ECONOMIC IMPACT OF WATER POLLUTION CONTROL REGULATIONS ON THE TOMATO PROCESSING INDUSTRY

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AGRICULTURAL ECONOMIC REPORT NO. 334
5-76

ECONOMIC RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

ECONOMIC IMPACT OF WATER POLLUTION CONTROL REGULATIONS ON THE TOMATO PROCESSING INDUSTRY. Peter M. Emerson, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 334.

ABSTRACT

The economic impact of the Federal Water Pollution Control Act Amendments of 1972 on the tomato processing industry is examined. The 1972 Act calls for uniform effluent limitations, and requires that municipalities establish pretreatment standards for waste and recover a proportionate share of capital and operating costs from industrial users. Tomato processors generate a highly seasonal, large-volume, biogradable waste load, characterized by substantial variations in volume and composition among processing plants and throughout the processing season. Municipal treatment, spray irrigation, and evaporation-percolation ponds are the preferred means of pollution abatement. Water pollution control regulations are expected to speed the decline of the tomato processing industry in the East and Midwest as many small plants close. In California the number of large-volume plants may increase slightly. Prices of processed tomato products are expected to rise 1.0 to 4.2 percent per year due to pollution control costs.

Key Words: Water pollution, Tomato processing Economic consequences, Waste treatment systems, Plants, Regional production

Washington, D.C. 20250 May 1976

CONTENTS

HIGHLIGHTS

This study evaluates the economic consequences of the Federal Water Pollution Control Act Amendments of 1972 on the processing tomato industry. The 1972 Act calls for strong Federal initiative in developing uniform effluent limitations and issuing discharge permits to control point source water pollution. Also, for the first time, municipalities receiving Federal grants must establish pretreatment standards and recover a proportionate share of capital and operating costs from industrial users.

Groups likely to be adversely affected by the new law include: processing plant owners, plant workers, tomato growers, and others directly dependent on processing plants; local communities in which plants are forced to close; and consumers of processed tomato products. The difficult task of measuring the value of water quality is beyond the scope of this study.

Once nature s waste-assimilative capacity is surpassed, Government intervention is called for because the free market will not protect the community's rights to water quality. Without environmental regulations, polluters may discharge waste water without regard to water users or degradation of the receiving water. Environmental regulations force the polluting firm to evaluate alternative strategies such as investing in private waste treatment facilities, using municipal treatment, or closing the plant.

Ability to invest in a private treatment facility is biased in favor of large plants. Many small plants will be forced to close. Plant closings will especially affect regions with few alternative employment opportunities. Increased processing costs will doubtless raise final product prices, reduce domestic product consumption, and increase competition from foreign producers.

Tomato processing produces a large volume of biodegradable waste. Because of a short processing season--about 8 weeks in the East and Midwest, and 16 weeks in California--the waste load is highly seasonal. Also, there is great variation in the volume and composition of waste water among plants and during the processing season, due in part to the method of tomato harvesting, condition and variety of the raw input, in-plant production processes, final product mix, plant capacity and age, and cleanup procedures.

Municipal treatment, spray irrigation, and evaporation-percolation ponds are used to dispose of 85 percent or more of the industry's waste water. Municipal sewage rates vary widely and rates for processors are expected to increase significantly because of the federally required capital cost repayment. Spray irrigation and evaporation- percolation ponds permit disposal at a relatively low cost for rural plants with access to adequate land. The success of these systems depends on a suitable climate, soil type, slope of land, cover crop, and careful management to avoid contaminating nearby water. Secondary waste treatment systems, such as aerated lagoons and activated sludge, require a large capital investment and represent a feasible alternative only in the case of large, relatively profitable plants.

The three major producing regions included in this study account for 98 percent of the U.S. processing tomato crop. In the East and Midwest, tomato production is usually part of a diversified farm operation. In California, farms average about 110 acres, and specialization lowers production costs. The East and Midwest have numerous relatively small processing plants and a short season. This contrasts sharply with the large, multiproduct plants in California.

Water pollution control regulations are expected to speed the shift of the tomato processing industry away from the East and Midwest. Assuming the Environmental Protection Agency ultimately requires 98 percent effluent cleanup, the number of plants is projected to decline from 180 in 1974 to about 60-70 by 1983. Industry capital costs will increase an estimated $27.6 to $35.4 million and annual operating costs, $4.6 to $6.2 million. Pollution control costs are expected to increase processed tomato prices from 1.0 to 4.2 percent per year. However, per capita consumption will probably fall less than 0.5 percent.

By 1983, it is projected that eastern production will be insignificant, and midwestern and California growers will account for about 12 percent and 86 percent of the U.S. crop, respectively. Rapid adoption of cost-reducing technologies such as direct seeding, mechanical harvesting, and bulk storage processing in the East and Midwest, or a significant increase in final product demand, could alter the projected trends.

By 1983, plant closings in the East and Midwest are expected to result in an annual loss to local communities of $60 to $65 million, including a loss of 8,120 jobs during the processing season and 1,100 during the rest of the year. Alternative employment opportunities are likely to be most favorable in metropolitan areas, where about 50 percent of the plants are located. Also, the largest firms will probably increase their share of the market. Reduced competition may raise final product prices for consumers and lower the prices paid to tomato growers.

ECONOMIC IMPACT OF WATER POLLUTION CONTROL REGULATIONS ON THE TOMATO PROCESSING INDUSTRY

by

Peter M. Emerson 1/

The Federal Water Pollution Control Act Amendments (FWPCA), enacted in 1972, call for strong Federal initiative in formulating water pollution control regulations to help protect the environment. Ultimate goal is to achieve a water quality level by 1983 that will make water throughout the Nation safe for swimming and fishing.

The Environmental Protection Agency (EPA) is charged with developing a comprehensive national program to eliminate water pollution. Abatement of point source pollution 2/ is to be achieved through effluent limitations and the use of industrial discharge permits, thereby placing the burden for improved water quality on firms using waterways for waste disposal. Responsibility for operating and monitoring the program rests with State and local governments, subject to Federal overview.

Food processors and other firms using municipal waste facilities will be required to satisfy pretreatment standards and pay their share of municipal waste treatment costs, including repayment of Federal grants for construction of facilities.

The tomato processing industry was selected for study because of its economic importance and heavy waste load. In 1973, the processing tomato crop accounted for about 40 percent of the total farm value of the 10 principal vegetable crops grown in the United States. Processing plants generated about 10 billion gallons of waste water and 445,000 tons of solid waste that year.

An important question is whether society wants to pay the cost for improved water quality. This study evaluates the costs of water pollution control regulations to the tomato

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2/ The discharge of any substance from an identifiable source that impairs water quality so that alternative uses are adversely affected.

processing industry. Specific economic impacts include: a number of plant closings, regional shifts in production, increase in final product prices, decline in local economic activity, and change in industry structure and performance. A basic premise of this study is that interdependencies between technical, environmental, and economic factors at the plant and industry level must be explicitly recognized.

This study does not consider the value of water quality or government costs of administering the environmental program.

OVERVIEW OF THE PROCESSING TOMATO INDUSTRY

The introduction of environmental regulations may alter the processing sector's demand for resources and/or the supply of final products, resulting in price-quantity adjustments that will be transmitted backward to farmers and other suppliers and forward to consumers. Economic characteristics of the tomato processing industry were studied to gain insight into the impact of forthcoming water pollution control regulations on that industry.

This section briefly reviews recent trends in farm production of processing tomatoes, the processing sector, and final product consumption. Historical adjustments in acreage and yield were analyzed for the study and used to project raw tomato production by major producing region. The number, volume, and geographical location of tomato processing plants were determined, and the direct economic contribution of a processing plant to the community in which it operates were estimated. Recent trends in per capita consumption of processed tomato products and foreign trade provided a basis for estimating future utilization.

A recent publication by King, Jesse, and French (13, pp. 1-128) 3/ provided in-depth discussions of industry structure, important historical trends, and an economic outlook for the industry.

Trends in Farm Production

Acreages of processing tomatoes planted and harvested peaked in the mid-1940's and have since declined more than 200,000 acres (table 1). Planted acreage averaged about 270,000 acres in 1971-73; an average of 9,000 acres were unharvested yearly. The steady upward trend in yield per acre (see table 1) reflects development of new varieties, improved

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3/ Underscored numbers in parenthesis refer to Reference List at end of report.

crop husbandry, and the increased importance of specialized production regions. Annual production peaked in 1968; sharp decline followed in 1969, but there have been modest increases yearly since then. Season average prices have fluctuated but show a general upward trend. In 1973, the season average price reached $42.00 per ton and farm receipts totaled about $248 million (table 1).

Table 1 --Acreage, yield, production, and prices of tomatoes for processing, 1930-73

Year	Acreage planted	Acreage harvested	Yield per acre	Production	Season price per ton
	1,000 acres	1,000 acres	Tons	1,000 tons	Dollars/ ton
1930-34	344.33	326.68	3.92	1,288.04	12.07
1935-39	449.90	419.87	4.52	1,875.82	12.40
1940-44	519.35	497.85	5.45	2,697.88	20.05
1945-49	475.34	457.54	6.49	2,900.56	27.75
1950-54	346.57	339.23	9.70	3,283.10	27.48
1955	335.60	330.50	9.90	3,278.32	24.90
1956	359.00	354.48	13.10	4,638.01	25.70
1957	312.67	304.32	10.90	3,314.13	25.20
1958	357.50	343.65	12.50	4,281.19	25.40
1959	300.33	296.93	11.90	3,539.03	24.46
1960	282.90	279.95	14.50	4,053.77	26.12
1961	307.45	304.55	14.00	4,257.90	29.65
1962	330.10	327.90	16.40	5,393.90	28.42
1963	252.57	250.46	16.40	4,099.69	26.74
1964	276.11	273.35	16.80	4,583.31	30.72
1965	260.99	257.36	17.50	4,501.14	37.16
1966	306.05	300.13	15.50	4,660.57	35.69
1967	333.43	327.56	15.80	5,187.45	42.80
1968	373.76	370.15	18.80	6,965.86	40.20
1969	272.35	266.94	18.35	4,897.70	34.70
1970	249.05	245.54	20.60	5,058.95	34.00
1971	256.86	251.73	21.65	5,514.96	35.50
1972	272.51	261.42	22.20	5,803.52	35.20
1973	302.34	292.30	20.30	5,933.69	42.00

Source: (29).

Production of tomatoes for processing is heavily concentrated in three regions: East (New York, New Jersey, Pennsylvania, Delaware, Maryland, and Virginia), Midwest (Ohio, Indiana, Illinois, and Michigan), and West (California). These three regions accounted for 98.5 percent of the U.S. tomato crop for processing in 1973 (tables 2,3,4).

Production in the East is mainly in southern New Jersey and the Delmarva Peninsula, in the bordering counties of southern Pennsylvania and northern Maryland, and along the shores of Lake Erie and Lake Ontario. Midwestern production takes place in northwestern Ohio, east-central Indiana, and scattered areas in southern Michigan and Illinois. About 85 percent of California's production comes from the Sacramento and San Joaquin Valleys. Unlike other producing regions, California has experienced steady expansion and today dominates the U.S. processing tomato industry.

Since 1940-44, acreages planted and harvested have declined more than 150,000 acres in the East and 80,000 acres in the Midwest. California acreage has shown a general trend upward, reaching a peak in 1968. Farm size has increased in all three regions as grower numbers declined. Between 1939 and 1969, average farm size increased from 3.4 to 10.6 acres in the East, from 3.3 to 15.5 acres in the Midwest, and from 14.4 to 111.3 acres in California (13, p.18). Differences in farm size reflect the fact that California producers are generally specialized tomato growers, while eastern and midwestern producers are more likely to include tomato production as part of diversified farm operation. Specialization in California has been accelerated by new technologies, such as direct seeding and mechanical harvesting. Producers in the East and Midwest continue to use the less efficient methods of transplanting and hand harvesting (26, p.289).

Yields of tomatoes to be processed vary considerably among the producing regions (note 1973 data in tables 2,3,4). Over the past 13 years, yields have remained nearly stable in the East, but have increased about 3 to 5 tons per acre in the Midwest and California. In the East and Midwest, rainy weather often slows the harvest and reduces yields. California producers, on the other hand, enjoy a comparative advantage because their crop is grown almost entirely on irrigated ground, and rainfall at harvest is generally nil.

The East is the only major producing region to show an absolute decline in production, although the relative position of the Midwest has also declined. In 1973, California produced 81.9 percent of total U.S. processing tomatoes (table 4). Regional shares of total production emphasize the steady growth and dominant position of California.

Table 2 --Acreage, yield, production, and prices of tomatoes for processing, and percentage of total U. S. production, eastern region 1/

Year	Acreage planted	Acreage harvested	Yield per acre	Production	Price per ton	Percent of total U.S. production
	1,000 acres	1,000 acres	Tons	1,000 tons	Dollars/ ton	Percent
1930-34	129.66	128.64	3.91	500.73	14.14	38.9
1935-39	162.86	157.68	4.63	723.50	13.50	38.6
1940-44	184.82	180.22	5.44	976.25	22.44	36.2
1945-49	163.18	155.64	5.39	805.38	32.47	27.8
1950-54	112.90	110.66	7.75	859.88	32.75	26.2
1955	96.20	93.50	4.82	451.06	31.97	13.8
1956	92.90	90.70	9.02	818.19	34.08	17.6
1957	76.40	74.80	7.01	524.15	34.92	15.8
1958	78.00	76.50	10.08	770.75	32.16	18.0
1959	64.80	63.90	8.81	562.65	30.87	15.9
1960	58.70	57.60	12.22	704.11	31.86	17.4
1961	61.00	60.60	13.14	796.23	32.13	18.7
1962	60.90	60.40	14.36	867.47	31.58	16.1
1963	48.80	48.50	12.19	591.23	31.75	14.4
1964	51.50	51.10	12.26	626.72	31.42	13.7
1965	54.60	54.10	14.38	777.90	33.56	17.3
1966	59.30	58.40	10.45	610.34	37.94	13.1
1967	56.40	55.40	12.94	716.74	42.35	13.8
1968	53.70	52.50	14.57	764.72	38.77	11.0
1969	42.00	40.90	12.98	530.87	39.00	10.8
1970	37.20	36.50	16.17	590.21	40.55	11.7
1971	35.20	34.60	12.97	448.76	42.08	8.1
1972	33.91	31.25	11.10	346.88	44.17	6.0
1973	33.30	30.30	12.72	385.42	48.42	6.5

1/ Includes New York, New Jersey, Pennsylvania, Delaware, Maryland and Virginia.

Source: (29)

Table 3 --Acreage, yield, production, and prices of tomatoes for processing, and percentage of total U. S. production, midwestern region 1/, 1930-73

Year	Acreage planted	Acreage harvested	Yield per acre	Production	Price per ton	Percent of total U.S. production
	1,000 acres	1,000 acres	Tons	1,000 tons	Dollars/ ton	Percent
1930-34	91.75	87.78	4.25	373.59	10.09	29.0
1935-39	124.00	118.53	4.63	542.22	11.29	28.9
1940-44	124.22	119.10	5.39	646.03	17.98	23.9
1945-49	117.56	113.84	6.06	683.28	25.12	23.6
1950-54	80.24	78.42	8.36	641.75	28.12	19.6
1955	62.60	61.30	9.46	579.83	27.54	17.7
1956	70.60	69.30	11.33	785.27	27.88	16.9
1957	69.20	64.90	8.59	557.64	28.17	16.8
1958	75.50	69.30	9.66	669.50	28.36	15.6
1959	66.60	65.30	11.64	759.99	26.93	21.5
1960	64.90	64.00	13.87	887.92	28.35	21.9
1961	65.30	64.10	13.87	889.29	27.56	20.9
1962	63.50	62.90	16.63	1,046.13	28.87	19.4
1963	48.60	48.10	17.09	822.22	27.53	20.1
1964	52.50	51.40	14.42	741.22	28.98	16.2
1965	59.00	58.00	18.64	1,081.21	30.61	24.0
1966	58.10	56.10	12.80	718.19	33.12	15.4
1967	61.00	60.10	17.31	1,040.15	38.00	20.1
1968	63.90	62.80	17.40	1,092.94	36.77	15.7
1969	56.70	54.20	15.47	838.45	37.19	17.1
1970	50.00	49.30	19.63	967.76	38.12	19.1
1971	48.10	47.80	20.77	992.81	38.26	18.0
1972	46.60	45.20	17.52	791.90	38.08	13.6
1973	39.40	37.90	15.81	599.20	38.25	10.1

1/ Includes Ohio, Indiana, Illinois, and Michigan.

Source: (29).

Table 4 --Acreage, yield, production, and prices of tomatoes for processing, and percentage of total U.S. production, western region 1/, 1930-73

Year	Acreage planted	Acreage harvested	Yield per acre	Production	Price per ton	Percent of total U.S. production
	1,000 acres	1,000 acres	Tons	1,000 tons	Dollars/ ton	Percent
1930-34	39.22	39.22	4.98	202.56	12.45	15.7
1935-39	67.65	67.65	5.64	376.34	12.70	20.1
1940-44	106.28	106.28	7.26	761.30	19.64	28.2
1945-49	112.24	112.24	10.32	1,128.86	26.52	38.9
1950-54	99.84	99.84	15.52	1,548.22	24.50	47.2
1955	116.30	116.30	17.10	1,988.70	22.80	60.7
1956	151.50	151.50	18.30	2,772.40	22.70	59.8
1957	129.60	128.70	15.70	2,020.60	21.90	61.0
1958	152.90	152.90	17.20	2,629.90	22.70	61.4
1959	129.70	129.70	15.40	1,997.40	21.80	56.4
1960	130.00	130.00	17.30	2,249.00	23.40	55.5
1961	146.80	146.80	15.80	2,319.00	30.10	54.5
1962	177.20	177.20	18.20	3,218.00	27.60	59.7
1963	129.00	129.00	19.10	2,463.90	25.40	60.1
1964	143.00	143.00	21.00	3,003.00	31.30	65.5
1965	122.80	122.80	20.10	2,468.30	41.60	54.8
1966	162.50	162.50	19.30	3,136.20	36.10	67.3
1967	186.70	186.70	17.10	3,192.60	44.90	61.5
1968	231.30	231.30	21.20	4,903.60	41.40	70.4
1969	154.00	154.00	21.90	3,372.60	33.50	68.9
1970	141.30	141.30	23.80	3,362.94	31.60	66.5
1971	163.70	163.70	23.70	3,879.69	34.00	70.5
1972	183.40	178.90	25.30	4,526.17	34.00	78.0
1973	224.40	218.00	22.30	4,861.40	41.10	81.9

1/ Consists of California.

Source: (29)

Season average prices are generally highest in the East and lowest in the West. Regional farm price differentials in 1969-72 averaged $3.54 per ton between the East and Midwest and $8.18 per ton between the East and West. Season average prices in California declined $13.30 per ton from 1967 to 1970, but exceeded the average Midwest farm price by $2.85 per ton in 1973. Eastern and midwestern producers benefit from proximity to major consuming centers, but their production costs are relatively high. A recent study reports a farm cost of $32.80 per ton for producing processing tomatoes in Michigan and $29.47 in Ohio, compared with $27.95 in California (13, p.99).

Although very little information is available, data published by the California Agricultural Extension Service reveal that direct seeding reduces preharvest costs about $10.30 per acre, and use of mechanical rather than hand harvesting reduces harvest costs $5.43 per ton per acre (13, pp.104-5). Although the above data apply only to California, they substantiate the argument that the future of the eastern and midwestern producing regions largely depends on increasing yields and adopting cost-reducing technologies (26, pp.479-80). As labor costs increase and the gap between eastern, midwestern, and California yields widens, the locational advantage of the East and Midwest steadily diminishes.

To supplement our knowledge of regional production trends, the data in tables 2, 3, and 4 were used to estimate nine regression equations explaining acreage planted, acreage harvested, and yield per acre. Table 5 gives the results. The equations are linear in the observations, and estimation is by the method of least squares. The data serve as input in projecting raw tomato production, which is used to calculate regional waste loads and costs of pollution abatement.

