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AIR POLLUTION EMISSIONS

FROM

EASTERN WASHINGTON GRAIN ELEVATORS

by

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ABSTRACT

An analysis has been made of emissions from grain elevators in eastern Washington. An emission factor of 0.5 lbs. particulate per ton of total throughput has been derived for country elevators and 0.4 lbs/ton for sub-terminal (river) elevators in Washington.

Using the above factor along with a detailed study of production, storage, transportation statistics, and total emission from eastern Washington grain elevators was determined to be 1,000 tons for 1973. This compares with a previous estimate of 11,000 tons as shown in the "Washington State Air Quality Implementation Plan," dated January 1973.

Emission tests indicate that although cyclones do not remove all the visible emissions, they can reduce emissions by over 90%.

An analysis was made of the impact emission from country elevators had on air quality at four selected air monitoring sites. In all cases, the time of maximum airborne particulate occurred at other than harvest time, and little correlation was found between elevator activity and ambient suspended particulate level. It was concluded that emission from country elevators had negligible effect on ambient air quality.

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AIR POLLUTION EMISSIONS FROM EASTERN WASHINGTON GRAIN ELEVATORS

Summary

The objective of this report is to provide an increased understanding of the grain handling industry in eastern Washington and its air pollution emissions. The study is primarily directed at the major grains, wheat and barley, which account for about 90% of the grain handled in the state. However, many aspects of handling other grains are similar, except processing of seeds, which accounts for about 5% of the total handling.

Once harvested, grain goes through a series of handling and transfer facilities before it reaches the ultimate user. The first of these is normally a country elevator or on-farm storage. Country elevators are located close to the fields and generally ship by rail to an export terminal, or by truck to a river terminal elevator for barge shipment to an export terminal on the coast.

All elevators carry out the same basic functions of receiving, storing and shipping, with the major difference between the types of elevators being the magnitude of operation. For example, a typical country elevator will handle between 100,000 and 300,000 bushels annually, 3000 to 10,000 tons, whereas a typical sub-terminal river elevator will handle at least two million bushels a year, 60,000 tons.

Emission factors for uncontrolled elevators are estimated to be 0.5 pounds per ton for country elevators, and slightly less for sub-terminal river elevators in Washington. Total emissions for all elevators in eastern Washington were calculated to be 1,000 tons per year, and about equally divided between the more than 400 country elevators and a dozen or so river sub-terminal elevators.

The major sources of emission from grain handling are: receiving, shipping, and handling within the elevator. Receiving is the most noticeable, and most likely to bring complaints. The total emission from grain elevators was found to be much less than previously estimated. Cyclones were found to be an effective control device, removing more than 90% of the potential emission. However, all cyclones observed had visible emissions.

AIR POLLUTION EMISSIONS FROM EASTERN WASHINGTON GRAIN ELEVATORS

I. Introduction

Purpose

This study was carried out to evaluate emissions from grain elevators in Eastern Washington for the purpose of providing the Department of Ecology with an increased understanding of the grain handling industry.

Scope

A grain elevator can be defined as a facility which stores grain and serves as a collection and transfer point. For the purpose of this study, the definition was further narrowed to include only those facilities whose primary function is as above, and that charged for storage and handling of the grain. For example, a seed plant, which not only stores and handles grain, but also cleans, sorts and treats it for making seed, was not considered an elevator. Also excluded is on-farm storage used for the farmer's own benefit.

The geographic area studied included the region of Washington State east of the Cascade Mountains. This area includes the Eastern, Northern, and South-Central Washington Air Quality Control Regions. These regions include all the country and sub-terminal river elevators in the state and none of the export terminals.

The definition of grain normally includes the cereal grains: wheat, barley, oats and field corn. However, dried beans, peas and lentils, as well as soy and milo, are also handled by grain elevators. Table I shows the major field crops grown in this state and the quantities produced in 1972 and 1973. Because handling and processing of all the crops, except corn, is essentially the same, and wheat and barley account for 90% of the total, limiting of the scope of the investigation to wheat and barley seems justified.

II. Industrial Structure

Patterns of Grain Movement in Washington State

Grain, once harvested, generally proceeds through a series of grain storage facilities before it reaches the ultimate user, or, in the case of Washington, is exported. Figure I shows how grain flows and estimates how much grain is handled in the state.

TABLE I

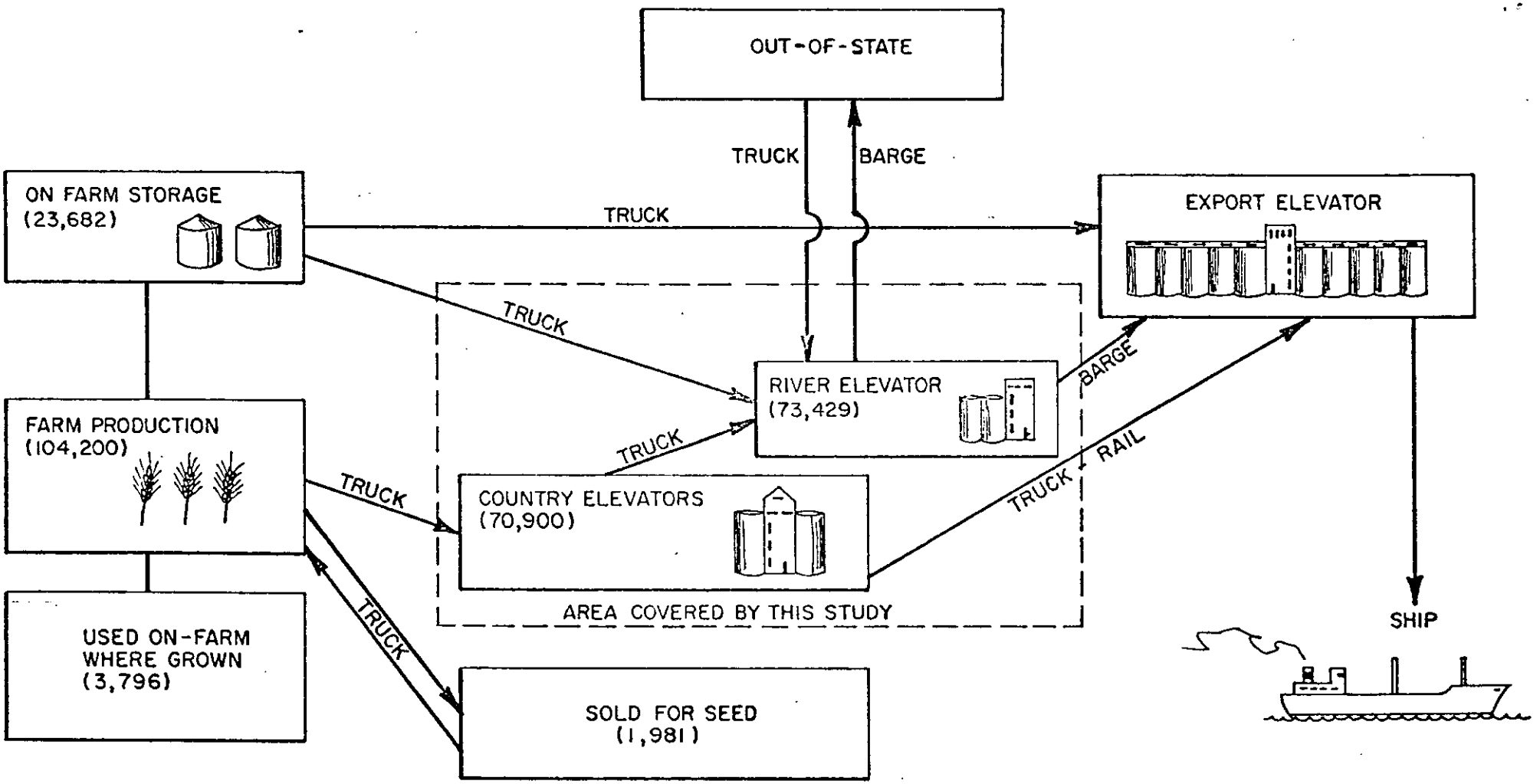
PRODUCTION OF MAJOR FIELD CROPS GROWN IN WASHINGTON STATE IN 1972 AND 1973

	1972		1973	
Wheat	123,328,000 Bu.	3,727,000 Tons	89,200,000 Bu.	2,676,000 Tons
Barley	14,190,000 Bu.	355,000 Tons	15,000,000 Bu.	375,000 Tons
Oats	2,030,000 Bu.	51,000 Tons	2,200,000 Bu.	55,000 Tons
Rye	276,000 Bu.	7,000 Tons	120,000 Bu.	3,000 Tons
Corn for Grain	5,184,000 Bu.	144,000 Tons	7,208,000 Bu.	200,000 Tons
Dry Beans	488,000 cwt.	24,000 Tons	324,000 cwt.	16,000 Tons
Dry Peas	1,191,000 cwt.	60,000 Tons	956,000 cwt.	48,000 Tons
Lentils	788,000 cwt.	39,000 Tons	655,000 cwt.	33,000 Tons

Note:

Wheat	60 lbs/Bu.
Barley	50 lbs/Bu.
Oats	50 lbs/Bu.
Rye	50 lbs/Bu.
Corn	55 lbs/Bu.

Reference: Washington Agricultural Statistics, 1973,
Washington Crop & Livestock Reporting Service, Seattle 1974



FLOW OF WHEAT AND BARLEY IN WASHINGTON STATE

(NOTE : QUANTITIES ARE 1000 Bu.)

