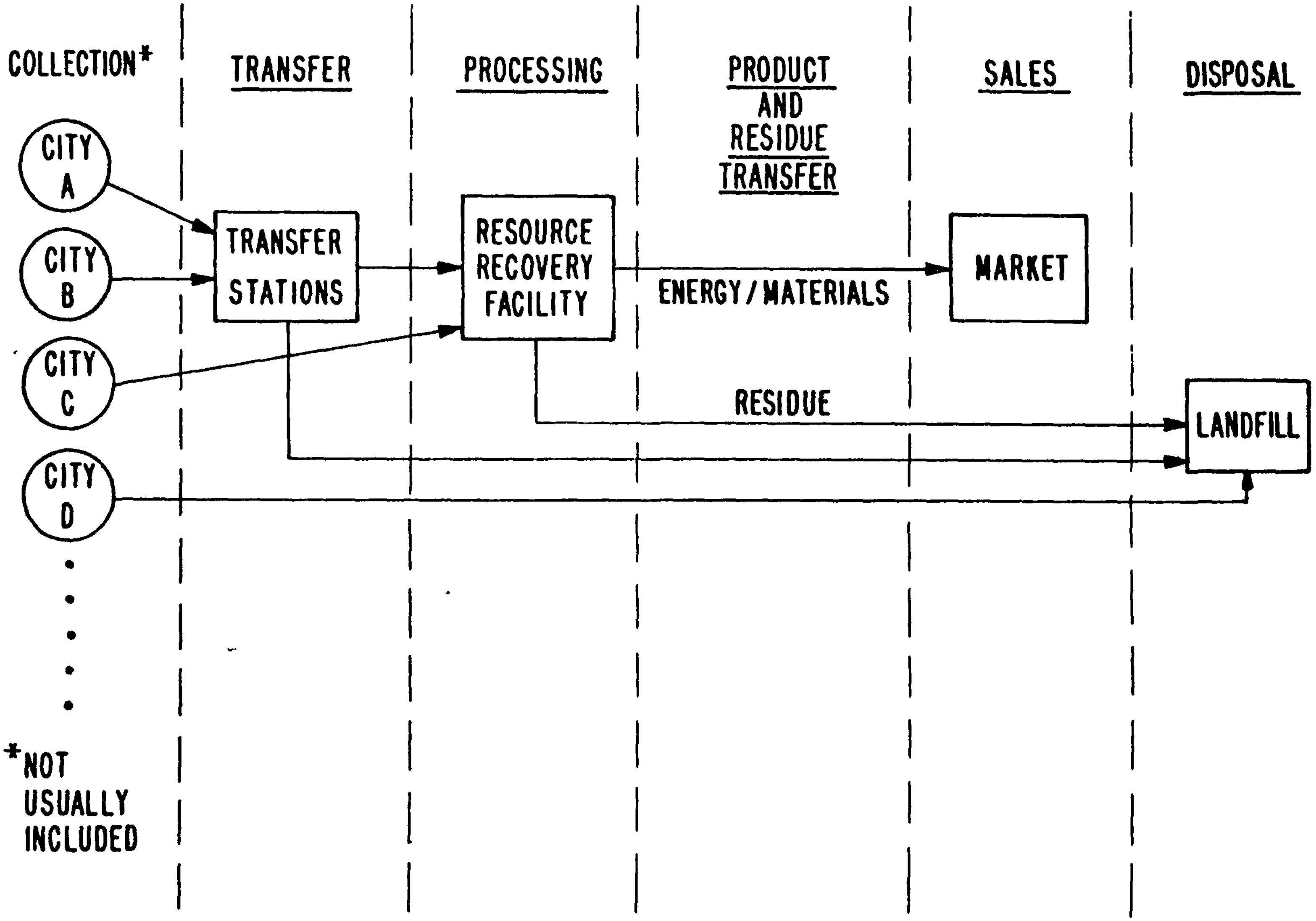


Figure 1

- by assisting the consensus by illuminating at least what cost differences are associated with political issues, and thereby assisting in their solution.

Figure 2 illustrates the basic tradeoff on centralization for a hypothetical region. The processing cost per ton declines continually as we move to the right in that figure, towards fewer, and larger, plants. This is the effect of the economies of scale. On the other hand, the haulage cost per ton, required to gather the waste into the processing centers, increases as we move to the right, towards more centralized solutions. In determining the proper degree of centralization we seek to minimize the sum of processing plus haul cost. Figure 2 illustrates the cost comparison for the four, two, and one plant cases, with the two-plant case showing the lowest total cost for processing and haul. Note that the solution must be discrete -- we cannot have one and one-half plants in our region.

Figure 3 illustrates some of the non-economic effects of regionalization. The processing plus haul costs curve would indicate a preferred plant size, and hence degree of centralization, at the lowest point of that curve. Other elements, which are difficult to quantify, such as political difficulty, implementation time, and possible vulnerability (to strike, unexpected breakdown, etc.) will tend to increase with larger region size. The vulnerability might be ameliorated by a modular plant design, but the other elements are intrinsic to the political process of consensus. In a state in which a state-wide authority over solid waste tonnage has been established, most of these political costs are absent, but in most states these costs exist, and should be considered. Their presence should tend toward the selection of smaller region sizes. The models and model applications we shall describe below ignore these latter costs, and hence tend to generate larger region sizes than would be appropriate for most states.

THE MODELS

We shall describe two models:

- WRAP (Waste Resources Allocation Program)
- RAMP (Recovery and Market Planning).

WRAP was designed and developed by MITRE with EPA support. WRAP is fully operational, fully documented, and available to the public through EPA.

RAMP is in an experimental stage. It is essentially hand-operated and undocumented. We have been using it at MITRE, and expect to develop it for public use in the near future. The application programs described below have been run on RAMP.