Acreage planted is expressed in terms of lagged season average price and time trend. A priori, a positive relationship is expected between acreage planted and lagged price. The time trend variable was used to allow for the impact of technological and institutional changes that influence producers' decisions to allocate acreage to processing tomatoes. The development and adoption of irrigation facilities, new varieties, direct seeding, and mechanical harvesting suggest that the trend coefficient will be larger in California than in the East or Midwest.

The coefficients of the acreage planted equations (table 5) appear logically consistent. Given a small change in lagged season average price, the response in acreage planted in the East exceeds the response in the Midwest and West. For example, 1-percent increase in lagged price causes acreage planted to increase 0.50 percent in the East, but only 0.31

Table 5 --Regression analysis of acreage planted, acreage harvested, and yield, by major producing regions, 1930-73

Region and dependent variables	Unit	Independent variables: Intercept	Price t-1 1/	Trend 1/	Acreage planted 1/	"Corrected" R^2	Durhan-Watson statistic
		Dollars/ton					
East							
Acreage planted . .	1,000 acres	163.301	1.938 (0.990)	-4.824 (0.763)		69.8	2/0.284
Acreage harvested.	1,000 acres	1.537			0.961 (0.006)	99.8	1.279
Yield	Tons/acre	2.040		0.267 (0.020)		81.5	1.262
Midwest							
Acreage planted . .	1,000 acres	121.756	3/0.434 (0.857)	-2.163 (0.630)		60.8	2/0.404
Acreage harvested.	1,000 acres	1.914			0.944 (0.009)	99.6	1.483
Yield	Tons/acre	0.930		0.381 (0.024)		86.0	1.171
West							
Acreage planted . .	1,000 acres	28.092	1.524 (0.828)	2.351 (0.599)		73.3	1.266
Acreage harvested.	1,000 acres	0.853			0.990 (0.003)	99.9	2/0.541
Yield	Tons/acre	2.310		0.489 (0.020)		93.7	2/0.904

1/ Figures in parentheses are standard errors. For price, regional averages lagged 1 year. For trend, 1930=1, 1931=2, ...

2/ Indicates positive serial correlation.

3/ Statistically insignificant at the 10-percent level.

percent in the West.4/ The price coefficients for California and the Midwest probably reflect the influence of increasing specialization in production and contracting which tends to reduce year-to-year fluctuation in acreage planted. The trend variable coefficient is positive in California and negative in the East and Midwest. Acreage planted is expanding at an annual rate of 2,350 acres in California, and is contracting at annual rates of 4,825 acres in the East and 2,165 acres in the Midwest. This trend suggests that recent technology and industry expansion has been biased in favor of acreage planted in California at the expense of the other producing regions.

The acreage planted equations for the East and Midwest are characterized by excessive serial correlation. Since the model used in the study is naive and some important explanatory variables are obviously omitted, this outcome is not surprising. Unfortunately, initial attempts to take serial correlation into consideration have not met with success. Acreage planted projections for the East and Midwest may be inefficient, since ordinary least squares estimators do not have minimal sampling variance in the presence of serial correlation.

Acreage harvested and yield are influenced by several variables. The most important include acreage planted, weather, cropping practices, development of new varieties, and timing and method of harvest. Acreage harvested in each producing region is expressed as a function of acreage planted. In the West, acreage harvested usually equals acreage planted. In the East and Midwest, unexplained variations in acreage harvested are probably due to bad weather at harvest time or the decision of processors not to accept delivery, or both.

Yield is expressed in terms of a time trend variable, because of the difficulty of obtaining time series data for the actual explanatory variables. The trend variable reflects the impact of improvements in plant breeding and cropping methods, as well as the influence of weather. The coefficients suggest that technological change has increased per acre yields at annual rates of 0.489 ton in California, 0.381 ton in the Midwest, and 0.267 ton in the East.

Important Characteristics of the Processing Sector

Since raw tomatoes are highly perishable and costly to

4/ The lagged price coefficient in the Midwest equation is statistically insignificant. Possibly, this is a result of a high degree of multicollinearity (93.1 percent) between lagged price and time trend.

transport, processing plants tend to locate near sources of production. Data in tables 6, 7, and 8 indicate general trends in the processing sector in recent years.

In 1974, tomatoes were processed by 124 firms operating 180 plants in the major producing regions. 5/ The average number of plants per firm was 1.2 in the East, 1.5 in the Midwest, and 2.0 in the West. However, a firm with headquarters in one region, say the West, may have processing plants in the Midwest and East. The total number of firms declined 30 percent between 1970 and 1974, and the number of processing plants declined 20 percent. The greatest changes were in the East where 26 firms and 32 plants disappeared. A decrease of 18 firms in the Midwest reflects a consolidation in the region and/or a trend toward the acquisition of midwestern firms (and their processing plants) by firms elsewhere. The number of processing plants in the Midwest remained about constant. In the West, firm numbers declined by 9 and plant numbers by 11.

The East and Midwest regions are characterized by a large number of relatively small firms. About 75 percent are classified in this report as volume code B or smaller. 6/ The decline in firms and processing plants in these regions has been mainly among the smallest firms. However, several of the largest firms in the Midwest may have discontinued tomato processing since 1972. In California, most firms are classified in volume code A or larger.

Most of the firms produce at least two tomato products (tables 6, 7, 8). Processors in the East emphasize whole pack tomatoes; a few firms also produce tomato juice, catsup, and puree. In the Midwest, whole pack tomatoes and juice are typically produced in combination, followed in importance by catsup and puree. In 1972, only 6 percent of the eastern plants and 15 percent of the midwestern plants packed more than three tomato products (13, p.7). On the other hand, more than 70 percent of the California plants packed four or more products, with emphasis on whole pack tomatoes and highly concentrated products such as paste and sauce. A recent study of interregional relationships in the processing tomato

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5/ Also, 41 firms operated 44 tomato processing plants outside the producing regions considered (see app. 1). The excluded firms and their plants, located primarily in southeastern and south-central States, account for less than 2 percent of the U.S. processed tomato pack. For most of these firms, processing tomatoes is a minor activity.

6/ The volume codes used in tables 6, 7, and 8 include the complete pack of a firm and are not restricted to tomato products only.

Table 6 --Tomato processing firms, plant numbers, volume, and product forms, by State, 1970.

Region and State	Firms	Plants	Volume code by firm 1/							Product forms by firm		
			D	C	B	A	AA	AAA	AAAA	Tomatoes for canning 2/	Tomato juice	Other tomato products 3/
	Number											
East												
New York	14	17	0	3	3	2	0	1	5	6	8	7
New Jersey	12	16	1	4	3	0	0	0	1	3	2	11
Pennsylvania	12	19	3	3	1	1	2	1	2	7	6	8
Maryland	31	35	19	6	3	1	0	0	1	1	0	9
Virginia	13	13	9	0	0	1	0	0	0	12	2	2
Delaware	4	4	0	0	0	0	1	0	0	4	0	0
Subtotal	86	104	32	16	10	5	3	2	9	56	18	37
Midwest												
Ohio	27	23	6	6	8	1	0	0	5	20	12	9
Indiana	20	30	5	3	3	1	1	1	5	15	11	11
Michigan	9	8	4	1	0	2	0	0	2	5	3	3
Illinois	4	6	1	0	1	0	0	1	1	3	2	2
Subtotal	60	67	16	10	12	4	1	2	13	43	28	25
West												
California	31	55	0	4	2	4	3	5	9	20	15	27
Total	177	226	48	30	24	13	7	9	31	119	61	89

1/ Volume codes are not reported for all firms. Codes are listed in terms of cases packed per firm. The following scale is used: D -- under 100,000 C--100,000 to 250,000; B--250,000 to 500,000; A--500,000 to 1,000,000; AA--1,000,000 to 2,000,000; AAA--2,000,000 to 5,000,000 AAAA--over 5,000,000.

2/ Whole, Italian, and stewed tomatoes.

3/ Catsup, sauce, chili sauce, paste, puree, miscellaneous.

Source: (12, 1970-71, pp. 1-246).

Table 7 --Tomato processing firms, plant numbers, volume, and product forms, by State, 1972

Region and State	Firms	Plants	Volume code by firm 1/							Product forms by firms		
			D	C	B	A	AA	AAA	AAAA	Tomatoes for canning 2/	Tomato juice	Other tomato products 3/
	Number											
East												
New York	10	11	1	2	1	1	0	0	4	4	8	5
New Jersey	15	15	1	3	1	2	0	2	4	2	4	14
Pennsylvania	17	17	4	2	1	2	2	0	5	7	6	10
Maryland	23	27	11	7	2	1	2	0	0	22	3	6
Virginia	13	13	8	0	1	1	1	0	0	12	2	2
Delaware	2	2	0	0	0	1	0	0	0	2	1	1
Subtotal	80	85	25	14	6	8	5	2	13	49	24	38
Midwest												
Ohio	24	27	6	5	4	2	0	0	5	18	12	11
Indiana	21	31	6	3	2	1	1	1	5	14	13	12
Michigan	7	7	2	1	0	2	0	0	2	3	4	4
Illinois	5	5	1	0	2	1	0	1	0	4	1	4
Subtotal	57	70	15	9	8	6	1	2	12	39	30	31
West												
California	28	51	0	1	0	4	2	5	11	21	14	27
Total	165	206	40	24	14	18	8	9	36	109	68	96

1/ Volume codes are not reported for all firms. Codes are listed in terms of cases packed per firm. The following scale is used: D--under 100,000; C--100,000 to 250,000; B--250,000 to 500,000; A--500,000 to 1,000,000; AA--1,000,000 to 2,000,000; AAA--2,000,000 to 5,000,000; AAAA--over 5,000,000.

2/ Whole, Italian, and stewed tomatoes.

3/ Catsup, sauce, chili sauce, paste, puree, miscellaneous.

Source: (12, 1972-73, pp. 1-250).

Table 8 --Tomato processing firms, plant numbers, volume and product forms, by State, 1974

Region and State	Firms	Plants	Volume code by firm 1/ D	C	B	A	AA	AAA	AAAA	Product forms by firms: Tomatoes for canning 2/	Tomato juice	Other tomato products 3/
							Number					
East												
New York . . .	9	11	1	0	2	1	1	1	3	3	3	6
New Jersey . .	8	8	1	2	2	0	0	1	1	2	2	8
Pennsylvania .	11	19	2	3	0	1	2	0	3	6	4	8
Maryland . . .	21	23	12	5	1	0	2	0	0	18	2	6
Virginia	11	11	8	0	1	0	1	0	0	10	1	2
Delaware	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	60	72	24	10	6	2	6	2	7	39	12	30
Midwest												
Ohio	15	16	5	2	6	1	0	0	0	14	7	7
Indiana	16	28	5	5	0	3	0	0	2	15	9	8
Michigan	5	8	2	1	1	1	0	0	0	4	0	4
Illinois	6	12	0	0	1	1	1	1	2	3	3	6
Subtotal . . .	42	64	12	8	8	6	1	1	4	36	19	25
West												
California . . .	22	44	0	1	0	3	2	6	8	17	9	22
Total	124	180	36	19	14	11	9	9	19	92	40	77

1/ Volume codes are not reported for all firms. Codes are listed in terms of cases packed per firm. The following scale is used: D--under 100,000; C--100,000 to 250,000; B--250,000 to 500,000; A--500,000 to 1,000,000; AA--1,000,000 to 2,000,000; AAA--2,000,000 to 5,000,000; AAAA--over 5,000,000.

2/ Whole, Italian, and stewed tomatoes.

3/ Catsup, sauce, chili sauce, paste, puree, miscellaneous.

Source: (12, 1974-75, pp. 1-263).

industry argues that the competitive position of the East and Midwest can be improved in whole pack tomatoes, juice, and catsup if cost-reducing technologies are introduced in growing and harvesting (that is, direct seeding, mechanical harvesting, and bulk handling) and if bulk storage processing is implemented (25, p.296). However, the authors conclude that in the industry's current economic environment, the long-run trend in favor of California production is likely to continue.

In 1974, 46 percent of eastern plants and 59 percent of midwestern plants processed only tomatoes, compared with 13 percent of California plants. Other canned vegetables, fruits, berries, and juices are frequent joint products. Tomatoes and peaches are a common combination in California. Output of additional products tends to benefit the processor by lengthening the relatively short processing season.

Most tomato processing plants are located near large cities. In 1972, 51 percent of the plants were in metropolitan fringe areas.7/ These areas are heavily populated, averaging 172 persons per square mile, and are economically dependent on adjoining major cities. Per capita income levels about equal the U.S. average. About 16 percent of the processing plants are in densely settled rural areas. Economic activity in these areas centers around smaller towns rather than major cities. Densely settled rural areas tend to have a disproportionately large share of low-income families. In 1960, 37 percent of the families in such areas had annual incomes below $3,000, compared with only 19 percent in metropolitan fringe areas. Alternative employment opportunities are usually better in metropolitan areas than in rural communities. A regional comparison indicates that midwestern and eastern processing plants are highly concentrated in metropolitan fringe areas, followed by densely settled rural areas. A few eastern plants are located in major metropolitan areas. California plants, on the other hand, are more evenly distributed among various size communities.

Tomato processors employed about 51,000 workers during the 1972-73 processing season and 15,500 workers during the rest of the year (table 9). About 70 percent of the work force was in California. Seasonal employees are drawn from local and migratory labor markets. Regional differences in the number of workers per 1,000 tons of raw tomatoes processed reflect variations in plant size and technology.

7/ "Economic regions," defined by Rand McNally and Co., are used to identify the general economic characteristics of communities in which processing plants are located (4, pp. 8-10).

Table 9 --Estimated numbers of workers employed in tomato processing, major producing regions, 1972-73

Producing region	Workers per 1,000 tons of raw tomatoes		Total work force	
	Processing season	Rest of year	Processing season	Rest of year
	Number			
East.........	21.4	1.3	7,426	451
Midwest......	11.0	6.9	8,712	5,465
West.........	7.7	2.1	34,850	9,565
Total........			50,988	15,481

Source: (20).

The economic importance of a food processing plant to the local community relates not only to the jobs it provides but to other factors as well. Estimates of processing plant expenditures in 1972-73 were: 8/

Expenditure	Dollars per ton of raw commodity
Wages and salaries	24.60
Raw commodity	37.00
Ingredients	19.35
Containers	46.35
Power and fuel	2.10
Local taxes and services	10.02

Based on the above data and table 9, we conclude that a

8/ These estimates were calculated using data supplied to the National Canners Association by fruit and vegetable processing plants.

medium size, midwestern processing plant (that is, a processor using about 10,000 tons of raw tomatoes per season) employs 120 workers during the processing season and 69 workers the rest of the year and pays annual wages and salaries of $246,000. About 40 to 50 midwestern growers depend on the processing plant for a market, and derive annual receipts of $370,000. Also, the processing plant purchases other factors of production--other ingredients, containers, and power--costing $679,000, and pays local taxes and purchases other local services amounting to $100,000. Therefore, the direct economic contribution of a medium size midwestern tomato processing plant is about $1.4 million per year. In terms of the community s total economic activity, the plant may be responsible for 4 or 5 times its direct contribution, taking into consideration the second-round effects of spending by resource owners who derive income from the plant.

Although many firms process tomatoes, relatively few firms process the bulk of the crop. In a competitive environment, one would expect to find many firms and a relatively low degree of concentration.

Table 10 shows the value of shipments and the percentage of sales of four food product classes by the largest U.S. companies. Processed tomatoes are included in each product class. The market is more concentrated in catsup and other tomato sauces and in canned vegetable juices than in canned fruit and vegetables or in canned vegetables. The data for canned vegetable juices and canned vegetables are assumed to be reasonable proxies for tomato juice and whole pack tomatoes. If so, the data are consistent with the observation that a relatively large number of small firms, primarily in the East and Midwest, process whole pack tomatoes and juice.

Canners may also exercise market power in procurring the raw product. Current institutional arrangements include production contracts and backward integration. The estimated percentage of processing vegetables grown under production contracts was 67 percent in 1960 and 85 percent in 1970; the percentage of processing vegetables grown under backward integration was 8 percent in 1960 and 10 percent in 1970 (17, pp.4-5). Production contracts appear to be considerably more important than backward integration in the canning industry.

Nearly all processing tomatoes are grown under contract with processors. Minor exceptions include tomatoes grown for fresh markets and subsequently sold to canners because of low fresh-market prices. Contract provisions generally govern planting and harvesting periods, variety specifications, grading procedures, tonnage restrictions, and maximum allowable damage to the product at delivery. Contract price is usually set by a recognized price leader. Processors provide supervision during planting and harvesting to

Table 10 --Total value of shipments and concentration ratios, selected products, 1958, 1963, 1967

Product class	Year	Value of shipments			
		Total	Share accounted for by --		
			4 largest companies	8 largest companies	20 largest companies
		Million dollars	Percent		
Canned fruits and vegetables	1967	3,222.3	23	35	52
	1963	2,585.8	24	35	49
	1958	2,191.5	1/	1/	1/
Canned vegetables.	1967	957.5	38	46	61
	1963	767.7	34	41	55
	1958	638.6	2/	2/	2/
Canned vegetable juices	1967	104.2	62	72	88
	1963	91.1	55	69	86
	1958	93.3	58	69	84
	1954	64.5	58	69	81
Catsup and other tomato sauces 3/	1967	507.7	55	68	86
	1963	297.9	49	63	80
	1958	245.6	55	65	80

1/ Figures prior to 1963 cannot be shown without disclosing the operations of individual companies in Alaska and Hawaii.

2/ Revised concentration ratios are not available.

3/ Includes paste, puree, and sauce.

Source: (30, pp. 5-6).

facilitate plant scheduling.

Trends in Consumption

The utilization of processed tomato products is influenced by their price, and price and availability of substitute and complementary products, consumer incomes and preferences, and population growth. Important substitutes include other canned vegetables, frozen vegetables, and fresh tomatoes. Use of complementary products (primarily, convenience foods) is an important determinant of catsup, tomato sauce, and tomato paste consumption.

Per capita consumption of processed tomato products more than doubled from 1930 to 1972, reaching a peak in 1969 (table 11). Per capita consumption of catsup, paste, and sauce increased from 1.9 pounds annually in 1930-34 to 10.1 pounds in recent years. Consumption of processed whole tomatoes declined slightly, while consumption of tomato juice, pulp, and puree remained stable. Per capita consumption of fresh tomatoes has remained stable over the past 40 years.

Increased away-from-home eating is likely to further strengthen the demand for catsup, chili sauce, and puree. Per capita consumption of tomato paste, an ingredient in prepared dinners, is also expected to rise. A continued decline in tomato juice consumption is likely, due to the availability of frozen concentrated orange juice.

Consumption of fresh fruits and vegetables (excluding tomatoes) has apparently declined, while consumption of canned fruits and vegetables and frozen vegetables has increased (table 12). Such trends reflect the impact of technological change, changing consumer preferences, and rising incomes. For example, rapid growth in the consumption of frozen vegetables is related to the development and widespread use of household refrigeration facilities, consumer preference for a convenient product of uniform quality, and rising consumer purchasing power.

Selected consumer price indices for the years 1953-72 indicate that canned tomato and processed fruit and vegetable prices declined slightly relative to the general consumer price level (table 13). Fresh tomato and fresh fruit and vegetable prices have increased at about the same rate as general consumer prices.