Air Pollution Emissions from Eastern Washington Grain Elevators

Washington State Department of Agriculture reports that about one-third of the grain harvested in the state is stored initially on farms.[1] The remaining two-thirds goes from the harvest field to country elevators. Grain going to country elevators is brought in directly from the field in trucks which normally carry from two to ten tons and average about six tons. A typical country elevator will hold between one and three hundred thousand bushels (3000 to 9000 tons), and serve 5 - 10,000 acres. Generally, elevators are located on rail lines five to ten miles by road from the harvest field. Often there are two or three adjacent at the same location.

Types of Grain Elevators

The literature[2] classifies grain elevators into three types, which are defined as follows:

A. Country Elevators

A country elevator receives grain directly from the field, stores it for an extended period of time, usually more than a month, and ships to another elevator.

B. Sub-Terminal (River) Elevators

These elevators serve as a point of transfer from one mode to another, usually from truck to rail or barge. Elevators studied in this classification are located on the Columbia and Snake Rivers; hence, the name river elevators. These river elevators receive grain by truck, and ship by barge to export terminal elevators.

C. Terminal Elevators

Terminal elevators serve as primary distribution points for grain enroute to the consumer, and by definition have a state grain inspector on the site. This classification can be sub-divided into inland terminals and export or tidewater terminals. The only inland terminals within the scope of the report are in Spokane. All the export terminals in the state are located in Western Washington and, therefore, out of the scope of this report.

Ownership

Ownership of grain elevators can be classified into three areas. Listed in order of size in Washington, the categories are: co-operative, chain and independent. Co-operatives are controlled by the farmers and established under cooperative laws and regulations. Independents are elevators

which are owned by individuals or merchants. A line elevator is owned by a large firm which owns or controls a chain of elevators. Nationally, in 1963, the number of elevators owned by each category was about equal[3], but by 1980, most of the independents are projected to be taken over by the Co-ops[4].

The Washington State Department of Agriculture lists[5] 444 currently licensed elevators which are owned by 86 different firms. The average firm owns about five elevators and has a total capacity of about 1.5 million bushels.

Fees and Costs

Fees charged for receiving and handling grain range from four cents to ten cents a bushel, and are generally about seven cents a bushel ($2.33/ton). Fees charged for storage by the elevator in Washington range from 1.0 to 1.5¢ per bushel per month (33¢ to 50¢ per ton), and average about 1.3¢/bushel per month. Both storage and handling fees are normally deducted from the price of the grain when it is sold by the farmer to the elevator company. Generally the cost of transporting to market is also subtracted from the price the elevator company pays the farmer. Hence, a typical country elevator with an annual throughput of 200,000 bushels and that stores grain for an average of six months, would have an income of 14.8¢ per bushel, or about $30,000. A typical river elevator, with a throughput of eight million bushels, would have an income of over $600,000.

The cost of transportation varies greatly with mode of transportation, as can be seen in Table II. For a 300 mile cross state trip, the truck-barge combination is most economical as long as the grain is trucked less than 50 miles. In Central Washington, however, grain stored on farms often goes directly to the export terminal by truck. This is at times more economical because the increased cost involved in transferring the grain from a truck to a rail transfer point, combined with the increased rail rates for shipments for shorter distances.

Currently, Washington farmers receive between $4.00 and $5.00 a bushel ($133 to $167 per ton) for wheat, up from $1.40 in January 1972. The current price of barley is $2.00 to $2.50 a bushel, up from about $1.00 three years ago.

TABLE II

TRANSPORTATION COSTS FOR GRAIN IN WASHINGTON STATE

Mode of Transport	Rate ¢/Ton Mile
Truck	6¢ to 7¢
Rail	2¢ to 3¢
Barge	3/4¢ to 1¢

TABLE III

TRANSPORTATION COST FOR GRAIN ON A TYPICAL 300 MILE TRIP ACROSS WASHINGTON STATE

Mode of Transport	Rate ¢/Ton Mile	Distance (Mile)	Cost $/Ton
Rail	2.5	300	$7.50
Barge	I.C.	260	2.60
Truck	6	40	2.40
Transfer Truck to Barge			2.33
			$7.33

TABLE IV

TRANSPORTATION COST FOR GRAIN ON A TYPICAL 150 MILE TRIP ACROSS WASHINGTON STATE

Mode of Transport	Rate ¢/Ton Mile	Distance (Mile)	Cost ($/Ton)
Rail	3	150	$4.50
Truck	6	150	9.00
Truck-Rail			
Truck	7	50	$3.50
Transfer Truck to Rail			2.33
Rail	3	100	3.00
			$8.83

III. Physical Description

Grain elevators have four main sections: The receiving area, the leg, the storage area and the shipping area. A typical country elevator is shown in Figure 2.

The receiving area is generally on the side, in a shed, or directly under one of the storage bins. The doors at both ends are normally opened for quick processing, and because the trucks are often longer than the receiving area. In the floor of the receiving area there is a grate, normally 10' x 10', which covers the receiving pit. Trucks drive over the receiving grate and dump the grain into the receiving pit. Grain leaves the pit either by gravity into the bottom of the leg (boot), or by augur into another pit, called the back pit, and then fed into the boot.

The leg is generally an enclosed bucket elevator which carries the grain to the top of the elevator (head house). It is then dumped into the distributor, which directs the grain to the desired storage bin.

The storage bins are silos from 50 to 200 ft. high, newer ones are of steel or concrete. Most Eastern Washington country elevators, however, have wooden, rectangular storage bins called "crib houses." Flat storage is also common, but only used if the other bins are full. Where there are several storage bins in a row, or where flat house storage is used, the distributor empties into a belt conveyor and the grain is then tripped or dumped into storage.

Grain is removed from the bottom of the storage bin and transferred to the boot, usually by belt conveyor, sometimes by augur. From the boot, the grain is re-elevated and loaded into a shipping bin which is equipped with a garner scale.

Outloading generally is by gravity feed from the shipping bin, but sometimes the leg is used. Often rail cars are loaded in an uncovered area on one side of the elevator, and trucks on the other. Grain is usually carried out to a barge loading dock by a covered belt conveyor, then by spout it is loaded into the barge.

The major physical difference between country, sub-terminal and terminal elevators is size and magnitude of operation. A typical sub-terminal river elevator has a storage capacity of one to three million bushels, about ten times that of a country elevator, and the export

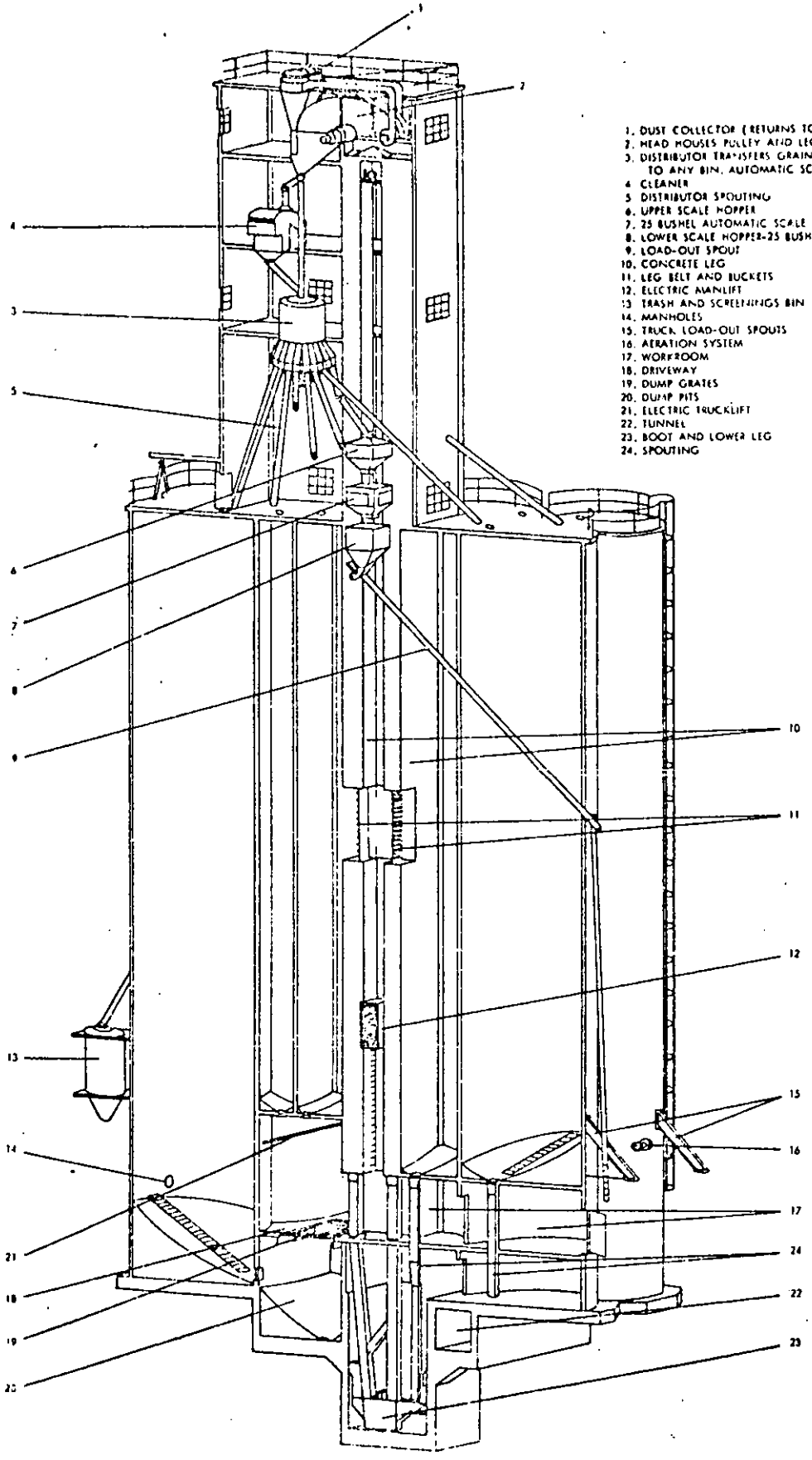


Figure 2 . Diagram of upright country elevator.

terminals in this state range from 4.1 to 5.4 million bushels[4]. Both river and export terminals are normally of concrete construction and may have two or three legs feeding rows of storage bins on either side of the legs. Export terminals differ from country and river elevators in that they normally will not have truck unloading facilities, but will have barge and rail unloading as well as ship loading.

