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PROGRESS REPORT ON THE PHASE DOWN OF RICE STRAW BURNING IN THE SACRAMENTO VALLEY AIR BASIN
1995-1996

Submitted by:
CALIFORNIA AIR RESOURCES BOARD
CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

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FOREWORD

This is the second draft of the 1997 biennial report to the Legislature mandated by the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991, the Act, (Assembly Bill No. 1378, Chapter 787, sec. 2, Statutes of 1991, as Health and Safety Code Sections 41865-41866). This report is second in a series of biennial reports and covers the years 1995 and 1996.

This report will inform the Governor, the California Legislature, and interested members of the public about how the phase down of rice straw burning in the Sacramento Valley (which is mandated by the Act) has gone to date and about the status of the current feasible alternatives to burning for managing rice straw. The Act directs two State agencies, the California Air Resources Board and the California Department of Food and Agriculture, to jointly prepare these reports to cover specified subjects. Future biennial reports on the progress of the phase down of rice straw burning must be updated in 1999 and 2001.

The Air Resources Board and the Department of Food and Agriculture jointly submit this report to fulfill the requirements of the Act. The *Report of the Advisory Committee on Alternatives to Rice Straw Burning* is included as a separate volume of this report.

CHAPTER I

Executive Summary

This is the *1997 Biennial Report to The Legislature-- Progress Report on The Phase Down of Rice Straw Burning in The Sacramento Valley*. The Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 (the Phase Down Act or the Act), requires that the Air Resources Board (ARB) and the California Department of Food and Agriculture (CDFA) prepare such reports biennially. The Act requires that rice straw burning in the Sacramento Valley be phased down and, after 1999, only allowed under specified conditions for disease management.

A. Background and Key Questions

1. What are the Phase Down Requirements and are Rice Growers Complying?

Beginning in 1992, the Phase Down Act limits the acres of rice straw burned by establishing a schedule of decreasing percentages of the acres planted that may be burned. The percentages of acres planted allowed to be burned under the Phase Down Act and the percentages reported as actually burned are shown in Table I-1 for the first five years of the phase down. During each year so far, the amounts of rice straw burned have been slightly less than allowed by the Act. Total rice acreage burned has been reduced from 303,000 acres in the first year of the phase down to 211,000 acres in 1996, less than any year in the past 15 years. During the five years preceding the start of the phase down, an average of 318,000 acres is estimated to have been burned per year.

Table I-1
Sacramento Valley Rice Straw Burning Phase Down
Maximum Allowable and Actual Burned

Burn Year:	1992	1993	1994	1995	1996
Phase Down Act: % Allowable Burn	90%	80%	70%	60%	50%
Compliance: % Actual Burn	75%	68%	57%	54%	41%
Acres Planted:	402,000	450,000	514,000	501,000	515,000

Acres Burned:	303,000	306,000	293,000	268,000	211,000

2. When Has the Decrease in Burning Taken Place?

The decrease in burning has taken place primarily in the spring. Since most growers prefer fall burning soon after harvest, the growers burn all they can from September 15 through about the end of November. This time period, called the Intensive Fall Burning Season, is strictly monitored. Since the Phase Down Act does not distinguish between fall and spring burning -- only specifying the maximum total acres that may be burned in a year -- it will not, by itself, restrict fall burning to less than historical amounts until 1998. In the interim, the Sacramento Valley Agricultural Burning Plan (which preceded the Phase Down Act and remains in place) specifies when, where, and how agricultural (including rice straw) burning is to be done.

3. What is the Burn Plan and How Does It Work?

Every year since 1983, the Sacramento Valley Basinwide Air Pollution Control Council (BCC) has been required to develop a Sacramento Valley Agricultural Burning Plan (the burn plan.) The burn plan specifies the criteria to be used to deciding when, where, and how much agricultural burning will be done on a daily basis. The amount of burning allowed each day is dependant upon prevailing meteorological and air quality conditions. The plan allows significant acreage to be burned on days with good ventilation, greatly restricts the acres burned on days with limited ability to disperse smoke, and allows no agricultural burning on days of adverse meteorological and air quality conditions.

4. Has Air Quality Improved Since the Phase Down Began?

The pollutant of principal concern in the burning of rice straw is particulate matter including smoke. Overall particulate matter loading to the air basin has been reduced as a result of the phase down, but primarily in the spring when rice straw emissions are less problematic. Ambient particulate matter concentrations are much greater in the fall than in the spring. This is primarily due to meteorological conditions. In the spring there is better vertical and horizontal mixing of the atmosphere which enables the particulate matter and smoke to be dispersed and diluted more completely. Ninety-seven percent of complaints due to smoke are received in the fall even though in the past more acres have been burned in the spring than in the fall. Because the reduction in burning under the Phase Down Act has taken place almost entirely during the spring, air quality during the fall has not been improved, and complaints from the public have not decreased.

5. What Progress Has Been Made To Develop Alternatives to Burning?

Currently about 99 percent of the straw that is not burned is incorporated into the soil. Alternative uses of large quantities of rice straw are still in the prototype or testing stages. The Rice Straw Burning Alternatives Advisory Committee (which was established in 1992 as required by the Act) estimates that approximately 8800 tons of rice straw per year are being removed from the fields for uses such as erosion control and livestock feed and bedding. No major commercial facility is in operation or under construction that would use a significant percentage of rice straw produced. The Committee has estimated that about two percent of rice straw in the year 2000 will be consumed by out-of-field uses. The Committee has also made recommendations which would encourage the development and commercialization of off-field alternatives which could use 25 percent of the rice straw by the year 2000 and 50 percent by the year 2003.

6. Are Rice Growers Satisfied With the Implementation of the Phase Down Act?

Because alternative uses of rice straw are still not commercially available for the vast majority of rice straw produced, and soil incorporation has increased the cost of farming, rice growers are generally dissatisfied with the phase down. Rice growers have organized to seek relief from the phase down at least until alternative uses for rice straw become available.

7. Is the Public Satisfied With the Progress of the Phase Down?

Because burning in the fall has not been reduced to date, and because fall is when most adverse smoke effects from rice straw burning are experienced, the public continues to suffer smoke effects from rice straw burning. Members of the public have stated that they are disappointed that the number of acres burned has not declined as fast as expected, even though the growers have more than fulfilled the phase down requirements. Some have expressed disappointment that the Act will allow some (up to 25 percent of planted acres) burning to continue indefinitely to the extent it is necessary for disease management.