Table 14 shows the results of a brief statistical analysis aimed at measuring the impact of retail prices, per capita disposable income, and consumer preferences on per capita

Table 11 --Per capita consumption of fresh and processed tomatoes and tomato products sold at retail, 1930-72

Year	Fresh tomatoes	Processed tomatoes and tomato produce: Whole tomatoes	Catsup and chili sauce	Paste and sauce	Pulp and puree	Tomato juice 1/	Total
			Pounds				
1930-34	9.7	5.7	1.6	0.3	0.7	0.8	9.2
1935-39	10.1	5.8	1.8	0.6	0.7	2.5	11.3
1940-44	10.3	5.7	2.2	1.3	1.0	3.6	13.8
1945-49	10.9	4.2	2.5	2.6	1.4	5.0	15.7
1950-54	9.8	4.6	2.7	2.8	0.7	5.1	16.0
1955	10.5	4.5	3.0	3.3	0.7	4.8	16.3
1956	9.7	4.6	3.1	3.3	0.9	4.6	16.5
1957	10.1	4.6	3.3	3.2	0.7	5.3	17.1
1958	9.6	4.6	3.5	3.4	0.7	4.7	16.9
1959	10.5	4.6	3.6	3.5	0.7	5.1	17.5
1960	10.5	4.6	3.8	2.8	0.7	4.7	17.6
1961	10.6	4.8	3.9	3.7	0.8	4.6	17.8
1962	10.8	4.6	4.1	3.9	0.8	4.7	18.1
1963	10.2	4.6	4.3	3.9	0.8	5.4	19.0
1964	10.3	4.5	4.6	3.9	0.8	4.5	18.2
1965	10.3	4.5	5.0	3.9	0.8	4.7	18.8
1966	10.5	4.6	4.8	4.2	1.0	4.4	18.9
1967	10.5	4.6	4.7	5.0	1.0	4.2	19.5
1968	10.1	4.9	2/ 9.8	-----	1.1	4.0	19.8
1969	10.2	4.9	10.1	-----	1.0	4.1	20.1
1970	10.4	4.8	10.1	-----	1.0	4.1	20.0
1971	9.7	4.9	9.9	-----	1.0	3.9	19.7
1972	10.3	5.0	10.1	-----	1.0	3.8	19.9

----- = Data not available

1/ Includes about 15 percent combined, and other vegetable juices. 2/ Includes tomato paste and sauce.

Sources: (10) and supplement for 1972.

Table 12 --Per capita consumption of fresh and processed fruits and vegetables (excluding tomatoes) sold at retail, 1930-72

Year	Fresh fruit	Fresh vegetables 1/	Canned fruit	Canned vegetables 1/	Frozen vegetables 1/
	Pounds				
1930-34	133.4	83.1	11.6	13.4	NA
1935-39	135.5	85.6	15.0	15.6	2/0.44
1940-44	134.7	89.4	15.2	19.7	0.93
1945-49	134.4	94.6	18.6	24.3	2.43
1950-54	111.1	84.0	20.7	22.3	4.53
1955	99.4	80.2	22.5	22.9	5.86
1956	98.9	83.7	21.7	23.1	6.04
1957	96.7	83.8	22.3	22.9	6.24
1958	94.0	82.7	22.7	23.5	6.60
1959	95.7	81.2	22.1	23.1	6.81
1960	93.4	85.7	22.6	22.5	7.05
1961	88.6	84.3	23.2	22.9	7.08
1962	83.4	82.9	22.8	23.8	7.69
1963	74.5	83.5	23.0	24.0	7.40
1964	78.7	80.8	23.0	24.3	7.96
1965	81.1	80.8	23.5	25.0	8.46
1966	81.4	78.0	22.9	25.5	8.80
1967	80.9	80.1	22.6	26.3	9.03
1968	78.3	81.1	21.9	27.6	9.58
1969	79.0	81.2	24.0	28.5	9.06
1970	80.8	80.9	22.6	28.0	9.60
1971	79.3	80.3	22.0	28.4	9.68
1972	NA	NA	NA	28.7	9.98

NA = Data not available.

1/ Other than tomatoes.

2/ 1937-39.

Sources: (10) and supplement for 1972.

Table 13 --Selected price indices and disposable personal income, 1939-72

(1967 = 100)

Year	Canned tomatoes	Processed fruits and vegetables	Fresh tomatoes	Fresh fruits and vegetables	Consumer price index
1939	36.8	NA	NA	28.5	41.6
1940-44	47.8	NA	NA	41.2	47.9
1945-49	69.0	NA	NA	60.5	64.6
1950-54	74.9	1/ 84.5	2/ 77.0	70.3	78.0
1955	76.6	88.5	78.2	73.2	80.2
1956	77.5	88.2	83.7	77.5	81.4
1957	77.0	86.3	83.5	78.0	84.3
1958	85.9	92.3	90.7	83.7	86.6
1959	79.6	96.2	83.7	79.7	87.3
1960	81.0	92.9	89.4	84.6	88.7
1961	82.6	96.7	81.9	83.3	89.6
1962	82.1	94.0	84.2	85.5	90.6
1963	81.9	99.2	91.1	90.6	91.7
1964	83.4	101.5	94.0	95.9	92.9
1965	84.4	98.3	97.1	97.1	94.5
1966	90.0	100.6	98.9	99.7	91.2
1967	100.0	100.0	100.0	100.0	100.0
1968	104.5	105.6	114.4	109.4	104.2
1969	100.8	106.5	118.7	111.1	109.8
1970	109.0	109.2	119.2	116.3	116.3
1971	115.6	116.2	131.8	121.0	121.3
1972	116.6	120.5	132.7	128.0	125.3

NA = Data not available

1/ 3-year average.

2/ 2-year average.

Sources: (10) and supplement for 1972

Table 14 --Regression analysis of processed tomato consumption, 1953-72

Equation number	Dependent variables 1/	Independent variables 2/ Intercept	CNTOM	PROFV 3/	PCPDI 4/	"Corrected" R^2	Durbin-Watson statistic
1	TOMPR-C	7.936	-0.025 (0.014)	5/ 0.036 (0.031)	0.004 (0.001)	90.9	1.305
2	WHTOM-C	5.028	5/ 0.017 (0.020)	0.049 (0.025	5/ 0.062 (0.072)	76.0	1.673

1/ TOMPR-C -- per capita consumption of all canned tomato products (pounds). WHTOM-C -- per capita consumption of whole packed tomatoes (pounds).

2/ CNTOM -- index of canned tomato prices (1967=100).

3/ PROFV -- index of processed fruit and vegetable prices (1967=100).

4/ PCDPI -- per capita disposable income deflated by the consumer price index (dollars).

5/ Statistically insignificant at the 10-percent level.

consumption of processed tomato products. 9/ The equations are linear in the observations, and estimation is by the method of least squares. Interpretation of the results of the analysis is hampered by a high degree of multicollinearity among the independent variables.

The index of whole canned tomato prices (CNTOM) is used as a proxy for the prices of total canned tomato products (TOMPR-C) in equation 1 in table 14. The results suggest that the consumption of processed tomato products is relatively unresponsive to changes in retail price. For example, if additional costs of production associated with environmental regulations cause CNTOM to increase 10 percent, we expect TOMPR-C to decline only about 1.2 percent, other things remaining constant. Although other processed fruits and vegetables are likely substitutes for processed tomatoes, the index of processed fruit and vegetable prices (PROFV) is statistically significant only in equation 2. There is no statistical evidence that fresh tomatoes are substitutes for processed tomato products.

Consumer income (PCDPI) was found to be positively related to TOMPR-C. A 10-percent rise in PCDPI leads to a 5.4-percent increase in TOMPR-C, holding prices and consumers preferences unchanged. Most of the increase in demand for processed tomato products associated with rising consumer incomes will occur as a result of increased use of convenience foods and away-from-home eating.

Foreign Trade

Exports of tomato products generally account for about 1 to 2 percent of total domestic production . Export volume tripled from 1963 to 1973 (table 15). Export earnings reached $13.3 million in 1973. Canada is our most important export market.

Imports of processed tomato products--particularly tomato paste and sauce--have increased gradually in recent years. Most of this growth is the result of rising consumer incomes and the efforts of manufacturers of convenience foods to obtain low-cost ingredients. Imports of whole pack tomatoes tend to fluctuate widely from year to year. Italy, Spain, and Portugal are our leading suppliers of tomato products.

In 1970-72, the U.S. balance of trade deficit in processed tomato products averaged $22.9 million per year. Expansion of production abroad and added pollution control costs in the United States are expected to contribute to a larger trade deficit in the future.

9/ A more sophisticated analysis of the demand for processed tomato products may be found in (13, pp.87-103).

TECHNICAL, ENVIRONMENTAL, AND ECONOMIC ASPECTS OF TOMATO PROCESSING

This section describes the technical characteristics of five hypothetical multiproduct tomato processing plants, identifies the raw waste load generated in processing, and measures the relative profitability of alternative plants and their ability to adopt pollution abatement strategies.

Interdependencies between technical, environmental, and economic factors at the food processing plant must be recognized in evaluating the overall economic impact of EPA water pollution control regulations. A variety of factors--such as product mix, method of tomato peeling, and age of plant--influence both the plant s raw waste load and its profitability. Scientific data needed to fully understand many of the relationships are limited.

Description of Model Plants

The model processing plants used in this study were developed by R. Uyeshiro at Purdue University (38, pp. 33-104). Uyeshiro used economic engineering techniques to construct model plants and allocate costs after detailed consultation with tomato processors, equipment manufacturers, and industry experts. Because the tomato processing industry is a collection of diverse plants and firms, the use of model plants involves a degree of simplification.

Model plants A-D, with initial land, building, and equipment investment requirements ranging from $0.7 million to $4.6 million, represent plants in the eastern and midwestern producing regions (table 16). The length of the processing season in these regions is typically 8 weeks or less. Model plant E represents the large, diversified processing plants found in California. The initial investment requirement is $7.5 million and the processing season is about 16 weeks. The availability of raw tomatoes within the processing season tends to follow a bell-shaped curve.

Industry sources participated in developing raw input capacities, final product specifications, rates of output, and product mix schedules. Seasonal raw input requirements were calculated, using assumed final product volumes and regional raw input to finished product conversion coefficients. Information on total operating hours and days per season was used to estimate maximum daily and seasonal waste loads. A thorough discussion of the assumptions used in constructing the model plants can be found in Uyeshiro's thesis (38, pp. 31-61). Appendix tables 2 through 5 give additional technical data relating to the model processing plants.

Table 15 --U.S. foreign trade in processed tomato products, 1963-73

Year	Exports			Imports		
	Whole pack	Paste, sauce and other products	Value	Whole pack	Paste, sauce, and other products	Value
	Million pounds		Million dollars	Million pounds		Million dollars
1963	4.3	15.8	3.6	9.5	49.7	6.6
1964	12.2	12.2	3.8	13.2	82.9	12.0
1965	18.4	13.7	5.3	24.1	87.6	12.6
1966	10.6	9.5	3.9	50.0	103.3	16.9
1967	8.0	6.9	3.1	155.2	133.7	33.5
1968	7.5	7.7	3.2	159.6	139.9	35.0
1969	14.6	15.2	4.9	87.4	110.2	23.5
1970	19.1	10.0	4.8	91.4	128.5	24.5
1971	17.4	6.8	3.9	97.8	108.6	23.0
1972	19.9	8.2	4.6	126.2	158.6	34.5
1973	24.7	36.9	13.3	NA	NA	NA

Sources: (31) and (32).

Table 16 --Important characteristics of five multi-product tomato processing plants

Item	Unit 1/	East and Midwest				West
		Model Plant A	Model Plant B	Model Plant C	Model Plant D	Model Plant E
Average raw input requirement	Tons	2,053	10,203	38,365	29,883	103,929
Average plant capacity .	Cases	100,000	416,000	1,000,000	1,018,000	2,000,000
Product Mix	NA	Whole pack Juice	Whole pack Juice Catsup	Juice Catsup Puree Paste	Juice Catsup	Whole pack Juice Catsup Puree Paste
Initial investment requirement	Mil-dols. 1972	0.7	2.3	4.6	4.2	7.5
Length of processing . . season	Weeks	<8	<8	<8	<8	<16
Wastewater	Mil-gals.	3.5-5.0	17.4-20.8	50.0-65.2	50.8-50.9	100.0-176.7
Solid waste	Mil-lbs.	0.3	1.5	5.7	4.5	15.6

NA = Not applicable.

1/ Per season.

Source: (38).

Production Centers and Sources of Waste

Large quantities of water are used in tomato processing to remove dirt and foreign material from the raw product, to transport and handle the product, as a means of heating and cooling products, and to lubricate and clean equipment. Two general types of waste materials are generated:

(1) Sugars, starches, and other carbohydrate-like compounds, excluded or leached from the raw or cooked product and discharged in waste water.

(2) Trimmings, peels, leaves, stems, defective pieces, and pomace as solid waste.

Each model plant is segmented into four functional centers of production: receiving, preparation, processing, and canning. The production centers are used to derive the equipment requirements of each model plant, consistent with desired raw input final product flows and product mix specifications.10/ In this study, the production centers and related processing activities are also used to identify major sources of waste. Figures 1 and 2 depict waste materials generated in producing whole pack tomatoes, and tomato juice and concentrated tomato products.

Raw tomatoes are hauled to the processing plant and processed as soon as possible after harvesting. Careful coordination of field operations and plant capacity helps minimize the waste load of damaged and undesirable tomatoes. On arrival at the plant, raw tomatoes are inspected, weighed, and dumped directly into tanks of water or large flumes. Most eastern and midwestern plants receive raw tomatoes in bulk units, such as bulk trucks and trailers. Water is used to float the tomatoes into the initial water flume. In California plants, raw tomatoes arrive in bulk bins and are unloaded by fork lifts which transfer the bins from a truck to a bulk-bin dumping system.

Gentle agitation in tanks, and high pressure water sprays located along water flumes and conveyors, remove soil, insects, and chemicals. Floating trash is skimmed off and field soil is allowed to settle. Water is customarily circulated from downstream flumes to the tanks where tomatoes are dumped. Water from the initial dump flume is discharged

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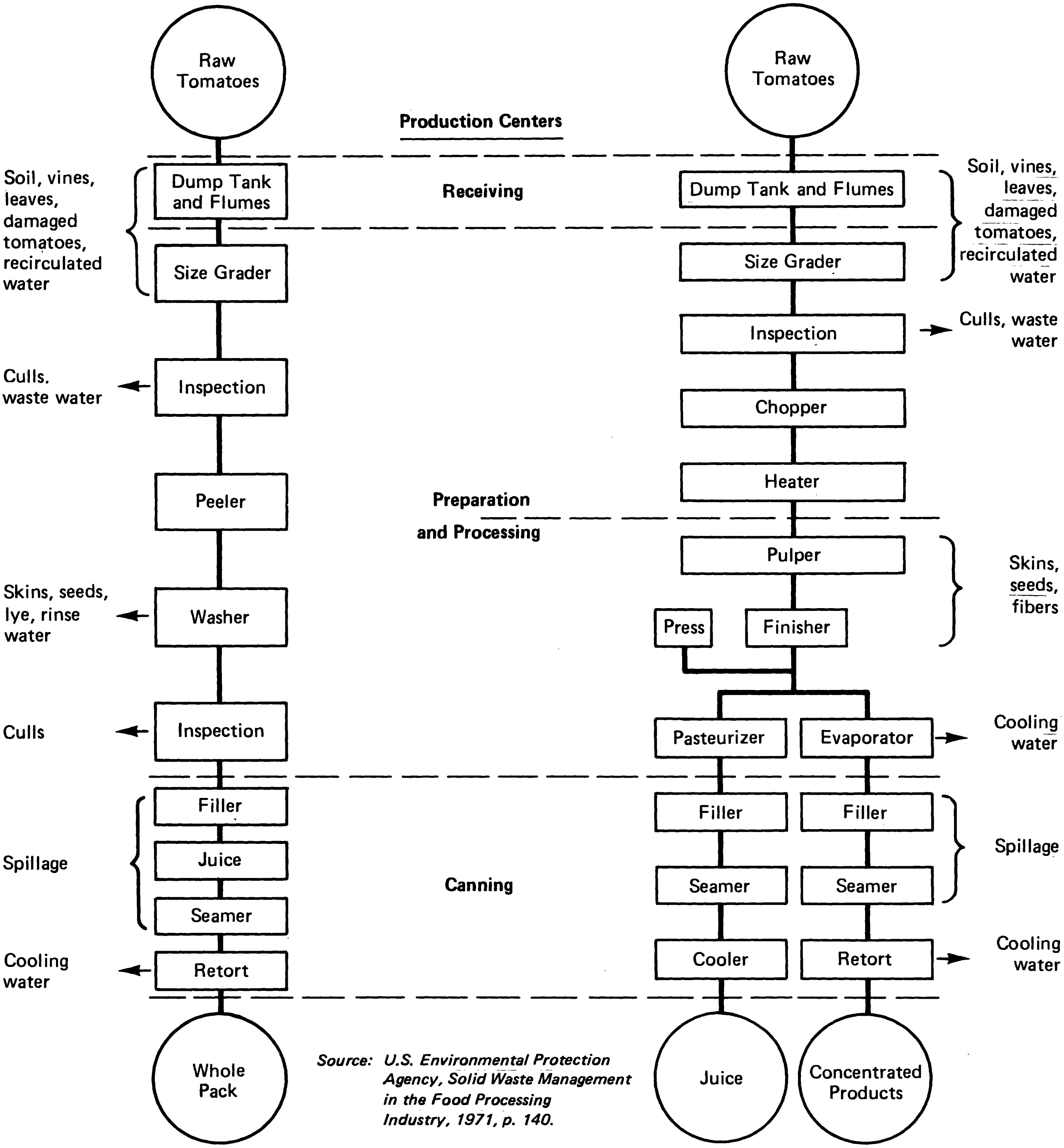
10/ For a discussion of in-plant equipment flow designs, see (38, pp.38-49). Equipment requirements, operational specifications, and investment-operating costs are primary inputs underlying the model plant profit-loss statements.

Waste Materials Generated in Producing Whole Pack Tomatoes by Production Centers

Waste Materials Generated in the Production of Tomato Juice and Concentrated Tomato Products



Source: U.S. Environmental Protection Agency, Solid Waste Management in the Food Processing Industry, 1971, p. 140.

Figure 1.

Figure 2.

into the disposal system.

The method of harvesting and delivering tomatoes is an important determinant of the amount of waste collected during dumping and initial washing. Mechanically harvested tomatoes tend to bring more waste into processing plants than do hand picked tomatoes. The new crack-resistant varieties are coreless but smaller than older varieties, and tend to carry more dirt and stem per unit of weight.

Preparation and processing centers for whole pack tomatoes are combined. Raw tomatoes are first conveyed to mechanical graders, where undersize tomatoes are culled. Sizing is not a major source of waste, since most culls are diverted to the production of juice and other tomato products. Peeling, washing, and final inspection follow.

The most common method of peeling uses hot lye. The tomatoes are placed in a chemical solution for a short period of time; the lye-softened skins are then removed via water sprays or mechanical skin removal sleeves. The peeled tomatoes are thoroughly rinsed. Waste materials are discharged to the gutter, and flumed over a screen to a hopper for disposal. Wastes from this process are highly alkaline and may require neuturalization prior to biological treatment. In addition, part of the raw product is dissolved by the lye and enters the waste stream. To reduce the disposal problem, the first rinse water may be segregated to produce an effluent with a high waste load. The lye solution is recirculated and used as a wetting agent to reduce the amount of lye required. Following the peeling-washing activities, culls and offcolor tomatoes are sorted out and sent to the products line or waste disposal bins.

In the canning center, whole pack tomatoes are cold filled and retorted. Whole tomatoes are usually hand packed; pieces are packed by machine.

After the final product is packed, the cans are filled with tomato juice and sealed for retorting. Slicing and cutting of tomatoes and the filling of cans must be carefully controlled to prevent spillage.

Tomato juice and concentrated product lines require unique equipment, and demonstrate the impact of different production activities on the waste load generated. In the preparation center, whole tomatoes are sorted, culls are sent to disposal bins, and the remaining tomatoes are conveyed to a chopper. The chopped tomatoes are sent to a "hot-break" tank, where they are rapidly heated and then discharged to specific product processing centers.

In pulping, the heated tomatoes are crushed and then passed on to the finisher, where the pulp is forced through small mesh screens to remove pomace. The remaining pulp (or flesh) is reduced to a juice containing finely divided insoluble solids. The pomace is passed to a screw or paddle press and the resultant juice is combined with juice from the finisher. The product is either canned or concentrated for use in other tomato products. The pressed pomace is sent to a dryer or collected for disposal. The waste load does not include lye rinse water that is generated in processing whole pack tomatoes.