CENTRALIZATION TRADE-OFF:
ECONOMIES OF SCALE vs. HAULAGE

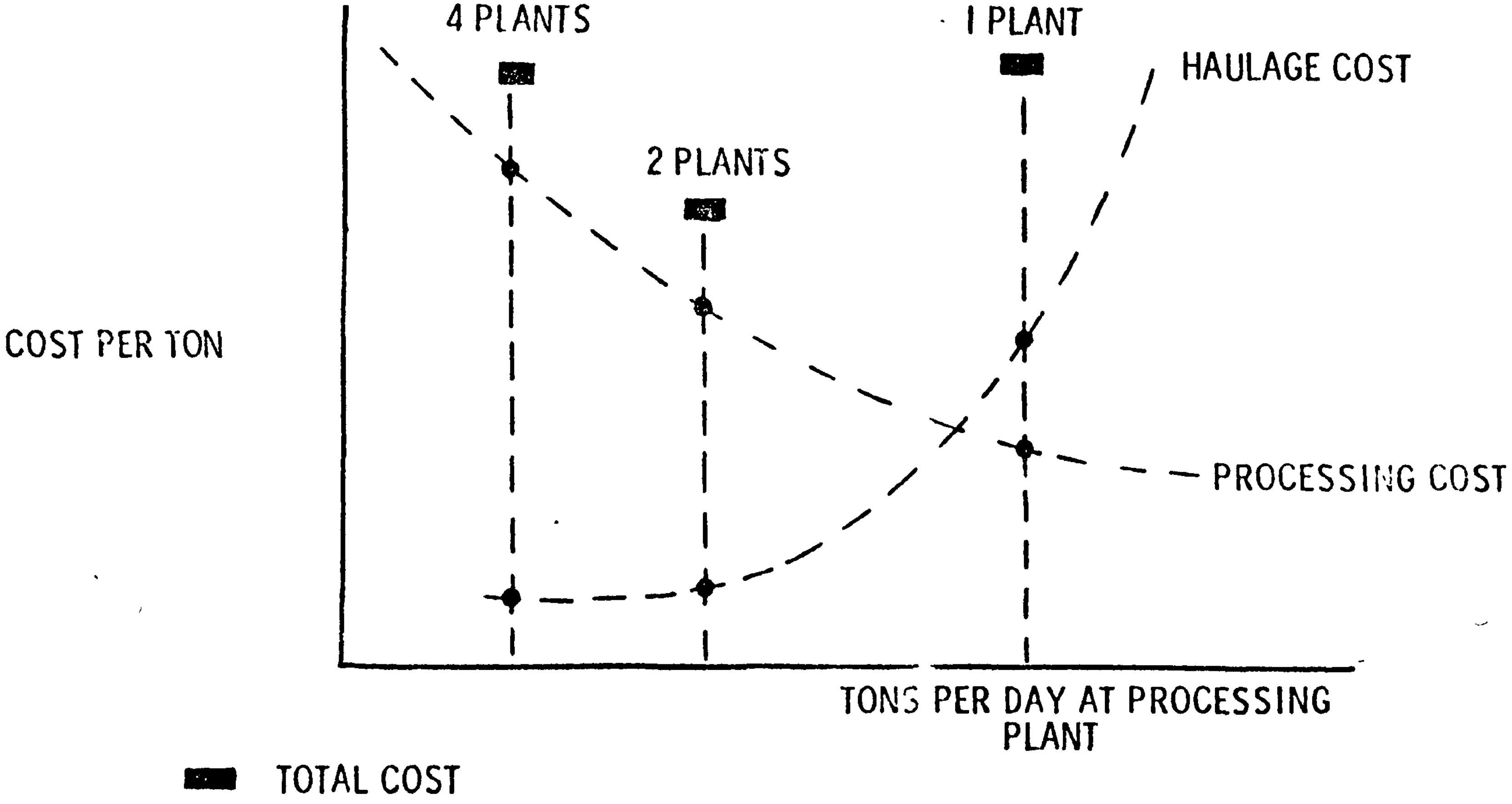


Figure 2

OVERALL DECISION CRITERION

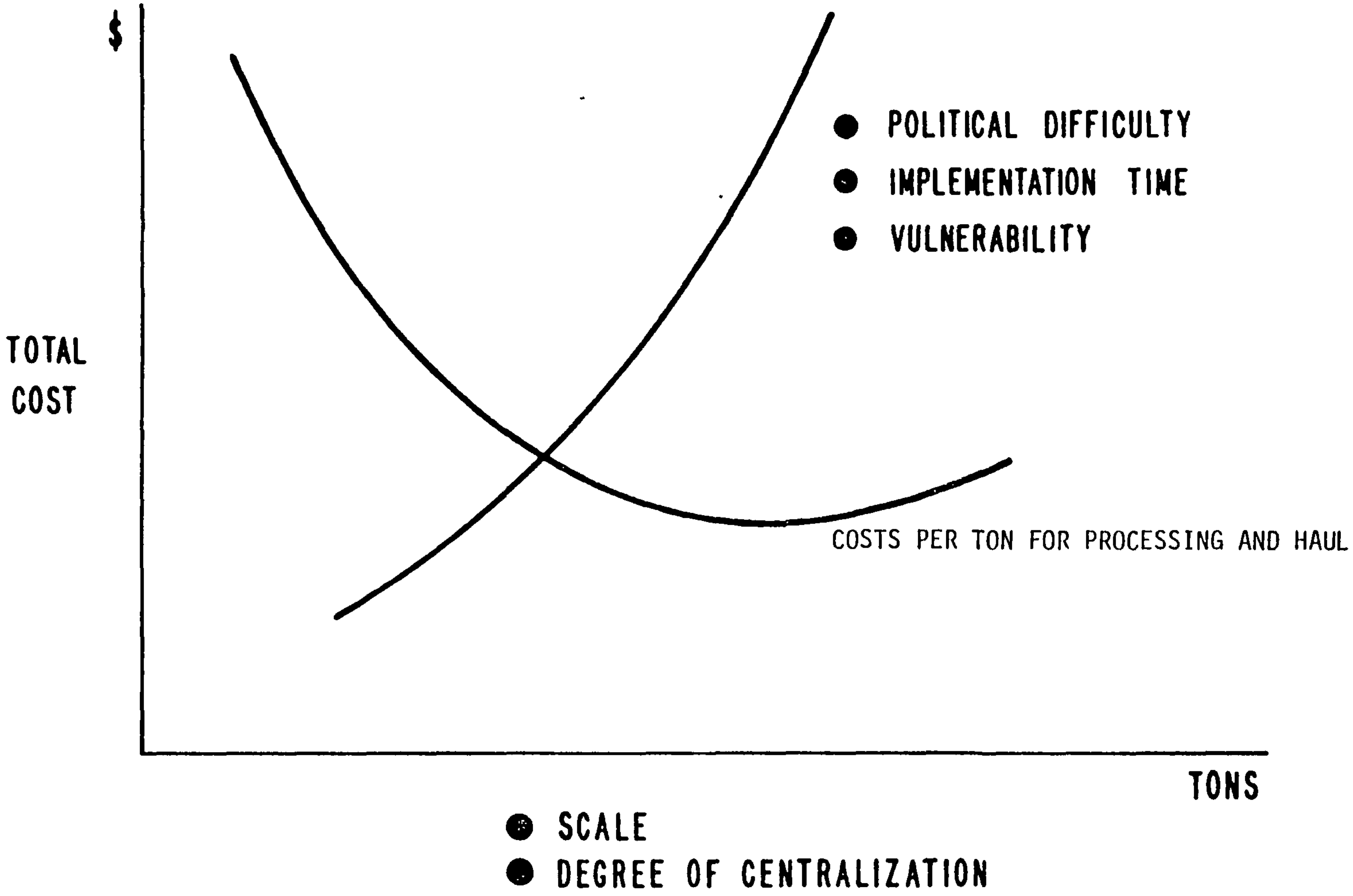


Figure 3

Figure 4 shows WRAP providing guidance to the decision-maker (the fellow on the right) on site selection, process selection, and other matters.

Figure 5 shows an overview of WRAP. The model will generate a regional plan which is the lowest cost plan which meets all requirements. In the process, it will:

- select sites, from among those offered
- select a process for each site, from among those offered
- size each site, and
- determine all links and flows from sources of waste generation to processing sites, and among processing sites.

The model uses a fixed-charge linear programming algorithm as the optimizer, which permits it to represent economies of scale (total cost curves which increase at a decreasing rate of increase) through linear segmentation, as in Figure 6. Ordinary linear programming encompasses cost functions defined as slopes only. With the use of the fixed charge algorithm (the fixed charges are the vertical intercepts of the cost functions) it becomes possible to represent the typical economy of scale cost function to any level of accuracy desired.

Figure 7 illustrates the levels of processing and allowed linkages in WRAP. Note that there are two levels of transfer station and two levels of secondary processing permitted. The former permits the model to select truck transfer linked to rail transfer. The latter permits more flexible structuring of process alternatives. There can be only one level of primary processing since, by definition, that implies an input of raw refuse and an output of something else.

RAMP Capabilities

RAMP offers a capability to study the saturation of markets and to optimize in the face of it, as illustrated by Figure 8. Note that in WRAP, all markets must be fixed price and unlimited in size. In RAMP, markets may be declining in price, and limited in size.

MODEL APPLICATIONS

The Planning Application

A model application for regional resource recovery planning should do two things: (1) it should help sort out the many variables and identify a minimum cost solution, and (2) it should help illuminate issues through

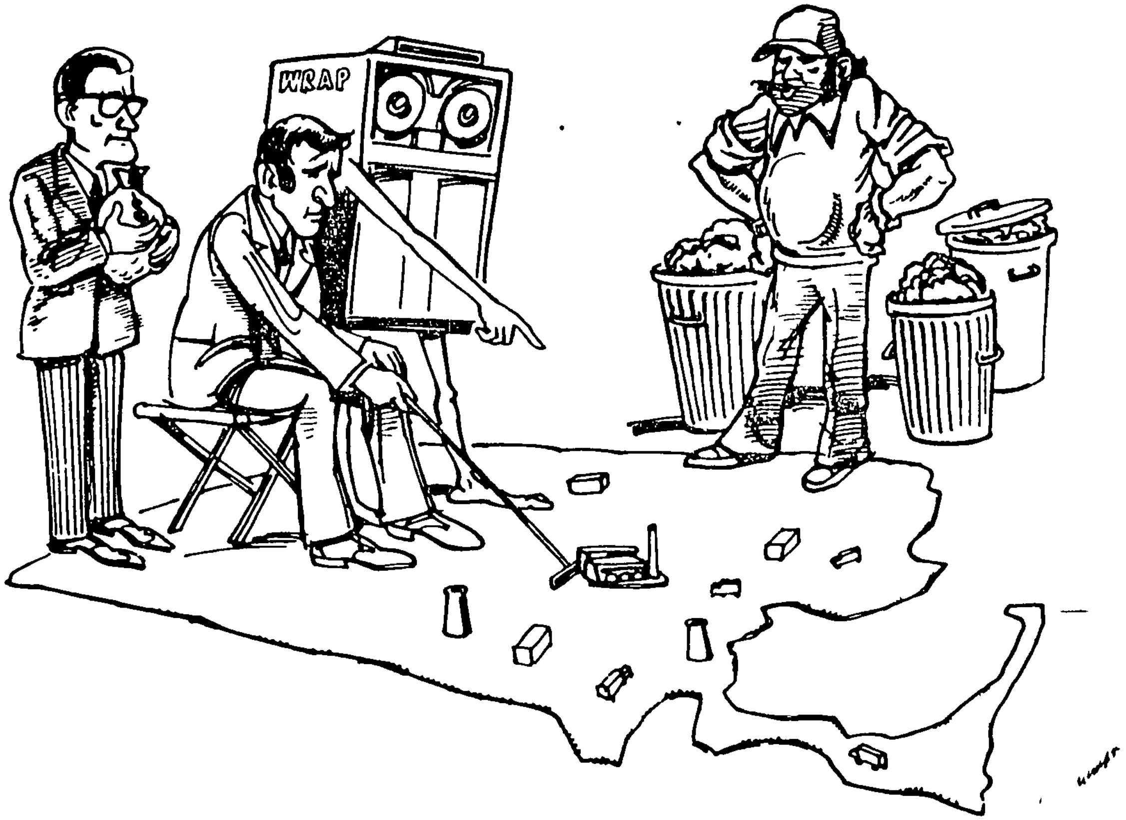


Figure 4

MODEL OVERVIEW

INPUTS:

