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Industrial Growth in the U.S. Border Communities and Associated Water and Air Probelms: An Economic Perspective

Harry W. Ayer

Paul G. Hoyt

INDUSTRIAL GROWTH IN THE U.S. BORDER COMMUNITIES AND ASSOCIATED WATER AND AIR PROBLEMS: AN ECONOMIC PERSPECTIVE*

HARRY W. AYER** and PAUL G. HOYT***

Political officials, researchers and portions of the general public have expressed concern about current and potential water and air problems along the U.S.-Mexico border. Concern is prompted by the relatively rapid (compared to the entire U.S.) industrial growth along the Mexican border in the last ten years.

Industry induced water and air problems result in increased social costs to society. Social costs include all direct and indirect costs such as higher water costs to individuals and businesses and psychological costs to individuals due to industries' demand for water or air as a recipient of waste. Costs to society, such as crop damage and health hazards, due to industrial pollution and the costs of treating industrial wastes in water or air all are included in total social costs. If these social costs are significantly large, then the industrial actions that caused these costs are considered to be a problem. If, however, industrial use of water or air results in only miniscule costs to society, then the problem should be considered insignificant.

This study attempts to establish whether or not significant water or air problems do or will exist in U.S. cities along the Mexican border. Where water or air problems exist, the economics of alternative solutions to these problems are discussed.

SUPPLY AND DEMAND OF WATER AS AN INDUSTRIAL INPUT

Water is used by industry in many production processes. In this portion of the paper, factors that affect the supply and demand for water as a material input (as distinguished from the demand for water as a means of waste disposal) are discussed. An evaluation is then made of the impact of U.S. border industry demand on monetary costs of water.

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**Harry W. Ayer is Agricultural Economist, U.S. Department of Agriculture, Economic Research Services, Natural Resources Division and Associate Professor of Agricultural Economics at the University of Arizona.

***Paul G. Hoyt is Research Assistant, Department of Agricultural Economics at the University of Arizona.

Water Supplies for Industry

Most water for industrial use is supplied from unused ground or surface water or by industry bidding water away from its current use in agriculture. The relative supply of ground water is indicated by its depth below the surface and known reserves of underground basins. Deeper wells incur higher pumping costs, implying that water has become more scarce. The relative supply of surface water is determined by the size of streams or reservoirs, by their proximity to the area of use, and by legal arrangements that determine the distribution of surface water among potential users. Relative supplies of water currently used for irrigation, but which could be supplied to industry, are indicated by the amount of irrigation water used near the city where industry is located. Irrigation water may offer an important supply for industry because irrigation frequently uses very large amounts of water in comparison to that used by industry. This agricultural production may be of a lower value than industries' production with the same water. Thus, industry may "bid" water away from agriculture, assuming the institutional structure allows water transfers.

The principal U.S. industrial cities along the border are shown in Figure 1. For each of these cities, Table 1 presents key data pertaining to the supply of ground, surface, and irrigation water that may be potential sources of water for industry.

The data in Table 1 indicate that San Diego and Calexico have attacked their water problems by importing water from other areas. Their poor quality ground waters are an insignificant amount of their total water supplies. While less than one-third of San Diego's water is

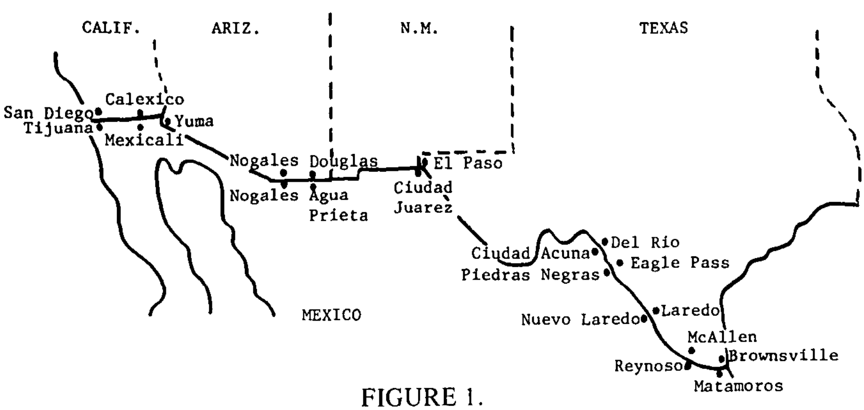

FIGURE 1.

U.S.-Mexico Border Cities

used for irrigation, almost all of Calexico's water supply is utilized for irrigation.

Yuma has an adequate water supply from both underground sources and from the Colorado River, most of which is used for irrigation. However, Arizona's other border cities, Nogales and Douglas, have no surface water and are depleting their groundwater. Again, irrigated agriculture accounts for the bulk of both cities' water use and depletion.

El Paso utilizes slowly depleting groundwater sources for most urban and industrial uses, while irrigation water is primarily supplied by water from the Rio Grande River and reservoir system.

Del Rio, Eagle Pass, and Laredo have relatively undeveloped groundwater supplies due to small populations and relatively small irrigated croplands. The bulk of water used for irrigation is from the Rio Grande River.

McAllen and Brownsville have poor quality groundwater which is little used. However, they have a large water allotment from the Rio Grande River, most of which is used for irrigation.

These data indicate that, with the exception of San Diego, all U.S. border cities use a significant amount of their available water for irrigation. Without institutional restraints,[1] this water could be bid away from agricultural production by industry with a higher value of product relative to the amount of water used. Cummings and Gisser have found that a 30 percent decrease in water available to agriculture would result in only a 7 percent loss in net farm revenues.[2] Thus, an industry with a higher marginal value product than agriculture could bid away a portion of agriculture's water without adversely affecting regional incomes.

From the standpoint of physical supplies and the economic feasibility of industry to bid water away from agriculture, water supplies would not appear to be limited, in comparison to rough estimates of industry demand, in most U.S. border cities. Better estimates of industrial demands for water as an input in the production process are discussed in the following section.

Demand for Water as an Industrial Input

The demand for water by each town's industries is a function of the size of the industries and the direct and indirect requirements of each

1. This is currently a problem in Tucson, for example, where the city wishes to purchase agricultural land and pump its water to the city. However, recent court rulings are limiting the ability to transfer water from one basin to another.

2. R. Cummings & M. Gisser, Reductions of Water Allocations to Irrigated Agriculture in New Mexico: Impacts and Technological Change (unpublished paper presented to U.S.-Mex. Transnat'l Resource Study Group Meetings, La Jolla, Cal., Nov. 4, 1976).

TABLE 1

Water Supplies, by Source, for U.S. Border Cities

City	Ground Water	Surface Water	Irrigation Water	Other Comments
San Diego California	Minor source of water due to increased pumping costs and lowering quality.[a]	Main source of water is imported from Colorado River and Northern California.[a] (See other comments)	Source: Mostly surface water. About 1/3 of all water use in San Diego region was for irrigation in the 1960's.[a]	Local water accounted for approximately 20% of all water used in the 1960s and is expected to become less significant in the future.[a]
Calexico, California	Not developed due to poor quality.[b]	From Colorado River, via the All American Canal.[b]	Source: Surface water from Colorado River.[b]	Land use in Imperial Valley, border area, 1958. 376,190 Ac. Irrigated Cropland. 580 Ac. Industrial 680 Ac. Commercial 24,390 Ac. Urban[b]
Yuma, Arizona	In Storage, Yuma Area: 34,600,000 acre-feet. Use in 1973: 272,000 acre-feet. Overdraft: None.[c]	From Colorado River. 720,000 acre-feet diverted in 1970.[c]	Source: Colorado River and some groundwater. Most groundwater pumped to drain water logged lands. 1970 withdrawal: 924,000 acre-feet.[c]	Yuma area use by municipal and industrial sector, in 1970: 16,000 acre-feet.[c]
Nogales, Arizona	In storage in Santa Cruz County 8,400,000 acre-feet. Average overdraft: 8,000 acre-feet/year.[c]	No uninterrupted supply available.[d]	Source: Ground water. 1965-1969 average use: 14,800 acre-feet.[d]	Ground water use in Santa Cruz County, 1965-1969 average: 1,400 acre-feet, Municipal 0 acre-feet, Industrial[d]
Douglas, Arizona	In storage in Douglas Basin 31,600,000 acre-feet. Overdraft in 1970: 64,000 acre-feet.[c]	None.[c]	Source: Ground water 1970 withdrawal: 103,000 acre-feet.[c]	Municipal and Industrial water use, 1970: 13,000 acre-feet.[c]