The final step in processing tomato juice is pasteurization of the liquid, which is accumulated in holding tanks. In catsup production, the hot raw product, containing about 5 to 6 percent solids, flows through an extractor where skins and stems are partly removed. The raw input is reduced to 40 to 50 percent of the original volume in open kettle cookers, where sugar, vinegar, and spices are added. Any remaining foreign material is removed after the cooking operation. Next, the product is passed through a mill that increases viscosity; it is then deaerated and conveyed to holding tanks prior to canning. Production processes for puree are similar to those for catsup except that sugar, vinegar, and spices are not added and the milling and deaerator operations are bypassed.

The processing of paste includes concentration and sterilization of raw input. Initially, the raw input is pumped to a vacuum concentrating operation, where 70 to 80 percent of the water is evaporated. The concentrated product is pumped to an initial holding stage through a sterilizer, and to a final holding stage. Typically, not all processing activities are independent. For example, in model plant C, the center for removing pomace is shared simultaneously between tomato juice and paste. Processing centers for catsup and puree are also shared, but not simultaneously.

Canning center activities include hot filling, closing, cooking (where applicable), and cooling. Some wastes are generated by spillage and cleanup, and large amounts of water are required for retorting and cooling. Labeling, casing, and palletizing are also carried out in the canning center.

Volume and Characteristics of the Waste Load

Although it is possible to describe production centers and sources of waste, it is much more difficult to accurately estimate the volume and characteristics of the raw waste load generated in tomato processing. Available evidence indicates there are great variations between individual plants and over the processing season, but the waste load is primarily biodegradable organic matter. Some of the most important factors contributing to plant and seasonal waste load variations include: method of harvesting, condition and variety of raw input, in-plant production processes, final product mix, plant capacity and age, and cleanup procedures. However, scientific information needed to quantify the relative importance of these various factors is not readily available. 11/

Tables 17 and 18 give raw waste load data from two independent sources. Data in table 17 were summarized from 21 studies judged to be most reliable by engineers and food scientists (34, pp.235-44). Strength of the effluent is measured in terms of biochemical oxygen demand (BOD) 12/ and suspended solids (SS) 13/ and an attempt is made to identify the importance of various production centers. Table 18 is based on 1973 data collected by the National Canners Association (20). It provides information on three additional parameters--chemical oxygen demand (COD) 14 / temperature, and pH. 15/

To simplify the following discussion, comparable data from table 18 are shown in parentheses following data from table 17. Estimated mean volume of waste water per ton of raw tomatoes processed is 2,740 (1,700) gallons. The volume of waste water discharged equals the volume of fresh water

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11/ Lack of data seriously complicates the task of EPA in setting effluent limitations and other environmental regulations. Under the FWPCA of 1972, EPA is directed to take into account age of equipment and facilities, size of plant, production processes, geographical location, and other factors bearing on economic equity.

12/ BOD measures the oxygen utilized by micro-organisms in the aerobic decomposition of wastes at 20°C over a 5-day period. As aerobic micro-organisms decompose organic wastes, available dissolved oxygen is used, giving rise to a phenomenon called oxygen sag. The decline in dissolved oxygen may have a damaging effect on aquatic life.

13/ SS measures the suspended material that can be removed from waste water by laboratory filtration, but does not include coarse or floating matter that can be screened or settled out readily. A high level of suspended solids is an indication of high organic pollution.

14/ COD measures the amount of organic and some inorganic pollutants present in a waste stream under a carefully controlled chemical oxidation test.

15/ pH measures the relative acidity of alkalinity of waste water.

'..ought into the processing plant. However, because of recirculation, the gross volume of water used is substantially greater. BOD and SS average 14 (11.8) pounds per ton and 7 (8.8) pounds per ton, respectively. Table 18 shows an average COD load of 16.9 pounds per ton, waste water temperature of 78° F at the point of discharge, and pH of 8.1. In addition to variation in average values, extremely wide ranges are reported in each table.

The receiving center discharges about 900 gallons of waste water per ton of raw input, or 33 percent of total plant water requirements. However, estimates range as high as 1,500 gallons of water per ton in the receiving center (34, p. 238). Also, about 15 percent of total BOD and 30 percent of total SS are generated, primarily during initial washing and fluming. Solid residuals generated in the receiving center include soil, leaves, stems, vines, and miscellaneous debris. Noticeably higher water requirement and suspended solids estimates reported at several plants are believed to reflect mechanical harvesting.

Production activities in the preparation and processing centers discharge an estimated 1,450 gallons of waste water per ton of raw input, or 53 percent of total plant water requirement. Also, about 10 pounds of BOD and 4 pounds of SS are generated per ton of raw input.

Data currently available are not adequate to support a detailed discussion of the differences in wasteloads between whole pack, tomato juice, and concentrated product lines. Peeling and rinsing activities probably use from 600 to 1,600 gallons of water per ton of raw input, and generate up to two-thirds of total BOD and SS. Relatively large quantities of waste materials are discharged with the rinse water. Chopping and pulping require less water and produce a waste load of skins, seeds, stems, fibers, and relatively fine particles.

Canning center activities result in about 290 gallons of waste water per ton of raw input, and generate 2 pounds of BOD and 1 pound of SS. Cooling water is often reused in the earlier canning procedures. Spillage is a major source of pollutants.

In tomato processing, solid waste materials are obtained primarily during initial washing, inspecting, and peeling or finishing. Nearly 7 million tons of solid waste were obtained from processing the 1968 tomato crop (table 19). The data indicate that each ton of raw tomatoes processed generates 150 pounds of solid waste. Nearly 90 percent of the waste load is produced in the 4-month period, July to October, emphasizing the seasonal nature of tomato processing.

Table 17 --Volume and characteristics of waste water per ton of raw tomatoes processed, 1971

Production centers	Volume	BOD [1]	SS [2]
	Gals./ton	Lbs./ton	Lbs./ton
Receiving center			
Initial washing and fluming	900	2	2
Preparation and processing centers			
Washing, sizing, and inspecting	350	1	1
Peeling and rinsing/or chopping and pulping	1,100	9	3
Canning center			
Canning, retorting, and cooling	290	2	1
Mean	2,740	14	7
Range	320-5,460	3-49	2-25

1 Biochemical oxygen demand. See text footnote 12 for detail.

2 Suspended solids. See text footnote 13 for detail.

Source: (34, pp. 235-244).

Table 18 --Volume and characteristics of waste water per ton of raw tomatoes processed, NCA survey

Item	Volume	BOD 1/	COD 2/	SS 3/	Temperature	pH
	Gals./ton			Lbs./ton	°F	
Mean	1,700	11.8	16.9	8.8	78	8.1
Range	300-5,000	1.0-64.0	6.0-28.0	0.4-27.0	70-91	4.3-11.3
Number of plants reporting	49	26	9	20	8	17

1/ Biochemical oxygen demand. See text footnote 11 for detail.

2/ COD measures pollutants in waste stream. See text footnote 13 for detail.

3/ Suspended solids. See text footnote 12 for detail.

Source: (20).

Table 19 --Summary of solid wastes from tomato processing, 1968

Regions	Raw tomatoes	Solid residuals												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
		1,000 tons												
Mid-Atlantic 1/	591							8	18	18	12			57
South Atlantic 2/	228	6	6	6	7	7	7			7			6	52
North Central 3/	1,108								26	28	21			75
South Central 4/	71								2	2	1			5
Mountain 5/	65								8	10	10			29
Southwest 6/	4,903						3	62	82	82	69	6	6	305
Total	6,970	6	6	6	7	7	10	70	137	147	113	6	6	523

1/ New York, New Jersey, and Pennsylvania.

2/ W. Virginia,Virginia, Maryland, Delaware, N. Carolina, Georgia, and Florida.

3/ N. Dakota, S. Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan, and Ohio.

4/ Texas, Oklahoma, Arkansas, Louisiana, Kentucky, Tennesee, Mississippi, and Alabama.

5/ Montana, Wyoming, Utah, Colorado, and New Mexico.

6/ California, Nevada, Arizona, and Hawaii.

Source: (37, pp. 235 and 284).

Roughly 10 billion gallons of waste water and 440,000 tons of solid waste were generated in tomato processing in 1972 and 1973 (table 20).

Table 20 --Estimated gross waste load generated in tomato processing, by producing regions, 1972 and 1973 1/

Producing region and year	Gross waste load			
	Volume	Waste water: BOD 2/	Waste water: SS 3/	Solid waste
	Million gallons	1,000 tons		
East				
1972	589.7	2.05	1.53	26.0
1973	655.2	2.27	1.70	28.9
Midwest				
1972	1,346.2	4.67	3.48	59.4
1973	1,018.6	3.54	2.64	44.9
West				
1972	7,694.5	26.70	19.92	339.5
1973	8,264.4	28.68	21.39	364.6
United States				
1972	9,866.0	34.24	25.54	435.3
1973	10,087.3	35.01	26.11	445.0

1/ It was assumed that each ton of raw tomatoes processed generates 1,700 gallons of waste water, 11.8 pounds of BOD, 8.8 pounds of SS, and 150 pounds of solid waste.

2/ Biochemical oxygen demand. See text footnote 11 for detail.

3/ Suspended solids. See text footnote 12 for detail.

Profit-Loss Statements for Model Plants

The profitability of the model tomato processing plants, assuming no pollution abatement, is indicated by the profit-loss statement in table 21. Accounting profit or loss provides an initial indication of the feasibility of alternative pollution abatement strategies. Investment requirements (table 16) and annual profit-loss statements are based on detailed in-plant equipment flow and building designs, and cost data developed by Uyeshiro (38, pp.55-61).

Table 21 --Model plant profit-loss statements, no pollution abatement, 1972

	Plant A	Plant B	Plant C	Plant D	Plant E
			Dollars		
Revenue	385,000	1,934,689	5,040,000	4,815,140	11,000,000
Cost of goods sold					
Direct costs	316,136	1,408,065	3,978,408	3,693,057	8,717,393
Indirect costs	137,652	270,705	590,497	574,964	992,337
Depreciation	60,697	186,183	381,723	337,872	614,568
Total	514,485	1,864,953	4,950,628	4,605,893	10,324,298
Profit	-129,485	69,736	89,372	209,247	675,702
Average cost per case	5.14	4.48	4.95	4.52	5.16
Per unit profit or loss per case	-1.29	0.17	0.09	0.21	0.33

Since pollution control often involves acquisition of durable assets, profit-loss statements are extended over a 20-year period--the expected life of buildings. We used 1972 as the base year for plant revenues and costs, including waste treatment costs presented in the next section, because it was the most recent year for which all indices needed for updating product prices and costs were available. The assumptions used in table 16 and the data generator are discussed below.

Revenue is obtained by multiplying final product prices times average final product outputs, and summing. Final product prices are updated to 1972, using the U.S. wholesale prices index for processed fruits and vegetables. Based on historical trends, final product prices are assumed to rise at the annual compound rate of 3 percent over the 20-year planning horizon.

Cost of goods sold include direct costs, indirect costs, and depreciation. Table 22 gives assumed annual compound rates of increase for direct and indirect costs. Raw product cost is obtained by multiplying the farm level price of processing tomatoes times average raw input requirement. The initial farm prices paid by eastern-midwestern processors and California processors are $39.78 per ton and $34.60 per ton, respectively. Raw product cost is a major expense item, ranging from 16 percent of the cost of goods sold in model plant A to 40 percent for model plant E.

Table 22 --Annual compound rates of increase for direct and indirect costs

Costs	Annual rate of increase
Direct	Percent
Raw product	2
Utilities	3
Labor	5
Processing supplies	4
Canning supplies	4
Repair and maintenance	3
Miscellaneous supplies	3
Pollution control	4
Operating capital	NA
Indirect	
Administrative salary	3
Business taxes	3
Insurance	3
Interest on borrowed capital	NA

NA = not applicable.

Electricity, natural gas, and water requirements for each model plant are calculated, given plant equipment capacity and desired rate of product flow. An average intake of 50 gallons of water per case of final product is used for all model plants. This assumption, based on engineering specifications, may be inconsistent with evidence in tables 17 and 18, suggesting that water consumption varies widely among processing plants in the industry. Utility rates are based on data provided by several utility companies in the major tomato processing regions.

Labor requirements are based on model plant specifications. Labor cost accounts for as much as 12 percent of cost of goods sold in model plant A and as little as 6 percent for model plant D. Hourly wage rates and salary schedules are based on data from midwestern and California processors. Hourly wage employees, excluding maintenance workers and fork lift operators, are employed only during the processing season. It is assumed that model plants A and B hire nonunion labor and that model plants C, D, and E hire union labor. Fringe benefits are included at 8.5 percent of hourly labor costs.

The cost of processing and of canning supplies depends on final product mix, volume, and allowance for damage and loss. Ingredient requirements for the various products are based on data from industry sources. Processing and canning supply costs range from 30 percent of the goods sold in model plant A to 44 percent for model plant D. Repair and maintenance costs are estimated at 0.4 percent of total equipment investment, and miscellaneous supply costs at 0.5 percent of total revenue. Pollution control costs are zero, since the profit-loss statements are based on the assumption that the processing plants provide no pollution abatement. The cost of short-term capital is 8 percent of one-half of total direct cost for 6 months.

Administrative salary is the most important indirect cost, ranging from 18 percent to 5 percent of the cost of goods sold in model plants A and E, respectively. Salaried employees are hired on a yearly basis and fringe benefits are 7.5 percent of total salary costs. Business taxes and insurance are estimated as a percentage of total land, building, and equipment investment.

Interest on borrowed capital is directly related to the plant's investment requirement, and accounts for about 5 percent of cost of goods sold. It is assumed that the firm borrows 60 percent of the capital required for land and buildings, and 50 percent of the capital required for equipment. Land and building debt is amortized over 20 years and equipment debt is amortized over 10 years, each at an annual interest rate of 8 percent. Equipment is replaced at the beginning of the 11th year of the planning horizon.

Table 23 shows capital investment requirements for each model processing plant. The land requirement is computed at 1.5 times the total building area; land is $50,000 per acre. Of course, this is an approximation since land prices vary widely, depending on location with respect to population centers, transportation systems, and site preparation expenses. Construction costs are about $5.20 per square foot in the receiving center; $25.00 per square foot in the preparation, processing, and canning centers; and $10.00 per square foot for warehouse space. Equipment cost estimates, obtained by Uyeshiro from manufacturers and secondary sources, are updated using the U.S. wholesale price index for special industry machinery and equipment. Freight, installation, and plant shakedown costs are included for durable equipment items.

Annual depreciation of capital goods, calculated using the straight line method, ranges from 12 percent of cost of goods sold in model plant A to 6 percent for model plant E.

Accounting profit or loss equals revenue minus cost of goods sold. Model plant E--the large, diversified California processor--is the most profitable, earning $0.33 per case of final product (table 21). This plant is able to achieve economies of size as a result of a relatively long tomato processing season. For example, indirect costs plus depreciation account for only 16 percent of cost of goods sold in model plant E, compared with 39 percent in model plant A. Model plant D is the most profitable in the East and Midwest. Its distinguishing characteristics include a large volume of output, and specialization in the production of juice and catsup. Model plant C is also a large-volume plant, but offers a diversified product mix. Model plants D and C earn $0.21 and $0.09 per case of final product, respectively. This suggests a trend toward specialization of processing plants in the East and Midwest, with puree and paste production primarily in California. Model plant B, an intermediate size plant, produces whole pack tomatoes, juice, and catsup and earns $0.17 per case of final product. Model plant A has an accounting loss of $1.29 per case of final product, indicating that investment in such a plant is not economically feasible under current product prices and costs. The continuance of small tomato processing plants in the East and Midwest probably reflects the facts that capital assets are fully depreciated and the salvage values of certain resources--such as labor and management provided by the owner--are low. For example, model plant A's loss is eliminated if we assume that depreciation and interest on borrowed capital are zero, and administrative salary is reduced by 40 percent.

Table 23 --Capital investment requirements by model plants, no pollution abatement, 20-year planning horizon

Item	Model plant A		Model plant B		Model plant C		Model plant D		Model plant E	
	Year 1	Year 11	Year 1	Year 11	Year 1	Year 11	Year 1	Year 11	Year 1	Year 11
	Dollars									
Land	5,716	0	19,772	0	43,500	0	43,400	0	51,000	0
Buildings	254,649	0	736,275	0	1,561,325	0	1,506,338	0	2,653,527	0
Equipment 1/	479,653	781,307	1,433,690	2,433,072	3,036,572	4,946,272	2,625,546	4,276,752	4,818,922	7,849,542
Total	740,018	781,307	2,249,737	2,433,072	4,641,397	4,946,272	4,175,284	4,276,752	7,523,449	7,849,542

1 Equipment costs were assumed to increase at the annual/compound rate of 5 percent between years 1 and 11.

ENVIRONMENTAL PROTECTION AGENCY REGULATIONS

EPA efforts to control water pollution began under the Federal Water Pollution Act of 1956 and 1965. This legislation provided for limited Federal intervention involving conferences to call attention to pollution problems, 180-day cleanup notices, and court action. Enforcement proved to be ineffective. In 1970, because of declining water quality, EPA initiated a control effort under the Rivers and Harbor Act of 1899 (also called Refuse Act). An individual polluter was required to obtain a discharge permit from the Army Corps of Engineers specifying the type and amount of effluent he intended to discharge. If the effluent did not meet applicable water quality standards, an abatement plan and compliance schedule were to be submitted. Issuance of permits and enforcement under the Refuse Act was subsequently halted by two court orders. 16/

Recognizing the need for stronger Federal regulation, both Congress and the Administration began working on new legislation late in 1971. Nearly a year later, after rejection of an Administration bill by Congress, veto of a Congressional proposal, and subsequent override of the veto, the Federal Water Pollution Control Act Amendments (FWPCA) of 1972 became law.

Under the FWPCA, effluent limitations are specified in terms of selected parameters. Parameters include biochemical oxygen demand (BOD) and suspended solids (SS) per unit of raw input processed, fecal coliform, and pH. 17/ Effluent limitations will be applied at each identifiable point source source of pollution.

EPA regulations establish maximum limitations for BOD and SS for any one day, as well as more restrictive limitations on average daily values for 30 consecutive days. There is a maximum limitation on fecal coliform at any one time, and a range for pH. By July 1, 1977, industrial polluters must have their effluent levels consistent with the best practicable control technology currently available (BPCTCA) and municipalities must achieve the equivalent of secondary treatment. BPCTCA is defined as the average of best existing performance in an industry, recognizing that plant age, size, and production processes may require some variation.

16/ For a more detailed discussion of Federal water pollution laws see (5).

17/ BOD, SS, and pH are explained in footnotes 12, 13, and 15. Fecal coliform tests reveal the presence of bacteria typically inhabiting the intestines of man or animal.

By July 1, 1983, industrial effluents are to be determined by the best available technology economically achievable (BATEA) and municipalities must apply best practicable waste treatment technology over the life of their facilities. Each polluting firm is expected to provide treatment at least equal to the best existing performance, which may require technology capable of being implemented though not yet in use. BATEA emphasizes both in-process changes and end-of-pipe control. Firms which began plant construction after the proposal of effluent limitations are classified as "new sources" and must immediately meet performance standards generally equivalent to BATEA. The year 1985 is cited as a goal, but not a third time phase, for the achievement of zero discharge.

Discharge of pollutants without an EPA-approved permit was unlawful after December 31, 1974. Industrial permits will be based on effluent limitations, toxic effluent standards, and existing water quality standards. Municipal permits will be written on the basis of secondary treatment, except in the case of more advanced treatment facilities which are expected to perform at design capacity. Administration of the permit program and compliance monitoring will be largely in State hands.

The FWPCA makes Federal grants, up to 75 percent of total capital cost, available to assist in the construction of municipal treatment facilities. Industrial firms using municipal facilities will be subject to pretreatment regulations designed to prevent the discharge of pollutants which interfere with or pass through municipal treatment. Also, to avoid the possibility of indirect subsidization, the act specifies that the municipality must recover capital costs from industrial users proportional to the strength, volume, and flow characteristics of the water received; and must impose a system of user charges to assure that each firm pays a proportionate share of the costs of operating and maintaining the treatment facility. The requirement of capital cost repayment is a fundamental change in the Federal grants program, and is expected to substantially increase the cost that industrial firms must pay for municipal treatment of waste. In the past, municipalities have received up to 55 percent Federal construction aid without repayment.