ZONES	PROCESSING SITES	DISPOSAL SITES	LINKS
WASTE AT EACH CENTROID LOCATION	LOCATION POSSIBLE PROCESSES COSTS: FIXED + VARIABLE FLOW COEFFICIENTS MAX. TONNAGE	LOCATION COSTS: FIXED + VARIABLE LAND AVAILABLE	COSTS: VARIABLE

MODEL: OPTIMIZER

FIXED CHARGE LINEAR PROGRAMMING MODEL

OUTPUTS: COMPREHENSIVE REGIONAL SOLID WASTE MANAGEMENT PLAN

- LOWEST COST
- MEET ALL REQUIREMENTS

BY

SITE SELECTION
TECHNOLOGY SELECTION
SIZING
LINKS AND FLOWS

Figure 5

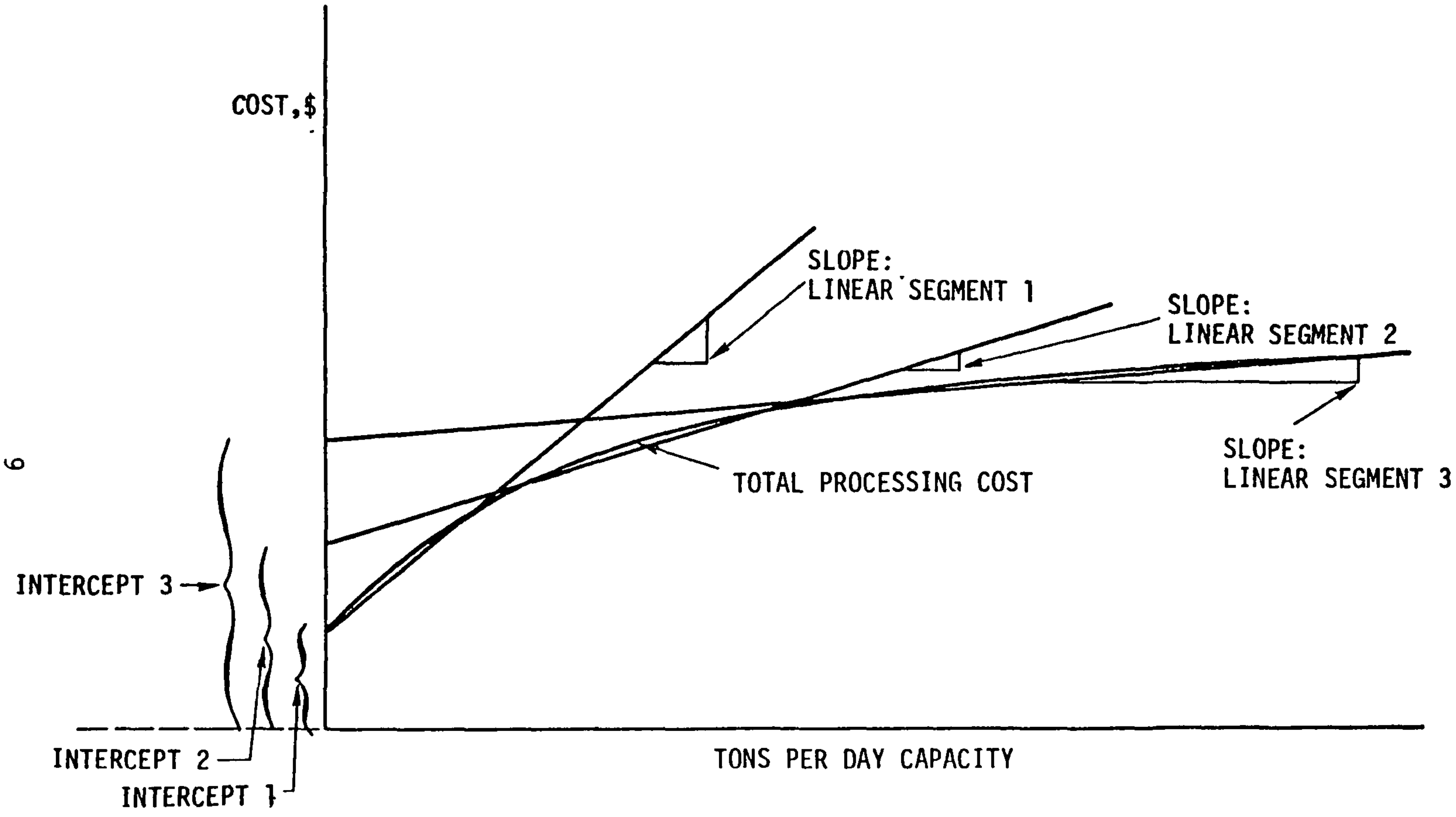


Figure . Piecewise Linear Approximation of a Concave Function
(Representing Economies of Scale)

Figure 6

LEVELS OF PROCESSING PERMITTED

SOURCE	TRANSFER STATION	PRIMARY PROCESSING	SECONDARY PROCESSING	LANDFILL
CENTROID	● TRUCK ● RAIL ● BARGE	ALL TECHNOLOGIES	● RESIDUE RECOVERY	● RAW REFUSE ● RESIDUE