B. FINDINGS

On the basis of the information available, the Air Resources Board and the Department of Food and Agriculture make the following findings pertaining to the Phase Down Act.

Phase Down Implementation

1. So far, the phase down has proceeded as specified in the Act, with growers slightly exceeding the phase down mandates. Virtually all (99 percent) of the unburned rice straw has been incorporated into the soil.

Economic Impacts

2. The per-acre cost of soil incorporation is estimated to range from about $8 to $75, with an average of about $36. Since the cost of burning averages $2 per acre, the additional cost of incorporation averages $34 per acre incorporated. In 1996, when 50 percent of acres planted were incorporated, the overall additional cost averaged over all acres planted was half that--$17 per acre planted. In 1996, rice growers' total revenue was estimated to be about $782 per acre, resulting in average cash earnings of about $200 per acre. When non-cash costs, such as imputed cost of capital invested in land, equipment and unpaid labor, are considered, total production costs average about $808 resulting in an economic loss of approximately $26 per acre. The additional cost of incorporation represents about two percent of production costs and about eight percent of cash earnings. In 1996, when growers averaged an economic loss of $26 per acre, the additional cost of incorporation contributed significantly to that loss. The phase down has resulted in a small, overall impact on the economy of the Sacramento Valley. However, the economic impact is more significant on the northern counties in the valley, which have larger rice bases and smaller economies than the southern counties.

3. Recent studies of straw management practices have found an increase in the incidence and severity of two major rice diseases, stem rot and aggregate sheath spot, in incorporated fields. Rice growers are concerned that this may result in reduced yields. Although yields have decreased by as much as 15 percent in the past two years, researchers have not been able to establish that yield reductions are attributable to incorporation. It is not known to what extent repeated straw incorporation may be responsible for the recent yield decrease since other factors such as yearly weather changes also affect yields and disease incidence.

4. There are differences in soil types in the Sacramento Valley. Some soils make incorporation of rice straw more difficult, and some do not support crops other than rice. Because of this, the phase down has not impacted all growers in the same way.

5. The phase down has affected county air pollution control districts that administer the agricultural burning programs. The ever increasing number of phase down acres, which districts have to administer, add to the districts' workload. At the same time, districts' revenues are decreasing because their fees are based on how many acres are burned, which the phase down has reduced.

Environmental Impacts

6. The phase down has resulted in a decrease in smoke and emissions due to rice burning on an annual basis, but it has not yet led to cleaner air nor reduced smoke impacts during the fall when air quality is worse. This is because the Act does not distinguish between fall and spring burning. Agricultural burning contributions to air quality problems in the fall will not be reduced by the Act until the phase down is virtually complete. Although the total amount of rice straw burning has decreased, virtually all of the reductions in burning have taken place in the spring. The number of acres burned during the fall continues to be limited by the Sacramento Valley Agricultural Burning Plan rather than the Phase Down Act.

7. Emissions from soil incorporation are caused principally by the operation of chopping and tilling equipment. These emissions are much lower than what would have resulted from burning straw. In addition, the types of particulates caused by burning and incorporation are different. Burning produces very small particles which may remain in the air for long times and travel long distances. In contrast, soil emissions from straw incorporation activities consist of larger particles which will generally not remain airborne as long nor will they travel as far. Since soil incorporation activities take place primarily in the fall, most of the added emissions occur in the fall, while the reduction in emissions from not burning occurs in the spring.

Alternatives Development

8. Currently about 99 percent of the straw that is not burned is incorporated into the soil, and incorporation will remain the only alternative to burning available for the vast majority of rice straw during the next several years. This situation could change with time, but only if several promising alternatives are aggressively pursued.

9. Financial and business strategies for nurturing the development of alternatives have not been established. A straw marketing strategy has not been developed to deal with the issues of how to best harvest, bale and transport the straw, taking it from the growers to the straw users, storing the straw year-round, and setting a price for the straw. The lack of alternatives is likely to prevail unless incentives emerge to encourage their development.

C. Ideas For Change Being Discussed By Stakeholders

After participating in the workshops and other public outreach efforts, rice growers and some members of the public realize that the air quality problems from rice straw burning occur primarily in the fall. The fact that the Phase Down Act has not yet improved air quality in the fall is disappointing to all affected stakeholders. In addition, all parties are disappointed that alternative uses of large volumes of rice straw have been slow to develop. Growers are concerned about potential disease effects, yield impacts, and increased costs of farming. The public is concerned about continued smoke effects on their health and on visibility. Because of these factors, rice growers and representatives of environmental organizations began to discuss how to develop mutually acceptable changes in the Phase Down Act which would address these concerns while at the same time help to develop alternatives and improve air quality. However, as of late August 1997, no consensus had evolved yet.

Listed below are ideas for reaching a compromise that have been discussed. Continued dialog among affected stakeholders will be needed to reach a consensus on the best solution to this complicated problem. The staffs of the Air Resources Board and California Department of Food and Agriculture will follow this process closely and will consider drafting recommendations for this report if the stakeholders are able to agree on an approach.

Ideas From Rice Industry:

l. Pause the phase down schedule until economical alternatives become available.

2. Give growers incentives to shift burning to the spring. For example, allow burning, say, 120 acres in the spring for giving up 100 acres in the fall.

3. Develop financial incentives to encourage the development of alternatives such as low interest loans, loan guarantees, and tax credits.

4. Create a clearinghouse for information on alternatives to burning and other aspects of rice straw management.

5. Establish a public education program about the burn program so that the public does not automatically assume that it is rice straw burning that is causing a smoke problem.

6. Change the procurement policies of government agencies to give preference to new products made from rice straw. This would help create a market for products derived from rice straw.

Ideas From Public Air Quality Advocates:

1. Implement a research program to clarify the specific impacts of rice straw smoke on the health and well-being of people. For example, (a) determine whether there is any unique component of rice straw smoke that makes it especially irritating to respiratory systems and responsible for the number and gravity of complaints that are voiced during the burn season; (b) identify the chemical fingerprint of aged rice smoke so that chemical mass balance analyses of ambient particulate matter samples collected in urban areas during the rice burn season will be able to quantify the fraction of such particulate that derives from rice straw burning.