Another important component of our environmental policy is the development and use of river basin water managment plans. The States are directed to play a leading role in drawing up areawide plans, estimating municipal and industrial waste treatment needs, and establishing priorities for construction of treatment facilities over a 20-year period. Effective water quality management involves a continuing and systematic compliance review, planning for control of current and potential problems, and technical assistance and financial support from the Federal Government.

PROJECTED ECONOMIC IMPACTS

This section discusses the economic impacts of forthcoming EPA regulations on the tomato processing industry. Factors for consideration include methods of waste handling and disposal, the relative profitability of model processing plants, and general economic trends. Analytical results presented here are based on the assumption that EPA will require tomato processors to achieve 98 percent BOD and SS removal by July 1, 1983. Final cleanup requirements will not be known with certainty until effluent limitations and pretreatment standards are published.

Common Methods of Waste Handling and Disposal

Food processing wastes are treated privately and/or discharged to municipalities (depicted in fig.3). An estimated 65 percent of the tomato processing industry's waste water undergoes municipal treatment (36, p.60). 18/ The five most important waste treatment techniques and practices used are discussed below. Table 24 gives capital and operating costs for alternative private waste treatment systems. Capital costs include excavation and fill (where necessary), construction, equipment, installation, and shakedown. Cost of land is excluded. Operating costs include power, labor, maintenance, and repairs.

18/ Although many food processors have viewed municipal treatment as an economically favorable waste treatment strategy, this position may change in the near future. These processors have been warned to expect significant increases in sewage rates, since they will have to repay Federal grants for new construction, and treatment plants will have to be updated to meet the provisions of the FWPCA (11, p.55) .

Methods of Handling and Disposing of Tomato Processing Plant Waste Materials

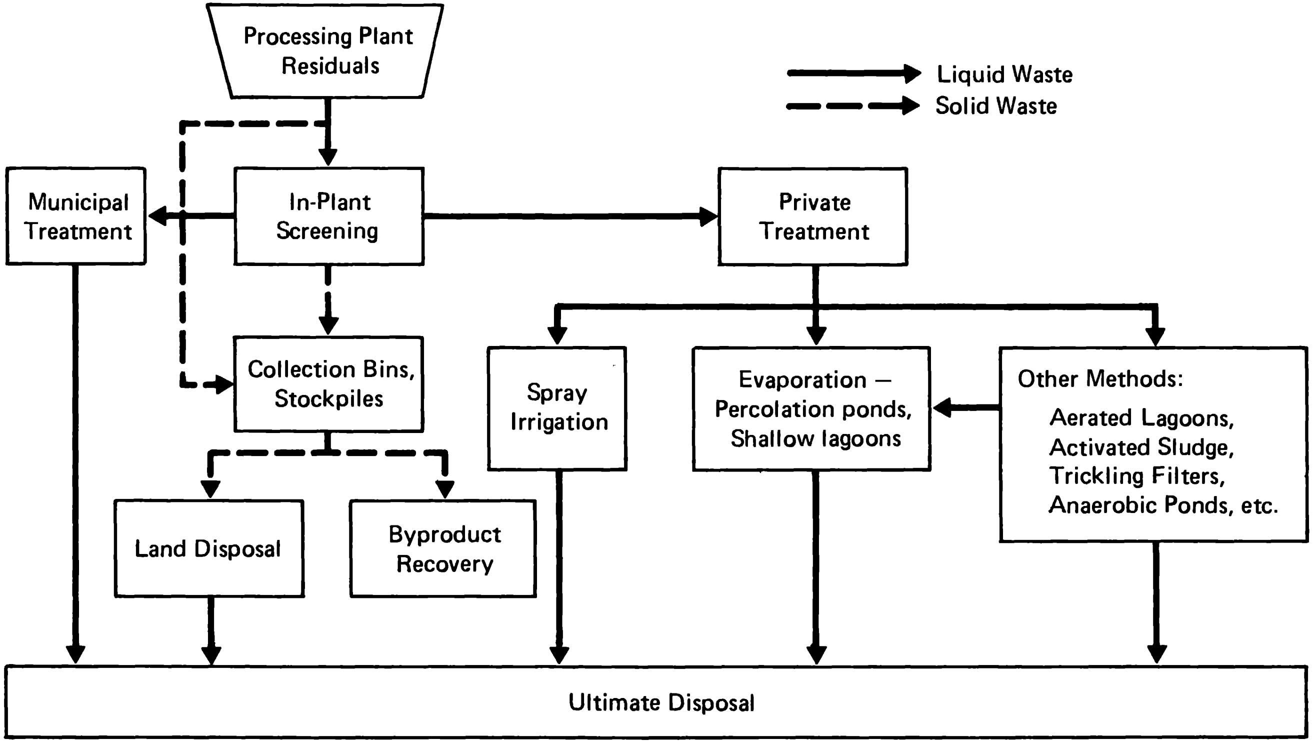

Figure 3.

Table 24 --Capital and operating costs for private waste treatment systems, by volume of waste water discharged 1/

Waste treatment system	Millions of gallons of waste water per day							
	0.5		1.0		2.0		4.0	
	Capital	Operating	Capital	Operating	Capital	Operating	Capital	Operating
	1,000 dollars							
Preliminary								
Screening	11.4	4.4	14.8	7.1	28.0	14.3	41.7	24.6
Primary								
Sedimentation with sludge disposal	39.0	2.2	72.7	4.1	135.3	7.6	251.4	44.6
Secondary								
Aerated lagoons	114.9	5.9	186.2	11.0	331.6	22.8	467.6	44.6
Aerated lagoons plus holding ponds	163.9	11.1	265.0	21.1	485.7	34.5	768.7	52.8
Activated sludge	230.5	19.8	362.4	26.5	738.9	37.0	1,402.8	54.2
Ultimate Disposal								
Spray irrigation	16.6	6.8	39.9	9.6	73.0	15.0	171.2	25.6
Evaporation-percolation ponds	187.7	2.6	338.2	4.7	645.7	8.9	1,283.2	17.4

1/ Capital excludes cost of land. Operating costs based on a 300-day processing season.

Sources: (1, pp. B-1 to C-4) and (33, pp. 129-149).

(1) Preliminary Treatment Systems

Screening is the most widely used type of preliminary waste treatment in food processing. Generally, the first step is to pass the waste water, containing both suspended and dissolved pollutants, through one or more screening devices. A variety of fixed-steel-bar, rotary, disc, and vibrating screens are used. Retained solids are conveyed to collection bins and stockpiled with solid wastes from other processing activities.

The efficiency of screening devices depends on the rate of flow of the waste stream, size of mesh relative to particle dimensions, screen motion, and volume of fibrous matter in the effluent. Screening is an effective means of removing materials which may interfere with the subsequent treatment of liquid effluents, but only small reductions in BOD are achieved. Screens that clog frequently may tend to increase BOD loading, because of the leaching of dissolved solids by the passing waste stream. Estimates of capital and operating costs are based on the use of 40-mesh vibrating screens, and screw and belt conveyors for transporting waste to storage hoppers. Costs vary directly with the volume of waste water and solid waste handled.

(2) Primary Treatment Systems

Primary waste water treatment refers to all systems that reduce floating and suspended solids by mechanical or gravitational means. Suspended solids that cannot be conveniently removed by screening can be separated by settling or clarification. A typical sedimentation system includes a settling basin, primary clarifier, and rotary vacuum filter. The clarifier provides mild agitation, which speeds the normal settling process; the rotary vacuum filter removes and de-waters settled sludge from the waste stream. Solid sludge materials are then collected for final disposal. Sedimentation prior to lagooning helps reduce odors.

BOD removal efficiency in sedimentation depends on the length of waste detention time and total amount of BOD in the suspended phase. However, the effectiveness of sedimentation basins is limited, since only 15-20 percent of total BOD is in suspension (1, p.146). The cost of a sedimentation system depends on the rate of waste inflow and length of detention time. Land area requirements are minimal, ranging from 0.1 to 0.4 of an acre.

(3) Secondary Treatment Systems

Biological treatment of waste water is an attractive alternative in food processing because a high proportion of the waste load is biodegradable material. Among most common methods of secondary treatment are: aerated lagoons, activated sludge, trickling filters, and anaerobic ponds.

The aerated lagoon system considered in this study consists of a series of mechanically aerated, continuous flow lagoons. The basic structure is a square lagoon, 10 to 15 feet deep, with riprap siding, and surface aerators mounted on platforms. Given a plentiful oxygen supply, aerobic micro-organisms biologically decompose organic matter, producing carbon dioxide and water. Solid waste production is low because the long aeration time used allows micro-organisms present to be almost completely destroyed by self-digestion.

Aerated lagoons achieve up to 95 percent BOD reduction, and require a relatively small amount of land, ranging from 2 to 11 acres (1, pp.150-7). Important cost variables for aerated lagoons are detention time and air supply required to achieve desired BOD reduction. A detention time of 9 to 10 days is assumed in this study. Major equipment includes catwalks, platforms, riprap siding, piping, and mechanical aeration units.

Unfortunately, aerated lagoons often do not reduce suspended solids to the degree required for the final stage in a secondary treatment system. Therefore, it is necessary to introduce an additional step, such as shallow holding ponds, to complete the treatment process. Waste water is discharged to holding ponds during the processing season, and is gradually released into a receiving stream later in the year. The maximum area and depth of holding ponds are limited to 10 acres and 6 feet. Algae growth is common and provides a source of oxygen for aerobic micro-organisms. However, when algae die they release organic matter, causing a secondary waste loading. When the ratio of organic matter to available oxygen is such that oxidation processes consume oxygen faster than it can be resupplied, biological activity in the holding pond becomes anaerobic. Decomposition of organic matter by anaerobic microbes produces hydrogen sulfide and other foul-smelling gases. Sludge at the bottom of a pond or basin undergoes continual anaerobic decomposition. In addition to odor problems, holding ponds also require large land areas.

Activated sludge is one of the most sophisticated and capital-intensive waste treatment processes used by food processors. The objective of the process is to employ an actively oxidizing microbial population to produce an effluent with excellent settling characteristics. Various activated sludge systems are used, but typically they include a mixed sludge reactor and a clarifier. The treatment process involves recirculating a liquid sludge mixture, obtained from previously settled sludge, to the incoming waste water. Micro-organisms in the liquid sludge feed on nutrients in the waste water. Air is supplied to provide the micro-organisms with oxygen required for their metabolism. The effluent is passed to a clarifier and a final sedimentation tank for removal and settling of solids. Activated sludge treatment is expected to remove 98 percent of the BOD in food-processing plant waste water (33, p.101).

Activated sludge requires only a small amount of land. In this study, land area requirements range from 0.6 to 4.0 acres. Disadvantages of the process include the fact that an external source of nitrogen may be needed to sustain desirable biological growth, start-up periods are required during which wastes must be discharged without complete treatment, and performance of the system is highly sensitive to changes in the character of the waste load (1, p.157). In estimating operating costs, it is assumed that anhydrous ammonia is added to maintain a favorable nitrogen to BOD ratio. High capital and operating costs associated with activated sludge treatment are also important disadvantages.

Other secondary treatment systems include trickling filters and anaerobic ponds. (Cost data for these systems are not included in table 24.) In a trickling filter, effluent is passed down through a bed of porous materials, where oxidation is carried out by bacteria living in a slime growth. Objective of biological filtration is to change soluble organic wastes into insoluble organic matter, discharged as humus. Treatment efficiency depends on rate of inflow and recirculation, medium porosity, pH, and temperature. Performance of trickling filters in the food processing industry has been variable, usually resulting in less than 90 percent BOD removal (1, p.184).

Anaerobic ponds are used for pretreatment prior to discharge to a municipal system, or as the first step in secondary treatment. Ponds are covered with plastic to ensure anaerobic conditions, retard heat loss, and retain obnoxious odors. Reductions of 85 percent in BOD and SS have been reported (33, p.104). Anaerobic ponds are easy to operate, require only small land areas, and can handle shock loading.

(4) Ultimate Disposal Systems

Disposal of liquid effluent through spray irrigation has become increasingly popular among food processors. It is estimated that 13 percent of the U.S. tomato processors use spray irrigation (36, p.63). The system consists of a detention tank, pump and motor, a fixed main line, movable laterals, and sprinkler nozzles. Screened waste water is pumped from the detention tank to the disposal area where revolving sprinklers, activated by pressure in the pipeline, distribute the effluent. The receiving soil acts as a living medium, where the biological activity of micro-organisms removes organic pollutants; the water evaporates or seeps into the ground.

The effectiveness and cost of a spray irrigation system depend on many factors including climate, cover crop, soil type, slope, and wind speed. Data given in table 24 are based on the assumptions of "a moderate to hot climate...cover crop of alfalfa...medium textured soil with a total storage capacity of 5 inches per irrigation...sloping at less than 5 percent...and wind speed less than 6 miles per hour" (1, p. 191). On this basis, it is assumed the soil has a total storage capacity of 5 inches per irrigation and a consumptive use rate equal to 0.25 inch per day, which implies that approximately 20 days are required between successive irrigations.

Total land area in spray treatment is a function of consumptive use rate and waste water flow rate. Land area requirements range from 50 acres to 384 acres, and are a major disadvantage of the system. Furthermore, several processors have discovered that it is extremely difficult to predetermine the amount of land required. Other important problems include eliminating suspended matter--which causes clogging of spray nozzles--and controlling runoff, which may contaminate nearby water supplies. Under proper environmental conditions and careful management, spray irrigation can give 100 percent treatment efficiency.

About 10 percent of U.S. tomato processors use evaporation-percolation ponds (36, p.11). These ponds are sized so that the annual inflow of waste water plus precipitation equals evaporation and percolation losses. For this study we assume that the net annual evaporation-percolation loss is 96 inches. Major problems are accumulation of solids and biological growth, which greatly decrease percolation rates. Operating costs include an annual charge for solid waste removal. Also, because of odors and insects, evaporation-percolation ponds should be located some distance from human habitations. If sufficient land is available (requirements range from 25.3 acres to 190.7 acres in this study) and contamination of ground water can be avoided, evaporation-percolation ponds may represent a favorable waste treatment strategy.

Food processors may view municipal waste treatment as an ultimate disposal system, since they are not responsible for the waste water after it is accepted by the municipality. 19/

19/ In reality, municipal treatment is seldom equivalent to ultimate disposal. Recent estimates indicate that the treatment efficiency of municipal plants varies widely, with BOD and SS removal averaging between 75 and 85 percent (36, p. 60).

Some municipalities require pretreatment, such as primary sedimentation. Important factors influencing the desirability of discharging waste to municipal treatment include: access to the local treatment plant, pretreatment regulations, basic volume rates and surcharges, and capital repayment requirements. Capital cost repayment and user charge provisions of the FWPCA of 1972 are expected to significantly raise municipal treatment costs for all industrial users, including tomato processors.

Information concerning current and expected future municipal treatment costs was obtained from a survey of fruit and vegetable processors. Average current (1973) and future municipal sewage rates are $212 and $576 per million gallons of waste water, respectively (table 25). These rates include surcharges, local taxes, and special assessments associated with municipal sewer services. There is an extremely wide range of municipal rates, but no significant differences based on the volume of waste water discharged. Extrapolating from the expectations of 31 processors, a 171-percent increase in municipal treatment costs is forecast for the near future. The extent to which this increase reflects the provisions of the FWPCA of 1972 is unknown.

Some municipalities have reported that the seasonal nature of tomato processing and relatively high BOD and SS waste loads cause serious difficulties. The problem for the processor is to determine the in-plant process changes and the levels of pretreatment, which combine with a given municipal sewage rate to minimize the cost of waste water treatment. As municipal sewage rates rise rapidly in the future, solution to this problem will become increasingly important.

(5) Solid Waste Disposal

In addition to liquid effluents, the tomato processing industry must also handle and dispose large quantities of solid waste. Solid wastes from specific processing activities and recovered during in-plant screening are conveyed directly to collection bins or stockpiles. Typically, leaves, vines, and other materials are collected as floating debris in the washing flumes and deposited in collection bins. Mud is often separated from wash water by means of special separators or settling tanks. A considerable part of the solid waste generated during inspecting, sorting, peeling, pulping, and finishing is discharged with the waste water. The liquid waste stream is moved through screens and/or shakers, where solids are removed and conveyed to temporary storage prior to ultimate disposal.

Land disposal (primarily landfill) and spreading on open land accounted for 73 percent of the solids generated by the tomato processing industry in 1968 (table 26). A small

Table 25 --Municipal sewage rates for fruit and vegetable processors 1/

Item	Current rates, (1973)				Expected rates 2/
	All plants	Small plants 3/	Medium-size plants 4/	Large plants 5/	All plants
	Dollars/million gallons				
Mean	211.65	143.77	263.23	191.26	575.78
Standard deviation	239.38	115.96	297.57	167.42	529.64
Range	15.30-1,730.77	15.25-340.00	35.00-1,730.77	30.68-638.46	95.13-2,204.55
	Number				
Plants	63	7	34	22	31

1/ Municipal sewage rates include a basic volume charge, surcharges on the volume and/or strength of the plants wasteload, and local taxes directly associated with municipal sewer services.

2/ Processors were asked to estimate future municipal sewage rates: 8 expected no change, 23 expected rates to increase.

3/ Plants processing 10,000 tons or less of raw commodity per year.

4/ Plants processing 10,000-50,000 tons of raw commodity per year.

5/ Plants processing 50,000 tons or more of raw commodity per year.

Source: (20).

quantity of solid waste was discharged in the liquid effluent and about 22 percent was used as a byproduct in feed. The potential for byproduct recovery in the tomato processing industry is limited by an extremely short processing season and a highly perishable waste material. In fact, byproduct recovery is negligible for small and intermediate size plants.

Table 26 --Disposal of solid waste generated in tomato processing, 1968

Alternative method	Quantities	Percentage
	1,000 tons	
Landfill or dumping..........	250	47.8
Spread on land..............	130	24.9
Total as solids...............	380	72.7
Stream and lakes.............	22	0.4
Holding or treatment ponds....	7	0.1
Public treatment systems......	0	0.0
Irrigation disposal............	1	
Total solids in liquid medium...	30	0.6
Total solid wastes............	410	78.4
Feed byproducts.............	113	21.6
Total solid residuals..........	523	100.0

Source: (37, p. 256).

In this study, it is assumed that the net cost of disposing of solid waste is \$0.40 per ton of raw tomatoes processed (37, p.309). This estimate includes in-plant handling, hauling, site costs, and byproduct sales. Although existing data are limited, solid waste disposal costs apparently vary widely among individual plants.

Feasibility of Alternative Pollution Abatement Strategies

Various strategies for food processing plants faced with environmental regulations are outlined in Appendix I. The most likely strategies--investing in a private waste treatment facility, discharging to municipal treatment, or closing down--are considered here.

In this study, the internal rate of return earned by the processing plant is used to measure its economic well-being.20/ Internal rates of return are calculated for each model processing plant assuming no pollution abatement, and for alternative waste treatment strategies. According to capital investment theory, a firm that maximizes profit will select the waste treatment strategy yielding the highest internal rate of return, provided the return is greater than or equal to the opportunity cost of capital. If the return is less than the opportunity cost of capital, management will likely close the plant, since the money tied up in the plant can bring in a better return in some other use. An important advantage of the internal rate of return approach is that it provides a concise and meaningful comparison of waste treatment strategies that differ with respect to capital cost, annual operating cost, and useful asset life.

Several crucial assumptions are used in the above analysis. First, all technical and economic assumptions relating to the model processing plants discussed in the preceding section are continued. For example, the planning horizon is 20 years, and processing plant revenues and costs increase at the annual rates given in table 22. Although pollution abatement tends to increase the processing plant's total capital requirement, it is assumed that the capital structure is unchanged. That is, the firm borrows 60 percent of the capital required for equipment. Land and building debt is amortized over 20 years and equipment debt is amortized over 10 years, each at the annual interest rate of 8 percent. Equipment costs increase at the annual rate of 5 percent between the beginning of year 1 and year 11.