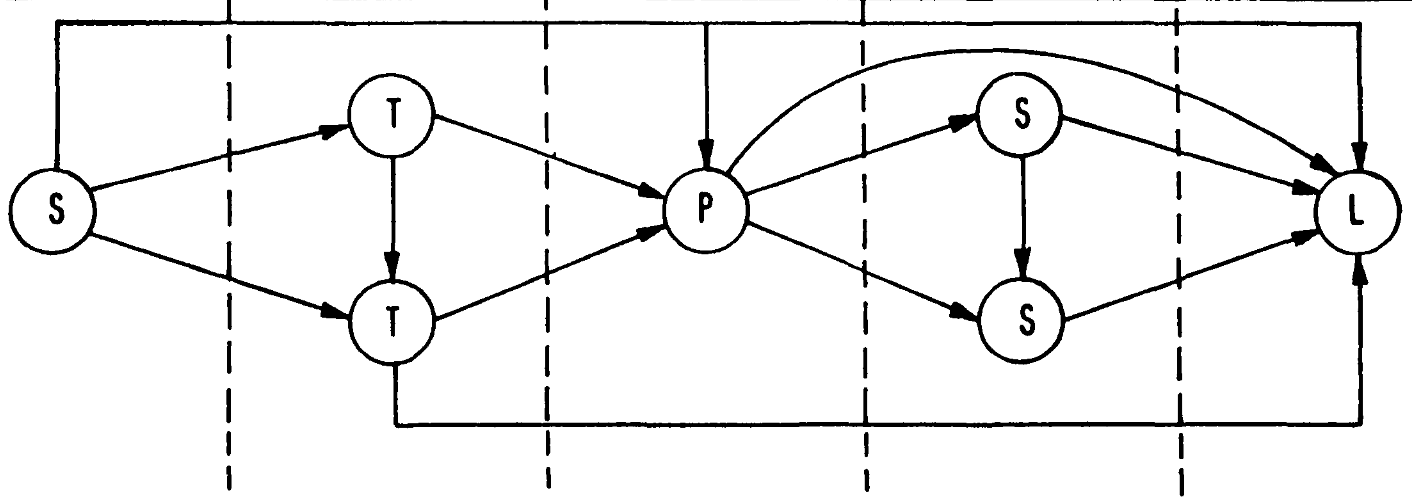
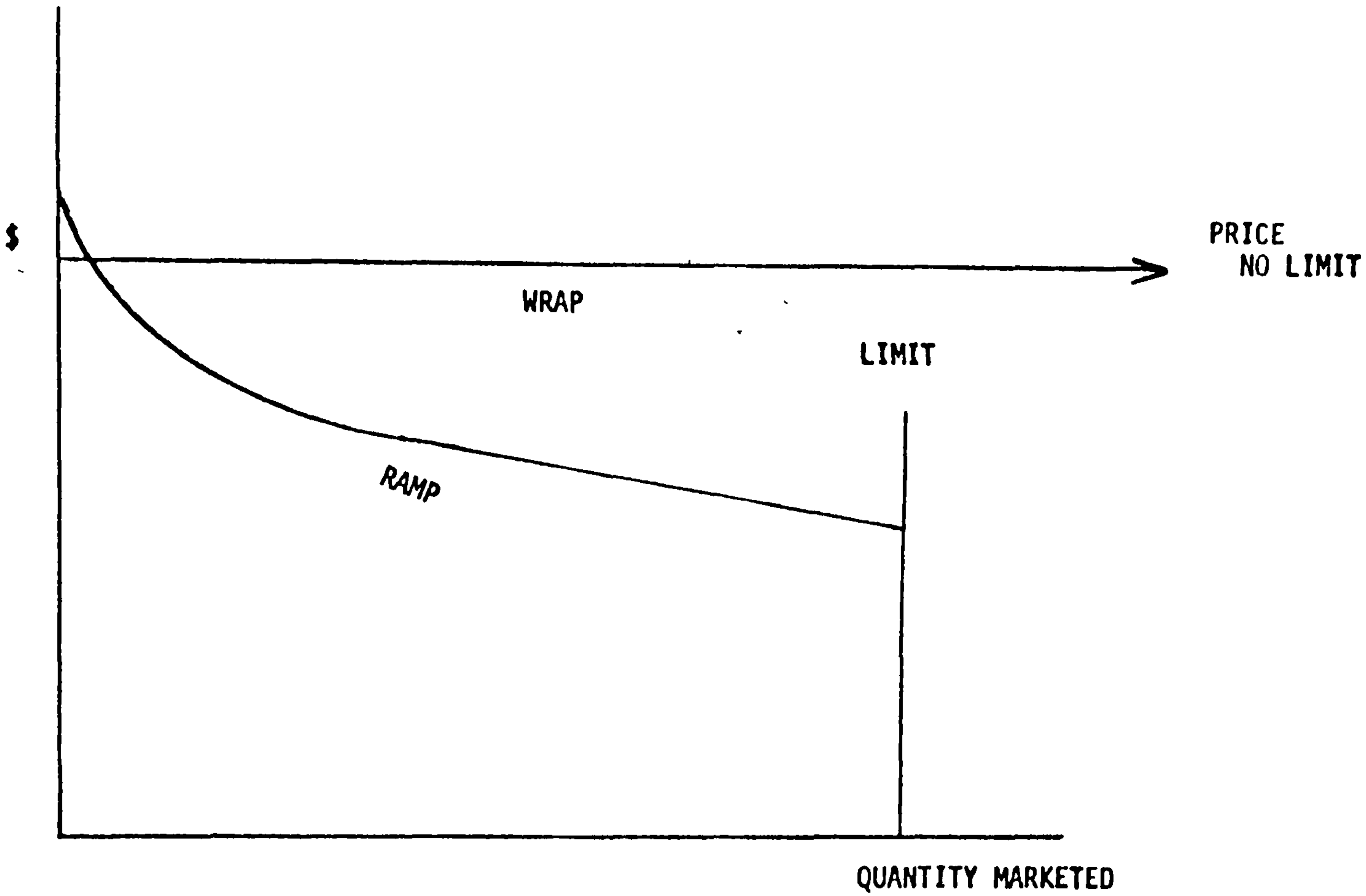


Figure 7



MARKETING IN WRAP AND RAMP

Figure 8

answering what-if questions. Figure 9 illustrates a number of what-if questions that have been answered in earlier applications of the model.

In illuminating issues, an application consisting of several "cases" is defined, and the model is run once for each case. Each case defines a particular situation of interest. It is important to note the fact that the model defines the minimum cost structure and the system cost for each case, so that in comparing the costs of two or more cases, we know that we are dealing with a meaningful cost difference -- none of the difference can be ascribed to a "poor" solution for one of the cases.

The model run for each case finds a solution which will handle all wastes, meet all environmental standards and meet the defined state of political acceptability represented by the case. Thus the incremental cost of moving from case to case represents the cost of easing a political constraint.

Figure 10 illustrates a hypothetical application. The economically preferred solution is shown on the left, representing the minimum cost way of handling the wastes and meeting environmental and other real constraints, such as tonnage and traffic limits. Each step to the right represents easing a political constraint, by abandoning a controversial site, or abandoning a controversial process, or opting for a politically easier regional structure, etc. The model defines the incremental cost of each such step, and in so doing, clarifies the importance of the political issue for all sides of the argument. It is hoped that this clarification of the incremental cost involved in an issue would help resolve it.

The Eastern Massachusetts Planning Application

Figure 11 illustrates the system costs per ton in a recent Eastern Massachusetts application of RAMP.

Since fixed-charge linear programming is a difficult kind of model to handle, it was not until run C that the base case, or economically preferred solution, was obtained. In run D, the ECOFUEL II process, with questionable markets for its products, was dropped. In run D, the model selected an incineration/steam/electric power option at one site, in lieu of the ECOFUEL II process at two sites which had been selected in run C. The system cost increased as illustrated in Figure 11. In run E, the Haverhill site, which has been subject to major planning as a primary processing site, and which turned up in runs A through D with only a transfer station, was forced into the solution for 2,880 tons per day of primary processing, representing the 53 communities included in the plan. The model elected to use that site for 11,000 tons per day of processing, using the Incineration/steam/electric power process. (The ECOFUEL II process was again introduced into this and succeeding runs, but with a limited market; it was not selected in runs E or F.) Since the City of Haverhill had in fact approved only 3,000 tons per day, an upper bound at that limit was entered into run F, and the model

ILLUMINATION OF ISSUES

WHAT-IF QUESTIONS:

WHAT-IF THE REGION SIZE IS --- ?

ST. LOUIS: STATE-BY-STATE
MASS: LARGE vs SMALL REGION

WHAT-IF A KEY PROCESS NOT AVAILABLE ?

FOR POLITICAL REASONS --- LANDFILL
FOR TECHNICAL REASONS --- GAS PYROLYSIS

WHAT-IF A KEY SITE NOT AVAILABLE ?

IT IS WORTH ________ TO FIGHT FOR THE SITE

WHAT-IF A KEY MARKET NOT AVAILABLE ?

WHAT-IF THERE ARE ESTIMATION ERRORS ?

TONNAGE --- MARKET PRICES --- PROCESS COSTS ?