El Paso, Texas	In storage, 7,500,000 (fresh water). Water table 5' to 300' and declining, depending on area.[c]	From Rio Grande River and Elephant Butte Dam.	Source: Rio Grande River supplemented by groundwater. 1974 use: 216,146 acre-feet.[h]	Urban development continues to expand on irrigated land in the El Paso area. 80% of urban water use is from ground water.
Del Rio, Texas	Little developed. Del Rio water from springs.[f]	From Rio Grande River and Amistad Reservoir, capacity 5,325,500 acre-feet.[g]	Source: Groundwater 1974 use 2,839 acre-feet drawn from 5,167 acre-feet in 1969.[h]	Little industry or irrigated agriculture in the area.
Eagle Pass & Laredo, Texas		From Rio Grande River and Amistad Reservoir, capacity 5,325,500 acre-feet.[g]	Source: Rio Grande River and groundwater 1974 use: 117,342 acre-feet from surface water. 10,929 acre-feet from ground water.[h]	Irrigated agriculture declining since 1969.[h]
McAllen and Brownsville, Texas	Poor quality, little used.[g]	From Rio Grande River and Falcon Reservoir. Share of water fixed by international agreement. Approximately 1,306,000 acre-feet for the 3 county lower Rio Grande Valley in 1971.[i]	Source: Over 92% from Rio Grande River. 1974 Use: 1,016,033 acre-feet.[h]	1971 land use in the 3 county Lower Rio Grande Valley Area: 689,800 acres irrigated cropland. 206,400 acres urban, commercial and industrial.[i]

a. 1 Cal. Dep't of Water Resources, Groundwater Occurrence and Quality: San Diego Region, Bull. No. 106-2 (1967).
b. Cal. Dep't of Water Resources, Desert Areas of Southeastern California, Land and Water Use Survey, 1958 (1963).
c. Ariz. Water Comm'n, Summary, Inventory of Resources and Uses (1975).
d. W. Matlock & P. Davis, Groundwater in the Santa Cruz Valley, U. Ariz. Agric. Exp. Station, Tech. Bull. 194 (1972).
e. Tex. Water Dev. Bd., Development of Groundwater in the El Paso District, Texas, Rep. 153 (1972).
f. Tex. Water Dev. Bd., Groundwater Resources of Val Verde County, Texas, Rep. 172 (1973).
g. Tex. Water Dev. Bd., Reconnaissance of the Chemical Quality of Surface Waters of the Rio Grande Basin, Texas. Rep. 180 (1974).
h. Tex. Water Dev. Bd., Inventories of Irrigation in Texas, 1958, 1964, 1969, 1974, Rep. 196 (1975).
i. Water Resources Inst., A Study of the Effects of Institutions on the Distribution and the Use of Water for Irrigation on the Lower Rio Grande Basin (1971).

industry.[3] The size of each industry, in terms of employment, is given for each border city for 1960 and 1970 in Table 2.

Industrial water requirements per employee, per year, are shown in Table 3. These data are useful when cross-referenced with census employment data as in Table 2. However, the water requirements listed in Table 3 apply to the technology existing in California in the late 1950's and, although they are the best available, they should be regarded as rather crude estimates of current industrial needs along the border.

Table 4 shows the direct and direct plus indirect water requirements[4] for various sectors of the Arizona economy in 1958. Again, these represent only crude estimates when applied to other areas or times. However, both Table 3 and 4 probably give a good idea of the relative water use of industries today. Table 4 indicates that agriculture is by far the largest water user in relation to value of output. Primary metals and mining, which in Arizona are copper mining and smelting, tend to be heavy industrial water users. Utilities also tend to be heavy water users, along with the food and kindred products sector. The chemical and fertilizer industry are also heavy water users. Table 3 also indicates that food, metals, and chemicals are all high water users. Significantly, the electrical machinery, textile and apparel industries (all growing industries along the Mexican border) are relatively low water users. The following paragraphs use the data of Tables 2, 3 and 4 to draw conclusions about industrial demand for water in each U.S. border town.

Data for San Diego indicate that the agricultural sector expanded between 1960 and 1970 at a much faster rate than did either the manufacturing sector or total city employment. Since nearly all agricultural sectors (even vegetables) require more water per dollar of output than do nearly all manufacturing sectors, it appears that water

3. The quantity of water demanded by industry may also change as the price of water changes. In the short run, some empirical evidence suggests that the industrial demand for water is price inelastic, DeRooy, *Price Responsiveness of the Industrial Demand for Water*, 10 WATER RESOURCES RESEARCH 403 (1974). Of course, in the long run there will be incentives to use recycled effluent, new water-saving technologies, and produce goods with lower water use requirements as the price of water rises. Thus, these water-saving techniques will themselves help ease the demand for water and thereby diminish water problems. However, this study overlooks these price effects and therefore overstates any water problems which may be caused by industrial demands.

4. Direct plus indirect water requirements refer to the total change in a region's or town's total water use as the effects of sales to final demand sectors from one industry ripple through the economy. This multiplier effect is illustrated in Table 4 for the Arizona economy. For example, Sector 1, Meat Animals and Products, requires only .407 acre-feet of water per $1000 of output. However, industries which supply feed for Sector 1 also use water and industries which supply the feed industry use water, etc. In order for Sector 1 to sell $1000 to final demand, the direct plus indirect water requirements are 9.258 acre-feet.

TABLE 2

Employment by Industry, Total Employment and Population, U.S. Cities on Mexican Border, 1960, 1970

	San Diego, Calif.			Calexico, Calif.			Yuma, Ariz.		
Industry	*1960*	*1970*	*% Δ[a]*	*1960*	*1970*	*% Δ[a]*	*1960*	*1970*	*% Δ[a]*
Agriculture	1,800	3,271	6.2	N	724	–	444	540	2.0
Mining	187	185	-0.1	O	0	–	8	0	–
Construction	12,100	11,469	-0.5	T	76	–	707	858	2.0
Manufacturing	45,206	40,392	-1.1		152	–	381	575	4.2
Wood Products	619	643	0.4	A	3	–	12	0	–
Metal Products	22,173	8,394	-9.3	V	0	–	16	14	-1.3
Machinery[c]	793	2,914	13.9	A	5	–	33	25	-2.7
Electrical Equipment	805	4,994	10.7	I	8	–	7	5	-3.3
Transportation Equip.[d]	10,706	12,052	1.2	L	0	–	34	49	3.7
Other Durables	1,323	3,115	8.9	A	48	–	28	98	13.3
Food Products	2,877	1,661	-5.3	B	43	–	133	69	-6.4
Textiles	921	1,641	5.9	L	9	–	4	173	45.7
Printing	2,967	2,995	.1	E	26	–	89	58	-4.2
Chemicals	381	634	5.22		4	–	21	22	0.5
Other Nondurables	631	1,349	7.89		6	–	4	62	31.5
Total Employment	179,589	228,112	2.4	–	2,947	–	8,542	10,578	2.2
Population	573,224	696,769	1.9	7,992	10,625	2.9	23,974	29,007	1.9

TABLE 2

Employment by Industry, Total Employment and Population, U.S. Cities on Mexican Border, 1960, 1970, continued