2. Phase down fall burning, and clarify and limit ultimate burning allowed for disease control. Some groups and individuals recognize that a change in the phase down that allows fewer constraints on spring burning may be acceptable in return for further decreases in fall burning.

3. Limit the number of acres allowed to be burned each year instead of the percentage of acres planted. This would prevent increases in burning when favorable markets promoted planting additional acreage.

4. Extend the burning phase down to all crops, in all areas of the State.

5. Provide additional funding to help develop of alternatives to burning, such as low interest loans, loan guarantees, and tax credits. For example, require that a rice straw acreage fee be established and continued until the acreage reaches the 25 percent disease management level. The ARB would collect the monies, and, under the recommendation of the Alternatives Advisory Committee, provide funding to promote the development of alternative uses of rice straw.

6. Increase fees to provide a funding source to promote the development of alternatives. For example, increase burn fees to the average cost of incorporation, and establish a tax on acreage planted instead of acres burned. Consider establishing a program which allows trading of burn permits which would require that a 10 percent “air quality tax” (i.e., acreage reduction of 10 percent when the

permit is traded), a 10 to 50 percent revenue sharing between the permit seller and a bank that would invest the funds in research, grants, and equity capital to encourage the establishment of alternative uses for rice straw.

7. Provide funding to study and evaluate methods other than burning for controlling rice diseases in order to reduce reliance on burning. Current practices rely mostly on burning infested fields.

D. Recommendation of the ARB and CDFA

One premise that appears to be accepted by all stakeholders is that the emergence of economically sound activities that consume large amounts of rice straw will be the key to the successful implementation of the Phase Down Act. To this end, the Air Resources Board and the California Department of Food and Agriculture recommend that an integrated policy be developed to support the development of rice straw alternatives involving all necessary State boards, departments and agencies working with the Legislature. This should include making funding available for the rapid development of alternatives to burning either as grants, loan guarantees, or through other mechanisms.

E. Recommendations of Rice Straw Burning Alternatives Advisory Committee

The Rice Straw Burning Alternatives Advisory Committee has released a revised progress report of the Committee's work to identify alternative uses of rice straw. One of the findings of the Committee was that only two percent of available rice straw would be used out-of-field by 2000. The Committee developed recommendations which, if implemented, would increase the projected use of rice straw to 25 percent by the year 2000 and 50 percent by 2003. The Committee's recommendations are:

1. To spread new technology investment risk among the beneficiaries of commercializing the new rice straw technologies (i.e., the developers, the investment banks and the public), legislation should be pursued to provide up to 30 percent loan guarantees for the first two commercial facilities of each new technology application in the Sacramento Valley. Some potential state agency funding sources for the loan guarantees are the (a) California Pollution Finance Control Authority and (b) the Alternative Energy Financing Authority.

2. The Rice Straw Tax Credit should be amended to allow broader support for the development of alternative use technologies. The annual aggregate cap of $400,000 represents approximately 9,000 acres out of 515,000 acres planted in 1996.

3. State, federal and local governments should encourage the use of rice straw ethanol for energy uses by: devoting research funds to improving the new technologies market efficiencies, conducting demonstration projects to educate the potential consumers and end-user businesses of the uses of rice straw as an energy source, and providing regulatory support for environmental analyses that support the development of these technologies in the market place and give credit for their environmental benefits to California.

4. The CARB, the CDFA, the California Energy Commission, the Rice Research Board, and other funding organizations with related interests should undertake jointly funded research and development efforts to improve the economics of collection, transportation and storage of rice straw for diversion to off-farm alternative market uses.

5. CARB, the CDFA, the Department of Consumer Affairs, the California Energy Commission, environmentalists, the rice industry, and Sacramento Valley cities and counties should continue to support appropriate construction standards for rice straw building construction. In addition, jointly funded demonstration projects are needed to educate the public, regulatory agencies, and potential commercial market users on rice straw in building construction.

6. State government, the University of California, and the rice industry should promote and facilitate research in crop rotation systems, including new crops, to provide additional straw disposal approaches as a means to increase the effectiveness of rice straw incorporation.

7. State government, the University of California, and the rice industry should promote and facilitate continued research on methodology and soil/crop impacts of in-field disposal and removal of rice straw.

8. Consider amendments to AB-1378 which would allow permit trading under the conditional burn section.

9. State, federal and local governments, and the rice industry should encourage the use of rice straw for environmental mitigation, educate the potential consumers and end-user businesses of the uses of rice straw as a raw material, and provide regulatory support for environmental analyses that support the development of this application in the market place, and give credit for the resulting environmental benefits to California.

    a. The High Sierra Resource Conservation Development Council and the Farm Services Agency for Placer County worked jointly on a project to

promote the use of rice straw for erosion control at construction sites. The committee strongly recommends that these agencies and growers continue to work together towards the formation of a cooperative or similar effort to stabilize prices and meet demand.

b. Much of the environmental mitigation work on roads and fire rehabilitation is under the direct control of state, local and federal agencies. Therefore, the CARB and the CDFA should assess the need and identify how to target the governmental agencies involved in planning and implementing environmental mitigation to optimize straw use in their rehabilitation efforts.

c. The Committee recommends that funds be budgeted in one or more state agencies, for example the California Department of Forestry and Fire Protection, to make straw available on an on-going basis. Such agency could contract for this service. If properly stored after cutting and baling, the straw could be transported on demand for erosion control or fire rehabilitation conducted by that agency.

CHAPTER II

Background

Introduction

This is the *1997 Biennial Report to The Legislature--Progress Report on The Phase Down of Rice Straw Burning in The Sacramento Valley*. The biennial reports are required by the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 (the Phase Down Act or the Act.) The Act requires that rice straw burning in the Sacramento Valley be phased down and, after 1999, only allowed under specified conditions for disease management. The California Air Resources Board (ARB), the Air Pollution Control Districts (APCD), and the California Department of Food and Agriculture (CDFA) are responsible for managing the phase down. Under the Act, the ARB and the CDFA must submit joint, biennial reports to the Legislature on the progress of the phase down of rice straw burning.

To gather information for this report, the ARB and CDFA devoted considerable effort to public outreach that included holding public workshops, stakeholders' forums, and individual meetings with interested parties. About 250 copies of the preliminary draft report were mailed out for public comment. The Advisory Committee on Alternatives to Rice Straw Burning also held a public meeting on May 29, 1997, to hear comments on the Committee's draft report.