RESULT: ----- COST ------ STRUCTURE

Figure 9

THE PLAN SET

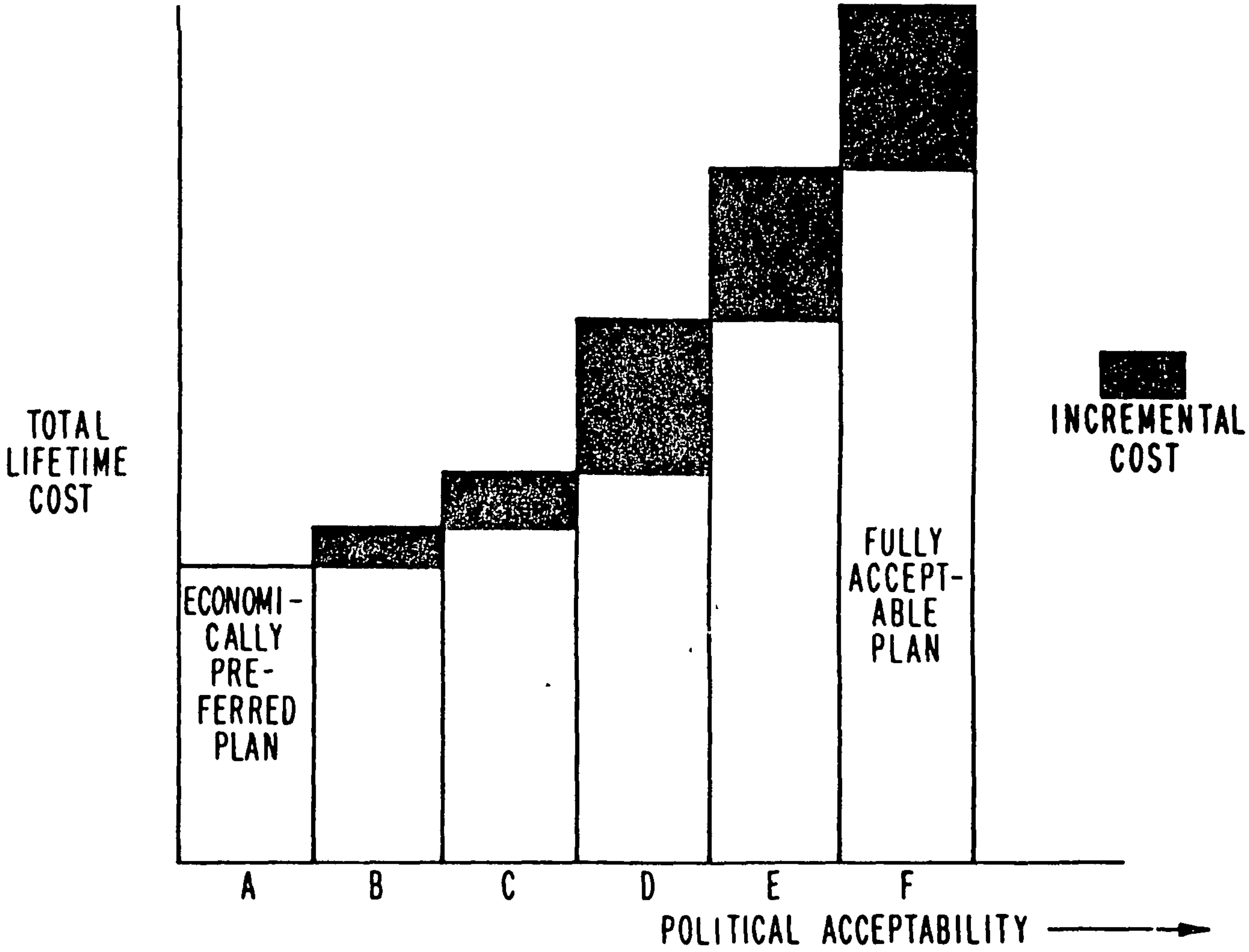
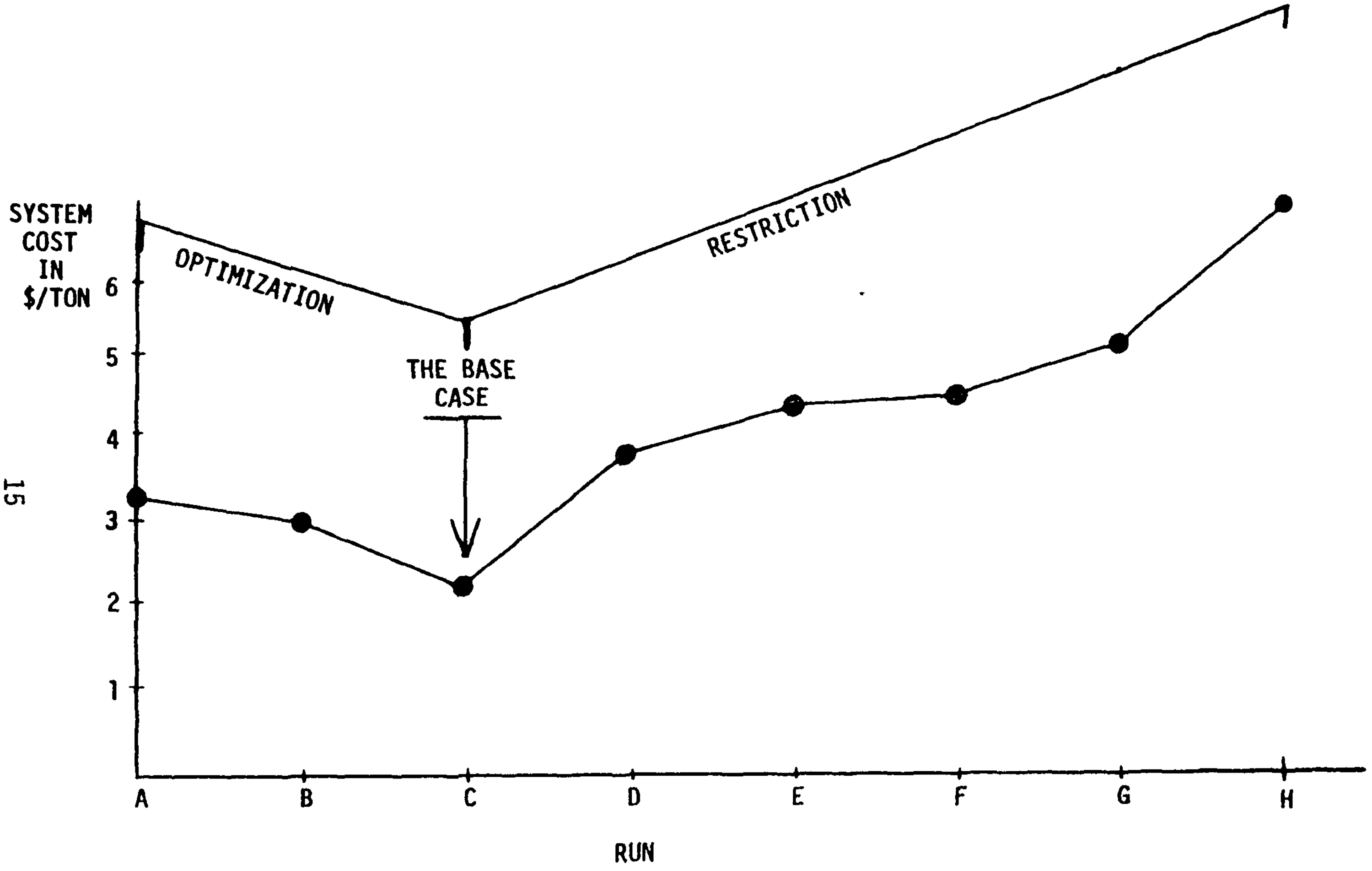


Figure 10



COST SUMMARY: EASTERN MASS. REGION RUNS

Figure 11

rerun. The model chose to allocate 3,000 tons per day to Haverhill (the upper limit rather than the lower limit) and selected a site on Route 128 near the Waltham/Weston line for 8,000 tons per day. In run G, we forced 379 tons per day, representing long-term contracts, into an existing ECO-FUEL II site at East Bridgewater. The model selected to divert just that amount of tonnage from the Waltham/Weston site, leaving roughly 7,600 tons per day at that latter site. In run H, a 3,000 ton per day limit was placed on all sites, and the model picked an additional site in Boston. Note that the incremental cost of this constraint (essentially a political constraint) was $1.80 per ton system-wide.

All runs included a lock-in of 712 tons per day at RESCO, Saugus, Massachusetts, representing existing long-term contracts.

Figure 12 and Table I illustrate the run G solution.

Table II displays summary information for runs C through H.

USING THE MODEL FOR POLICY EVALUATION

The RAMP model was run, using the same Eastern Massachusetts region previously studied, plus a new three-state region called INOKY (Indiana, Ohio, Kentucky), to evaluate policy issues for the U. S. Congress, Office of Technology Assessment, as part of an assessment on resource recovery, recycling, and reuse of materials from municipal solid waste. The runs described below will be documented in a supplement to the report on that assessment.

The effects of two different kinds of subsidies were studied:

1. a subsidy equal to the value of ferrous scrap in the market (assumed paid to the resource recovery processor) and
2. a capital grant of 75 percent of the capital costs of new resource recovery facilities.

Summary of Eastern Massachusetts Runs

In Run 1, the base case, the Non-Recovery Alternative (i.e., landfill) was offered at a cost ranging from $20 per ton (Boston) to $7 per ton. This represented MITRE's best estimate for the costs of haul and landfill processing. The result was 100% of tonnage in the resource recovery system.

In Run 2, the modified base case, the cost of the Non-Recovery Alternative was lowered to a range of from $12 per ton (Boston) to $2 per ton. The result was 95.1% of tonnage in the resource recovery system.

This run was used as a basis for the comparison with runs 3-6.