	Nogales, Ariz.[b]			*Douglas, Ariz.*			*El Paso, Texas*		
Industry	*1960*	*1970*	% Δ[a]	*1960*	*1970*	% Δ[a]	*1960*	*1970*	% Δ[a]
Agriculture	284	282	0.0	33	123	14.1	791	888	1.2
Mining	50	83	5.2	104	41	-8.9	136	1,384	26.1
Construction	221	302	3.2	320	186	-5.3	6,089	6,559	0.7
Manufacturing	113	239	7.8	670	819	2.0	13,629	17,211	2.4
Wood Products	0	0	–	0	0	–	160	297	5.8
Metal Products	13	0	–	517	521	0.1	1,931	2,100	0.8
Machinery[c]	0	0	–	5	0	–	298	240	-2.1
Electrical Equipment	0	24	–	9	0	–	681	595	-1.3
Transportation Equip.[d]	0	–	–	4	0	–	519	183	-9.9
Other Durables	36	111	11.9	17	96	18.9	1,002	1,422	3.6
Food Products	28	20	-3.3	58	30	-6.4	2,038	1,316	-4.3
Textiles	9	20	8.3	4	148	43.5	3,078	8,270	10.4
Printing	13	4	-11.1	48	8	-16.4	1,162	933	-2.2
Chemicals	5	7	3.4	8	16	7.2	199	169	-1.6
Other Nondurables	9	53	19.4	0	0	–	2,552	1,686	-4.1
Total Employment	3,576	4,416	2.1	3,410	3,585	0.5	81,872	101,608	2.2
Population	10,808	13,966	2.6	11,925	12,462	0.4	276,687	322,261	1.5

TABLE 2

Employment by Industry, Total Employment and Population, U.S. Cities on Mexican Border, 1960, 1970, continued

	Del Rio, Texas			*Eagle Pass, Texas*			*Laredo, Texas*		
Industry	*1960*	*1970*	% Δ[a]	*1960*	*1970*	% Δ[a]	*1960*	*1970*	% Δ[a]
Agriculture	390	385	-0.1	357	298	-1.8	1,417	1,036	-3.1
Mining	16	26	5.0	31	65	7.7	65	73	1.2
Construction	407	525	2.6	174	231	2.9	1,007	1,207	1.8
Manufacturing	431	533	2.1	244	728	11.6	1,004	1,193	1.7
Wood Products	4	0	–	5	4	-2.2	37	43	1.5
Metal Products	4	11	10.6	0	20	–	49	101	7.5
Machinery[c]	0	5	–	4	0	–	65	73	1.2
Electrical Equipment	8	15	6.5	0	6	–	4	139	42.6
Transportation Equip.[d]	0	6	–	0	6	–	19	10	-6.2
Other Durables	12	6	-6.7	17	14	-1.9	49	137	10.8
Food Products	102	72	-3.4	70	47	-3.9	364	272	-2.9
Textiles	227	317	3.4	121	564	16.6	230	113	-6.9
Printing	67	37	-5.8	14	0	–	170	154	-1.0
Chemicals	4	6	4.1	0	6	–	5	10	7.2
Other Nondurables	3	58	34.5	13	61	16.7	12	131	27.0
Total Employment	4,751	5,908	2.2	2,904	3,826	2.8	15,257	18,180	1.8
Population	18,612	21,330	1.4	12,094	15,364	2.4	60,678	69,024	1.3

TABLE 2

Employment by Industry, Total Employment and Population, U.S. Cities on Mexican Border, 1960, 1970, continued

Industry	*McAllen, Texas* 1960	1970	% Δ[a]	*Brownsville, Texas* 1960	1970	% Δ[a]	*United States* 1960	1970	% Δ[a]
							←(1000)→		
Agriculture	1,016	742	-3.1	737	961	2.7	4,519	2,840	-4.5
Mining	338	297	-1.3	25	58	8.8	714	631	-1.2
Construction	720	792	1.0	728	909	2.2	4,302	4,572	0.6
Manufacturing	999	955	-0.4	2,049	2,082	0.2	18,536	19,837	0.7
Wood Products	20	12	-5.0	4	0	–	1,057	553	-6.3
Metal Products	26	24	-0.8	16	22	3.2	2,659	2,395	-1.0
Machinery[c]	42	24	-5.4	34	61	6.0	1,633	1,991	2.0
Electrical Equipment	8	0	–	26	87	12.8	1,565	1,905	2.0
Transportation Equip.[d]	9	27	11.6	45	73	5.0	1,947	2,139	0.9
Other Durables	36	34	-0.6	64	97	4.2	816	2,758	13.0
Food Products	562	300	-6.1	1,302	996	-2.6	1,956	1,390	-3.4
Textiles	84	170	7.3	322	317	-0.2	2,263	2,184	-0.4
Printing	110	105	-0.5	103	124	1.9	1,177	1,192	0.1
Chemicals	53	17	-10.7	54	165	11.8	890	988	1.0
Other Nondurables	49	242	17.3	79	140	5.9	1,771	2,210	2.2
Total Employment	10,977	12,241	1.1	13,592	14,558	0.7	64,639	77,309	1.8
Population	32,728	37,636	1.4	48,040	52,522	0.9	179,326	203,210	1.3

a. Compound average annual percent of change, 1960 to 1970.
b. Figures for Santa Cruz County, Arizona. Nogales is the only major city in Santa Cruz County.
c. Except electrical machinery.
d. Includes auto parts, etc.

Source: 1 U.S. BUREAU OF THE CENSUS, CHARACTERISTICS OF THE POPULATION, pts. 1, 4, 6 and 45 (U.S. Summary, Ariz., Cal. & Tex. 1963 and 1974).

TABLE 3

Water Use per Employee, per Year, by Industrial Subsectors (1957-59 average)[a]

Industrial subsector	Use per employee per annum (acre-feet)
1. Food and kindred	0.713019
2. Textiles	0.190592
3. Apparel	0.027234
4. Lumber	0.349573
5. Furniture	0.039699
6. Paper	1.553275
7. Printing	0.069461
8. Chemical	1.082675
9. Petroleum	4.735634
10. Rubber	0.291075
11. Leather	0.034440
12. Stone, clay, and glass	0.650090
13. Primary metals	0.381792
14. Fabricated metals	0.349127
15. Instruments	0.080078
16. Miscellaneous	0.202267
17. Machinery	0.134367
18. Electrical machinery	0.067192
19. Transportation equipment	0.081422
20. Weighted average	0.335134

a. For more complete water use by particular industry, *see* Cal. Dep't of Water Resources, Water Use by Manufacturing Industries in California, 1957-1959, Bull. No. 124, 66-72 (1964).

Source: D. Seckler, California Water 42 (1971).

prices were not increased primarily by industrial demands. Furthermore, of the city's industries, those that require relatively large amounts of water (metal products and food products) were decreasing in size while those requiring relatively small amounts of water (textiles, electrical equipment, machinery) were increasing in size.

Data on Calexico suggest the importance of agriculture to the town and indicate that manufacturing is a relatively minor sector. Only 152 people were employed in all types of manufacturing in 1970. Industrial demand for water is probably small, and agricultural demand relatively great.