Two public workshops were held--on Wednesday evening, April 3, 1997, at Colusa County Fairgrounds and on Saturday afternoon, April 5, at the ARB headquarters, in Sacramento. Rice growers primarily attended the Colusa workshop relating the problems they have had with the phase down. The growers said they saw no relief in sight since alternatives to burning, other than soil incorporation, seemed no further along than they were two years ago. Attendees of the Sacramento workshop included rice growers, representatives of environmental organizations, straw technology entrepreneurs, and members of the public concerned about the smoke impacts of burning. Some of the ideas presented at the workshops are included in *Chapter 1 - Executive Summary, Section C - Ideas for Change being Discussed by Stakeholders.*

On March 3, 1997, a stakeholders' forum was held to encourage the exchange of information among rice growers, environmental and public health representatives, straw technology entrepreneurs, and members of the public concerned about the smoke impacts of burning. On June 19, 1997, a forum was held on "Investment Opportunities Associated with Rice Straw Burning Alternative Technologies." This forum was jointly sponsored by the ARB, the CDFA, and the California Trade and Commerce Agency. The purpose of this forum was to showcase the potentially available technologies, to

present information about financial resources available to help those technologies to be commercially effective, and to identify strategies for promoting public and private partnerships to finance emerging technologies.

This report covers the progress of the phase down during the first five years (1992-1996), with the focus on 1995 and 1996. The report describes the agricultural burning program in the Sacramento Valley, explains the requirements of the Act, reports the progress of the phase down, gives the economic and environmental assessment of the phase down, and reports the progress of the development of alternatives to burning. The *Report of the Advisory Committee on Alternatives to Rice Straw Burning* is included as a separate volume of this report.

A. Definition of Problem

Rice is the most widely planted crop in the Sacramento Valley, and the acres under rice cultivation have been increasing during the last several years. After Sacramento Valley rice growers harvest the grain in the fall, they must clear rice straw from hundreds of thousands of acres (about 515,000 acres in 1996-97) in preparation for future crops. Typically, three tons of rice straw are produced per acre. Burning the rice straw has traditionally been the means of choice for disposing of rice straw after the crop has been harvested. Besides being relatively cheap and easy, burning is used to control rice diseases which can reduce the yields of future crops.

Growers prefer to burn in the fall, soon after harvest. Unfortunately, fall is also the time of poor air quality primarily because of stable meteorological conditions which cause the skies in the valley to stay smoky. In contrast, in the spring there is better vertical and horizontal mixing of the atmosphere, and this enables the particulate matter emissions to be dispersed and diluted more completely. Although more acreage has traditionally been burned in spring months, the public primarily associates agricultural burning with the fall months, sometimes even assuming that there is no burning occurring in the spring since the smoke effects are minimal. In contrast, smoke effects during fall burning can be significant, especially on days when meteorological forecasts are not successful and the smoke drifts to the populated areas of the valley.

The biggest problem with burning rice straw is the emissions of smoke and other pollutants into the atmosphere and their effects on ambient air quality, visibility, and public health. Many citizen complaints and air pollution problems occur during the intensive fall burning period, from September 15 until about the end of November, when pressure to burn as much acreage as possible is at its peak, and meteorological conditions for smoke dispersion are usually near their worst. People with respiratory

illnesses, such as asthma, bronchitis, and allergies, are especially susceptible to the adverse effects of smoke.

Agricultural burning in the Sacramento Valley went from being unregulated prior to 1971 to being managed by increasingly sophisticated smoke management programs. Under the current program, the amount of burning allowed each day during the fall is dependant upon prevailing meteorological and air quality conditions. Timing and location of the burning are carefully managed. Though the annual numbers of public complaints and smoke impacts have declined since the beginning of this smoke management program in 1981, both still persist.

B. The Phase Down Act

Public complaints and adverse effects of the burning on visibility and air quality led to the passage of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 (the Phase Down Act or the Act). The Act requires that rice straw burning in the Sacramento Valley be phased down and eventually allowed only under specified conditions for disease control. The Act specifies the percentage of acres that may be burned based on the number of acres planted. The burn year (September 1 through August 31) is based on the year the crop was planted. The resulting phase down program, separate from the agricultural burning program (described in Section B), began in 1992 and has significantly reduced the yearly amounts of rice straw burning. In the 1996 burn year, 211,000 acres were burned compared to 303,000 acres in the 1992 burn year. The phase down program has not yet produced fall air quality benefits and is not expected to do so, under the present law, until 1998 (at the earliest) when 25 percent of the rice acres planted may be burned. The Phase Down Act is included as Appendix A.

Table II-1
Rice Straw Burning in SVAB Phase Down Schedule

In Burn Year	% of Planted Acres Allowed To Be Burned
1992	90%
1993	80%
1994	70%
1995	60%
1996	50%
1997	38%
1998	25%
1999	25%
2000	up to 25%

Starting in the year 2000, burning will be allowed only for disease control using conditional burn permit regulations. Under this provision, the maximum allocation will be the lesser of :

1) a total of 25 percent of each individual applicant's planted acres that year; or,

2) the total of 125,000 acres in the Sacramento Valley may be burned, which ever is smaller.

The Act requires that each biennial status report include the following:

- The progress of the phase down;
- An economic and environmental assessment of the phase down;

- The status of feasible and cost-effective alternatives to burning;
- Recommendations from the Advisory Committee on the development of alternatives to rice straw burning;
- Any recommended changes to the Act; and
- Discussion of any other related issues.

The law mandated the establishment of two advisory committees. The Rice Straw Burning Alternatives Advisory Committee is charged with evaluating potential alternatives to burning. In July 1997, the Alternatives Committee issued an updated report on the status of alternatives.

The Disease Management Committee is charged with developing recommendations for procedures to be used to issue conditional burn permits when rice disease has caused significant yield losses. The Committee has been meeting since January 1997.