Second, capital and operating costs (table 24) are assumed to be representative of private waste treatment systems in tomato processing. Operating costs are adjusted to reflect an 8-week processing season in the East and Midwest, and a 16-week processing season in California. Operating costs associated with waste treatment and disposal appear as a direct cost, under the heading Pollution Control, in the processing plant data generator; they increase at the annual rate of 4 percent over the plannning horizon. The general relationship between plant size and the cost of pollution abatement can be demonstrated by comparing two model plants. Adoption of an activated sludge system will add $24.86 to initial capital costs per ton of raw tomatoes at model plant D and $13.56 at model plant E. Operating costs in year 1, on

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20/ The internal rate of return (r) is the time discount factor which makes the present value of the stream of internal (ownership) capital outlays, annual cash flows, and salvage values equal to zero. This concept is discussed in Appendix I.

the other hand, increase about $0.13 per ton of raw tomatoes processed at each plant.

The cost of acquiring land for private waste treatment systems is assumed to be $1,700 per acre. Since land requirements increase proportionately with the volume of waste water discharged, economies of size are somewhat less significant for land-intensive waste treatment system. For example, a spray irrigation system will add $12.42 to initial capital costs per ton of raw tomatoes processed at model plant D and $7.93 at model plant E. The net cost of handling and disposing of solid waste is $0.40 per ton of raw tomatoes processed. Average current and future municipal treatment rates of $212 and $576 per million gallons of waste water (table 25) are assumed to be relevant for tomato processors discharging to municipalities.

Third, the internal rate of return is found by solving a polynomial equation of degree 20. Coefficients of the equation are derived from internal capital outlays at the beginning of year 1 and year 11, annual cash flows, and salvage value at the end of year 20. 21/ Internal capital outlays depend on total capital requirements (tables 23 and 24) and assumptions concerning capital structure. Annual cash flow equals accounting profit or loss, plus depreciation and minus capital debt retirement. Thus, annual cash flow represents a residual payment for the use of internal (ownership) capital. Income taxes, calculated using corporate tax rates, include a 7 percent investment tax credit for pollution control facilities, which may be carried forward 7 years and backward 3 years. The possibility of rapid amortization of pollution control facilities is not considered. The salvage value of land, buildings, equipment, and inventory at the end of the planning horizon is arbitrarily assumed to be zero. This assumption is imposed because of the difficulty of forecasting the salvage value of processing plant assets 20 years in the future.

Results of the economic feasibility analysis are shown in Figures 4-7. Model plant A is not included because annual cash flow is negative throughout the planning horizon,

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21/ Solutions or roots, which become internal rates of return, are found by setting the polynomial equation equal to zero. The number of roots is determined by the degree of the equation. That is, quadratic equations have two roots, cubic equations have three roots, and so on. In higher degree polynomials, serious difficulties may arise in interpreting multiple roots. Fortunately, the values of the polynomial coefficients used in this study yield one positive real root, resulting in a unique and economically meaningful internal rate of return.

assuming no pollution abatement. Clearly, the possibility of constructing such a small processing plant (that is, annual raw tomato requirements of 2,053 tons) is not economically feasible, and it is expected that existing plants in this size category will rapidly drop out of tomato processing irrespective of environmental regulations.

Private waste treatment systems attached to each model processing plant are designed to handle maximum daily flows of waste water. Maximum flows are based on plant engineering specifications and assumed distribution of raw input supply over the processing season. Estimated maximum waste water flows are: 1.0 million gallons per day (MGD) for model plant B, 2.0 MGD for model plants C and D, and 4.0 MGD for model plant E.

The following secondary waste treatment systems are considered: (1) in-plant screening plus aerated lagoons; (2) in-plant screening plus aerated lagoons plus holding ponds; and (3) in-plant screening plus activated sludge. System (1) is expected to give 95 percent BOD removal, which may provide adequate effluent reduction to comply with EPA regulations to be met not later than July 1, 1977. However, most experts agree that the equivalent of systems (2) and (3), that is, 98 percent BOD removal, will be required to comply with EPA regulations to be met not later than July 1, 1983. In broad terms, systems (2) and (3) represent the range of secondary waste treatment systems likely to be used by tomato processors. The capital and operating costs of other secondary systems--such as in-plant screening plus trickling filters plus aerated lagoons--would tend to fall between systems (2) and (3). Therefore, it is hoped that careful evaluation of systems (2) and (3) places upper and lower bounds on the economic feasibility of secondary waste treatment.

Even without pollution control, internal rates of return earned by model processing plants in the East and Midwest are surprisingly low, ranging from 7.3 percent to 12.1 percent. If the longrun opportunity cost of capital is 8 percent, the decision to invest in model plant B or C should be rejected. 22/ Recall that model plants B, C, and D represent intermediate size processors, large processors with a diversified product mix, and large processors with a specialized product mix, respectively.

22/ A realistic estimate of the opportunity cost of capital (i) is difficult to determine. In this study, it is assumed that i equals the cost of borrowed capital. Of course, i may be higher or lower, depending on the investment opportunities available to the firm.

The order in which the management of model plant B would rank the alternative waste treatment strategies is clearly indicated in Figure 4. The most favorable strategy is in-plant screening plus municipal treatment, resulting in an internal rate of return of 4.5 percent using current municipal treatment rates, or 4.0 percent using expected future treatment rates. If the municipality requires pretreatment activity, such as sedimentation, the internal rate of return declines to 1.8 percent. The most unfavorable strategy for model plant B is in-plant screening plus activated sludge, resulting in an internal rate of return of minus 7.3 percent. Capital-intensive secondary waste treatment systems are not feasible alternatives for intermediate size plants. Final disposal systems, involving spray irrigation and evaporation-percolation ponds, rank below municipal treatment but above the secondary systems. If land can be bought at less than $1,700 per acre, the relative desirability of both spray irrigation and evaporation-percolation ponds would increase. Model plants C and D are very similar in terms of average plant capacity, capital investment requirements, and waste load (figs. 5 and 6). The overall ranking of alternative waste treatment strategies is unchanged from model plant B. However, the internal rate of return earned by model plant D--characterized by a specialized product mix--averages 5-6 percent above the rate earned by model plant C--characterized by a diversified product mix. For example, assuming screening plus municipal treatment (using expected future rates), model plant D earns 8.8 percent and model plant C earns 3.2 percent. If we assume screening plus spray irrigation, model plant D earns 7.8 percent and model plant C earns 2.9 percent. Secondary waste treatment systems continue to yield relatively low internal rates of return. Model plant D is the only East-Midwest plant with sufficient taxable income to take full advantage of the 7 percent investment tax credit for pollution abatement facilities.

Model plant E represents large, diversified processing plants in California. Internal rates of return for model plant E (fig. 7) range from 12.9 percent for screening plus activated sludge, to 17.6 percent for screening plus municipal treatment (using expected future rates). Screening plus spray irrigation continues to rank second among the waste treatment strategies, with an internal rate of return equal to 15.4 percent. Secondary waste treatment systems appear relatively more favorable because of economies of size, and the tendency for land requirements of ultimate disposal systems to increase in constant proportion with the volume of waste water discharged. Unlike the smaller processing plants, annual cash flows earned by model plant E are sufficiently large so that all secondary treatment systems are economically feasible.

From this analysis we conclude that a larger proportion of the tomato processing plants in the East and Midwest will have

Internal Rates of Return After Taxes Assuming No Pollution Abatement and Alternative Waste Treatment Strategies, Model Plant B

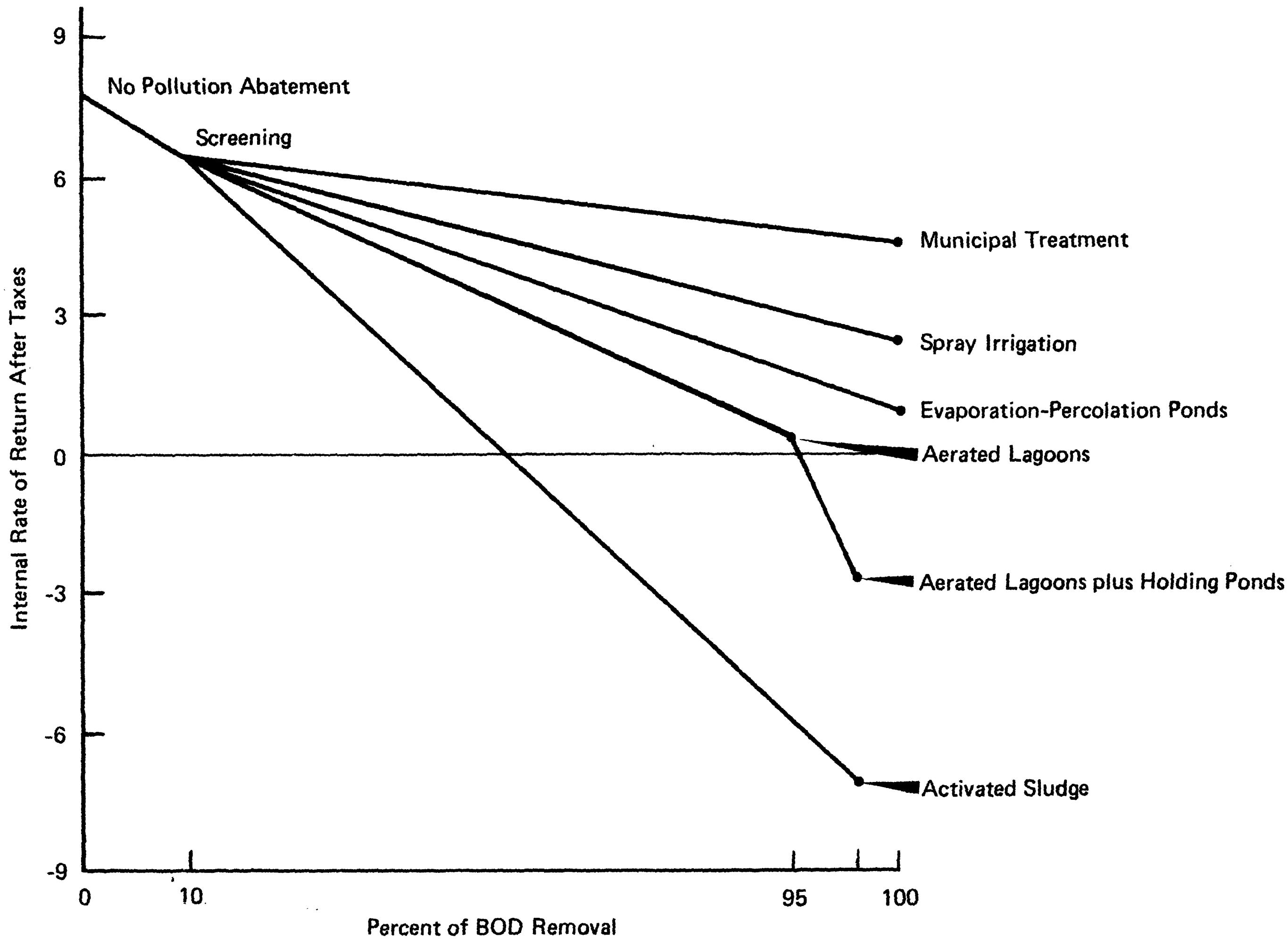

Figure 4.

Internal Rates of Return After Taxes Assuming No Pollution Abatement, Municipal Treatment, and Ultimate Disposal Systems, Model Plants C and D

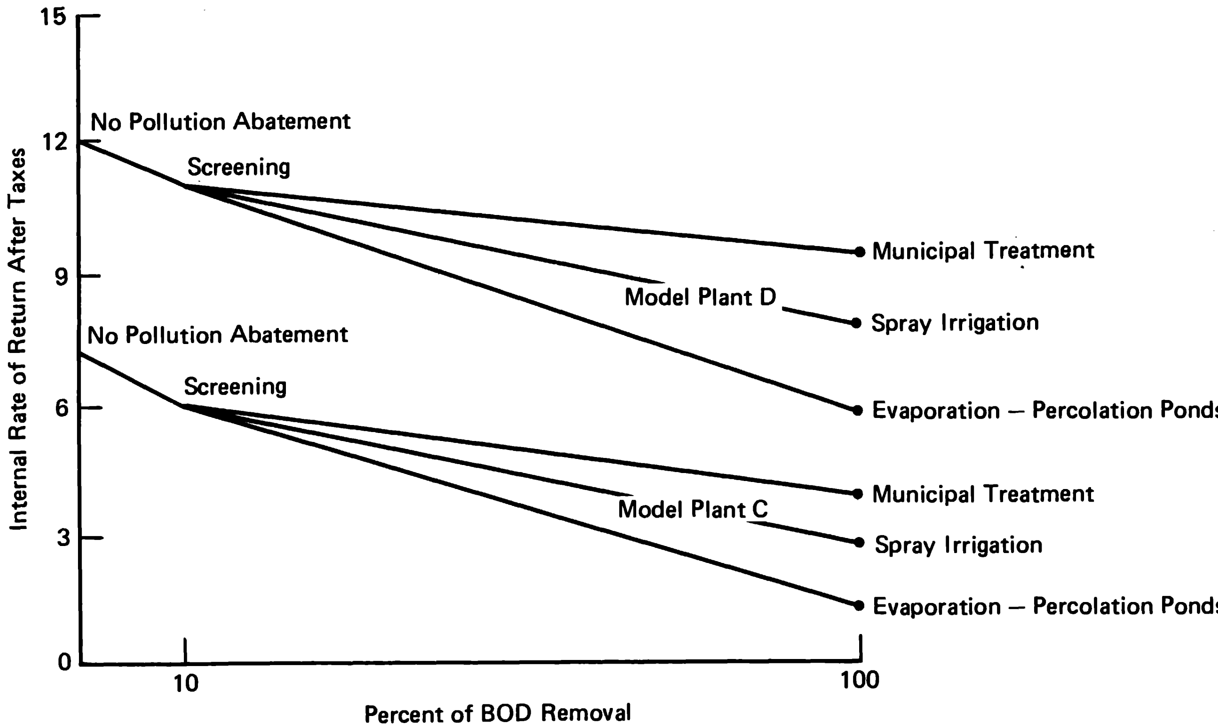

Figure 5.

Internal Rates of Return After Taxes Assuming No Pollution Abatement and Alternative Secondary Waste Treatment Systems, Model Plants C and D

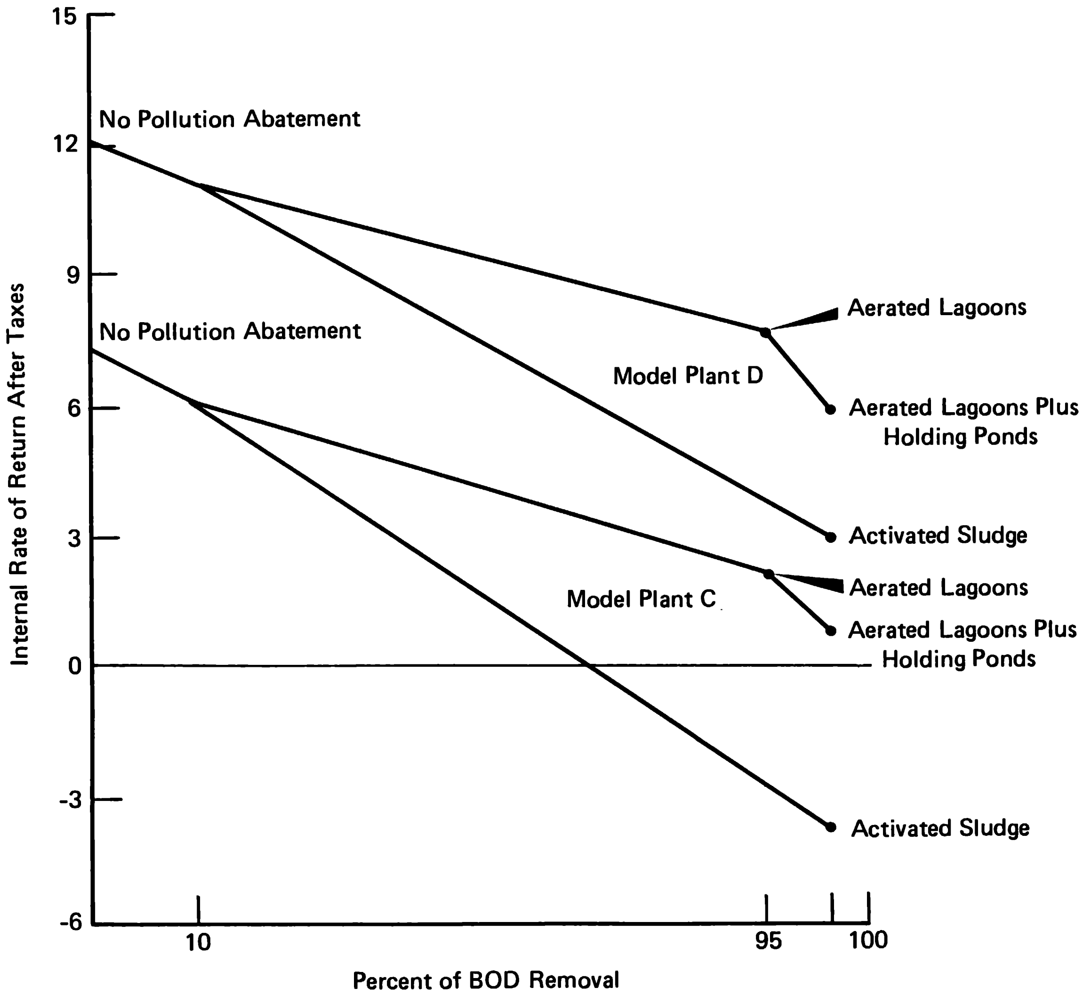

Figure 6.

Internal Rates of Return After Taxes Assuming No Pollution Abatement and Alternative Waste Treatment Strategies, Model Plant E

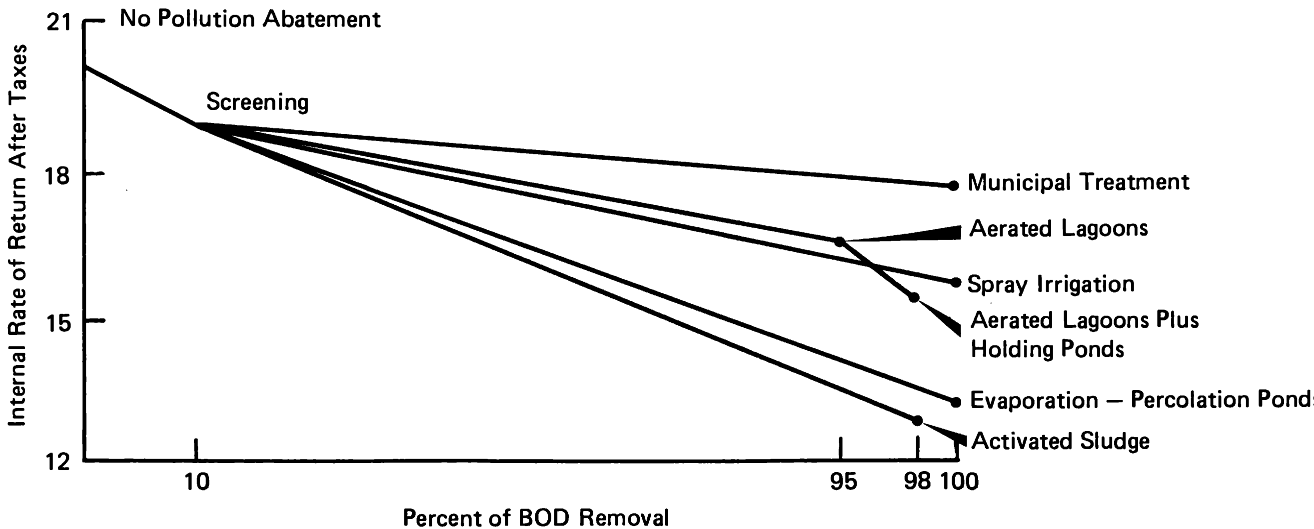

Figure 7.

serious economic difficulty in complying with forthcoming environmental regulations. About 70 percent of these plants fall in the small and intermediate size categories represented by model plants A and B. Clearly, there is no economic incentive to build new plants of this type. Some existing plants continue to operate because their capital assets are fully depreciated and/or the use value of productive resources exceeds current salvage value.