For Yuma, the most notable change between 1960 and 1970 was for the textiles sector. The average annual rate of growth of textile employment was 46 percent, and by 1970 this industry employed nearly twice as many as any other manufacturing sector. In terms of water demand, the textile sector uses relatively small amounts per

TABLE 4

Direct and Direct plus Indirect Water Requirements by Sector for the Arizona Economy, 1958[a]

Sector	*Direct Requirement per $1,000 of Output*	*Direct & Indirect Requirement per $1,000 of Final Demand*
	Acre-Feet	
1. Meat Animals and Products	.407	9.258
2. Poultry and Eggs	.008	13.969
3. Farm Dairy Products	.252	15.167
4. Food and Feed Grains	42.087	43.438
5. Cotton	12.551	13.560
6. Vegetables	6.413	6.542
7. Fruit and Tree Nuts	9.950	10.169
8. Citrus Fruits	11.154	11.798
9. Forage Crops	46.938	47.077
10. Miscellaneous Agriculture	6.408	10.252
11. Grain Mill Products	.019	12.898
12. Meat and Poultry Processing	.012	5.575
13. Dairy Products	.010	7.554
14. Canning, Preserving, and Freezing	.043	.811
15. Miscellaneous Agricultural Processing	.020	1.688
16. Chemicals and Fertilizers	.030	.293
17. Petroleum	.020	.033
18. Fabricated Metals and Machinery	.003	.038
19. Aircraft and Parts	.004	.033
20. Primary Metals	.187	.321
21. Other Manufacturing	.009	.182
22. Mining	.147	.215
23. Utilities	.210	.246
24. Selected Services	.010	.031
25. Trade and Transportation	.010	.031
26. Unallocated Services	.010	.064

a. "Other manufacturing" includes the following industries: Textiles, logging, wood products, furniture, paper products, printing and publishing, rubber products, leather products, clay and glass products, and miscellaneous manufactured products.

Source: A. Tijoriwala, W. Martin & L. Bower, Structure of the Arizona Economy, 23 U. Ariz. Agric. Exp. Station, Tech. Bull. 180 (1968).

employee. A second notable characteristic of the Yuma economy is the relative importance of water intensive agriculture and the fact that this sector grew at nearly the same rate as total employment between 1960 and 1970.

Nogales also had relatively large numbers of its population employed in agriculture in both 1960 and 1970. The most important growth during the decade of the 60's was in the other durables sector and other nondurables sector. However, recent water use studies show that industry is not a significant factor in the demand for water in Nogales.[5]

In Douglas, three important trends occurred between 1960 and 1970. First, employment in agriculture expanded sharply and the sector became one of the largest employers for town residents. Second, the water intensive mining industry, which was an important employer in 1960, cut its employment by less than one-half by 1970. Third, the most rapid rate of growth was in textiles, which uses relatively small amounts of water per employee.

In El Paso, the mining sector expanded very rapidly during the 60's and by 1970 was one of the most important employers. The metal products sector was also an important employer in both 1960 and 1970. Since mining and metal products often use relatively large quantities of water, these sectors may be a potential source of pressure on water prices. By far the single most important employer in 1970 was the textile industry, an industry that grew rapidly between 1960 and 1970. As previously stated, textile production uses little water, either directly or indirectly.

Del Rio and Eagle Pass both had significant employment in agriculture, and by 1970 their textile sectors had become by far the most important industries. These facts suggest that industrial demand on water has not caused water price increases.

Agricultural employment in Laredo was far greater than employment in any industrial sector during the decade. Of the industrial sectors, the electrical equipment industry grew fastest and by 1970 was the third most important industrial employer. This sector uses relatively low amounts of water per employee. Again, it appears that industrial demand was not pressing against water supplies.

Total employment in both McAllen and Brownsville grew very moderately between 1960 and 1970 and employment in manufacturing actually declined in McAllen and increased by only .2 percent per year in Brownsville. The food products sector, which is one of the greatest industrial users of water when both direct and indirect effects are considered, declined in both towns. In McAllen this decline in employment was compensated for by increases in the other nondurables and textile sectors, and in Brownsville by increases in the electrical equipment, chemicals, and other nondurables sectors. With the possible exception of chemicals, the growth industries use far less water than the declining food products sector, and accordingly there was probably a net decrease in industrial demand for water. As with most of the border towns, agricultural employment in McAllen and

5. W. Matlock & P. Davis, Groundwater in the Santa Cruz Valley, U. Ariz. Agric. Exp. Station, Tech. Bull. 194 (1972).

Brownsville was relatively great, again suggesting that industry will not be facing significant water restrictions and will not cause the price of water to be significantly increased.

In summary, the analysis suggests that in the recent past industry has not caused the price of water to rise in border cities. Furthermore, if the trend in the types of industries that were expanding and contracting during the decade of the 60's continues, industry will not be the cause of rising water costs in the foreseeable future. Less water intensive industries have been growing and in many cases water intensive industries declining. Also, the availability of ground or surface, particularly irrigation water, in nearly all U.S. border towns appears great relative to industrial needs, and therefore industry will not cause large price increases.

The following section goes beyond the trend analysis and discusses particular factors that will affect the future growth or decline of the border industries. The future growth or decline will, of course, affect the derived demand for water.

Factors Affecting Future Growth of U.S. Border Industries

Industrial growth in U.S. border towns in the future will be influenced by a number of factors. Two of the most important factors will be the relative wage rate in U.S. border towns compared to other towns where industry might expand and the growth of sister plants (vertically integrated plants) in Mexican border towns through the Border Industry Program.[6]

Relative Wage Rates

Two sets of data are available on the relative wage rates in the border towns. The data in Table 5 on hourly wages are more current, but the data in Table 6 on median annual earnings are available for more of the border towns. The data of these tables indicate that wage rates in San Diego and Calexico tended to be higher than the U.S. average. Wage rates in Arizona border towns tended to be somewhat below the U.S. average, except for the smelter town of Douglas. All Texas border towns have had wage rates considerably below the U.S. average. Accordingly, considering the wage factor alone, the incen-

6. Other factors which will influence industrial growth along the border include the availabiilty of minerals to be used in mining and metal products (generally smelting) industries, and the relative availability and price of various types of infrastructure (communication and transportation facilities, public services, etc.) in border towns. Little data was found on these factors. However, from Table 2 it can be inferred that mining and metal products employment, and presumably mineral supplies, have been quite important in only Douglas and El Paso. In Douglas, mining and metal products activity has and can be expected to decline because nearby copper ores have been economically exhausted.

TABLE 5

Average Hourly Wages of Production Workers on Manufacturing Payrolls, Selected U.S. Locations, 1955, 1960, 1965, 1970 and 1974

Location	*1955*	*1960*	*1965*	*1970*	*1974*
San Diego	2.13	2.73	3.24	4.12	4.72
El Paso	–a	–a	1.94	2.21	2.98
U.S. Average	1.86	2.26	2.61	3.36	4.41

a. Data not available.

Source: U.S. DEP'T OF LABOR, EMPLOYMENT AND EARNINGS, STATES AND AREAS, 1939-74 (1975).

tive for industrial development along the border appears to increase along the border going from San Diego to Brownsville.

Wage rates in most border towns tend to be relatively low in part because of the supply of labor from Mexico. Migration of people from the southern parts of Mexico to the north, and then to the U.S., has been occurring for many years. It is estimated that there are over 7 million illegal immigrants now in the U.S. But, as so poignantly described by Baerreson,[7] this immigration is likely to increase dramati-

TABLE 6

Median Earnings in Dollars of Experienced Male Laborers, Except Farm and Mine Laborers, U.S. Border Towns and the U.S. Average, 1960 and 1970

Location	*1960*	*1970*
San Diego	3,873	5,167
Calexico (Imperial County)	3,150	5,099
Yuma	2,797	4,187
Nogales (Santa Cruz County)	1,854	3,946
Douglas	2,844	5,552
El Paso	2,361	3,761
Del Rio	2,080	2,974
Eagle Pass	1,294	2,294
Laredo	1,114	2,741
McAllen	1,384	2,731
Brownsville	1,486	2,531
U.S. Average	2,940	4,647

Source: 1 U.S. BUREAU OF THE CENSUS, CHARACTERISTICS OF THE POPULATION, pts. 1, 4, 6 and 45 (U.S. Summary, Ariz., Cal. & Tex. 1963 and 1973).