THE RUN G SOLUTION

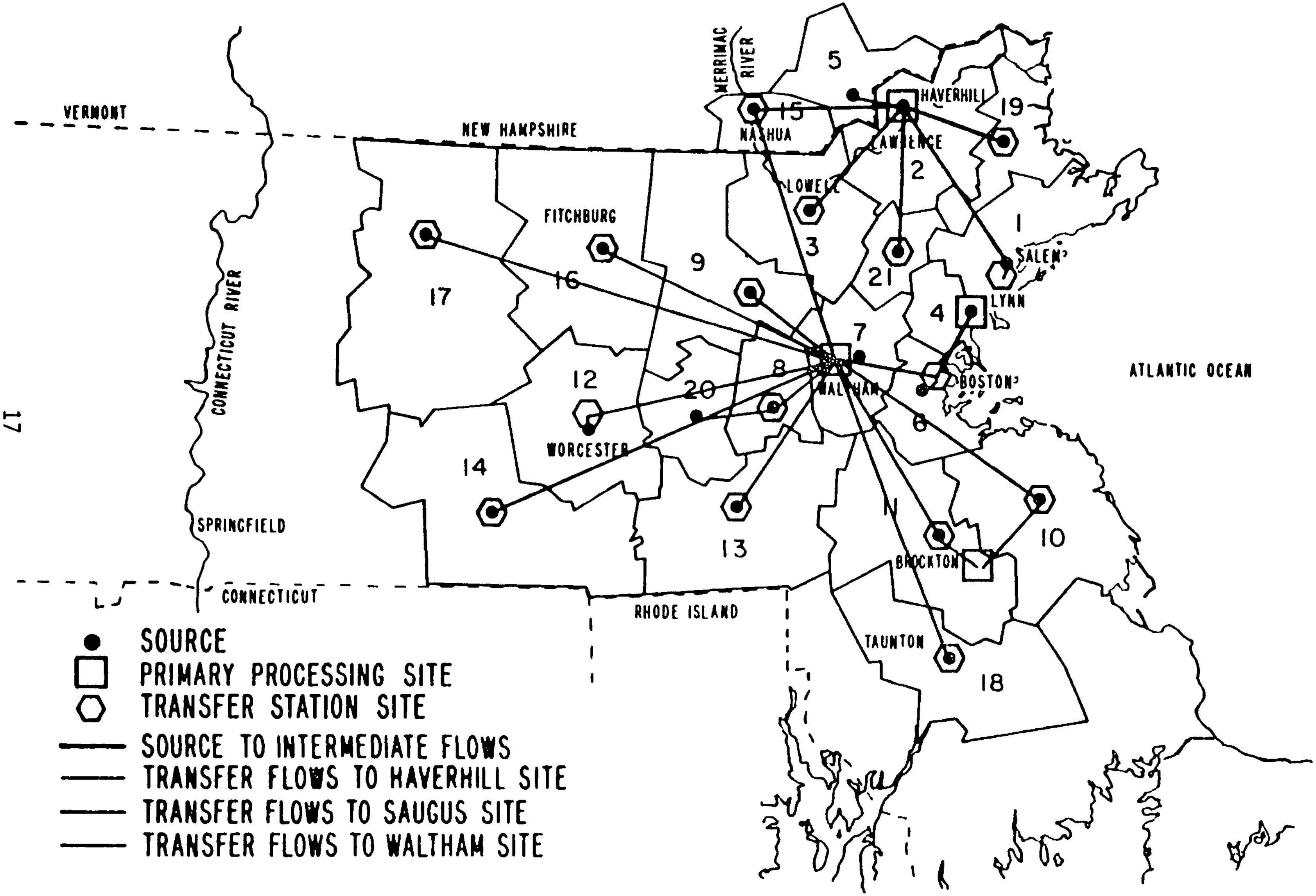


Figure 12

Table I

RUN NARRATIVE: RUN G
LOCK IN E. BRIDGEWATER COMMUNITIES

ASSUMPTIONS:

ECOFUEL II PROCESS AT E. BRIDGEWATER ONLY; ECOFUEL II MARKET LIMITED AT $1.40/MBTU AND UNLIMITED AT 40¢/ MBTU; 53 COMMUNITIES LOCKED IN AT HAVERHILL AT 2,880 TPD; 10 COMMUNITIES LOCKED IN AT SAUGUS AT 712 TPD; 5 COMMUNITIES LOCKED IN AT E. BRIDGEWATER AT 379 TPD; 3,000 TON PER DAY LIMIT AT HAVERHILL

SOLUTION:

	LOCATION	PROCESS	LEVEL (TPD)
PROCESSING:	SAUGUS	INCIN/STEAM	1200
	HAVERHILL	INCIN/ELECT	3000
	WALTHAM	INCIN/ELECT	7613
	E. BRIDGEWATER	ECOFUEL II	379

TRANSFER: TRUCK TRANSFER STATIONS AT 21 LOCATIONS

	LOCATION	COMMODITY	ANNUAL QUANTITY	ANNUAL VALUE $M
MARKETS:	LYNN	STEAM	2.05 B LBS	4.65
	HAVERHILL	ELECTRIC POWER	0.52 BKWH	10.40
	WALTHAM	ELECTRIC POWER	1.33 BKWH	26.60
	FITCHBURG	ECOFUEL II	9.22 x 10^{11} BTU	1.29

SYSTEM SUMMARY ANNUAL COST: $19.9M / ANNUAL TONS: 3.8M / COST PER TON: $5.24

Table II

SUMMARY OF EASTERN MASSACHUSETTS REGION RUNS

[10 SAUGUS COMMUNITIES LOCKED IN AT 712 TPD IN ALL RUNS]

RUNS A-C BASE CASE (RUN C WAS FIRST OPTIMIZING RUN)	SPECIAL ASSUMPTIONS: UNLIMITED ECOFUEL II MARKET	RESULTS: (RUN C) SAUGUS (INCIN/STEAM) AT 1200 TPD LOWELL (ECOFUEL II) AT 5421 TPD BOSTON (ECOFUEL II) AT 5571 TPD	SYSTEM COST: $2 25 PER TON
RUN D ELIMINATE ECOFUEL II FROM ALL SITES	SPECIAL ASSUMPTIONS NONE	RESULTS. SAUGUS (INCIN/STEAM) AT 6081 TPD LOWELL (INCIN/ELECT) AT 6110 TPD	SYSTEM COST . $3 94 PER TON
RUN E LOCK IN HAVERHILL COMMUNITIES	SPECIAL ASSUMPTIONS 53 HAVERHILL COMMUNITIES LOCKED IN AT 2,880 TPD ECOFUEL II AT E. BRIDGEWATER ONLY LIMITED ECOFUEL II MARKET	RESULTS. SAUGUS (INCIN/STEAM) AT 1,200 TPD HAVERHILL (INCIN/ELECT) AT 10,992 TPD	SYSTEM COST: $4 50 PER TON
RUN F TONNAGE LIMIT AT HAVERHILL	SPECIAL ASSUMPTIONS: 53 HAVERHILL COMMUNITIES LOCKED IN AT 2,880 TPD TONNAGE LIMIT AT HAVERHILL AT 3,000 TPD ECOFUEL II AT E. BRIDGEWATER ONLY LIMITED ECOFUEL II MARKET	RESULTS. SAUGUS (INCIN/STEAM) AT 1,200 TPD HAVERHILL (INCIN/ELECT) AT 3,000 TPD WALTHAM (INCIN/ELECT) AT 7,992 TPD	SYSTEM COST. $4.62 PER TON
RUN G LOCK IN E BRIDGEWATER COMMUNITIES	SPECIAL ASSUMPTIONS 53 HAVERHILL COMMUNITIES LOCKED IN AT 2,880 TPD TONNAGE LIMIT AT HAVERHILL AT 3,000 TPD 5 E BRIDGEWATER COMMUNITIES LOCKED IN AT 379 TPD ECOFUEL II AT E. BRIDGEWATER ONLY LIMITED ECOFUEL II MARKET	RESULTS SAUGUS (INCIN/STEAM) AT 1,200 TPD HAVERHILL (INCIN/ELECT) AT 3,000 TPD WALTHAM (INCIN/ELECT) AT 7,613 TPD E BRIDGEWATER (ECOFUEL II) AT 379 TPD	SYSTEM COST: $5 24 PER TON
RUN H 3000 TPD LIMIT AT ALL SITES	SPECIAL ASSUMPTIONS 53 HAVERHILL COMMUNITIES LOCKED IN AT 2,880 TPD 5 E BRIDGEWATER COMMUNITIES LOCKED IN AT 379 TPD ECOFUEL II AT E. BRIDGEWATER ONLY LIMITED ECOFUEL II MARKET TONNAGE LIMIT AT ALL SITES AT 3,000 TPD	RESULTS SAUGUS (INCIN/STEAM) AT 2,768 TPD HAVERHILL (INCIN/ELECT) AT 3,000 TPD WALTHAM (INCIN/ELECT) AT 3,000 TPD E BRIDGEWATER (ECOFUEL II) AT 423 TPD BOSTON (INCIN/ELECT) AT 3,000 TPD	SYSTEM COST $7.03 PER TON

In run 3, the equivalent of the market value of ferrous scrap was assumed to have been paid as a subsidy directly to the resource recovery processor. The result was 96.1% of tonnage in the resource recovery system.

In Run 4, capital costs of new resource recovery systems were assumed to be subsidized to the extent of seventy-five percent of system capital costs. The result was 98.3% of tonnage in the resource recovery system.

In Run 5, a smaller region size was simulated by applying a 2,000 ton per day limit at all sites. The result was 36.1% of tonnage in the resource recovery system.