If management has to decide whether to invest in pollution abatement technology, it should recognize that the rate of return on new ownership capital is less than its opportunity cost, and therefore decide to close down. Even if management is willing to accept an extremely low internal rate of return, most commercial lending agencies would not risk loans to processors with unfavorable annual cash flows. In the case of plants discharging to municipal treatment, management will decide to close down if rising municipal sewage rates and pretreatment costs cause the use value of the processing plant to fall below its salvage value.

Between 1970 and 1974, the number of small and intermediate size processing plants declined from 79 to 50 in the East, and from 46 to 42 in the Midwest. 23/ Considering the profit-loss statements and economic feasibility analyses for model plants A and B, the remaining 92 plants will probably rapidly disappear. However, this estimate should be viewed as an upper limit on plant closings, since the assumptions underlying model plants A and B cannot possibly be representative of all small and intermediate size plants. Some managers may be willing to accept very low rates of return on internal capital. Other plants may have unusually low pollution control costs because of favorable municipal treatment rates or access to inexpensive land for spray irrigation. Recognizing these factors, the 49 eastern and midwestern plants represented by model plant A may serve as a lower limit on plant closings in these categories. However, only a small proportion of the 43 eastern and midwestern plants represented by model plant B are likely to continue operating after EPA regulations for 1983 have been fully implemented. It is estimated that the number of small and intermediate size processing plants in the East and Midwest will range from 37 to 45 plants in 1977 and from 5 to 7 plants

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23/ Estimated plant numbers are based on volume codes D, C, and B given in tables 6 and 8.

in 1983. 24/

The number of large processing plants declined from 25 to 22 in the East between 1970 and 1974, but held constant at 21 plants in the Midwest.25/ Model plant D, representing large-volume processing plants specializing in tomato juice and catsup, has an economic advantage for all waste treatment strategies, and appears to have a relatively strong economic future. Model plant C, representing large eastern and midwestern processors with a diversified product mix, is in a position similar to the smaller processing plants. It is expected that 20-22 large eastern and midwestern plants of this type will close. Plant closings will result in increased average plant size and a definite trend toward increased specialization. Large plants in the East and Midwest are projected to drop to 28-32 plants in 1977 and 15-19 plants in 1983. Most of the tomato processing wastes will be handled through municipalities or land disposal.

Between 1970 and 1974, the number of small tomato processing plants in California declined from 26 to 13, but

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24/ Plant numbers for 1977 and 1983 presented in this section were estimated, using a balance sheet approach to integrate information on the economic feasibility of model plants, plant numbers and capacities by regions, and expected trends in farm production and utilization of processed tomato products. The balance sheet guarantees sufficient domestic processing plant capacity to satisfy U.S. consumption plus exports minus imports. Information inputs, such as projected consumption and foreign trade, are based on data presented earlier in the report. For example, U.S. per capita consumption of processed tomato products is estimated at 21.8 pounds in 1977 and 23.1 pounds in 1983, using equation (1), table 14. Regional production shares follow the patterns indicated in table 5. That is, the level of production declines in the East and Midwest, with the greatest decline in the East, and expands in California. Plant capacities are estimated, using firm volume codes and plant numbers published by Edward E. Judge and Sons (12) and the assumption that the distribution of plant capacities is proportional to the distribution of firm volume codes. In 1974, 42 percent of the tomato processing firms in the East were classified in volume code D, leading to the conclusion that about 30 eastern plants (= .42 x 72 plants) are represented by model plant A. Also, the technical rate at which U.S. processors convert raw tomatoes into tomato products is assumed to equal the annual average for 1972-74.

25/ Estimated plant numbers are based on volume codes A and larger, given in tables 6 and 8.

the number of large plants increased from 29 to 31. 26/ This trend is expected to continue. Large California processors will probably find it considerably easier to adjust to environmental regulations than other processors. In fact, capital-intensive secondary waste treatment systems are likely to be used at many of the large plants. Because of economies of size, secondary systems tend to promote larger volume plants. With the expansion of production in California and the decline in the East and Midwest, it is estimated that large California plants will number 32-34 plants in 1977 and 35-37 plants in 1983.

Total industry capital and annual operating costs of meeting environmental regulations depend on many factors. Among the most important are the level of effluent cleanup required by EPA, the availability and cost of alternative waste treatment systems, and the rate at which plants are closed or consolidated. Assuming that EPA requires 98 percent BOD and SS removal and the industry disposes of 50-65 percent of its waste water through municipal treatment, 10-20 percent through secondary treatment systems, increases in total industry capital costs will probably range from $27.6 to $35.4 million and annual operating costs from $4.6 to $6.2 million.

Final Product Price Increases

The increase in capital and operating costs associated with environmental regulations are likely to increase final product prices. That is, tomato processors are not likely to absorb the added costs of pollution abatement entirely through lower profits or reduced output. Longrun product price increases will be determined by pricing policies of the industry.

In an industry characterized by many small firms, there are no supernormal profits, no one firm has price-setting power, and longrun price increases will about equal per unit cost increases. In an industry characterized by concentration of economic power, there are often supernormal profits, and final product prices depend on policies of firms having price-setting power. The tomato processing industry is believed to lie somewhere between these two extremes.

The final product price increases in table 27 were calculated, assuming the model processing plant has sufficient market power to increase its final product prices so that it will maintain the rate of return with or without pollution

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26/ Volume codes AAA and AAAA given in tables 6 and 8 are used to estimate the number of large plants. All other plants are classified as small.

abatement. For example, if the management of model plant D elects to satisfy EPA regulations using in-plant screening plus spray irrigation, final product prices would increase at the annual rate of 1.8 percent in order to achieve an internal rate of return of 12.1 percent, equal to the rate with no pollution abatement. Adding the final product price increase due to pollution control to the 3-percent rate of increase assumed in the data generator would raise final product price about 5 percent per year over model plant D's 20-year planning horizon.

Table 27 --Annual final product price increases for alternative waste treatment strategies

Alternative waste treatment strategies	Model plants			
	B	C	D	E
Screening plus --		Percent		
Municipal treatment (expected future rates)	1.1	1.1	1.0	1.1
Spray irrigation	1.9	1.5	1.8	2.2
Evaporation-percolation ponds	3.4	2.6	3.3	4.0
Aerated lagoons	3.5	1.8	2.0	2.1
Aerated lagoons plus holding ponds	4.2	2.7	2.8	3.0
Activated sludge	5.1	3.2	3.7	4.2

The lowest annual final product price increases occur under in-plant screening plus municipal treatment and the highest under in-plant screening plus activated sludge. If processors aim to achieve internal rates of return equal to those earned under no pollution abatement and if processors represented by model plants D and E play a leading role in pricing, we can expect increases in final product prices ranging from 1.0 percent to 4.2 percent per year. Price increases of this size are expected to have only a small impact on the consumption of processed tomato products. For example, a 3-percent increase in the index of canned tomato prices would cause per capita consumption of processed tomato products to fall only about 0.4 percent (table 14). Furthermore, this decline in consumption would be more than offset by a 2-percent increase in real consumer income.

At least two cautions should be exercised in interpreting the annual price increases in table 27. First, all reported price increases result in extremely low internal rates of return for model plants B and C. If model plant C adopts a waste treatment system involving in-plant screening plus evaporation-percolation ponds and is able to increase its final product prices 5.6 percent per year, its internal rate of return would be only 7.3 percent. A more acceptable internal rate of return, say 12 percent, would require a final product price increase of about 9 percent to 10 percent. Second, since the model processing plants differ with respect to final product mix, average final product prices also differ. Therefore, a 5-percent final product price increase in year 1 equals $0.25 per case of final product at model plant C, but only $0.22 at model plant D.

Other Effects of Pollution Control

Environmental regulations will have several other direct and indirect effects. Two of the most important--impact on local communities and structural change--are considered here. Other factors, such as the impact on the U.S. balance of payments, are ignored. Clearly, if prices of processed tomato products rise, imports will increase at the expense of domestic production, but the reduction in our balance of payments is expected to be minimal.

The introduction of environmental regulations is likely to accelerate the decline of the tomato processing industry in the East and Midwest. These regions now account for about 20 percent of U.S. processing tomato production, but by 1983, it is expected their share will drop to 13 percent and only the Midwest will remain important. As small and intermediate size plants close, communities in which these plants operate will suffer. The size of the economic disruption will depend largely on the availability of other employment opportunities for displaced resources.

Earlier in this report, the direct economic contribution of a processing plant to the local community was estimated at $139.52 per ton of raw tomatoes processed. That is, an intermediate size processor in the East or Midwest contributes about $1.4 million per year to the local economy. 27/ In 1972-73, tomato processors in the three regions employed about 51,000 workers during the processing season and 15,500 workers during the rest of the year. About 30 percent of the labor force is in the East and Midwest. In addition to plant workers, farmers, manufactured input suppliers, and local merchants depend on the processing plants for a part of their livelihood.

27/ The profit-loss statement for model plant B, given in table 21, indicates this estimate may be slightly low.

Comparing 1974 and 1983, the estimated decline in the annual direct economic contribution of the tomato processing plants to local communities in the East and Midwest is 60 to 65 million dollars. About 70 percent of the reduction will occur in the East. Also, a loss of 8,120 jobs during the processing season and 1,100 jobs during the rest of the year is expected.

The ultimate economic impact of plant closings depends on the reemployment opportunities for displaced resources. Although adequate data are not available to fully consider this problem, some rules of thumb are suggested. Tomato processing plants are highly concentrated geographically, and local economic impact may tend to be more severe than for geographically dispersed industries. The closing of older, small plants will result in a disproportionate loss of jobs because new plants are more mechanized than old plants and require less labor per ton of tomatoes processed. Alternative employment opportunities are expected to be most scarce in rural areas. The economic impact of plant closings will be less severe on part-time than on full-time workers. On the other hand, an increase in the number and volume of large plants will probably have a positive net economic impact on local communities in California.

In addition to adverse community impacts, environmental regulations will bring about changes in the structure and performance of the tomato processing industry. The food processing industry has historically been regarded as highly competitive, characterized by a large number of firms and plants. However, the number of tomato processing plants in the three major producing regions will likely decline from 180 plants in 1974 to 59-68 plants in 1983. As the number of plants decline, the market share held by the largest firms will increase and competition will drop. The increased market power of a few large processors may be used in product pricing and competitive strategies at the expense of consumers, and in the procurement of supplies. Tomato growers may find the decline in the number of alternative buyers (processing plants) particularly serious because of product perishability and the high cost of transporting raw tomatoes to more distant plants.

APPENDIX I

ECONOMIC MODEL

This section presents a conceptual framework for analyzing the implications of point source water pollution control in the processing tomato industry. The discussion is based on the premises that: (1) water quality is a resource base, and (2) ownership of water quality is vested in the community. 28/ Water quality is a common property resource and the community is responsible for efficient and equitable control of its use over time.

A static, partial equilibrium model is used to establish the rationale for pollution control, indicate the direction and implications of needed change, and analyze firm behavior under environmental regulations. The model demonstrates the difficulty of imposing a socially optimal effluent limitation, given changing community environmental preferences and alternative pollution abatement technologies. The general approach of this study is to build from microeconomic units to determine the industry impacts of the FWPCA on final product prices, profits, plant closings, structure, regional location, and performance.

Introduction

The analysis begins with a hypothetical profit-maximizing, food processing plant. The plant is viewed as a technical unit that transforms m resources into n outputs, subject to the rules specified by its production function. Assuming our model is "well-behaved," and the first- and second-order conditions are satisfied, we may derive the firm's m resource demands:

$$(1)\quad X' = D(C,P)$$

and n product supplied

$$(2)\quad Y' = S(C,P)$$

where X and Y denote (1 x m) and (1 x n) quantity vectors of resources and final products, respectively; and C and P denote corresponding price vectors.

The properties of (1) and (2) describe the behavior of the

28/ Boundaries of the community are probably best determined by the physical linkage, either actual or potential, of water uses and users.

firm (see discussin in 6, pp.454-61; 19, pp.782-3). The strongest restrictions are that resource demand is negatively related to own-price, the cross-price slopes are negative if two resources are complementary in production, and the product supply is positively related to own-price. The remaining partial derivatives of (1) and (2) are a priori indeterminate. Throughout this study, we assume the firm uses water in the production process and that pollutants are discharged in the form of waste water.

Substituting free market prices 29/ into the behavioral relation gives initial equilibrium values (X_1, Y_1), denoting a production plan characterized by excessive point source water pollution. That is, we impose the assumption that members of the community have issued a mandate to "do something about improving the water quality of the region," and that point source pollution has been identified as an undesirable factor. When the firm discharges waste water, it damages water quality and reduces the community's consumption alternatives. Therefore, the common property resource--water quality--is no longer free and decisions must be made concerning its allocation among alternative uses. It follows that the cost of using water quality in industrial waste disposal is determined by the value of opportunities foregone by the community.

Point source water pollution problems arise because property rights are not fully defined and because of interdependence among decisionmaking units. Without government intervention, the free market does not reflect the community's property rights in the allocation of common property resources. Privately owned resources are allocated among competing uses via market prices, which indicate their opportunity costs and encourage conservation. On the other hand, a firm discharging waste water into a nearby stream is not required to recognize the value (or opportunity cost) of water quality destroyed. Water quality, a scarce common property resource, goes unpriced, reflecting a failure of the free market.

We recognize the physical linkage among users of water quality, as well as users' interdependence in decisionmaking. When a firm discharges waste water, the community's water quality is lowered (a negative externality is created). The cost of pollution is not borne by the polluting firm, but by members of the community who want to use the water at downstream sites. The interests of the two parties--polluting firm and community--are mutually opposed. The firm's decision

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29/ A set of prices derived in a smoothly functioning, competitive market place characterized by many buyers and sellers and the absence of government intervention.

to discharge waste water is detrimental to the community, but society's decision to control the discharge of waste water is detrimental to the firm because of the cost of pollution abatement.

The government intervenes to correct the free market failure by placing the cost of pollution abatement on the polluting firm, rather than on the community. Specific environmental regulations attach a price to the use of common property resources. The price may be explicit as in the case of a tax (paid by the polluter) or a bribe (paid to the polluter), or implicit as in the case of an effluent limitation. 30/ A use price will increase the cost of pollution-intensive methods of production, promote pollution abatement, and reduce consumption of pollution-intensive products.

Graphical Analysis of Firm Behavior

Figure 8 (a and b) presents the firm's demand for a single resource (x) (water used and discharged) and supply of a single product (y). The axes are defined as follows:

c--water acquisition and disposal cost

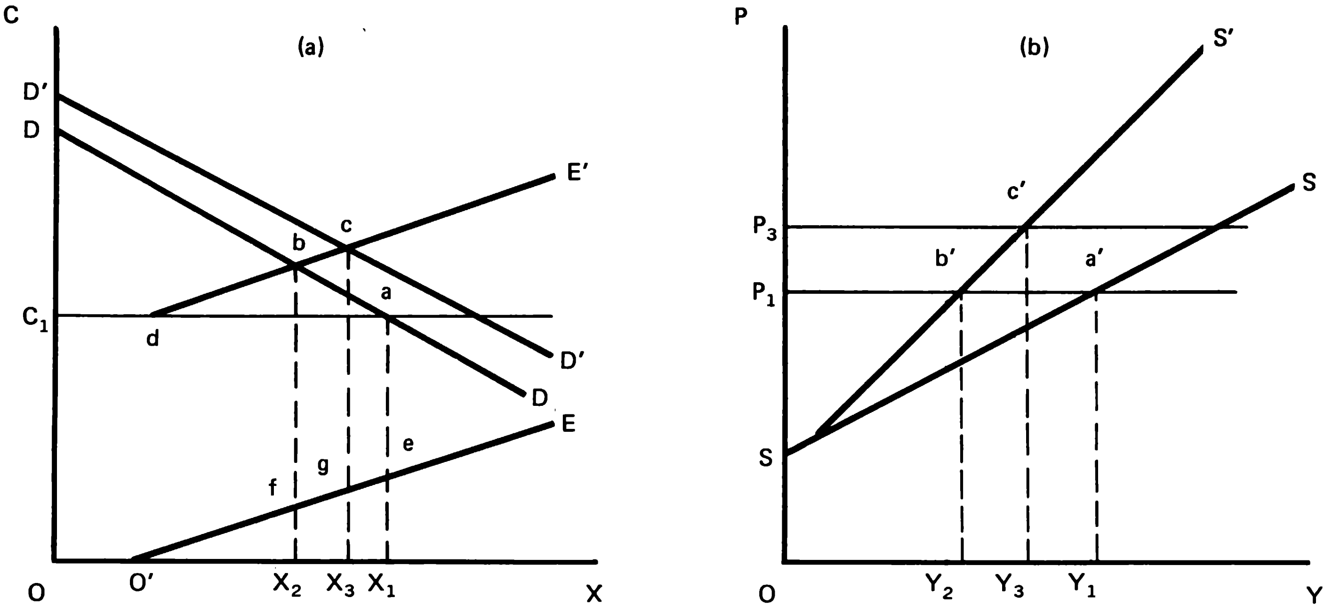
x--quantity of water used and discharged

p--product price

y--quantity of product sold.

30/ For a given effluent limitation there is a tax which will lead the firm to an identical production decision (16, p. 316).

The Firm's Resource Demand, Product Supply, and Environmental Damage Function[1]



[1]*Linear relations are used to simplify the graphical presentation.*

Figure 8.

The firm views its supply of water and waste disposal services and product demand as perfectly elastic. Also, we continue to assume that the firm's decision to discharge waste water damages the quality of the community's water.

The firm's behavioral relations are represented by DD in the resource market and SS in the product market. The profit maximizing firm uses resource x up to the point where the marginal value product of the resource equals its supply price (as perceived by the firm), and the marginal cost of producing y equals the marginal revenue generated. Graphically, these conditions are satisfied at points a and a′, denoting a free market solution. The firm's economic gain from the unrestricted use of water (and water quality) is equal to the area of ΔC_1aD, holding other resource and product prices constant.

Since the discharge of waste water adversely affects the community, the firm's environmental damage function (E) is introduced. The hypothetical damage function presented in Figure 8 (a),

$$(3)\quad E = E(x \mid \ldots\ldots)$$

reflects the marginal external cost associated with the firm's use and discharge of water. Thus, the graph illustrates the effect of changes in water quality caused by the firm's production activities, measured in dollars per unit of water used and discharged. We assume that over an initial range, O to O′, the environment can assimilate and remove the pollutants discharged by the firm and there is no perceptible change in water quality. However, beyond O′, water quality declines steadily, or environmental damage increases, as the firm uses and discharges larger quantities of water. We also assume there is a positive relationship between the rate at which the firm uses x and the pollution generating inputs (say, raw tomatoes). The external cost of the free market solution is equal to the area under the firm's damage function, or $\Delta 0'x_1e$, which measures the value of opportunities the community must forego because of the firm's decision to use and discharge x_1 units of water.

The damage function is constructed assuming a given set of community preferences with respect to water use, and a given state of pollution abatement technology. Community environmental preference, or the manner in which the community wishes to use its water, influences the external cost of a given volume of waste water. For example, suppose a river can be used for one of the following activities: (1) industrial water supply, (2) water contact sports, or (3) public water supply. Since each activity requires a successively higher water quality, which is increasingly costly to attain, the marginal external cost of x increases as we move from activity

(1) to (3). In recent years, community preferences have apparently shifted in favor of activities requiring high quality common property resources.

The environmental damage function is also influenced by the pollution abatement technology employed by the firm. Suppose Figure 8 depicts a processing plant using only in-plant screening of waste water prior to discharge. If the firm adopts additional pollution abatement technology (say, an evaporation-percolation pond), which will increase waste water disposal cost but will do a better job of cleaning up the effluent, the marginal external cost of x' is reduced. Of course, in the absence of government regulation, the firm assigns a zero price to the common property resource and has no incentive to adopt an effective pollution abatement program.