IV. Determination of Emission Factors

Published Data

There is very little published emission data available on grain elevator emissions. The data available is often vague and based on questionable estimates or losses reported by industry. For example, in "Computation of Air Pollution Emission Factors,"[7] the EPA lists emission factors for various operations carried out by grain elevators. These values are partly based on an article written by Themsen and Aften, which appeared in JAPCA in November 1969,[8] that is based on estimates by "experienced elevator superintendents" for a terminal elevator built seventy years ago in Chicago. In another EPA reference, emissions from the unloading of a truck carrying wheat were measured. The emissions from two cyclones were measured to be 0.01 lbs. per ton, and that of fugitive dust was estimated forty times that at 100 lbs. per hour. Other estimates are equally as nebulous in that the grain quantity or quality is not specified, or only emission concentration and sometimes the rate is given and not a process weight factor.

One reference,[9] a study Midwest Research Institute did for the EPA, does list emission factors for various processes carried out at a grain elevator (see Table V). The study was carried out at a midwest terminal elevator which was equipped with a well designed particulate collection and filtering system. The particulate collected by the filter was measured for various types of grain and different grain qualities for several operations. The study examined both short term (one and two hour collections) and long term (one week) emissions for a six month period.

Data collected by this method has some limitations. It measures only particulate collected and excludes fugitive dust and any particles which pass through the cleaning system. Secondly, the collection system itself generates turbulence; hence, more particles become airborne than would have been had there been no collection system. Also, if there was no collection system, much of the particulate would settle out within the elevator.

Table V. COMPARISON OF EMISSION FACTOR DATA FROM PUBLISHED DATA

Operation	MRI Data	Published Data Ref. 1	Ref. 2	Ref. 3
Truck unloading	0.64	2.0	1	0.8
Car unloading	1.30	1.0	1	0.7
Car loading	0.27	1.0	1	1.1
Cleaning	5.78 (corn only)	5.0	5	6.0
Transfer point (gallery belt)	0.11	--	--	--
Tunnel belt	1.40	1.5[a/]	2[b/]	1.0[c/]
Headhouse	1.49	0.5	--	--

Ref. 1 - Thimsen, D. J. and P. W. Aften, "A Proposed Design for Grain Elevator Dust Collection", Journal of the Air Pollution Control Assn., November 1968.

Ref. 2 - Compilation of Air Pollutant Emission Factors, USEPA, April 1973. Values specified in this EPA document for terminal elevators are at least partially based on those of Thimsen (Ref. 1 above).

Ref 3. - Private Communication, Results reported for Cargill Chicago elevator based on calculated material balances ("shrink") over a period of 18 years.

a/ Value of 1.5 was for transferring or turning bins for cooling and may therefore include sources other than just the tunnel belt.

b/ Value of 2 lb/ton is for transferring, conveying, etc.

c/ Identified in Ref. 3 as "transferring".

Air Pollution Emissions from Eastern Washington Grain Elevators

Industry Reports

One method suggested by industry for estimating total particulate emissions is to use total losses as an upper limit. When we questioned about twenty elevator firms in eastern Washington about their total unaccountable losses, their answers ranged from near zero, or none, to less than 0.5% (10 lbs/ton). This figure includes spillage and other intangible quantities such as loss of moisture content of the grain, as well as air emissions.

Another possible upper limit on total particulate emissions is the amount of dust and other foreign matter in the grain. All of the grain sold in the state is measured for dockage by the Washington State Department of Agriculture. For wheat, dockage includes dust, broken or small kernels, as well as chaff, stems, beards and other plant parts, and is measured in one-half percent increments. All those asked about dockage, including the state grain inspector in Seattle, stated that about 95% of the grain grown in Washington State is less than 0.5% dockage (about 10 lbs/ton). Because it is generally recognized [10] that grain requires a velocity of 3,500 fpm (about 40 miles per hour) to be suspended, only a small amount of the dockage can become airborne. Hence, from dockage, the maximum amount of emissions for Washington grown wheat from each handling operation might be one or two pounds per ton.

Emissions from grain handling or turning operations can also be estimated by the amount of dust collected from existing collection devices. Many of the elevators visited in eastern Washington had dust collection systems which feed into medium sized cyclones with diameters of two to four feet and served the leg and head houses. Judging from measurements made during the field investigation phase of the study, such cyclones were found to be about 90% efficient. Since many elevators keep excellent records on the dust collected, a potential emission factor could easily be determined.

Source Tests

During the field investigation phase of the study five grain elevators were selected for emission measurements. The sites were selected on the basis of effectiveness of control equipment, type of elevator, and access for testing.

Measurements

Mass concentration measurements were taken using an Intermediate Volume Sampler. Measurements were made at both the inlet and outlet of the cyclones tested.

At selected sites Cascade impactor samples were taken to determine particle size. In some instances the cyclone outlet was inaccessible with the impactor.

In all cases, total flow was measured with a pitot tube and manometer. In most cases the total flow was assumed to be constant and only one velocity traverse was made. Normally this velocity traverse was made on the inlet side of the cyclone. Attempts were made to measure velocity across the dump pit grates, but the velocities were too low and varied too much to be measured with the equipment available. Wind across the pit was one of the factors causing the large variation in flow rates.

Particulate samples were taken to correlate with the operation being measured. For example, when measuring the emissions from a receiving operation, IVS samples were taken over a whole receiving cycle; that is, from the start of one dump to the start of the next, or until the dump pit was empty, whichever came first. Impactor samples ran for several complete cycles.

TableVI summarizes the tests.

RESULTS

Receiving

Potential uncontrolled emissions from receiving operations range from 0.04 lbs/ton to 0.8 lbs/ton for wheat. The range of emissions can be attributed to two major factors, variation of the grain and variation of the collection system efficiency. The lowest emission factor was obtained at a location where the average grate velocity was about twenty feet per minute compared to an estimated seventy feet per minute for the source with the highest emission factor. In those two cases, variation in the dust content of the grain is possible, although the two sites were only 30 miles apart. Some of the grain received by the elevator with the highest emissions was from out of state. In general, emissions from one truckload to another was found to be 50%.

Inlet concentrations were found to range from 0.2 to 5.0 gr/SDCF, with at least 50% to 90% respective, of the particulate above 5 μ. Emission from cyclones generally were below 0.1 gr/SDCF, and 50% of the particulate weight from particles below 2.3 μ in size. Visible emissions were still evident with concentration below 0.05 gr/SDCF.

Judging from this data, and other data on cyclone collections, 0.2 lbs/ton for receiving would be a reasonable estimate.

TABLE VI

SUMMARY OF FIELD MEASUREMENTS ON GRAIN ELEVATORS

			INLET		OUTLET		
Type	Operations	Control Equip.	Conc. Gr/SCF	Emission Factor Lbs/Ton	Conc. Gr/SCF	Emission Factor Lbs/Ton	Cyclone Efficiency (%)
Country	Receiving	None	0.383	0.0398			
Sub-Terminal	Receiving	Cyclone	4.95	0.77	0.17	0.0094	98.8
Sub-Terminal	Handling	Cyclone	0.684	0.488	0.028	0.011	97.7
Sub-Terminal	Rec.& Hand.	Cyclone	0.483	0.054	0.073	0.010	81.5
Country	Rec.&Hand.	Cyclone	0.186	0.16	0.20	0.16	-
Country/Pea	Handling	Cyclone	3.9	7.1	0.083	0.15	97.9
"/Lentils	Receiving	Cyclone	7.84	6.82			
"/Lentils	Rec.&Hand.	Cyclone	8.23	14.04	0.466	0.708	95.0

NOTE

NOTE

Handling

Only one wheat elevator had a dust collection system that served only the handling operations. Here there was a collection system that served the boot, leg and gallery areas. The emission factor was found to be about 0.5 lbs/ton. The source had no collection system serving the dump pit itself, and because much of the fine particulate would have been collected by such a system, the emission factor does not necessarily represent a control source. One sample taken at another source representing handling out of the receiving pit which also would be representative of internal handling. The potential emissions were measured to be 0.04 lbs/ton. This site, however, had a dust collection system serving the receiving pit.

Dust generated from internal handling is not necessarily emitted to the atmosphere; most of it normally settles out inside the elevator. Hence, a dust collection system which serves the handling operation is primarily for housekeeping. An estimate is that a quarter of the dust generated by internal handling is emitted to the atmosphere through doors, windows and vents. Thus, if 0.2 lbs/ton is generated, only 0.05 lbs/ton will leave the building for an uncontrolled source.

For the single source sampled that had a control system serving the handling operation, the emissions from the cyclone were 0.03 gr/SCF and 0.01 lbs/ton.

Shipping

No measurements were attempted of the shipping operations. However, emissions from shipping should be somewhat less than receiving and about the same as internal handling. This is in part due to the fact that there is no large dumping operation during shipping and much of the material that would have become airborne is already taken out of the grain during receiving and handling.

Table VII summarizes the estimated emission factors.