In Run 6, a smaller region size with a better shredded fuel market was simulated. The 2,000 TPD limit at all sites was repeated, but with the addition of an improved market for shredded fuel, and with the offering of a shredded fuel process (ECOFUEL II) at more locations. The result was 52.5% of tonnage in the resource recovery system.

Table III presents a statistical summary of the six policy evaluation runs in Eastern Massachusetts.

Summary of INOKY Runs

The general structure of the series of seven INOKY runs is shown in Figure 13. In all runs the same alternatives were offered for processing technologies and locations, and for transportation linkages. Runs 1 to 3 differed from 4 to 7 in the lower non-recovery alternative (NRA) costs for the latter.

Run 1 is the base case for all runs, from which the effects of a ferrous scrap subsidy (run 2) and a capital subsidy (run 3) were studied. The subsidies were defined as in the Eastern Massachusetts runs. The percentages of INOKY tonnage in resource recovery were 92.0 in run 1, 97.4 in run 2, and 95.0 in run 3.

Since runs 1, 2, and 3 had all generated strong resource recovery solutions, the NRA was made more attractive in run 4 (decreased by $2 per ton in all zones) to evaluate how robust the resource recovery solution was. Run 4 generated a solution with 81.6 percent of all tonnage in resource recovery.

Run 5 introduced a 2,000 ton-per-day limit at all sites to simulate the inability to form regions of the size generated in runs 1 through 4, for any of a number of reasons ranging from the difficulty in achieving political consensus in a large region to the non-availability of technical planning support. Run 5, using the favorable landfill prices of run 4, generated a 69.3 percent resource recovery solution. Run 5 then was used as a base case to evaluate again the effects of a ferrous scrap subsidy (run 6) and a capital subsidy (run 7). In run 6, 84.2 percent of the tonnage went into resource recovery, and in run 7 76.8 percent of the tonnage was so allocated.

Table III

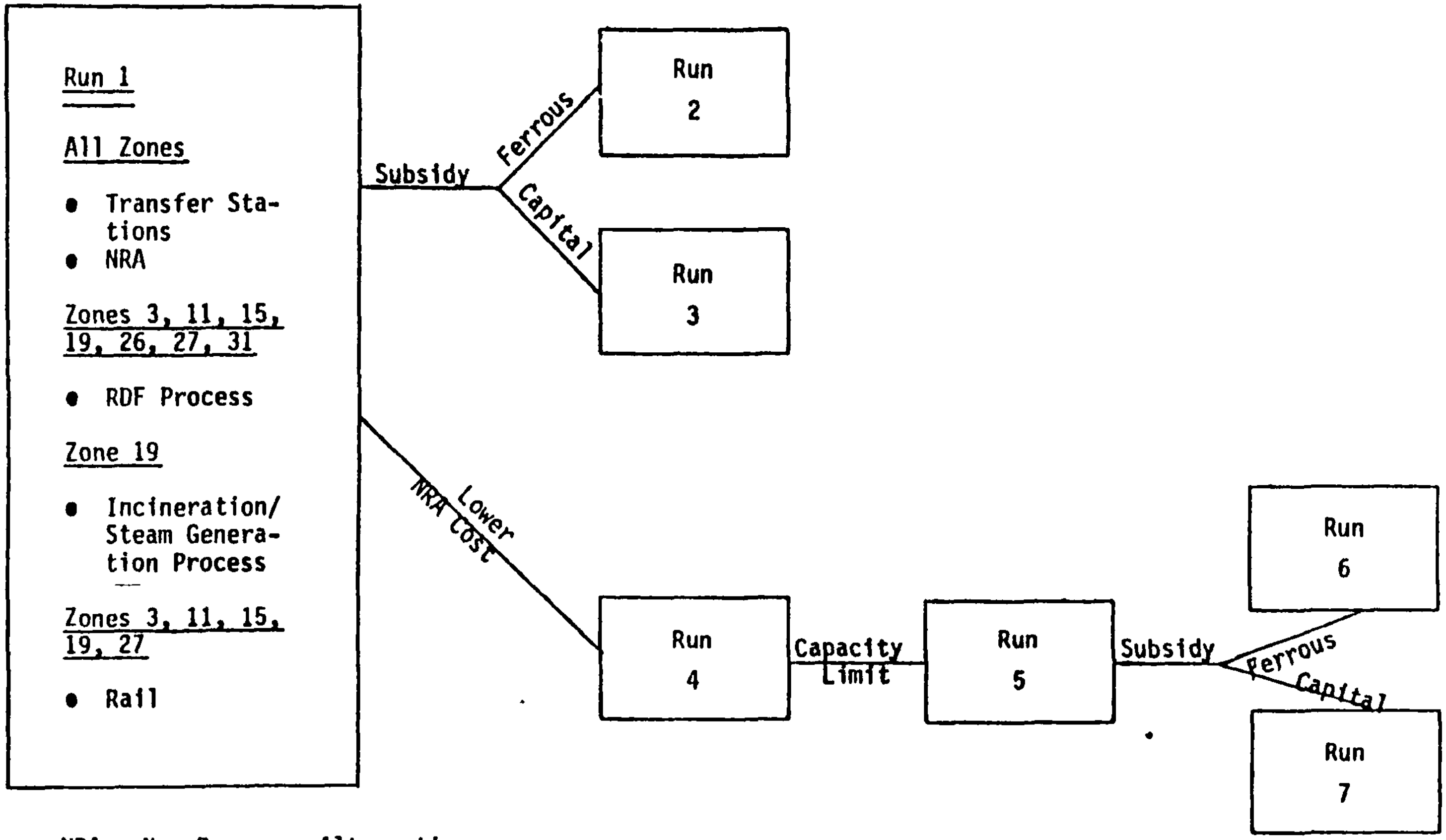
Policy Evaluation Runs in Eastern Massachusetts

STATISTICAL SUMMARY OF RUNS (Annual Flows and Costs)
Total for Region: 3,803,700 tons

	RUN					
	1	2	3	4	5	6
System Cost (million dollars)	12.0	11.4	7.4	-5.7	23.2	16.2
System Cost Per Ton (dollars)	3.15	3.01	1.96	-1.49	6.09	4.26
Tons in Resource Recovery (thousand tons)	3804	3619	3656	3739	1372	1996
Percent in Resource Recovery	100.0	95.1	96.1	98.3	36.1	52.5
Unincinerated Ferrous (thousand tons)	8.3	8.3	13.5	8.3	26.2	113.6
Incinerated Ferrous (thousand tons)	258.0	245.0	242.4	253.5	69.9	26.2
Electric Power (million KWH)	18154	1751	1729	1818	349	0
ECOFUEL II (BTU x 10^{10})	96	96	157	96	303	1314
Steam (billion lbs)	2.05	2.05	2.05	2.05	2.05	2.05
Cost of Subsidy Per Year (million dollars)	NA	NA	4,1*	17.3	NA	NA
One-Time Cost of Subsidy (million dollars)	NA	NA	NA	176.8	NA	NA
Cost of Subsidy Per Incremental Ton in Resource Recovery (dollars)	NA	NA	112*	144	NA	NA
Cost of Subsidy Per Incremental Ton of Ferrous (dollars)	NA	NA	1595*	2059	NA	NA
Cost of Subsidy Per Ton of Ferrous Converted to Unincinerated Form (dollars)	NA	NA	1525*	∞	NA	NA

*Only the portion of the ferrous market subsidy cost which flows to the resource recovery system is considered.

STRUCTURE OF INOKY RUNS



NRA = Non-Recovery Alternative
RDF = Refuse-Derived Fuel

Figure 13

Table IV presents a statistical summary of the INOKY runs; Table V presents the structures of solutions of those runs, and Figure 14 displays the structure of the base case (run 1).

Analysis of Policy Runs

In should be noted that the resource recovery system appears viable in both the Eastern Massachusetts and INOKY regions without subsidy, if the economies of scale, which appear to be available from centralized processing, are not barred by political considerations or by an insufficiency of planning capability.

Subsidy or resource recovery in both regions would be expensive, partly because so much of it would be "windfall" (that is, would lower the cost of resource recovery which would take place anyways). Subsidy in both regions would also ineffective for the reason that there is little room for improvement.

CONCLUSION

We are convinced as a result of these runs that the selection of the correct region size is an important adjunct of regional resource recovery planning, and can influence the viability of resource recovery considerably.