C. Description of Agricultural Burning Program

Agricultural burning has been regulated pursuant to section 41850 *et seq.*, of the Health and Safety Code since 1971. Regulatory guidelines for implementing the program are set forth in Title 17 of the California Code of Regulations (CCR), sections 80100 *et seq.*, as well as in the rules and regulations of the Sacramento Valley's air pollution control districts. Agricultural burning in the Sacramento Valley is regulated with a unique, variable acreage burning program. This program was developed in 1981, tested during the falls of 1981 and 1982, and approved by the ARB on September 30, 1983. From 1971 until the fall of 1981, agricultural burning in the Valley was regulated using a simple *burn* or *no-burn* control program similar to that now used in the rest of the State. Prior to 1971, agricultural burning was unregulated by the State. Since the variable acreage program was instituted, visibility at Sacramento Executive Airport has improved greatly. Figure II-1 illustrates how the increasingly sophisticated burn management programs have improved visibility at this location.

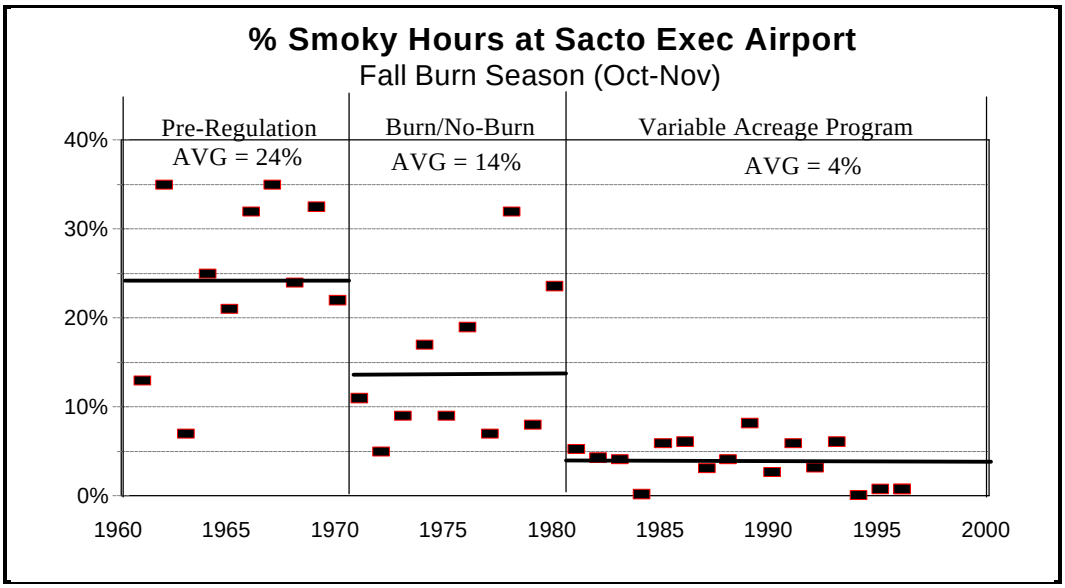


Figure II-1

Each year the Sacramento Valley Basinwide Air Pollution Control Council (BCC) and its Technical Advisory Committee (TAC) prepare the Sacramento Valley Agricultural Burning Plan. The BCC is comprised of representatives of all the air pollution control districts in the Sacramento Valley. Title 17 requires the ARB and the BCC to cooperate in developing the burn plan to be effective from September 1 through August 31 of each year. The ARB contributes to the development and revision of the plan through participation with the district staff, growers, and the public at meetings and workshops held by the BCC. The pertinent Title 17 sections are included as Appendix B. As specified in Title 17, the BCC submits a revised burn plan annually to the ARB for approval. The plan specifies the criteria to be used in deciding when, where, and how much agricultural burning will be done. The amount of burning allowed each day is dependant upon prevailing meteorological and air quality conditions. Using the criteria outlined in the plan, ARB meteorologists determine the number of acres allowed to be burned each day. Distribution of the allocated acres is done by the coordinator of the BCC during the intensive fall burn season and by the ARB the rest of the year.

The burn program is based on allocation formulas that are designed to match the amount of burning allowed each day to the ability of the atmosphere to disperse smoke on that day. The program's goal is to allow agricultural waste to be burned without causing or contributing to violations of the State ambient air quality standard for suspended particulate matter or significantly deteriorating existing air quality. Every day during the fall intensive burning period, the number of acres that the ARB

determines may be burned is distributed among the districts by the coordinator of the BCC in accordance with the annual burn plan. The distribution is based on district needs (acres ready to burn), amount of rice planted, air quality, and prevailing meteorological conditions. Burn acreage is distributed among the districts through a computerized telecommunications network. *The 1997/1998 Sacramento Valley Agricultural Burning Plan* is included as Appendix C.

The intensive fall burn season begins on September 15 and ends at the beginning of the fall rain season each year since the rains make the agricultural debris too wet to efficiently burn. The allocations are higher during the months of March and April due to improved atmospheric dispersion. Figure II-2 illustrates that although more acreage has been burned on average in the spring, public complaints about agricultural burning are overwhelmingly received in the fall months (97 percent.). Despite the burning of more acres during the spring, complaints and poor air quality are nearly all received during the fall. Because of this, fall burning is more strictly monitored by the burn program.