Peas and Lentils

Only one pea and lentil elevator was sampled, and it had an emission factor of about 7 lbs/ton for dumping lentils and about an equal amount for handling them. The results were similar for peas. In this case, handling included scalping (an initial phase of cleaning), which was not the case for wheat elevators. Peas and lentils are cleaned first because of the high content of dust and organic matter. In this case, large amounts of dust were still being emitted from the receiving pit; hence, total emissions would be somewhat higher.

TABLE VII

EMISSION FACTORS FROM UNCONTROLLED GRAIN ELEVATOR OPERATIONS

Operation	Emission Factor* (Lbs/Ton)
Truck Receiving	0.2
Turning (Handling)	0.5
Outloading into Trucks	0.1
Hopper Rail Cars	0.1
Boxcars	0.5
Barges	0.07

TABLE VIII

EMISSION FACTORS FOR A TYPICAL UNCONTROLLED COUNTRY ELEVATOR

Operation	Factor*(Lbs/Ton)	
Receiving	0.25	
Truck Receiving		0.2
Turning into Storage		0.05
Shipping	0.28	
Turning out of storage		0.05
Trucks (1/3 x 0.1)		0.03
Hopper Cars (1/3 x 0.1)		0.03
Boxcars (1/3 x 0.5)		0.17
Total	0.53	

TABLE IX

EMISSION FACTORS FOR A TYPICAL UNCONTROLLED RIVER ELEVATOR

Operation	Emission Factor* (Lbs/Ton)	
Truck Receiving	0.2	
Turning into Storage	0.05	
Turning out of Storage	0.05	
Loading into a Barge	0.07	
Total	0.37	0.4

*For Washington Grown Wheat

TABLE X

ESTIMATED THROUGHPUTS AND UNCONTROLLED PARTICULATE EMISSIONS OF GRAIN ELEVATORS BY COUNTY

County	Country Elevators				Sub-Terminal		
	1973 Production 1000 BU.	80% Storage Capacity 1000 Bu.	Estimated Throughput Tons	Total Pounds	Tons Estimated Throughput	Estimated Uncontrolled Emissions Pounds	Total Emissions Pounds
SOUTH CENTRAL WASHINGTON INTRASTATE AIR QUALITY CONTROL REGION							
Benton	3,118	318	9,540	5,060	300,000	120,000	125,060
Franklin	5,089	1,719	51,570	27,330			27,330
Kittitas	445	308	9,240	4,900			4,900
Klickitat	2,601	1,048	31,440	16,660			16,660
Walla Walla	13,124	2,361	70,830	37,540	976,256	370,500	428,040
Yakima	2,279	740	22,200	11,770			11,770
Sub-Total	26,656	6,494	194,820	103,260	1,276,256	510,500	613,750
EASTERN WASHINGTON/NORTHERN IDAHO INTERSTATE AIR QUALITY CONTROL REGION							
Adams	10,184	10,184	305,550	161,940			161,940
Asotin	1,507	238	7,140	3,780			3,780
Columbia	6,720	2,957	88,710	47,020	122,254	48,900	95,920
Garfield	4,944	2,682	80,460	42,640	90,000	36,000	78,640
Grant	8,099	8,099	242,970	128,770			128,770
Lincoln	9,834	9,834	295,020	156,360			156,360
Spokane	5,931	5,508	165,240	87,580			87,580
Whitman	21,964	21,964	658,920	349,230	714,363	285,750	634,980
Sub-Total	69,183	61,466	1,844,010	977,320	925,616	— 370,650	1,347,970

TABLE X

ESTIMATED THROUGHPUTS AND UNCONTROLLED PARTICULATE EMISSIONS OF GRAIN ELEVATORS BY COUNTY

County	Country Elevators				Sub-Terminal		
	1973 Production 1000 BU.	80% Storage Capacity 1000 Bu.	Estimated Throughput Tons	Total Pounds	Tons Estimated Throughput	Estimated Uncontrolled Emissions Pounds	Total Emissions Pounds
NORTHERN WASHINGTON INTRASTATE AIR QUALITY CONTROL REGION							
Chelan	65	65	1,950	1,030			1,030
Douglas	6,200	2,544	76,320	40,450			40,450
Ferry	31						
Okanogan	176	176	5,280	2,800			2,800
Pend Orielle	27						
Stevens	678	158	4,740	2,510			2,510
Sub-Total	7,177	2,943	88,290	46,790			46,790
TOTAL	103,016	70,903	2,127,020	1,127,370	2,202,872	881,150	2,008,520

Cleaning Efficiency

In general, cyclones were found to be between 80 and 98% efficient for removing particles during the receiving operation. This is substantially more than was expected at the beginning of the program. (The most efficient cyclone at small particulate size was a cyclone of the Stairmand Cherrett design.) However, every cyclone tested had visible emissions generally around 20% opacity.

Particle Analysis

The results of five particle size tests are combined in Figure 3. All of the rest were on wheat receiving operations. The figure shows cumulative concentration of particles smaller than a given size. That is, for receiving wheat there was an average of 0.02 gr/SCF of particles smaller than 5 μ. Figure IV is a similar graph for pea and lentil receiving and handling.

To calculate cyclone capture efficiency, first a least squares fit curve of the mass distribution versus particle size, see Figure V., was made for both upstream and downstream of a long cone (Stairmand Cherrett design) cyclone. These two curves were then used to determine the capture efficiency of the cyclone at any particle size, as shown in Figure VI.

From the above analysis, it can be seen that if a long cone cyclone with 95% capture at 5 μ was used on a wheat receiving operation, the emissions could be expected to be near 0.02 gr/SDF.

V. DETERMINATION OF EMISSIONS BY COUNTY

Country Elevators

To determine particulate emissions for each county, a model country elevator was used to obtain a general emission factor for country elevators. The model assumed that all grain is received by truck, as is the case in eastern Washington. Only one of the country elevator terminals visited turned the grain after it was loaded for storage; hence, the model assumed no turning. Outloading of country elevators is done by truck, boxcar and hopper cars, although very few elevators use all three. Commonly there is a mix of boxcars and hopper cars, or boxcars and trucks. Whatever the case, the total emissions would vary from 0.4 lbs/ton, for hopper carloading only, to 0.8 lbs/ton for boxcar loading only. In Table III, truck, box and hopper cars are assumed to be equally used, which results in an overall emission factor of 0.53 lbs/ton.

Country elevator emissions occur at two very distinct times: receiving and shipping. Receiving, which includes truck unloading and turning into storage, occurs over a three to four week period in July and August. Shipping normally is spread from early September to early May. As can be seen from Table III, emissions from shipping and receiving are about equal, hence about half of the emissions are generated in a four week period.

Figure I II

Grain loading from five tests of wheat dumping pits.