7. D. Baerresen, Population Pressure and Border Industrialization in Mexico (Paper presented at Allied Soc. Sci. A. meetings, San Francisco, 1974).

cally in the immediate years ahead. Consider the following: (1) Mexico's population is expanding at an annual rate of 3.4-3.6 percent, and at this rate her population will double in less than 21 years. (2) Forty-six percent of Mexico's entire population is less than fifteen years old (compared to 28.5 percent for the U.S.), and accordingly there will be a tremendous new wave of people entering the labor force within the next few years. (3) It is estimated that 40 percent of Mexico's labor force is underemployed or unemployed. (4) Even given current conditions, there are strong incentives for Mexicans to migrate northward across the border to the U.S. In the fiscal year ending June 30, 1974 there were 677,615 Mexicans apprehended in the Southwest for illegal entry into the U.S. Rough estimates are that only one-fourth to one-tenth of those entering illegally are apprehended. Thus, the wage rate in border towns, where Mexican workers first enter the U.S., is likely to be depressed because of this labor supply, thereby encouraging industry to locate there. More specifically, labor intensive industries will be encouraged to expand more than capital intensive industries.

The Border Industry Program

The Border Industry Program is a series of agreements between the U.S. and Mexico to encourage U.S. firms to locate in Mexico and thereby employ abundant Mexican labor. The program has also encouraged vertically integrated portions of U.S. plants to locate on both the Mexican and U.S. side of the border. In the recent past these twin plants have been an important source of industrial growth in several U.S. border towns, as shown in Table 7, and discussed by Ayer and Layton.[8] Two of the most important factors that will affect future growth or decline of the twin plants are the wage rates in Mexico relative to other countries where U.S. firms might locate and the exchange rate between the peso and the dollar.[9] Both of these factors have changed significantly during 1976.

Wage rates in Mexico have been substantially below those of the U.S. and have been the strongest factor encouraging U.S. plants to

8. Ayer & Layton, *The Border Industry Program and the Impacts of Expenditures by Mexican Border Employees on a U.S. Border Community: An Empirical Study of Nogales*, 8 ANNALS REGIONAL SCI. 105 (1974).

9. Mexican and U.S. government regulations pertaining to the Border Industry Program will also directly affect the industry's viability. In the U.S., labor unions have long opposed U.S. tax regulations which favor U.S. firms locating on the Mexican side of the border. Legislation to retract this favorable tax status has been introduced, but has not been enacted in the past. Mexico recently passed and then rescinded (mid October, 1976) export taxes which would have acted disfavorably on the Border Industry Program, Wall St. J., Sept. 9, 1976, at 36, col. 4; Tucson Daily Citizen, Oct. 26, 1976, at 1, col. 1.

TABLE 7

Twin Plants Located in U.S. Border Towns as of October 1973 or Scheduled for Completion in the Near Future, and Twin Plant Employees (Approximate Numbers)

	Calexico Calif.	*Nogales Az.*	*Douglas Az.*	*El Paso Texas*	*Eagle Pass Texas*	*Laredo Texas*	*Brownsville Texas*
Plants	1	5	2	20	12	4	34
Twin Plant Employees	90	500	350	2,000	800	300	7,300
Twin Plant Employees as % of 1970 Total Employ.	3%	20%	10%	2%	20%	2%	50%

Source: Ayer & Layton, *The Border Industry Program and the Impacts of Expenditures by Mexican Border Employees on a U.S. Border Community: An Empirical Study of Nogales*, 8 ANNALS REGIONAL SCI. 105 (1974).

locate there. Other countries, however, offer even more attractive wage rates, as shown in Table 8. Because of these wage differences, many U.S. industries have located plants in Hong Kong and Korea.

Given the rate of unemployment in Northern Mexico, it might be expected that wage rates there would be reduced, but labor union pressures have maintained and increased wage rates and fringe benefits. In December of 1975, Mexico's new minimum wage was increased an average of 21 percent[10] and in September of 1976 the government agreed to wage increases of 23 percent for those earning less than $505 per month.[11] In part because of these wage increases, some U.S. plants left Mexico, and payrolls were cut. In Sonora, for example, the number of U.S. plants fell from 100 to 84 in the first half

TABLE 8

Monthly Manufacturing Wages, in Dollars, for Selected Countries, 1974

Hong Kong	$111.12
Japan	486.59
Korea	62.42
Mexico	225.20
U.S.	764.40

Source: UNITED NATIONS, YEARBOOK, 1975 (1976).

10. Wall St. J., Dec. 30, 1975, at 15, col. 4.
11. *Id.*, Sept. 28, 1976, at 8, col. 4.

of 1975, and employment in these plants from 10,000 to 7,000.[12] Should these wage trends continue, growth of border industries, including the twin plants on the U.S. side, will be hindered.

Recent devaluations of the peso will counteract the above mentioned wage increases and encourage border industries. The initial devaluation of the peso by 40 percent more than offset the most recent wage increases. The current (October, 1976, but before the devaluation of October 26) total wage rates (including fringe benefits) in Nogales and Agua Prieta are approximately $195 per month,[13] which are actually below the average monthly wages in Mexico in 1974 (Table 8).

The analysis suggests that industrial demands for water as an input in the production process have not and will not in the foreseeable future result in increasing water prices. The supply of water, especially considering the possible transfer of water from agriculture to industry, is great relative to industry's demands—even assuming industrial expansion. Industries that have grown the fastest have generally had low water requirements. Future industrial growth caused by the Border Industry Program will also be by low water intensive companies.

SUPPLY AND DEMAND OF WATER AND AIR FOR INDUSTRIAL WASTE DISPOSAL

Some industries use water and air as a means to dispose of industrial wastes. In many cases, the supply of water and air for this purpose may be great enough, relative to the amount of wastes, to disperse, store, or assimilate them without causing a significant deterioration of water or air quality. In other instances, however, the opposite may be the case and air and water pollution exist. The problem occurs in large part because water and air are often "community resources" that are not subject to private control and not bought and sold in the market place. Accordingly, the price of water and air as waste receptors for industry is often zero (or there is no additional marginal cost for added loads of pollutants). Although the direct cost of water and air to industry for waste disposal may be zero, the cost to society is not. The ability of water and air to support human life, provide amenity services, and serve as material inputs for other industries is impaired, thus causing at least an implicit cost to society.

In the following sections, information is given on the supply and demand for water and air as receptors of industrial wastes. The

12. *Id.*, Nov. 21, 1975, at 48, col. 1.

13. Personal communication with F. Mangin, Ariz. Office Econ. Plan. & Dev.

analysis of the severity of industry-induced water and air pollution problems is necessarily crude, however, because of a shortage of data and empirical studies.

Supply of Water and Air for Waste Disposal

As discussed in the previous section, the physical quantity of water available to industry is great in many respects. However, the ability of either surface water or the groundwater basin to store, disperse, or assimilate wastes is not easily estimated, and in many respects is beyond the scope of this paper.

Similar difficulties exist for assessing the capacity of air sheds to store, disperse, or assimilate industrial wastes. Available information does suggest, however, that sulfur dioxide pollution, generally caused by copper smelters, is considered a problem (by some people) in El Paso and Douglas. Emission of particulate from rock and concrete related industries, carbon monoxide from the petroleum and chemical industries, nitrogen oxides and hydrocarbon from fuel combustion of electric utilities and from the chemical industries, and emissions of heavy metals such as lead, cadmium and arsenic are considered a border problem by some people.[14] Qualitative information from public officials concerned with air pollution in Nogales indicate there is essentially no significant industrial air pollution. And in Douglas the closed loop system of preventing substandard amounts of air pollution has been very successful.[15] Table 9 presents data on the absolute amounts of these pollutants for the border states.