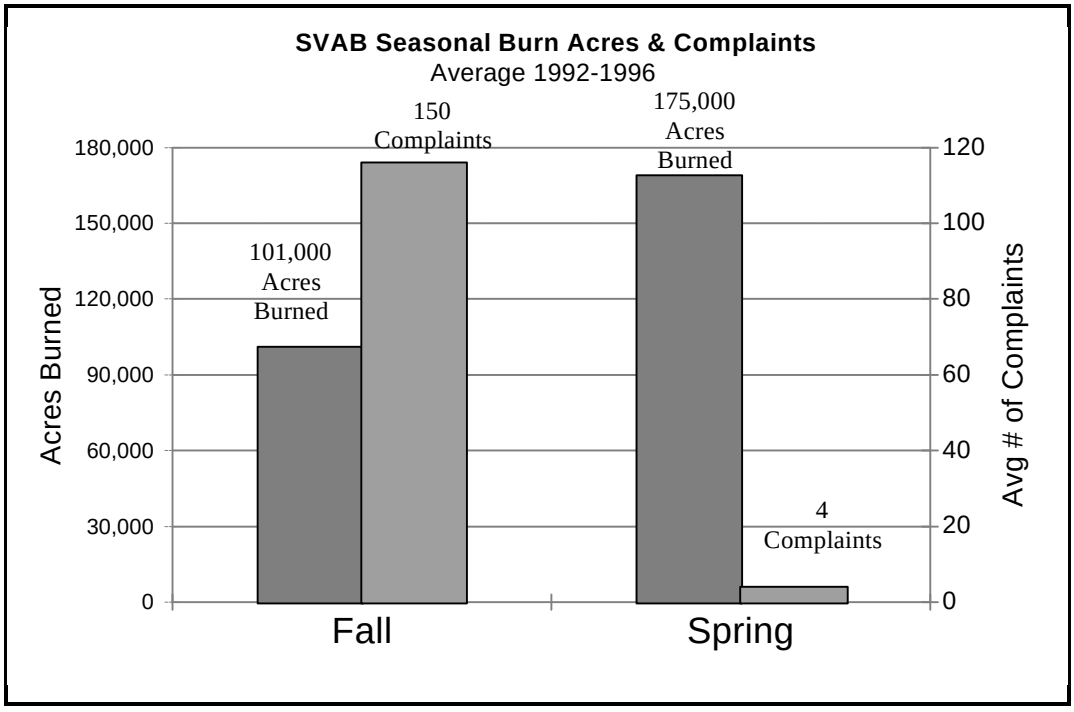


Figure II-2

Because the Phase Down Act specifies the percentage of rice straw that may be burned for the entire burn year, the burn plan is followed to determine the allowable

burn acreage each day, and in determining when and where the acreage is to be burned. The amount of burning allowed each day is dependent upon prevailing meteorological and air quality conditions. The plan allows significant acreage to be burned on days with good ventilation, greatly restricts the acres burned on days with limited ability to disperse smoke, and allows no agricultural burning on days of adverse meteorological and air quality conditions. However, there are some days when meteorological forecasts are not successful and smoke impacts affect populated areas of the valley.

The burn program manages burning of all agricultural residue, not only rice straw. Figure II-3 illustrates the different types of agricultural burning in the fall of 1996. Table II-2 lists, for the last five years, the last day of the fall intensive burn season, the total agricultural acreage and rice acreage burned, and the percentage of acreage burned that was rice straw. Although 1995 had the longest fall burn season, it had the fewest number of acres burned. This is because the fall of 1995 experienced especially poor air quality (see Chapter IV), and so the burn program restricted burning in order to not contribute to the air quality problem.

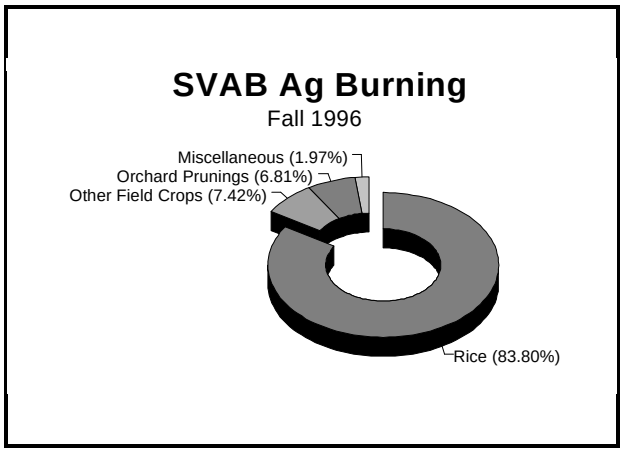


Figure II-3

Table II-2
Rice versus All Agricultural Acres Burned
Fall Intensive Burn Season

Year	Last Day	All Ag Acres	Rice Acres	Rice Acres as % of All Ag Burned
1992	Nov 29	165,000	137,000	83%
1993	Nov 29	108,000	84,000	78%
1994	Nov 9	113,000	102,000	90%
1995	Dec 3	101,000	75,000	74%
1996	Nov 17	128,000	109,000	85%

D. Health Effects of Particulates and Smoke Emissions

Airborne pollutants resulting from open-field burning have been recognized as both harmful and irritating to people. Due to the irritancy, smell, and visual impairment that smoke causes, public complaints rise when the Sacramento Valley area skies are smoky. When smoke exposures occur, people with respiratory illnesses, such as asthma, allergies, and bronchitis, are likely to suffer health impacts.

The key components of rice smoke that are of health concern include directly emitted particles, particles (and aerosols) formed from emitted materials, and gaseous, vapor-phase materials. There is no direct epidemiological or toxicological information that specifically explains how rice residue smoke impacts health. However, there is a great deal of information on how the constituents of smoke, in general, can worsen existing illnesses. There is also evidence that prolonged exposures to smoke may cause permanent health effects. Recent research has indicated that higher exposures to PM_{10} particles correspond with increased daily mortality rates and the worsening of symptoms in people with respiratory diseases.

Fine particles, those less than 2.5 microns ($PM_{2.5}$) in size, may be more harmful than larger particles. Approximately 85 percent of the particulates from the burning of rice straw are $PM_{2.5}$. The federal Environmental Protection Agency recently announced new air quality standards for $PM_{2.5}$. Recent information indicates that levels of asthma have increased greatly in the last decade in this country and worldwide. Although researchers have not drawn conclusions attributing a cause for this increase, the relevance here is that the population of people who are acutely sensitive to smoke from agricultural burning has increased greatly.

CHAPTER III

Progress Of The Phase Down Of Burning Rice Straw 1995 and 1996

This chapter addresses compliance with the phase down requirements including how the ARB and the air pollution control districts are implementing the phase down program. The emphasis is on the 1995 and 1996 burn years, although some data from the first three years of the phase down are included. Methods used to manage rice straw in the Sacramento Valley and other regions are also discussed. Recent legislation relating rice straw burning is also summarized.

A. Compliance With Phase Down Requirements

Decreasing Rice Straw Burning

The Phase Down Act limits the acres of rice straw that can be burned to a percentage of rice acreage planted each burn year. The maximum acreage percentages allowed to be burned under the Phase Down Act and the percentages reported as burned are shown in Table III-1 for the first five years of the phase down. In each year so far, rice straw burning has been reduced slightly more than required by the Act. Total rice acreage burned has been reduced from 303,000 acres in the first year of the phase down to 211,000 acres in 1996, less than any year in the past 15 years.

Table III-1
Sacramento Valley Rice Straw Burning Phase Down
Maximum Allowable and Actual Burned

Burn Year:	1992	1993	1994	1995	1996
Phase Down Act: % Allowable Burn	90%	80%	70%	60%	50%
Compliance: % Actual Burn	76%	70%	59%	55%	42%
***Acres Planted:**	402,000	450,000	514,000	501,000	515,000
Acres Burned:	303,000	306,000	293,000	268,000	211,000

* Revised to include rice acreage growing seed.