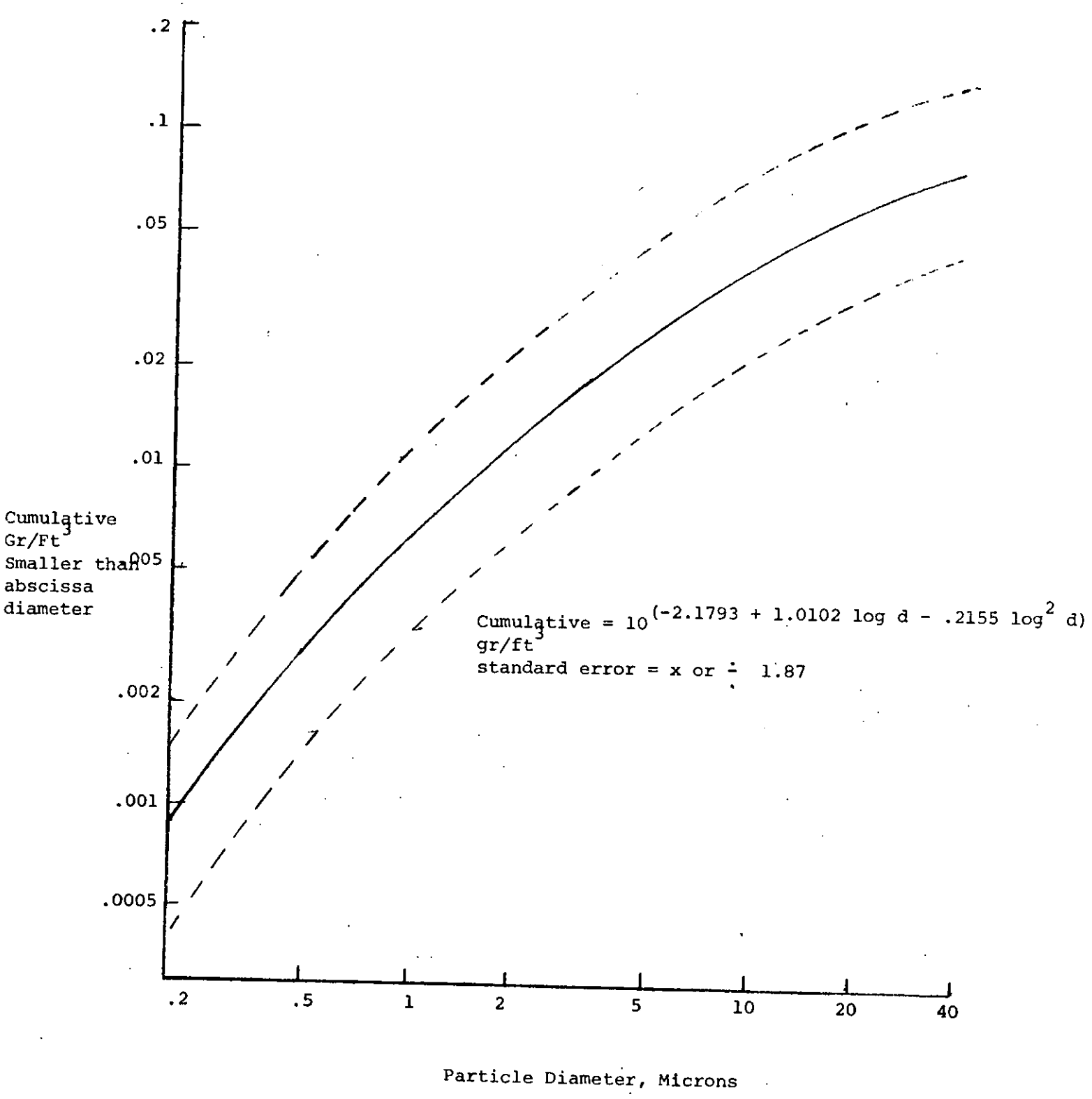
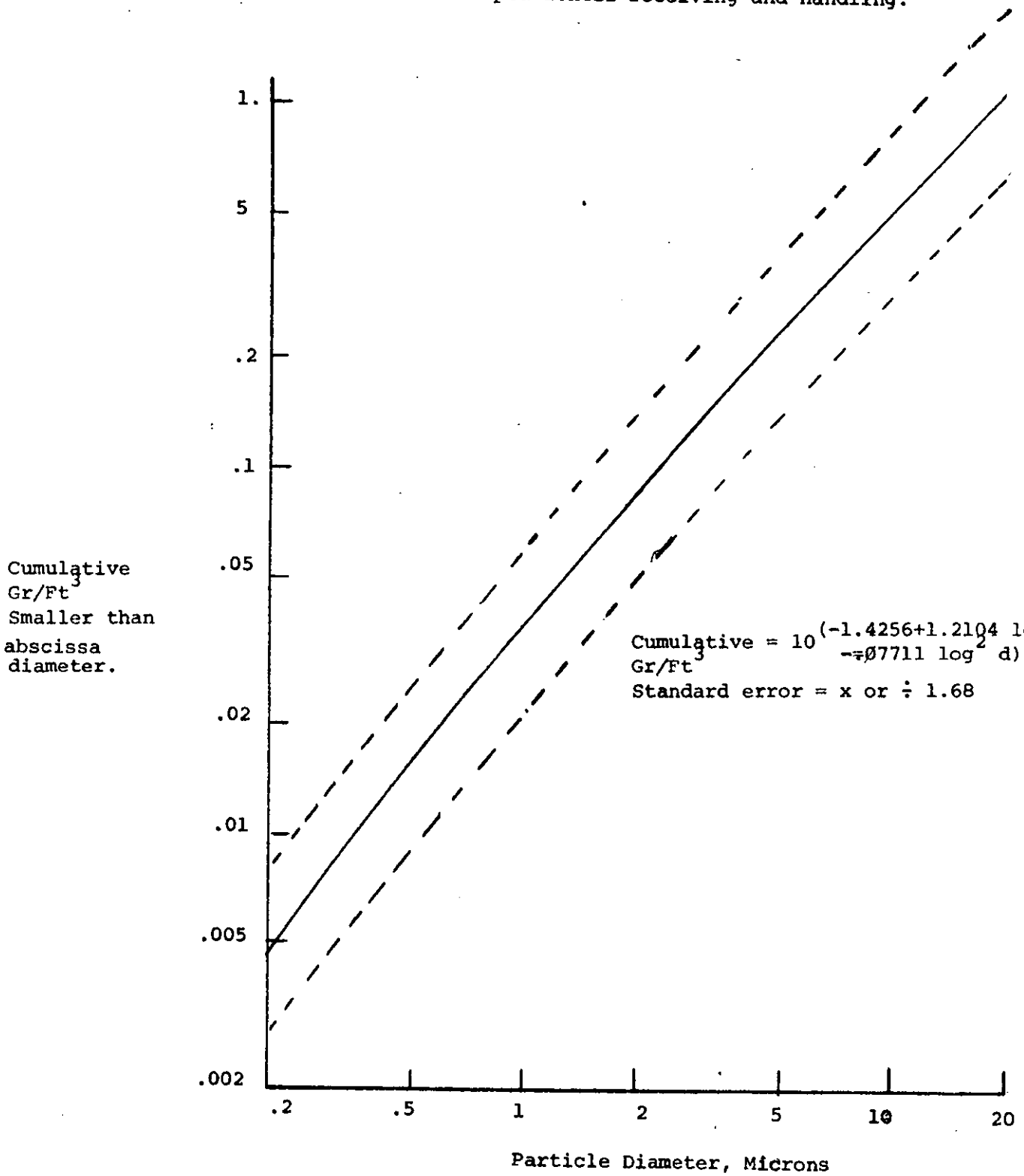


FIGURE IV

Grain loading from three tests of pea-lentil receiving and handling.



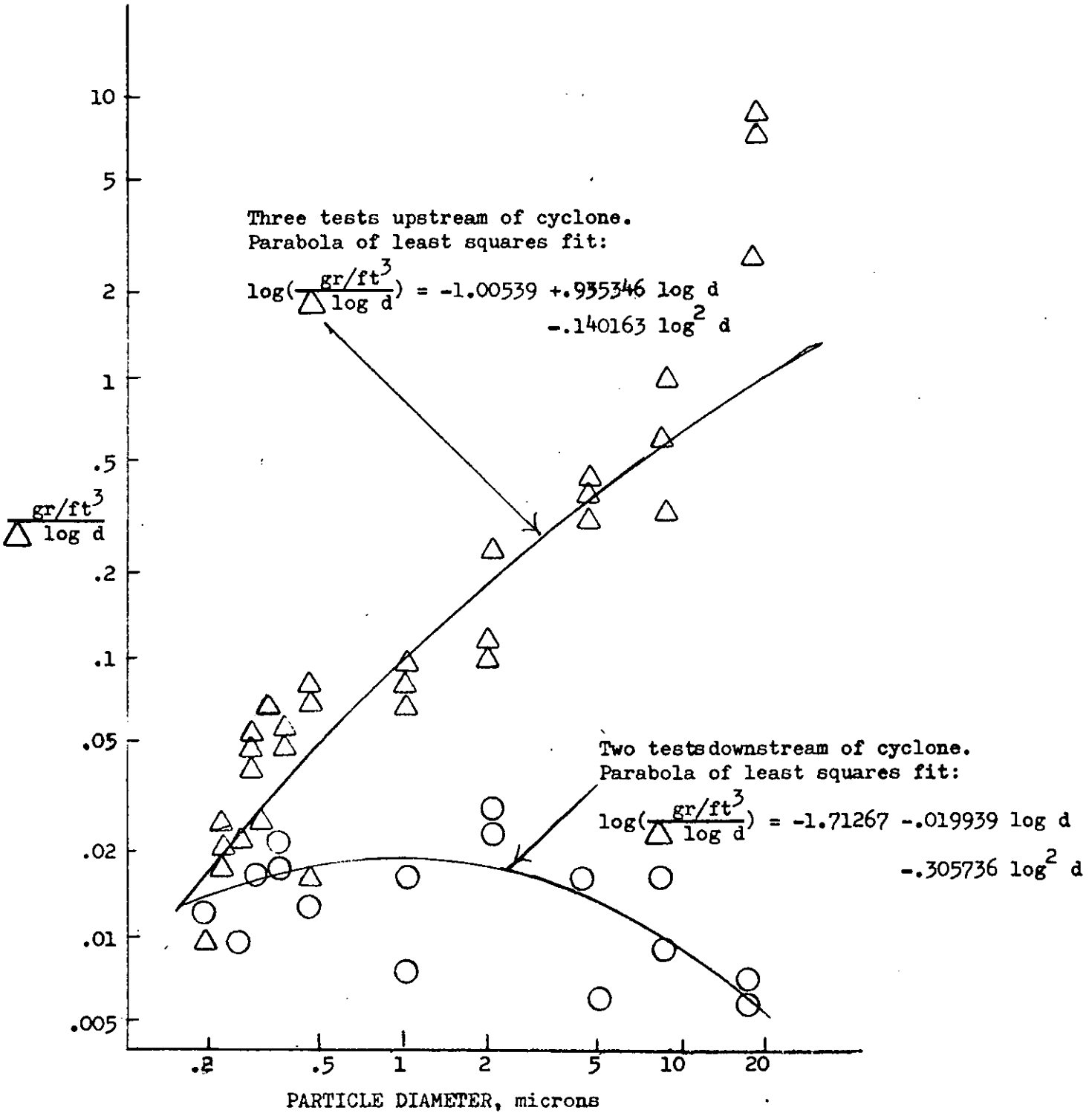
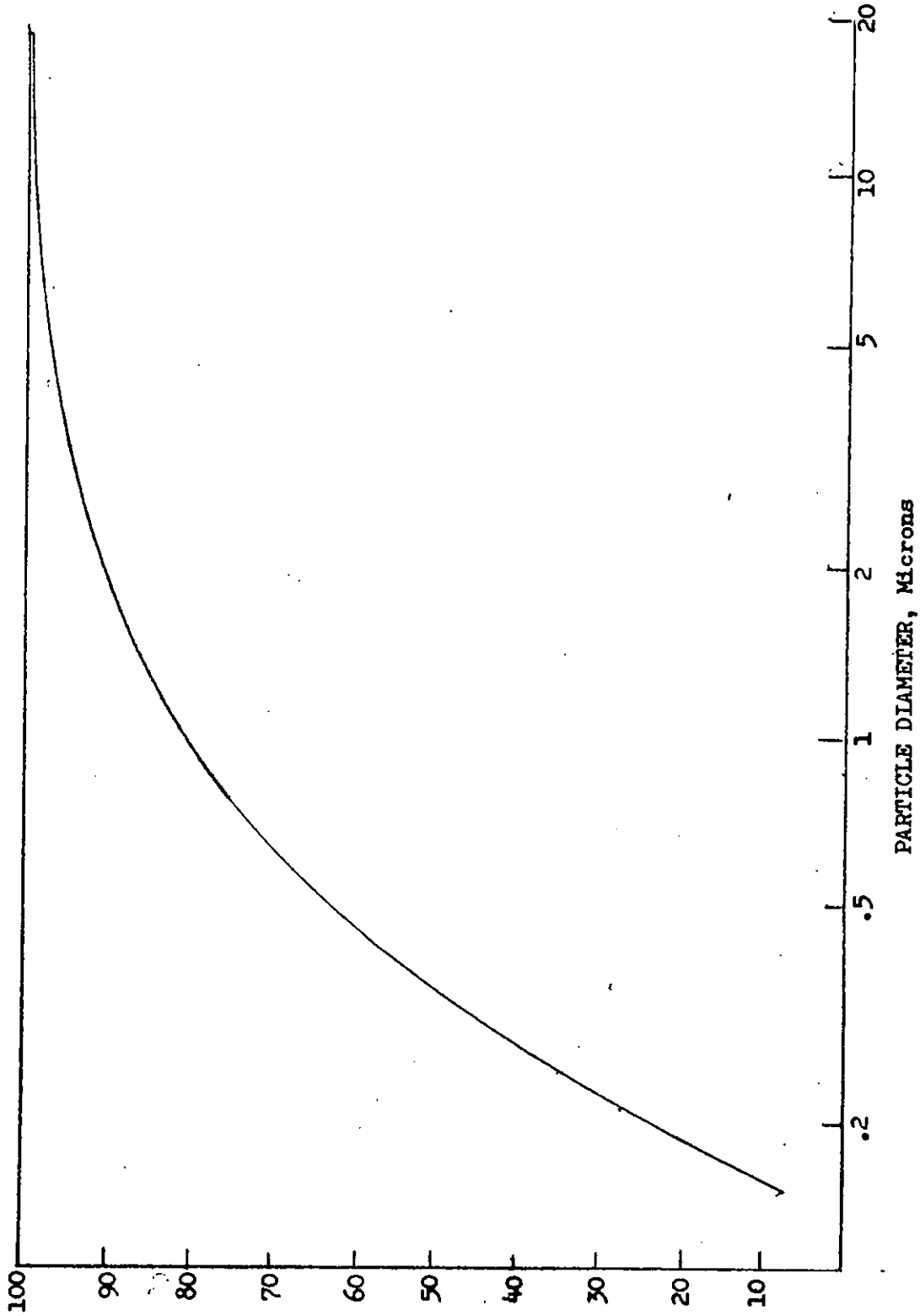