Demand for Water and Air for Waste Disposal

Industry's demand for water and air as a receptor of waste is a function of the size of the industry and the direct and indirect requirements of the industry to discharge pollutants into the air.[16] The size and growth of each industry for each border town was given in Table 2. Information on the types of industries expected to expand because of the Border Industries Program was also given.

A rough idea of which industries are considered to be highly water-polluting is given in Table 10. Information in Table 10,

14. Shoults, *Air Pollution From United States Industrial Sources Along the United States-Mexico Border*, in AIR POLLUTION ALONG THE UNITED STATES-MEXICO BORDER 28 (H. Applegate & C. Bath eds. 1974).

15. Personal communication with W. Columbus, Ariz. Bur. Air Quality Cont., Tucson (Oct. 28, 1976); personal communication with J. Guyton, Ariz. Bur. Air Quality Cont., Phoenix (Sept. 17, 1976).

16. The quantity of air and water demanded for waste disposal has not generally varied because of the price of these resources simply because the price to industry for this use was a constant zero. Recent and future pricing mechanisms may alter this, however.

TABLE 9

Summary of United States Point Source Emissions, United States-Mexico Border, in Metric Tons/Year

Source	*Particulate*	SO_x	NO_x	*HC*	*CO*
Texas	38,286	256,187	34,147	23,590	112,247
New Mexico	37,583	224,623	8,145	2,399	3,899
Arizona	35,294	525,345	6,215	642	4,033
California	59,568	7,649	19,503	5,838	3,037
Total	170,731	1,013,804	68,010	32,459	123,216
% of U.S. Emission along the Border	1.41	18.56	37.77	.66	1.25

Source: Shoults, *Air Pollution From U.S. Industrial Sources Along the U.S.-Mexico Border*, in AIR POLLUTION ALONG THE U.S.-MEXICO BORDER 31, 33 (H. Applegate & C. Bath eds. 1974).

combined with that of industry size in each city (Table 2), suggests that the demand for water as a carrier of waste has not been great in most cases, and the trend is for even lower water requirements for industrial waste. A city by city discussion follows.

Industry-induced water pollution in San Diego is probably not a great problem and has been decreasing since 1960. Total employment in manufacturing declined between 1960 and 1970. Among manufacturing industries, the metal products sector, which includes the high polluting coating, engraving and allied services industry (SIC 3471 in Table 10), was very large in 1960 but was less than ½ as large in 1970. Food products, another rather large sector in 1960, which controls many types of high polluting industries, also decreased significantly between 1960 and 1970. Industries that grew during the decade and that can be expected to grow with the Border Industries Program (machinery, electrical equipment, transportation equipment, textiles, including clothing manufacture) are not considered high water polluters.

Industrial employment in Calexico, Del Rio and Eagle Pass is so small that it is unlikely that industrial water pollution is a problem.

In Yuma, textiles (clothing) is the largest manufacturing sector, and water pollution would not likely be a problem.

Supplementary information from the Arizona water quality office[17] indicates that water pollution is not a problem in either Nogales or Douglas. Sectors that grew in those towns during the 60's and will

17. Personal communication with R. Miller, Ariz. Bur. of Water Quality Cont., Phoenix (Sept. 24, 1976); personal communication with W. Helland, Ariz. Bur. Water Quality Cont., Tucson (Oct. 7, 1976).

TABLE 10

High Water Polluting Industries, by 4-Digit SIC Category, After Nemerow[a]

20 Food and Kindred Products			
	2011	2031	2063
	2013	2032	2082
	2015	2033	2083
	2021	2034	2084
	2022	2035	2085
	2023	2036	2086
	2024	2037	2095
	2025	2044	2099
	2026	2046	
22 Textile Mill Products			
	2211	2262	2284
	2221	2269	2291
	2231	2281	2292
	2242	2282	2293
	2262	2283	2294
			2297
26 Paper and Allied Products			
	2611	2621	2631
28 Chemicals and Allied Products			
	2812	2819	2892
	2814	2841	2894
	2818	2873	
29 Petroleum Refining and Related Industries			
	2911		
30 Rubber and Misc. Plastics Products			
	3011	3021	3031
			3069
31 Leather and Leather Products			
	3111		
32 Stone, Clay, and Glass Products			
	3211	3221	3229
			3231
33 Primary Metal Industries			
	3312	3316	3322
	3313	3317	3323
	3315	3321	
34 Fabricated Metal Products			
	3471	3479	
38 Professional, scientific, controlling industries; photographic, optical goods; watches and clocks.			
	3861		

a. N. NEMEROW, THEORIES AND PRACTICES OF INDUSTRIAL WASTE TREATMENT (1963).

Source: W. Isard & E. Romanoff, Water Utilization: Input-Output Coefficients, Regional Sci. Research Inst., Tech. Paper No. 5 (1967).

tend to expand with the Border Industries Program, such as other durables (computer and television components and assembly) and textiles (clothing), are low polluters.

The data give a mixed picture of possible pollution in El Paso. The metal and food products sectors, potential high polluters, were very large in 1960. However, food products decreased significantly during the decade, and metal products grew very slightly. The largest sector and the one that grew the most, textiles (clothing), is a "clean" industry.

In Laredo, electrical equipment and other durables showed significant employment gains and became two of the largest industries by 1970. Food products declined significantly. These trends are favorable in terms of decreasing water pollution.

McAllen experienced large gains in the non-polluting textiles industry and significant declines in the chemicals and food products sectors.

In Brownsville, increases in the electrical equipment and transportation equipment sectors and a decrease in the food products sector resulted in a decreased demand for water as a receptor of pollution. There was, however, a large increase in the high polluting chemicals industry.

Trends in Brownsville, which decreased the net demand for water as a receptor of pollution, showed increases in electrical equipment and transportation equipment and a decrease in the food products sector. There was, however, a large increase in the high polluting chemicals industry.

Overall, it appears that industry along the border is demanding less water as a receptor of waste. In general, during the 60's there was a trend away from the high polluting metal and food products sectors and toward the low polluting machinery, electrical equipment, transportation equipment, and textile (clothing) sectors. These same types of trends are likely to continue if the Border Industry Program expands.

Demand for Air as a Receptor of Industrial Waste

The demand for air as a receptor of industrial waste is a function of the size of the industry and the direct and indirect requirements of each industry to use air for this purpose.[18] Industry size and growth potential were previously discussed. The direct and direct plus

18. Again, the effect that changes in the price of air pollution might have on the demand for air are overlooked here but discussed in the final section of the paper. In the past, effluent changes to industries have been negligible, but some current and proposed pricing systems may change the situation.

indirect air pollution of various types caused by different industries is given in Table 11. Table 11 pertains to West Virginia, and since the data are for a state, the direct plus indirect coefficients are probably larger than those for a single border city. They do represent, however, the type of data needed to judge the demand of different industries for air as a recipient of wastes and to give a rough idea of the order of magnitude of pollution by industry along the border.[19]

The data indicate that pollution from particulates is likely to vary directly with city population. Similar data on nitrogen oxides from Leontieff and Ford suggests a similar conclusion for these pollutants.[20] Pollution from both particulates and nitrogen oxides tends to be high for the electric utility, water, and sanitary services and for some transportation sectors. Accordingly, as industries expand and city population grows, these forms of pollution may become a problem. San Diego and El Paso would seem particularly susceptible to these forms of industry-induced air pollution. However, industry is not necessarily the principal antagonist. In San Diego, for example, the manufacturing sector actually declined in employment between 1960 and 1970, and yet total employment and population grew, presumably because of an expanding service sector.

San Diego and El Paso also experience particulate pollution from the metal products industry. This is a large industry in both towns and is one of the largest users of air for particulate disposal. The chemical industry may also cause particulate pollution, especially in San Diego where that sector was expanding rapidly during the 60's.