Table IV

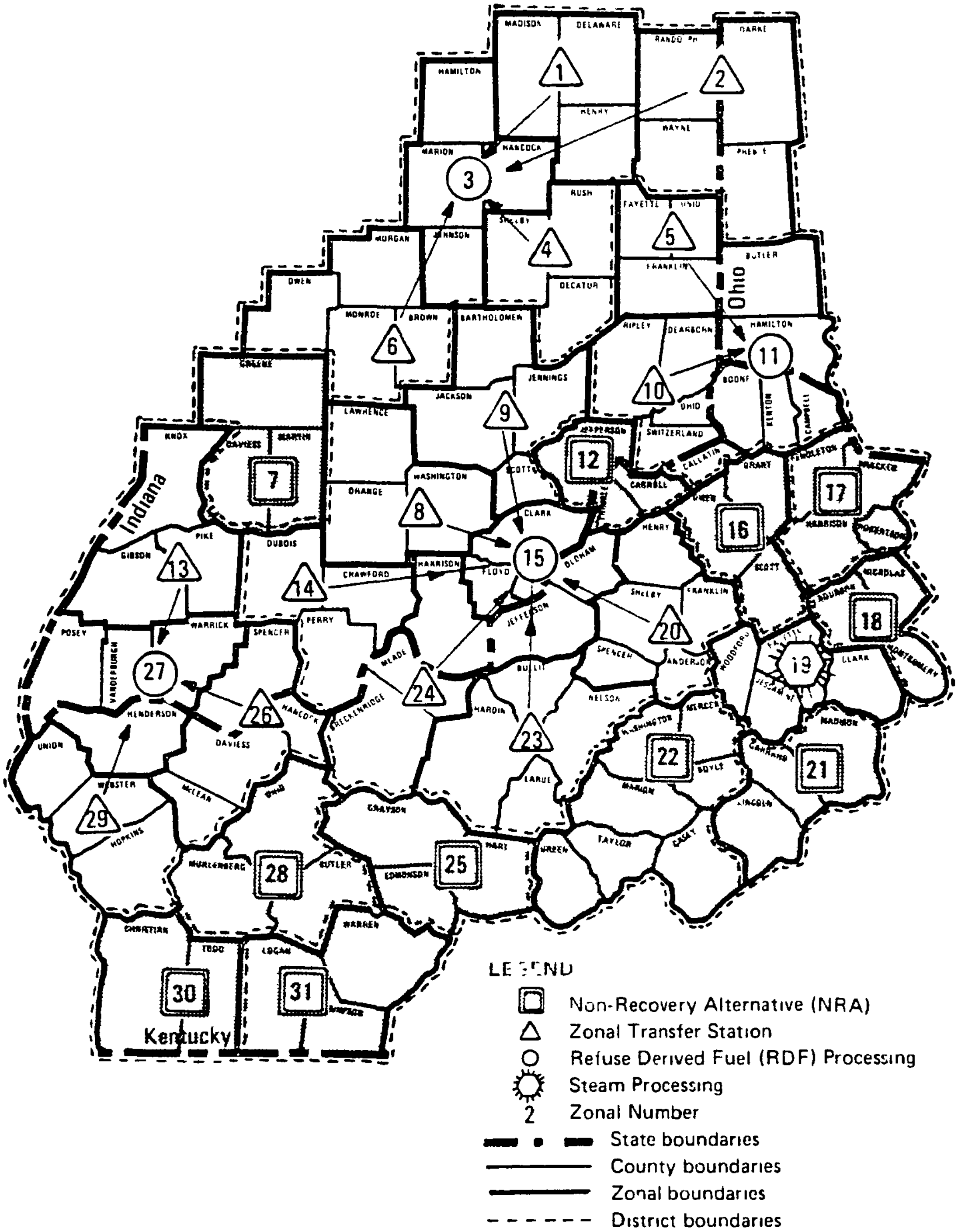
POLICY EVALUATION RUNS IN INOKY
STATISTICAL SUMMARY OF RUNS (ANNUAL FLOWS AND COSTS)
TOTAL FOR REGION: 4,709,400 TONS PER YEAR

	Runs						
	1	2	3	4	5	6	7
System Cost	-$9,636,363	-$17,917,332	-$17,391,648	-$10,960,652	-$7,226,758	-$13,923,315	-$15,959,875
System Cost Per Ton	-$2 05	-$3 80	-$3 69	-$2 33	-$1.53	-$2.96	-$3.39
Tons in Resource Recovery	4,331,200	4,585,800	4,473,600	3,841,000	3,263,100	3,965,300	3,615,400
Percent in Resource Recovery	92 0	97 4	95 0	81 6	69 3	84 2	76.8
Unincinerated Ferrous (Thousand Tons)	290 0	307 9	298 4	255 7	215 3	264.4	238 3
Incinerated Ferrous (Thousand Tons)	13 1	13 1	14 7	13.1	13 1	13.1	14 7
Aluminum (Thousand Tons)	20 7	22 0	21 3	18 3	15 4	18 9	17.0
Glass (Thousand Tons)	487 7	517 6	501.7	430 0	362 0	444 6	400 7
Electric Power	00 0	00 0	00 0	00 0	00 0	00 0	00 0
Steam (Million Pounds)	1,029	1,029	1,155	1,029	1,029	1,029	1,155
Refuse-Derived Fuel (BTU x 10^9)	29,002 4	30,786 0	29,840 3	25,573 1	21,527 1	26,441 8	23,831 4
Cost of Subsidy Per Year (Million Dollars)	NA	8 556	8.376	NA	NA	7 371	9 753
One-Time Cost of Subsidy (Million Dollars)	NA	NA	85.4	NA	NA	NA	99.4
Cost of Subsidy Per Incremental Ton in Resource Recovery (Dollars)	NA	33 58	58.74	NA	NA	10 50	27.70
Cost of Subsidy Per Incremental Ton of Ferrous (Dollars)	NA	479 7	839.1	NA	NA	150.0	395 7

Table V

SOLUTION STRUCTURES OF POLICY EVALUATION RUNS IN INOKY

	Run 1 (Base Case)	Run 2 (Ferrous Subsidy)	Run 3 (Capital Subsidy)	Run 4 (Decreased NRA)	Run 5 (Decreased NRA, Capacity Limit)	Run 6 (Ferrous Subsidy Decreased NRA Capacity Limit)	Run 7 (Capital Subsidy, Decreased NRA, Capacity Limit)
Processing **501 (Anderson)** Annual Tonnage Daily Tonnage Process	(Truck Transfer Station)		420,700 1,348 RDF-Seg. 2	(Truck Transfer Station)	280,100 898 RDF-Seg. 2	Same as Run 3	Same as Run 5
503 (Indianapolis) Annual Tonnage Daily Tonnage Process	1,346,200 4,315 RDF-Seg 3	Same as Base Case	925,500 2,966 RDF-Seg. 2	1,310,400 4,199 RDF-Seg 3	624,000 2,000 RDF-Seg. 2	A 406,300 1,302 RDF-Seg. 2 B 624,000 2,000 RDF-Seg. 2	A 624,000 2,000 RDF-Seg. 2 B 163,500 524 RDF-Seg. 1
511 (Cincinnati) Annual Tonnage Daily Tonnage Process	1,311,600 4,204 RDF-Seg 3	1,331,000 4,266 RDF-Seg 3	Same as Run 2	1,237,300 3,966 RDF-Seg. 3	A 613,300 1,966 RDF-Seg 2 B 624,000 2,000 RDF-Seg. 2	A 624,000 2,000 RDF-Seg. 2 B 624,000 2,000 RDF-Seg. 2	Same as Run 5
515 (Louisville) Annual Tonnage Daily Tonnage Process	1,094,100 3,507 RDF-Seg 3	1,260,400 4,040 RDF-Seg. 3	1,120,300 3,591 RDF-Seg. 3	795,700 2,550 RDF-Seg. 2	624,000 2,000 RDF-Seg 2	Same as Run 5	A 624,000 2,000 RDF-Seg. 2 B 91,600 294 RDF-Seg 1
519 (Lexington) Annual Tonnage Daily Tonnage Process	187,800 602 Inc /Steam-Seg 1	Same as Base Case	210,700 675 Inc./Steam-Seg 1	Same as Base Case	Same as Base Case	Same as Base Case	Same as Run 3
526 (Owensboro) Annual Tonnage Daily Tonnage Process			(Truck Transfer Station Process 901 in all runs)				
527 (Evansville) Annual Tonnage Daily Tonnage Process	391,300 1,254 RDF-Seg. 2	460,400 1,476 RDF-Seg 2	Same as Base Case	309,900 993 RDF-Seg. 2	Same as Run 4	454,400 1,456 RDF-Seg 2	Same as Run 4
531 (Bowling Green) Annual Tonnage Daily Tonnage Process	(Truck Transfer Station)		74,100 238 RDF-Seg. 1		(Truck Transfer Station)		Same as Run 3
NRA Annual Tonnage Daily Tonnage	378,4001 1,213	123,600 396	235,800 756	868,300 2,783	1,446,300 4,636	744,200 2,385	1,094,200 3,507



Structure of the Base Case (Run 1)
Figure 14