FIGURE V.

Mass distribution of particles upstream and downstream of dump pit for pea and lentil processing facility.

FIGURE VI.

Capture efficiency of a cyclone at a pea and lentil processing facility.



Annual throughput by county was estimated from capacity, elevator reports, and county production. Over the last five years, the average throughput of country elevators which we visited was 65 to 95% (except in Lincoln County, where the average was 40 to 45%). Eighty percent of the storage capacity listed in the Washington State Department of Agriculture publication "Public Grain Warehouses," was estimated to be the throughput of those elevators for which we had no special information. The total value was determined for each county in eastern Washington. Then the production of the major grains, wheat and barley, as reported by Washington Crops and Livestock Reporting Service, was added by county. Finally, the smaller of the total production and 80% of storage capacity were selected as the average throughput for 1973. This throughput was multiplied times the emission factor for county elevators to obtain total particulate emissions from country elevators by county and by air quality region, as shown in Table X, and is revised from the March 1975 estimate.

Sub-Terminal River Elevators

A similar model was used for river elevators located on the Snake or Columbia Rivers that shipped by barge. The model river elevator carried out the following operations: receiving by truck, unloading, handling into storage, handling out of storage, and loading into a barge. The emission factors and the overall emission factors are shown in Table IX to be about 0.4 lbs/ton. Since river elevators normally receive and ship all year around, their emissions are more uniform than country elevators and, hence, shipping and receiving were not calculated separately. The 0.4 lbs/ton emission factor for river elevators might be high because many of these elevators have low efficiency cyclones; on the other hand, the figure may be low because most of what they handle is out-of-state grain that contains more dust.

The throughput of river elevators was determined from the amount of grain going down the Columbia and Snake Rivers. The Walla Walla district of the Corps of Engineers supplied the quantity of grain shipped through each lock on the Columbia and Snake Rivers from McNary Lock (fifty miles downstream from Kennewick) or upstream to Idaho. From this, and knowing the throughput of some elevators, we estimated the totals for each county. Even if the estimates for each county are not accurate, the totals for the region are. For example, all elevators between McNary and Ice Harbor are in the Tri-Cities area.

The estimated throughputs were checked by adding the estimated total of all country elevators to half the capacity of all the terminal elevators. The result is approximately the same quantity that was reported by the Washington State Department of Agriculture to be in storage on October 1, 1973. Half of the storage capacity of terminal elevators was used because generally these elevators have a throughput several times the capacity and at any one time can be assumed to be half full. The year 1973 was

selected because it represents a typical production year; 1972 was a record production year, and the figures for 1974 were unavailable. Estimated emission for 1972 and 1974 would be about 30% greater, reflecting greater production.

Relative Significance

To establish the relative significance of emission from the grain handling industry, we incorporated the total emission for each air quality control region into the emission reduction figures, as published in the "Washington State Air Quality Implementation Plan," January 1973 Edition[12]. The same percent reduction was assumed and is shown in Tables XI, XII and XIII.

The emission estimates obtained in this study are between a third and a tenth of the previous estimates, indicating that emissions from grain handling may be much less a significant problem as that previously thought. The 1975 project emissions from grain handling range from 0.3% of the total emissions for the Northern Washington Intrastate A.Q.C.R. to 20% in the Eastern Washington-Northern Idaho Interstate A.Q.C.R.

VI. Potential Pollution Problems

Potential areas for complaint about grain elevator emissions can be classified under three major areas, which are: opacity, local fallout, and suspended particulate.

Opacity

Complaints generated by opacity are most likely to be a result of grain receiving. As grain is dumped from trucks and strikes the bottom of a receiving pit, the turbulence generates dust. As unloading continues, the turbulent dust laden air boils up out of the dump pit and into the receiving tunnel. At times the opacity from an uncontrolled unloading operation can exceed 60% for the two or three minutes it takes to empty a single truck. The problem is amplified by the wind tunnel effect in the receiving tunnel. This wind tunnel effect is created because wind is forced to accelerate as it flows around the main structure and through the receiving tunnel. Hence, the wind velocity in the receiving area is greater than the ambient wind speed. The problem of dust from unloading at country elevators is coincidental with other harvest activities which generate greater amounts of dust.

TABLE XVI
1975 EMISSION REDUCTION FIGURES
NORTHERN WASHINGTON INTRASTATE A.Q.C.R.

Source Category		Emissions (ton/yr.) 1970	1975	Per Cent Reduction
Particulates				
Process Losses				
Kraft Pulp Mills		--	--	--
Sulfite Pulp Mills		--	--	--
Aluminum Plants		800	800	0
Grain Handling		23 ~~516~~	21 464	10.0
Asphalt Batch Plants		252	189	25.0
Ferro-Alloy Plant		17,500	500	97.2
Other		4,510	4,510	0
	Totals	~~23,578~~ 23,085	~~6,463~~ 6,020	~~72.6~~ 73.9
Fuel Combustion				
Wood-fired Boilers		840	560	33.0
Area Coal		39	39	0
Other		949	949	0
	Totals	1,828	1,548	15.3
Transportation		389	442	-13.0
Solid Waste Disposal				
Wigwam Burners		2,105	527	75.0
Slash Burning		442	442	0
Open Burning		742	742	0
Other		115	115	0
	Totals	3,397	1,826	46.2
Misc. Area Sources				
Agric. Burning		0	0	0
Other		8,431	8,431	0
	Totals	8,431	8,431	0
Total Particulates		~~37,623~~ 37,030	~~18,710~~ 18,267	~~50.2~~ 50.7

TABLE XVII
1975 EMISSION REDUCTION FIGURES
EASTERN WASHINGTON - NORTHERN IDAHO INTERSTATE A.Q.C.R.

Source Category		Emissions (ton/yr.) 1970	1975	Per Cent Reduction
Particulates				
Process Losses				
Kraft Pulp Mills		0	0	0
Sulfite Pulp Mills		0	0	0
Aluminum Plants		3,400	1,200	65.7
Grain Handling	674	~~6,274~~	560 ~~5,009~~	16.8
Asphalt Batch Plants		442	332	25.0
Other		1,036	931	10.1
	Totals	~~11,853~~	~~8,272~~	~~30.0~~
		5,552	3,023	45.5
Fuel Combustion				
Wood-fired Boilers		702	332	52.7
Area Coal		1,081	27	97.5
Other		1,016	1,016	0
	Totals	2,799	1,375	51.0
Transportation		1,079	1,200	-10.0
Solid Waste Disposal				
Wigwam Burners		431	108	74.9
Slash Burning		393	296	25.0
Open Burning		604	302	50.0
Other		169	124	26.6
	Totals	1,597	830	48.0
Misc. Area Sources				
Agric. Burning		1,632	816	50.0
Other		0	0	0
	Totals	1,632	816	50.0
Total Particulates		~~18,960~~	~~12,493~~	~~34.2~~
		12,659	7,244	42.8

TABLE XVIII

1975 EMISSION REDUCTION FIGURES
SOUTH CENTRAL WASHINGTON INTRASTATE A.Q.C.R.

Source Category		Emissions (ton/yr.) 1970		1975	Per Cent Reduction
Particulates					
Process Losses					
Kraft Pulp Mills		2,797		502	82.0
Sulfite Pulp Mills		--		--	--
Aluminum Plants		0		350	--
Grain Handling	307	~~3,271~~	276	~~2,944~~	10.0
Asphalt Batch Plants		1,237		929	25.0
Other		2,539		2,539	0
	Totals	~~9,844~~		~~7,234~~	~~26.1~~
		6,880		4,596	33.2
Fuel Combustion					
Wood-fired Boilers		796		530	33.0
Area Coal		155		155	0
Other		3,155		3,155	0
	Totals	4,106		3,840	6.5
Transportation		810		913	-13.0
Solid Waste Disposal					
Wigwam Burners		644		166	75.0
Slash Burning		854		643	25.0
Open Burning		1,825		913	50.0
Other		305		305	0
	Totals	3,648		2,027	44.5
Misc. Area Sources					
Agric. Burning		740		370	50.0
Other		1,617		1,617	0
	Totals	2,357		1,987	15.6
Total Particulates		~~20,~~		~~16,325~~	~~21.4~~
		17,801		13,363	24.9

Dust clouds can also be generated during loading of trucks, boxcars and hopper cars. This problem is much less than truck unloading and occurs for less than 200 hours over the time from September to May at country elevators.