During the last 16 years, rice acreage has varied from 300,000 to 550,000 per year. Prior to the phase down, most of the straw was burned. Since the phase down started in 1992, the acreage burned has decreased substantially. In 1996, about 515,000 acres of rice were planted. Figure III-1 shows the historical rice acreage planted and burned.

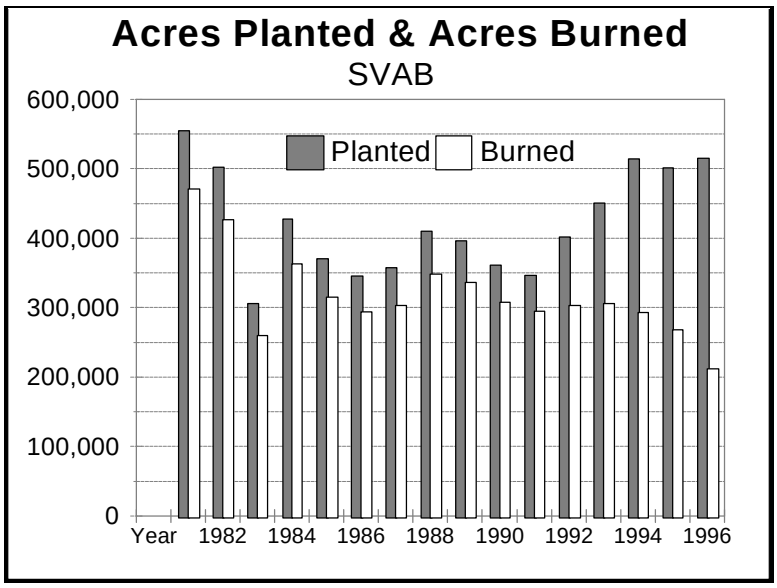


Figure III-1

The phase down has been accomplished by decreasing the burning primarily in the spring. Most growers prefer fall burning, soon after harvest, for a variety of reasons such as: waiting to burn may delay spring planting, burning is used to control diseases, and some soils take too long to dry out in the spring. Because of these reasons, the preference is to burn from September 15 until about the end of November. This time period, called the Intensive Fall Burning Season, is strictly monitored. The Phase Down Act does not distinguish between fall and spring burning, only specifying the total yearly burn as a percentage of acres planted. The Sacramento Valley Agricultural Burning Plan is used to specify when, where, and how agricultural burning is to be done. Figure III-2 shows how spring and fall burning

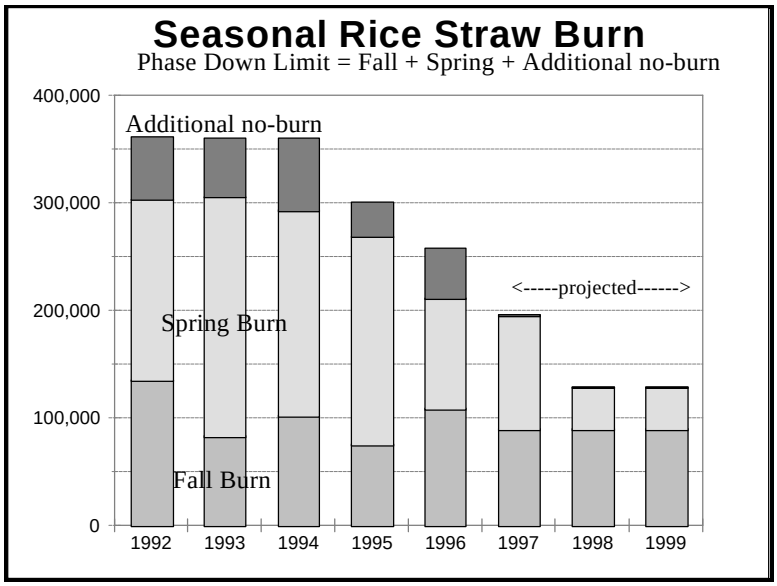


Figure III-2

have changed since the phase down.

District Implementation of Phase Down

The districts have implemented this mandate by requiring each rice grower to phase down the burning of rice straw. Rice growers are asked to identify on field maps the portions of their rice fields which will not be burned. Growers make these designations each year when they register their fields with the districts for the purpose of obtaining burn permits. During this registration process, district staff verify that the acreage designated *no-burn* for each grower meets or exceeds the minimum phase down requirement of the Act. Growers are at liberty to modify these no-burn designations, including the trading of burning rights with growers in other counties, with the approval of the air pollution control district, provided that the minimum phase down requirements continue to be met for the valley as a whole.

Pursuant to the annual Sacramento Valley Agricultural Burning Plan, the air pollution control districts provide the ARB with summary reports on the total rice acreage planted for the year, with the acreage identified that will not be burned in meeting the phase down schedule. These reports are submitted before October 31 of each year. Table III-2 shows the revised data for crop years 1995 and 1996. As shown, the rice burn acreage reductions required by the Act have been met in each of the last two years of the phase down. In 1996, substantially more acres were not burned than the Act required: 59 percent of the acreage was not burned compared to 50 percent required to be not burned.

Table III-2
Phase Down Summary SVAB 1995 and 1996 Burn Years

	1995				1996		
County	**Acres Planted**	**No-Burn Acres**	**%Not Burned**		**Acres Planted**	**No-Burn Acres**	**%Not Burned**
Butte	90,433	52,503	58		103,550	63,485	61
Colusa	127,264	50,687	40		137,680	83,404	61
Glenn	86,939	37,456	43		86,441	45,923	53
Placer	16,100	6,120	38		16,800	8,601	51
Sacramento	10,269	4,621	45		11,050	5,400	49
Sutter	107,863	50,457	47		95,820	56,544	59
Tehama	1,858	1,404	76		1,500	750	50
Yolo	25,012	14,505	58		25,999	18,303	70
Yuba	34,967	14,736	42		35,880	20,988	58
TOTALS:	501,000	232,000	46		515,000	303,000	59
Total no-burn acreage required under the Act:		200,000	40%			257,000	50%

Administration of Phase Down

The ARB staff has worked closely with districts' staffs during the last five years to ensure that these agencies are implementing the Act. At least once every fall, the ARB's Compliance Division staff visits each of eight air districts in the Sacramento Valley where the rice is mainly grown to evaluate the operation of their rice field burning programs. Areas of interest include the burn permit fee structure, rice grower education efforts, acreage allocation practices, and district staffing levels during and after regular work hours.