Sulfur dioxide is also a likely problem in the largest cities, San Diego and El Paso. Electric utilities, water and sanitary services, hotels and lodging, restaurants and bars, and bakeries all tend to have a relatively large direct plus indirect impact on sulfur dioxide emissions. Also, some primary metals and chemical industries are heavy sulfur dioxide polluters and are rather large industries in the two largest border cities.

With but few exceptions, industry-induced air pollution is not expected to be great in the other border cities. One possible exception

19. For other empirical studies of the direct and indirect amount of air pollution caused by each industry, *see* Leontief & Ford, *Air Pollution and the Economic Structure: Empirical Results of Input-Output Computations* in INPUT-OUTPUT TECHNIQUES (A. Brady & A. Carter eds. 1972); B. Udis, C. Howe & J. Kreider, The Interrelationship of Economic Development and Environmental Quality in the Upper Colorado River Basin: An Interindustry Analysis (1973) (unpublished report to U.S. Econ. Dev. Ad.). The Leontief and Ford study is for the entire U.S. and is compared with W. MIERNYK & J. SEARS, AIR POLLUTION ABATEMENT AND REGIONAL ECONOMIC DEVELOPMENT (1974) in the latter's book. The Udis, Howe and Kreider study is for the Upper Colorado River Basin and reports direct but not direct plus indirect air pollution technical coefficients.

20. Leontief & Ford, *supra* note 19.

TABLE 11

Direct and Direct Plus Indirect Air Pollution Coefficients, West Virginia, 1965
(1000 Tons Emitted per $1,000,000 of output, 1965 Prices)[a]

	Direct Particulate	Direct & Indirect Particulate	Direct SO_2	Direct & Indirect SO_2	Direct HC	Direct CO	Direct & Indirect HC	Direct & Indirect CO
1. Agriculture		.02714	.00749	.03998			.00038	.00046
2. Coal mines (undgd.)	.03471	.08896		.08255			.00043	.00026
3. Coal (strip & auger)		.06954		.03237			.00054	.00067
4. Petroleum & natural gas	.00264	.02764	06420	.09348	.02580	.05529	.02771	.05899
5. All other mining		.03723		.04763			.00071	.00081
6. Building contractors		.09169	.01361	.05406			.01207	.02309
7. Non-building contractors		.08188		.03122			.00169	.00268
8. Special contractors		.01994		.01988			.00058	.00083
9. Food products (n.e.c.)		.04854	.00430	.07599			.00103	.00148
10. Dairies		.01842	.00430	.03032			.00072	.00115
11. Bakeries		.08644	.00430	.13217			.00135	.00177
12. Beverages		.01819	.00430	.02449			.00192	.00333
13. Apparel & accessories		.01525		.01968			.00052	.00067
14. Logging & sawmills		.02715	.00690	.04556			.00088	.00123
15. Furn. & wood fabrication		.01859		.02500			.00061	.00098
16. Printing & publishing		.01206	.00330	.01420			.00082	.00099
17. Chemicals	.09500	.13922	.05000	.09269	.00830	.01800	.01108	.02325
18. Petroleum products	.08930	.12560		.03824			.00352	.00745
19. Glass	.00334	.07436		.10033			.00080	.00084
20. Stone & clay products	.55000	.63000	.01300	.09932			.00147	.00171
21. Primary metals	.27000	.28757	.16500	.18705			.00092	.00159
22. Fabricated metals		.05089	.05940	.05249			.00104	.00182

23. Machinery (except elec.)		.02740	.01000	.03748			.00073	.00126
24. Electric machinery		.10374	.00830	.12084			.00325	.00666
25. Transportation equip.		.03556	.00130	.03648			.00121	.00153
26. Instruments & products		.01274		.01086			.00684	.00162
27. All other manufacturing		.01684		.02209			.00045	.00049
28. Restaurants & bars		.08068		.11985			.00115	.00143
29. Wholesale trade		.03637		.05020			.00130	.00229
30. Retail food store		.05355	.00770	.08540			.00155	.00243
31. Auto service stations		.02860	.00770	.04425			.00179	.00297
32. All other retail		.03329	.00770	.05375			.00164	.00272
33. Banking		.01598		.02329			.00044	.00071
34. Other finance		.00714	.00340	.01372			.00028	.00059
35. Insurance agents		.00251	.00340	.00695			.00018	.00034
36. Real estate		.02147		.02478			.00231	.00454
37. All other FIRE		.01123		.01527			.00103	.00190
38. Hotels & lodgings		.09183		.13313			.00216	.00329
39. Medical & legal services		.01176		.01613			.00214	.00400
40. Educational services		.03146		.03616			.00201	.00364
41. All other services	.00200	.02888	.00960	.03696			.00141	.00249
42. Railroads	.00164	.01380	.00660	.02023	.02020	.06700	.02100	.00723
43. Trucking & warehousing	.13870	.15330	.00273	.02161	.01150	.00544	.01155	.00613
44. All other transp.	.01300	.02884	.03900	.06289	.02960	.94030	.03284	.10244
45. Communications		.01597	.00760	.02618			.00063	.00041
46. Electrical systems	1.47030	1.57509	2.20000	2.34144	.00870	.03000	.01005	.00407
47. Gas systems		.00774		.01493			.00350	.00769
48. Water & sanitary services	.03300	.13647		.13657	.28800	.56000	.29400	.57044

a. Blank cells indicate insignificant amounts of pollution.

Source: W. MIERNYK & J. SEARS, AIR POLLUTION ABATEMENT AND REGIONAL ECONOMIC DEVELOPMENT (1974).

is Douglas, where copper smelting is an important industry. Both particulates and sulfur dioxide are emitted from the smelter. And, contrary to other smelters in Arizona, the old Douglas smelter is not being converted to remove sulfur dioxide by producing sulfuric acid. Instead, the closed loop system is being employed as a means to decrease the social costs of this form of air pollution in the U.S. Although the closed loop system is regarded as a temporary measure and does not actually cut down on total emissions, it has been a very effective way to meet air pollution standards. In essence, the smelter is taking advantage of the different characteristics of the air supply that exist at different times of the day. When the air supply is stagnant and emissions cannot escape the population center, production is cut back until air supply conditions are reversed. Authorities indicate that the residents of Douglas do not consider air pollution a problem in Douglas.[21] Because an important source of copper ore for smelting has recently been economically depleted, the length of time the obsolescent Douglas smelter will remain in operation is questionable.

Nogales also may have some air pollution problems, but these are not produced by industries on the U.S. border. Rather, there is likely some carbon monoxide problem at the border crossing because of the heavy concentration of automobiles. Also, there is some particulate pollution due to heating and cooking fires, especially in Nogales, Sonora.

In summary, industry induced air pollution along the U.S. side of the border is apparently a problem in only San Diego and El Paso. Most labor-intensive industries associated with the Border Industries Programs are themselves low air polluters. However, where they induce a large population change, particulate and nitrogen oxide pollution may be significant. We anticipate that only in the largest cities would this source be considered a problem.

AN ECONOMIC PERSPECTIVE OF POLICY FOR INDUSTRY-INDUCED WATER AND AIR PROBLEMS ALONG THE BORDER

U.S. industry along the border is not expected to cause greatly increasing water costs in any of the border cities. The supply of water from unused ground and surface sources and from irrigated agriculture is very large relative to present or projected industrial demand; nor is water pollution expected to be greatly increased because of future industrial expansion. In fact, in some cities where water for industry is bid away from irrigation agriculture, the quality of water

21. W. Helland, *supra* note 17; J. Guyton, *supra* note 15.

may actually increase. Irrigation agriculture frequently causes salinity problems that are not usually associated with industry. Finally, industry-induced air pollution is not expected to be a problem in any border cities except San Diego and El Paso.

In this section policy conclusions are presented for the above findings. The conclusions rely heavily on what economic theory and empirical economic studies suggest about ways to deal with water and air problems where they exist.