Sub-terminal river elevators receive and ship almost constantly all year around, hence, the dust problem would be greater.

Local Fallout

Probably the most noticeable and significant dust problem in the neighborhood of grain elevators is fallout. Whenever grain from the field falls freely through the air, some of the lighter fractions, such as chaff, become airborne. Depending upon wind and weather conditions, these lighter fractions can settle out 20 to 2000 feet downwind, creating a nuisance in the area. This fallout represents most of the particulate emissions by mass.

Suspended Particulate

Suspended particulate are much smaller and will remain airborne much longer than chaff or other plant particles that contribute to local fallout. Suspended particulates are generally made up of field dust and are of less than 10 microns in diameter and can remain suspended for long periods of time. For example, a two micron diameter field dust particle,with a specific gravity of 2.0, will have a settling velocity of about two millimeters per second[11]. If emitted at a point 50 feet high, with an average wind of five miles per hour, the particulate will settle out about ten miles downwind. Some weather conditions could cause it to remain airborne for over one hundred miles. Fortunately, suspended particulate is only a small portion of the total emission, thus the effect a long distance downwind is minimal.

VII. Impact on Ambient Air Quality

To evaluate the impact country elevators have on ambient air quality, data from four Hi-Vol stations located near country elevators was examined. It was concluded that the country elevators had little effect on the ambient air quality.

Hi-Vol stations at Colfax, Davenport, Lind and Pullman were selected because they are in rural areas within five miles of two or more country elevators and isolated from other industrial emissions. The Colfax station is within a half mile of several elevators and about a mile from some pea seed plants. Since the town of Colfax is in a

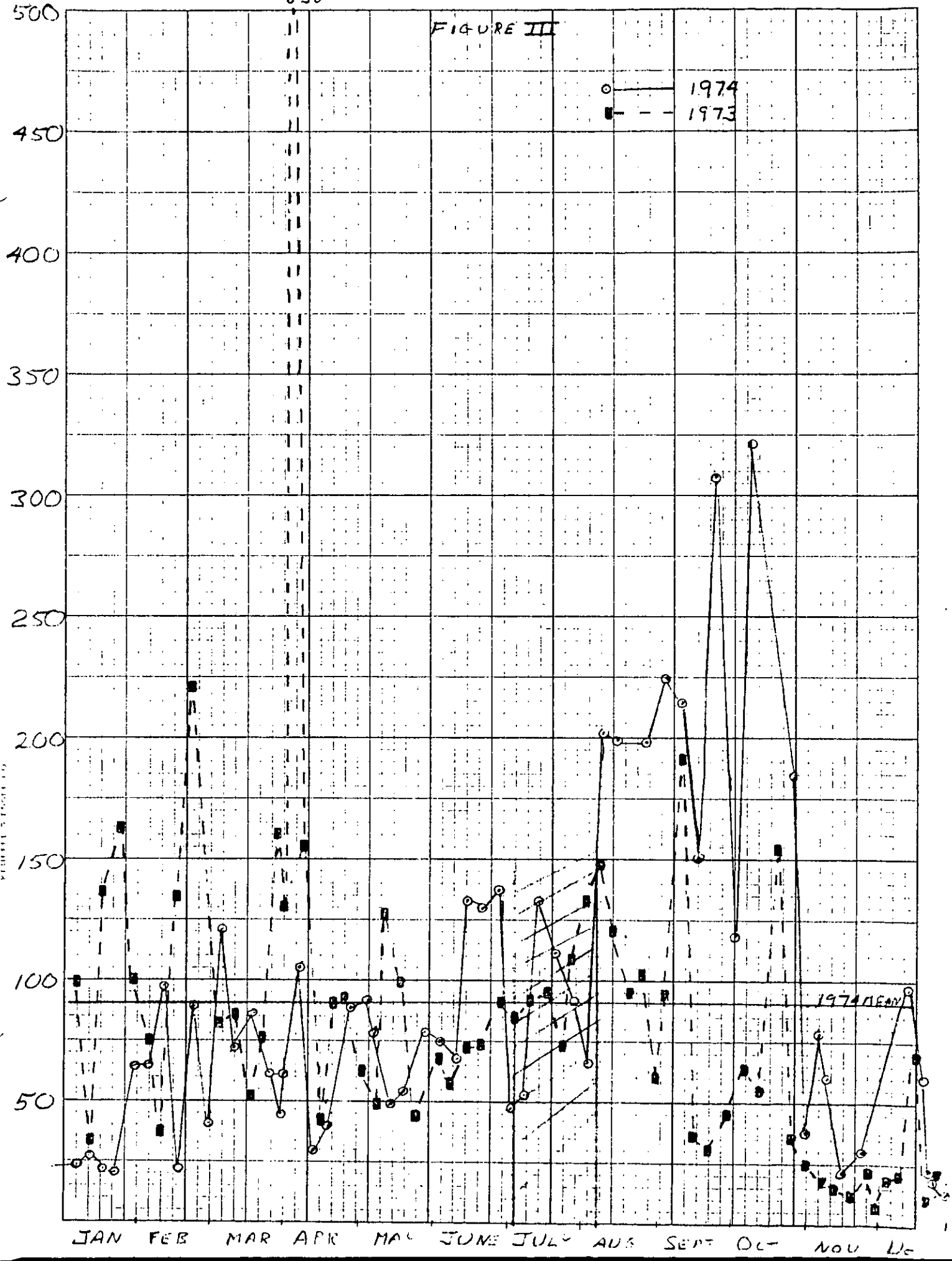
valley, the station should be most affected by sources within the town. The Davenport station is similar, but the terrain is much flatter; thus, the surrounding fugitive dust source would be expected to have a greater effect. Both the Lind and Pullman stations are in remote fields two or three miles from the elevator, with Lind downwind of the elevators and Pullman cross wind from the elevators.

The 1973 and 1974 suspended particulate concentrations were plotted against the date in Figures III, IV, V and VI. The harvest season is indicated by cross hatching on the graphs. Since most emissions by country elevators occur during harvest, one could assume that its greatest effect on air quality would be noticed at that time.

Examination of the charts indicates the Lind station was the only station that experienced average concentrations greater than the annual mean during harvest, experienced the highest value for the year during harvest, and had violations of the 150 ug/M^3 ambient air quality standard during harvest. However, all stations had levels above 250 ug/M^3 at other times. Even at the Lind station, it would be difficult to attribute the increased concentration to the elevations rather than general field activity at that time.