Recognizing that the measure of environmental damage--the effect of pollution on the common property resource--depends on the quality of water demanded by the community and the effectiveness of existing pollution abatement technology, we define the environmental damage function (E) in Figure 8 (a) as follows:

$$(3') \quad E = E(x \mid P_2, T_1, \ldots \ldots)$$

where P_2 denotes the community s desire to use the river for water contact sports, and T_1 denotes pollution abatement technology equivalent to in-plant screening of waste water. Many other factors may influence E. They include the volume and characteristics of waste water discharged by other polluters, and hydrological characteristics of the river. We assume these remain constant.

Adding the environmental damage function to the cost of water and its disposal gives C_1dE'. If the firm is required to pay the external cost of discharging waste water, the quantities of water used and the product sold will drop to x_2 units and y_2 units, respectively. The revised cost of water and product supply (SS') is obtained by adjusting the free market relations for the marginal external cost of water pollution initially ignored by the firm. At the new equilibrium, denoted by points b and b , the marginal value product of x equals its adjusted supply price, and the marginal private and external cost of production equals the marginal revenue generated. The profit maximizing levels of x and y are reduced, the firm pays an amount equal to $\Delta O'x_2f$ for use of the common property resource, and the economic gain from the use and discharge of water is equal to area C_1dbD.

Points b and b represent a shortrun equilibrium. If each firm is required to pay the marginal external cost of discharging its waste water, the industry product supply function will tend to shift upward and to the left. As the production cost of the firm rises, its survival will depend on excess profits and/or an upward shift in its product demand function. Firms that cannot cover average costs after all adjustments will be forced to shut down. In Figure 8 we assume that a shift in industry supply causes product price to rise from P_1 to P_3, increasing the firm s water use from x_2 to x_3 and output from y_2 to y_3. D´D´ represents the firms´ demands for water after the external cost of water pollution is imposed, allowing time for price-quantity adjustments in the product market.

A socially optimal resource allocation is reached at points c and c´. Once the firm decides to use and discharge x_3 units of water, private and external cost will equal $[C_1x_3 + 0'x_3g]$ and its economic gain will equal the area C_1dcD'. Given the community´s environmental preferences (that is, the desire to use the river for water contact sports) and the firm´s pollution abatement technology (that is, in-plant screening) 31/, the reduction in output from y_1 to y_3 and in water used and discharged from x_1 to x_3 yield a longrun equilibrium.32/ That is, the community is satisfied with the tradeoff between the reduction in product supply and the increase in pollution control (or improved water quality). For more restrictive pollution control (that is, some $x<x_3$), the value of final product given up exceeds the reduction in private and external cost; and for less restrictive pollution control (that is, some $x>x_3$), the value of additional final product is less than the increase in private and external costs.

Three important observations can be drawn from this discussion. First, a socially optimal resource allocation does not require that the negative externality be completely eliminated, but it does require that the externality be limited to the right amount. The environment´s natural capacity for self-cleaning is fully utilized and a tradeoff between product supply and water quality is recognized. Second, introducing the external cost of the product decision changes the product price and the distribution of economic

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31/ By assumption, the firm is forced to continue using its existing pollution abatement technology. In a more realistic setting, this would be viewed as only one of several alternative strategies and would not necessarily be selected.

32/ It is possible for x_3 to shift to the right of x_1, depending on the magnitude of the change in product price (15, p.3). Also, if y_3 is to the right of y_1, we may conclude that the industry is made up of fewer and larger firms in the longrun, since reduced product supply is expected at the industry level.

surplus. In the real world, the final outcome of pollution control will largely depend on the respective bargaining powers of the firm versus the community. The introduction of government-sponsored environmental regulations reflects the weakness of the community's free market bargaining power. Third, the longrun equilibrium level of pollution control will tend to change over time, subject to change in community environmental preference and/or efficiency of pollution abatement technology. Monitoring these changes and adjusting environmental regulations in an appropriate manner will be a complex task.

Costs and Implications of Pollution Control

In the preceding section, we assumed that the firm must recognize the external cost of its decision to discharge waste water. This allowed us to concentrate on the effects of pollution abatement without considering environmental policy. Now, we briefly turn our attention to the policy issue, and to the Federal Water Pollution Control Act of 1972 in particular.

Environmental policy must relate the objectives of the community to the organization, coordination, and control of our common property resources. To accomplish this, FWPCA directs the EPA to establish effluent limitations, issue industrial and municipal discharge permits, and specify a timetable for cleaning up our waters.

EPA must impose an effluent limitation (or pretreatment standard if the firm discharges to a municipality) that induces the firm to use and discharge x_3 units of water and produce y_3 units of final product (fig. 8). Assuming the agency imposes the optimal effluent limitation, the firm interprets the environmental constraint as follows: The price of using the common property resource is C_1 up to x_3; beyond that level the price is infinite.

The supply of waste disposal capacity available to the firm is fixed at x_3 units, and the imputed marginal value of the constraint in terms of the firm's objective is $\emptyset g$ (or $C_1 c$) dollars per unit of water used and discharged. This is the price at which the marginal value of water quality in waste disposal equals its marginal value in alternative uses specified by the community.

Effluent limitations offer the advantage of political equity, since each firm must comply with regulations, expressed in terms of maximum quantities of selected pollutants per unit of raw input processed. But, once the firm has satisfied the effluent limitation it does not have a continuing incentive to reduce the discharge of pollutants, as in the case of an effluent tax. Also, the community is not likely to receive efficient pollution abatement, since uniform effluent limitations will not equate the marginal cost of removing a unit of pollution among firms with different volume of output, product mix, production processes, and geographical location.

Investing in Pollution Abatement Technology

We have discussed a special case in which the firm is able to satisfy the environmental regulation by reducing final product output and water used and discharged, without changing its pollution abatement technology. We now expand our discussion and assume that the firm considers alternative pollution abatement technologies (T_2, T_3,.....,Tg). 33/ In many real world situations, a firm cannot comply with a particular environmental regulation using its existing technology, or a more profitable technology may be available. Since the decision to adopt a new pollution abatement technology typically involves capital investment, the analysis must be extended to multiple time periods, and the firm must find a means of comparing technologies with differing capital investment requirements and annual operating costs.

The profit maximizing firm seeks a pollution abatement technology that satisfies environmental regulations and maximizes--in present value terms--the sum of annual cash flows plus the salvage value of physical facilities and inventories minus internal (or ownership) capital requirements over the planning horizon. Annual cash flow is a residual payment for the use of internal capital, and the time discount factor is the market rate of interest (i). Internal capital measures the direct investment of owner's capital to purchase the services of durable assets such as land, buildings, and equipment; and i is assumed to measure the opportunity cost of capital.

If a firm can find the pollution abatement technology that will yield a maximum present value, a maximum rate of return on internal capital will be realized. The internal rate of return (r) is the time discount factor which makes the present value of the entire stream--internal capital outlays, annual cash flows, and salvage values--equal to zero. If the present value of a pollution abatement technology is positive, r is greater than i, and owners of the firm find it profitable to invest their capital internally. If present value of a production plan is negative, r is less than i, and the owners have no

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33/ Pollution abatement technology includes both end-of-pipe treatment and production process modifications. The former emphasizes changing the form of the pollutant, or the medium to which it is discharged; the latter is concerned with reducing the generation of pollutants.

economic incentive to invest their capital internally. In fact, they should liquidate the firm and receive a rate of return equal to i by investing their capital elsewhere.

The internal rate of return is a central concept of investment theory and a convenient summary statistic which can be used to compare alternative investment opportunities. If r for an investment over n years is equal to λ, the businessman is justified in thinking that his investment is equivalent to one in which his internal capital outlay is compounded forward at the annual rate of λ for n years. Since investment in pollution abatement technology increases the firm's internal capital requirement and annual costs, r tends to fall. Theoretically, the firm will select the pollution abatement technology yielding the highest r, provided r is equal to or greater than i. If r is less than i after investment in pollution abatement technology, the firm has an economic incentive to shut down.

The above assumption that investment in pollution abatement technology causes the firm's internal capital requirement and annual cost to rise is generally valid. For example, end-of-pipe technologies are neutral to in-plant production processes. However, some in-plant technologies that are introduced to help satisfy environmental regulations may increase production efficiency, and there may be economies of size in pollution abatement that will alter cost structures in favor of firms with large output.

In evaluating investment decisions, it is important to distinguish between a potential entrepreneur considering whether to set up business (and therefore be at the beginning of a planning horizon) and a firm already in operation (3, pp. 747-59). A new entrant selects the investment plan yielding the highest internal rate of return, and employs each resource up to the point where use value (that is, marginal value product) equals acquisition cost, taking the time dimension of the planning horizon into consideration. An established firm continues operating provided the use value of durable resources exceeds their salvage value, even though current salvage value may be well below acquisition cost. Such resources are fixed or trapped in production because of the difference between acquisition cost and salvage value; this may be an important factor explaining why small, seemingly obsolete processing plants remain in business. 34/

At any given time, the salvage value of a resource depends on its age, extent of specialization, location, and general

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34/ Darrell Good uses two sets of cost curves generated by valuing durable resources at their acquisition cost and salvage value, in his discussion of fixed resources (8, pp. 60-85).

economic conditions. Certain resources have few alternative employment opportunities and tend to be used in specialized production, almost without regard to their earnings, because their salvage value is nil. However, low returns on durable capital (that is, capital losses) should not persist in the longrun, since capital resources are eventually worn out and will not be replaced unless their use value exceeds acquisition cost.

Some Additional Considerations

The introduction of environmental regulations is likely to have many economic consequences that are not immediately obvious in our partial equilibrium analysis. For example, it is important to consider the fate of unemployed resources if environmental regulations result in plant closings and regional shifts in production. It is often assumed that displaced resources are able to move to equally favorable employment alternatives. However, this assumption is unrealistic when dealing with geographic regions in which economic activity is depressed; or when considering the future of resources, such as unskilled labor and highly specialized capital assets. Plant closings adversely effect local economic activity as a result of direct and indirect adjustments. Initially, community employment falls and resource suppliers find their market eliminated, or at least reduced. This leads to reduced consumer and business spending, which causes indirect or second-round reductions in economic activity. Eventually, the community may experience an outmigration of population.

Our increasing concern with the environment has placed an additional element of uncertainty in the businessman s decisionmaking. One important source of uncertainty is the degree of environmental quality that will eventually be demanded by society. Also, many firms are inexperienced in the area of waste management, and often lack information concerning the effectiveness of alternative pollution abatement technologies. It has been argued that uncertainty due to environmental regulations and practices affects firm behavior much like an output tax, leading to reduced product supply and higher prices (16, p.320). At the very least, the businessman must recognize the possibility of rapid obsolescense of equipment and facilities due to changing technology and environmental regulations. Environmental uncertainty may have a differing effect among firms, since larger firms often have an advantage in obtaining information about current and forthcoming regulations, and in dealing with the technical aspects of pollution control.

Domestic environmental regulations may also influence international trade (2, pp.420-65). The primary argument for free international trade is that it permits a country to import products that can be produced cheaply abroad in exchange for products that can be produced cheaply at home. The decision of country A to impose high pollution control costs on domestic firms, particularly if similar controls are not imposed in other countries, diminishes A's comparative advantage in trade. Growth in national income in country A may be temporarily slowed and its balance of payments weakened as imports from countries with lower production costs increase and exports decline. However, in the longrun, it is important that domestic and international prices reflect all costs, including pollution abatement. Other things constant, heavy waste load industries should be induced to locate in countries with natural capacity to assimilate waste.

General considerations such as those discussed above must be recognized in evaluating the economic consequences of environmental regulations. Of course, many other factors may also be important. Among segments of the food processing industry, capital constraints are likely to be severe. Investment in pollution abatement technology requires the firm to generate new capital through retained earnings and/or to obtain credit from commercial sources. Food processors with historically low profits may find both alternatives infeasible. Longer run adjustments must also be acknowledged. Over a period of years, environmental regulations may contribute to an industry structure of a few large firms, and have potentially adverse consequences for consumers and resource suppliers.

Conclusions

The real world problem of distributing common property resources--such as water quality--is complicated by the fact that demand for services of the environment are expanding, both for use in disposal of waste materials and for consumption in recreation, as natural beauty, and for other ecology related activities. Effluent limitations and industrial discharge permits are the primary means of controlling point source water pollution under the FWPCA. Government environmental regulations are necessary because of the absence of fully defined property rights and interdependence among decisionmaking units.

A socially optimal resource allocation is achieved when the marginal value product of water used and discharged by the firm equals the sum of private and external costs. Or water pollution control regulations should move the community to the point where additional benefits, measured in terms of the value of improved water quality, approximately equal additional costs, measured in terms of the value of reduced product supply, government costs of administering environmental regulations, and other costs such as a decline in community employment. Surely, if benefits from an optimal allocation of water quality do not cover government costs, the community will be better off with unabated pollution. The real world task of setting effluent limitations is complicated because EPA does not have access to detailed information concerning factors that influence the firm's environmental damage function, and because such factors tend to vary among firms and geographic regions.

Confronted with environmental regulations the firm must pursue one of the following strategies:

(1) Reduce final product output and use less of the pollution generating input,

(2) Discharge to municipal treatment,

(3) Invest in new pollution abatement technology and waste management practices,

(4) Use some combination of the above, or

(5) Discontinue production.

In general, food processing plant cost structures are expected to rise, causing industry product supply to shift upward and to the left, with consequently higher product prices. Firms discharging to municipal treatment should expect to pay significantly higher sewage rates as a result of capital repayment under the FWPCA. Some firms will find it advantageous to invest in new pollution abatement technology. The feasibility of this strategy tends to vary directly with profitability, since more profitable firms generally find it easier to generate capital internally and attract commercial credit. Firms that cannot cover higher average costs after pollution abatement will be forced to shut down.

Appendix table 1 --Tomato processing firms: plants, numbers, volume, and product form, by excluded States, Canada, and other countries, 1974

Area	No. of firms	No. of plants	Volume code by firm 1/							Product forms by firm		
			D	C	B	A	AA	AAA	AAAA	Tomatoes for canning 2/	Tomato juice	Other tomato products 3/
Southeastern Region												
Alabama	1	2	0	0	0	2	0	0	0	1	0	1
Florida	10	10	2	1	4	0	0	0	0	8	1	2
Georgia	1	1	0	0	0	0	0	0	0	11	0	0
Kentucky	2	2	0	0	1	0	0	0	1	1	1	1
South Carolina	2	2	1	1	0	0	0	0	0	2	0	0
Tennessee	3	4	0	0	0	1	1	0	1	3	1	1
West Virginia	1	1	1	0	0	0	0	0	0	1	0	0
Subtotal	20	22	4	2	5	3	2	0	2	17	3	5
Southcentral Region												
Arkansas	4	4	0	2	0	0	0	0	2	4	0	1
Louisiana	3	3	1	0	0	0	0	0	0	2	0	33
Texas	3	3	0	0	1	0	1	1	0	3	1	3
Subtotal	10	10	1	2	1	0	1	1	2	9	1	7
Other States												
Colorado	3	3	1	1	1	0	0	0	0	2	2	3
Kansas	1	1	1	0	0	0	0	0	0	1	1	0
Massachusetts	1	1	0	1	0	0	0	0	0	0	0	1
Minnesota	2	3	1	0	0	0	0	0	0	2	1	0
Montana	1	1	0	0	1	0	0	0	0	1	0	0
Utah	2	3	2	0	1	0	0	0	0	3	3	2
Total Excluded States	41	44	11	6	9	3	3	1	4	35	11	18
Total United States	165	224	47	25	23	14	12	10	23	127	51	95
Canada	37	41	14	7	2	4	3	0	1	30	7	15
Other Countries	7	7	0	0	0	2	2	0	0	2	3	6

1/ Volume codes are not reported for all firms. They are listed in terms of cases packed per firm. The following scale is used: D--under 100,000; C--100,000 to 250,000; B--250,000 to 500,000; A--500,000 to 1,000,000; AA--1,000,000 to 2,000,000; AAA--2,000,000 to 5,000,000; AAAA--over 5,000,000. 2/ Whole, Italian, and stewed tomatoes. 3/ Catsup, sauce, chili sauce, paste, puree, miscellaneous.

Source: (12, pp. 1-250)

Appendix table 2 --Description of selected tomato products for model plants

Finished product category	Units per case	Size of container	Type of container
Juice	48	5½ oz.	Can
Juice	12	46 oz.	Can
Catsup	24	14 oz.	Bottle
Catsup	24	30 oz.	Bottle
Catsup	12	26 oz.	Bottle
Catsup	6	10	Can
Puree	6	10	Can
Paste	6	10	Can
Whole pack	24	303	Can

Source: (38, p. 40).

Appendix Table 3 --Product mix, rate of product output, and capacity, by product category and model plant

Product category	Model plant A			Model plant B			Model plant C			Model plant D			Model plant E		
	Product mix	Rate of output	Capacity	Product mix	Rate of output	Capacity	Product mix	Rate of output	Capacity	Product mix	Rate of output	Capacity	Product mix	Rate of output	Capacity
	%	Cases/ hour	1,000 cases/ season	%	Cases/ hour	1,000 cases/ season	%	Cases/ hour	1,000 cases/ season	%	Cases/ hour	1,000 cases/ hour	%	Cases/ hour	1,000 cases/ season
Juice 48/5½ oz. . .	--	--	--	--	--	--	--	--	--	--	--	--	7.2	200	143
Juice 12/46 oz. . . .	50.0	150	50	13.5	300	56	34.0	600	340	36.4	600	370	14.5	500	291
Catsup 24/14 oz. . .	--	--	--	13.5	600	56	18.9	600	189	26.9	600	274	3.9	600	78
Catsup 24/20 oz . .	--	--	--	5.8	500	24	8.1	500	81	8.7	500	89	6.6	500	133
Catsup 12/26 oz. . .	--	--	--	5.8	500	24	8.1	500	81	817	500	89	--	--	--
Catsup 6/10	--	--	--	13.5	225	56	18.9	450	189	19.3	450	196	8.0	450	159
Puree 6/10	--	--	--	--	--	--	3.0	450	30	--	--	--	7.7	450	154
Paste 6/10	--	--	--	--	--	--	9.0	200	90	--	--	--	23.0	480	640
Whole pack 24/303	50.0	150	50	48.0	400	200	--	--	--	--	--	--	--	500	402
Average plant capacity			100			416			1,000			1,018			2,000

-- = Not applicable

Source: (38, pp. 35 and 39).

Appendix Table 4 --Total operational hours and days per season, by product category and model plant

Product category	Model plant A		Model plant B		Model plant C		Model plant D		Model plant E	
	Hrs.	Days	Hrs.	Days	Hrs.	Days	Hrs.	Days	Hrs.	Days
Juice 48/5-½ oz.	---	---	---	---	---	---	---	---	834	68
Juice 12/46 oz.	322	32	374	43	571	45	591	45	536	48
Catsup 24/14 oz.	---	---	118	12	340	32	467	41	165	20
Catsup 24/30 oz.	---	---	96	12	203	26	178	17	268	33
Catsup 12/26 oz.	---	---	86	12	174	15	236	28	---	---
Catsup 6/10	---	---	296	37	452	46	496	47	409	48
Puree 6/10	---	---	---	---	66	5	---	---	344	28
Paste	---	---	---	---	488	46	---	---	1,334	80
Whole pack 24/303	270	39	502	47	---	---	---	---	836	70

--- = Not available

Source: (38, pp. 35 and 37).

Appendix table 5 --Raw input to finished product conversion coefficients by product category and region

Product category	Eastern-midwestern	California
	Cases/ton	
Juice 48/5½ oz.	--	96.97
Juice 12/46 oz.	42.15	46.40
Catsup 24/14 oz.	42.83	36.50
Catsup 24/20 oz.	30.37	25.55
Catsup 12/26 oz.	45.96	--
Catsup 6/10	19.88	18.67
Puree 6/10	20.00	23.44
Paste 6/10, 26%	8.60	9.54
Whole pack 24/303	57.80	60.29

-- = not applicable

Source: (38, p. 140).

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