1. The total amount of political and research resources expended on industry-induced problems of water quantity and quality should be minimal. Water quantity and quality problems caused by the demand of U.S. border industries for water as an input or for waste disposal simply will not be of large magnitude. Marginal efforts to reduce industry demand for water as an input or recipient of wastes may yield net marginal benefits, but certainly total efforts should be kept very small. The key criteria for judging the economic efficiency of programs to change water supply or demand are that the marginal social costs of the programs should equal the marginal social benefits derived from them.

2. It is important that government regulations do not prohibit the transfer of water from one location to another or from one industry to another. If an industry that produces a high value of output for the last unit of water is allowed to bid water away from an industry that is producing a smaller value for its marginal water increment, then net gains to society can be realized. For the border region, this implies that water should be transferable between irrigated agriculture and industry.[22] If water transfers are prohibited, then there may be industry-induced water quantity problems.

3. Uniform treatment standards should not be imposed on industries causing water or air pollution. Such standards are inefficient in theory and have been shown to be inefficient in practice. A much more efficient means of pollution control is to impose a uniform tax on the quantity of waste discharged to reflect the external costs of pollution. Research has shown that charging for sewage disposal has often led to rapid and dramatic decreases in discharge of industrial waste. A particular example pertains to the Delaware Estuary. There

22. For the relationship between economic growth and water used in agriculture and industry in Arizona, *see* M. KELSO, W. MARTIN & L. MACK, WATER SUPPLIES AND ECONOMIC GROWTH IN AN ARID ENVIRONMENT (1973). One of their principal conclusions is that economic growth can be enhanced by facilitating instead of restricting the transferability of water. Mackintosh makes a similar argument and gives a fuller discussion of different types of water rights and what each type implies about reaching an economically efficient water allocation, D. MACKINTOSH, THE ECONOMICS OF AIRBORNE EMISSIONS: THE CASE FOR AN AIR RIGHTS MARKET (1973).

a uniform effluent charge reduced waste discharges as much or more than if all industries had been required to achieve a uniform level of treatment. The net social cost of the uniform change was only ½ as great as a standards program.[23]

4. Subsidies (direct payment or tax incentive) from one government body to another or from the government to private industry to install pollution control equipment should not be made. Subsidies, as theory would predict, have proven a very inefficient means of pollution control. Even given the subsidy, it is still often cheaper to pollute than to install the equipment. And present programs of allocating subsidies have almost no relationship to requirements. Thus, cities that do not need added pollution control capital have it, and those that do need added capacity do not have it. Bain[24] and Mackintosh[25] describe these and other drawbacks of subsidies.

5. Consideration should be given to the establishment of an "air market" in San Diego and El Paso and adjoining Mexican cities, if further research confirms a significant air pollution problem in these cities. Under the "air market" scheme, an agency (public, nonprofit, or proprietary) would have authority to establish the total (threshold) amount of pollution that the cities' airsheds could adequately assimilate. Total allowable pollution would then be divided into units, perhaps one unit being .001 equivalent tons per 24 hours. For each unit, the agency would create a "share" or "right" to be sold in an open market. The agency would also be responsible for policing pollution emissions. Industry could bid for the rights to pollute. Or environmental groups or residents, through an annual referendum or through their elected officials, could purchase pollution rights and not use them and thereby preclude industries from polluting. This scheme offers incentives for industries and individuals not to pollute and helps assure an economically efficient use of air resources—i.e., air would be used such that the marginal social cost of polluting it would equal the marginal social benefits from doing such. Mackintosh argues persuasively for this form of air pollution abatement, and describes the many advantages of it.[26] The "air markets" scheme is a more sophisticated form of taxing pollution as described in (3) above.

6.. An overriding conclusion to be drawn from the literature, and one implied in the above discussion of policy alternatives, is that water and air problems, where they exist, are *economic* problems. The implication is that expected costs as well as expected benefits must be

23. J. BAIN, ENVIRONMENTAL DECAY 88-96 (1973).
24. *Id.*, at 91-101.
25. D. MACKINTOSH, *supra* note 22.
26. *Id.*

evaluated before a policy action can be taken. Determining that some program will reduce pollution is simply not adequate; it may cost too much in comparison to the benefits. Furthermore, if the pollution control program is to be voluntary, it will not be utilized by industry unless its benefits to them are greater than costs.

RESEARCH NEEDS

Our study of the industry-induced water and air problems along the U.S.-Mexico border suggests the following research needs:

1. Research should be focused primarily on San Diego and El Paso and should deal primarily with air pollution.
2. Greater quantities of more accurate data need to be gathered on the amount of pollution emitted by different industries. Much of the data used in the tables of direct and direct plus indirect pollution was very rough, somewhat antiquated, and often too highly aggregated for easy application to the cities of direct concern. Once such data is available, the input-output framework of analysis, as utilized by Miernyk and Sears for West Virginia,[27] will provide an excellent method for establishing the costs, in terms of foregone income and employment, of alternative pollution control schemes.
3. Research, both theoretical and empirical, needs to be done on the economics of establishing an "air market" in San Diego-Tijuana and El Paso-Juarez. Although this appears to be a viable solution theoretically for one metropolitan area, the theory has not been worked out for the case of adjoining cities in two separate countries. The two-country case is complicated by several factors: resources may not be permitted to flow freely between countries, inflexible exchange rates may prevent an efficient allocation of resources, and nationalistic goals may affect the most efficient type of pollution control program to install. Besides these theoretical considerations, there needs to be empirical research on just how much the residents of each U.S. and Mexican city would benefit, in what form benefits would be realized (decreased pollution, increased wage rates, etc.), and the distribution of these benefits and costs among different socioeconomic groups of people. Clearly such empirical information would be needed in order for the public to be informed of the advantages and disadvantages of paying for a resource that is generally considered free.
4. Economic research, evaluating the costs, the benefits, and the distribution of costs and benefits, needs to be done for any proposed water or air program before it is put into effect. Too often only the

27. W. MIERNYK & J. SEARS, *supra* note 19.

benefits are considered. Benefits need to be compared to costs to help society get the most for its limited resources.

RESUMEN

Los problemas de aire y agua resultando de la industria causan incrementos en gastos sociales a la sociedad, tanto directos como indirectos. Este trabajo tiene el objeto de determinar si ya existen o puedan existir problems significantes de agua y aire en ciudades fronterizas de los Estados Unidos, y donde sí existen estos problemas, hay discusiones sobre la economía de soluciones alternativas.

Un análisis de datos sobre usos de agua en ciudades fronteras de los Estados Unidos indica que probablamente hay bastante agua para satisfacer el uso industrial actual y futuro sin incrementar significamente el precio. Esta situación viene de dos razones. Primera, la mayoridad de agua actualmente usada va para regar agrícultura, un gran parte de que es de cosechas de valor menor comparado con el valor de producción industrial en la misma área. Sin limitaciones industriales, la industria podría pagar más que la agrícultura para agua. La segunda razón es que las industrias que usan poca agua (por valor de producción total o por empleado) como las de textiles o electrónicos, han sido creciendo substantivamente mientras que la agrícultura y las industrias que usan much agua se han disminuído en importancia.

Un análisis de datos que existen sobre contaminación de aire y agua a lo largo de la frontera indica una falta de datos básicos para llegar a conclusiones definitivas. Por supuesto las industrias que han crecido y que probablamente van a crecer en el futuro son los que no producen mucha contaminación y los con mucha contaminación se han reducido en tamaño. La contaminación iniciada por industria solamente puede representar un problema significativo en El Paso y San Diego.

Las indicaciones básicas revelan que no hay problemas importantes de aire y agua resultando de industria en ciudades de los Estados Unidos a lo largo de la frontera, con las posibles excepciones de San Diego y El Paso. Donde existen estos problemas, son problemas económicos. Hay una discusión de las implicaciones económicas de varias alternativas y de la necesidad de estudios adicionales.