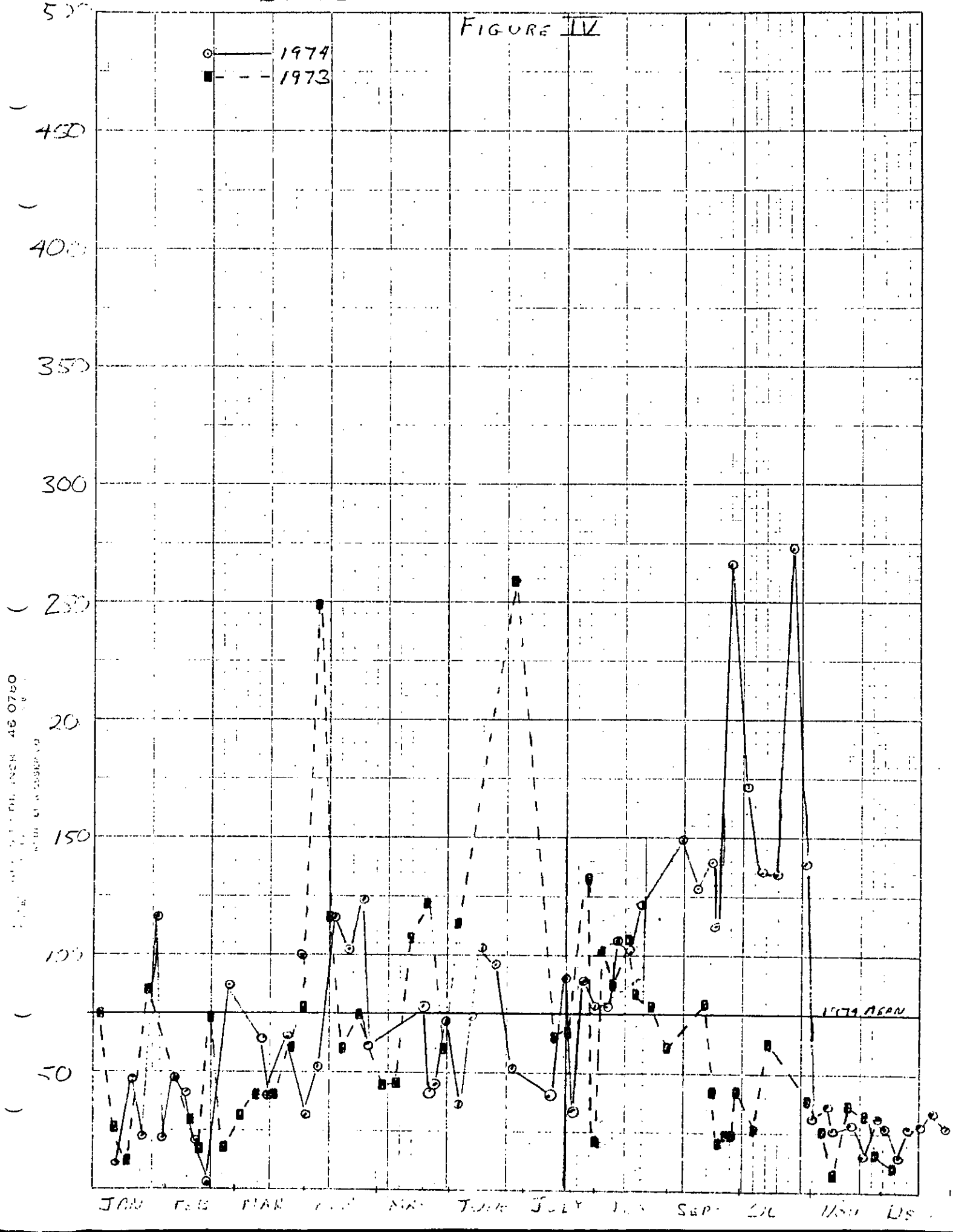
COLFAX

FIGURE III



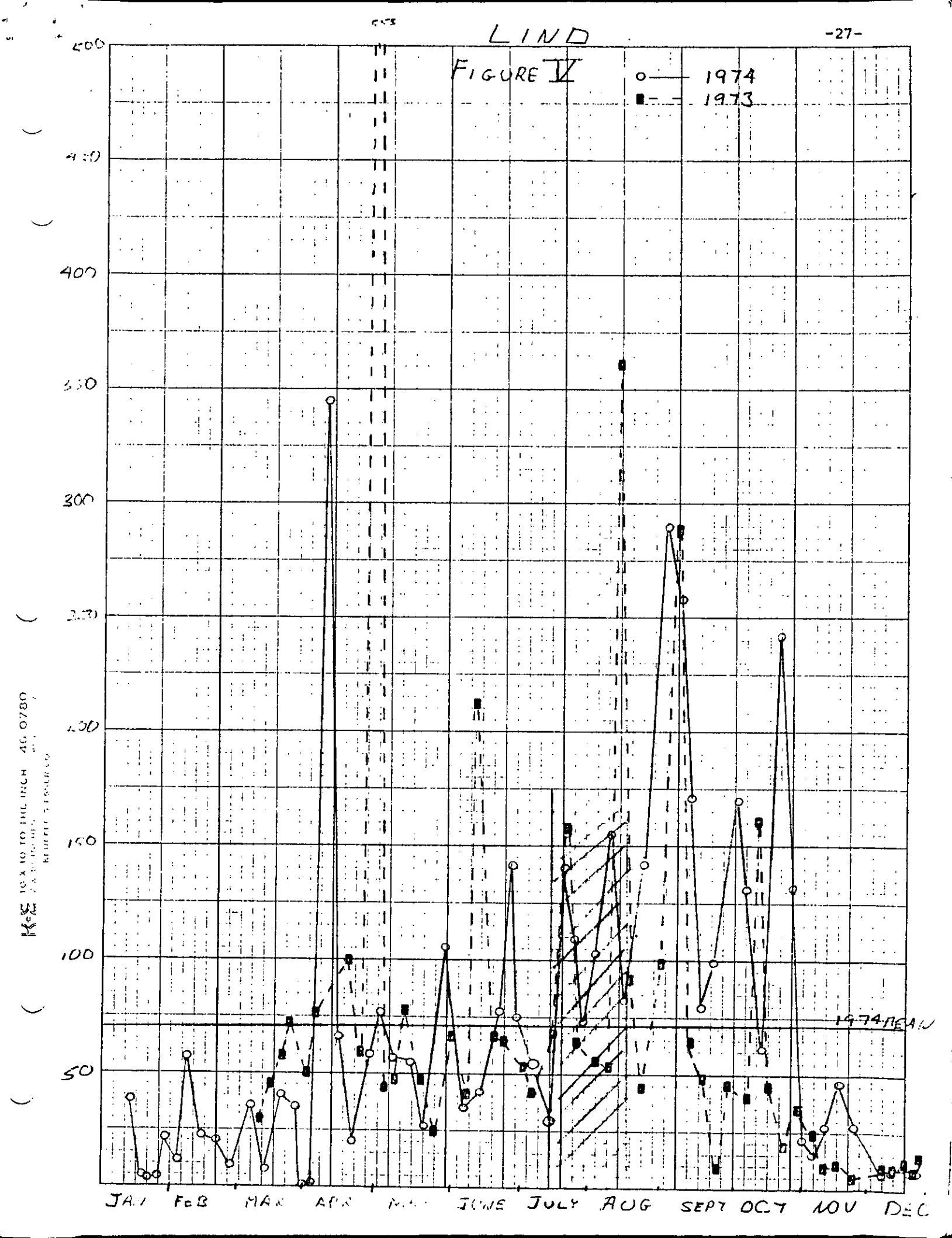
DAVENPORT

FIGURE IV



LIND

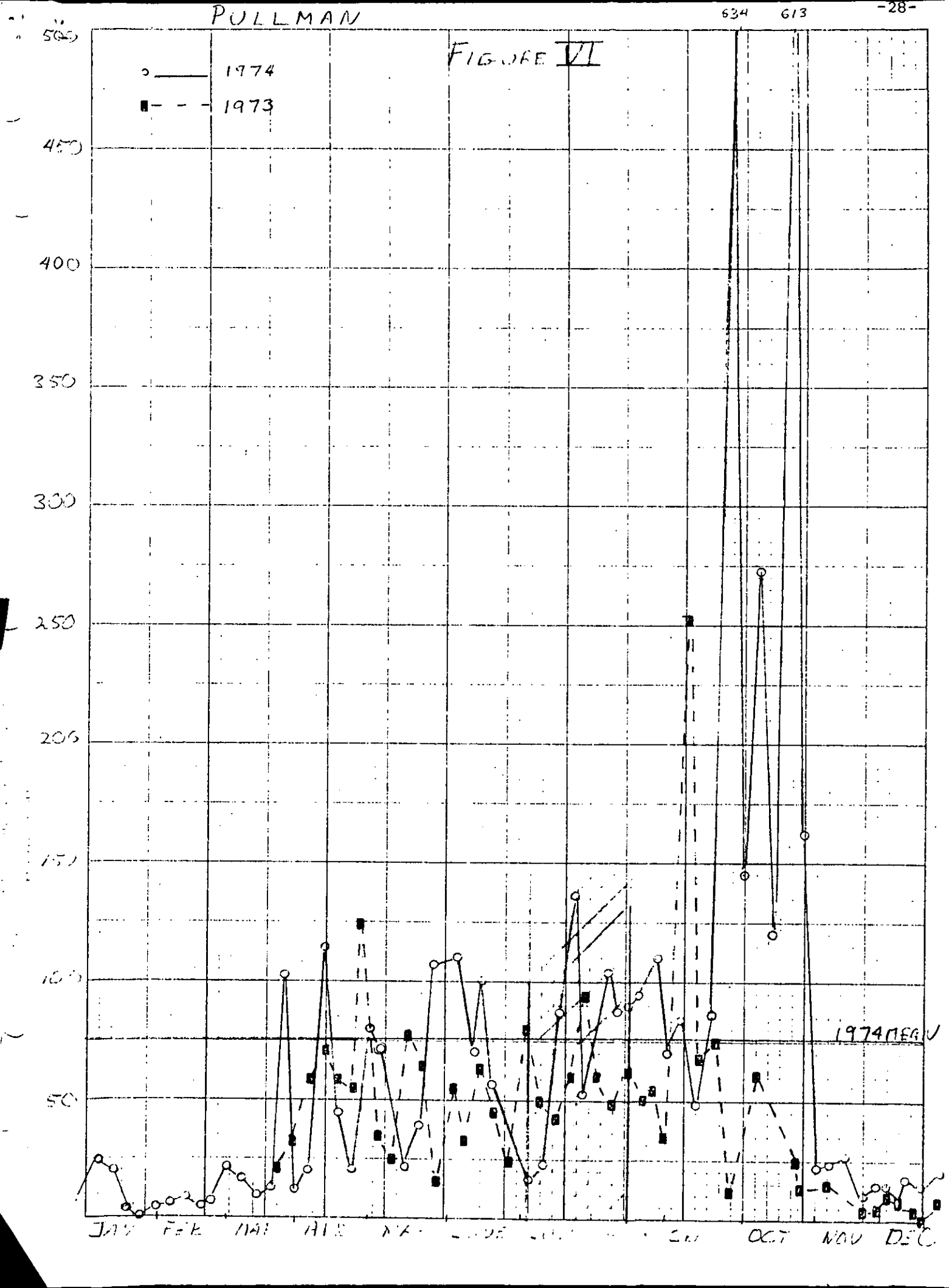
FIGURE IV



PULLMAN

634 613

FIGURE VI



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