All the districts report having staff on duty on the weekends in 1995 and 1996 during the fall intensive burn season to distribute acreage allocations, and all districts also had staff available for field surveillance on these weekends in 1995. All but one district reported staffing for weekend surveillance in 1996.

In addition, the ARB staff routinely conducts aerial surveillance, both with and without district participation, to verify that the designated phase down fields are not being burned and that the burns observed are conducted within legal limits. Flights are conducted on burn and on no-burn days, and before, during, and after burn hours. The surveillance team uses a Geo Positional Satellite receiver to fix the position of a noted activity and promptly communicates the details to the pertinent air district by transceiver.

The districts' staffs provide the ARB with quarterly enforcement reports concerning agricultural burning activities, including any violations documented and the enforcement actions taken. This is required by the annual Sacramento Valley Agricultural Burning Plan.

Most districts do not have sufficient numbers of inspectors in the field to detect violations of the agricultural burning regulations as they are occurring. In addition to conducting the district compliance inspections, districts' staffs have reported to the ARB that they rely upon the neighbors of the growers to inform them of illegal burning. The phase down results in greater numbers of fields that may not be burned and which must be patrolled and verified, and districts do not have enough inspectors to ensure that some fields are not illegally burned.

The findings of the aerial surveillance observations are summarized in Table III-3. Detailed directions to the locations of the alleged burning violations observed during aerial surveillance flights are turned over to the affected districts for further investigation and enforcement action. These include no further action needed, issuing a

written warning, and issuing a Notice of Violation (NOV) and pursuing a penalty settlement. The Sacramento Valley districts reported issuing a total of 15 NOVs in 1996, and 11 in 1995, for burning violations during the fall rice burning season.

Violations involving the burning of phase down acreage have not been observed during aerial surveillance, and the districts have not reported any cases where phase down acreage was intentionally burned. In a few instances, fires reportedly spread accidentally from burnable acres into phase down acres. Districts have not reported (in the quarterly enforcement reports submitted to the ARB) issuing any Notices of Violation for the burning of phase down fields.

Table III-3
Aerial Surveillance Observations Fall 1992 - 1996

	1992	1993	1994	1995	1996
No. of Flights	5	9	4	4	6
No. of Violations	21	9	6	1	18
Prunings Violations	15	3	0	0	4
Field Crop Violations	0	6	5	1	12
Other Violations	6	0	1	0	2

Table III-4
Aerial Surveillance Observed Field Crop Violations
Fall 1992 - 1996

Details of Violations	**1992**	**1993**	**1994**	**1995**	**1996**
No. of Fields in Violation	0	6	5	1	12
No. of Rice Fields in Violation	0	3	0	0	10
No. of Corn Fields in Violation	0	3	0	0	0
Burning on No-Burn Day	0	0	0	0	4
Burning on Prunings-Only Day	0	1	0	0	0
Burning After Burn Hours	0	1	5	1	8
Unauthorized Lighting Technique	0	4	0	0	0
Burning of Phase Down Acreage	0	0	0	0	0

Future Impacts of Phase Down

The ARB's and districts' staffs are concerned that as the phase down continues, the funding available for district enforcement of agricultural burning requirements will be diminished. Burn fees are assessed on the basis of rice acres allowed to be burned, and under the phase down, fewer acres will be burned each year. The air pollution control districts have the authority to increase their fees to cover the cost of administering the phase down program, but due to the strong opposition to increased fees, they have been unsuccessful in doing so. In fact, at a fall 1994 meeting, one county board of supervisors ordered its director of air quality to suspend field inspections as a result of fiscal constraints.

As the phase down continues, it is important that enforcement efforts be maintained in order to ensure compliance. If non-compliance rates increase, it may be necessary to increase monitoring of agricultural burn activities by regulators and to institute larger penalties for violations.

B. Air Pollution Control Districts Program Administration

Policies and Procedures

After the passage of the Act, the air pollution control districts within the Sacramento Valley revised their burning program policies and procedures to implement the new law. The basic provisions of the rice straw burning phase down program required changes in six areas:

1. Developing the computer software to calculate the phase down requirements by year and the required reductions;

2. Collecting appropriate data on the phase down from rice growers;

3. Developing methods to track fields not burned;

4. Maintaining the computer databases to support the emission reduction credit program and trading of fields;

5. Conducting surveillance; and

6. Preparing annual acreage phase down summary reports to the ARB.

Two policy changes requested by the growers, field trading and improved information management, have been implemented to aid them in complying with the phase down.

The districts have adopted a policy that permits growers to *trade* fields, that is, to substitute burning in one grower's field for burning in another's. Rice growers requested field trading as part of the phase down program. Trading has given growers flexibility in meeting the phase down requirements, and its use has increased as the phase down has progressed.

Improved information management capabilities have been provided to both districts' staffs and the Basinwide Air Pollution Control Council's Central Computer Operator through the purchase of new computer hardware and an upgrade to the software program which tracks all the burning related information. A computer database and a telecommunications system are used to implement these new features.

Phase Down Increases District Workloads

Growers are asked to provide more information by the end of September to identify which fields they will not burn. A basinwide policy has been adopted which requires the growers to complete the pre-registration process before any fields may be placed on the ready-to-burn list or to qualify them for trading. Growers must have valid burn permits and must specify their no-burn acreage to the districts after they harvest in order to place a field on the ready-to-burn list. The grower-identified fields are placed on a ready-to-burn list in the order of harvest. As the burning progresses, the district's staff updates the burn records to ensure that each grower and the district as a whole comply with the phase down.

The database management program tracks burning activities for each field and grower, calculates the resulting phase down percentage for each grower, and creates lists for ready-to-burn and no-burn fields. The software program also assists in: 1) preparing the paperwork for completing field inspections; 2) tracking the phase down; and 3) creating the annual report to the ARB.

Administration of the phase down program is accomplished in the following three ways:

1. Registration data from the rice growers;

2. Operation of the daily agricultural burning program; and

3. Periodic field inspections.

Administration of the phase down program is closely related to the administration of the variable acreage burning program because, in each case, only authorized fields are allowed to be burned. Field inspections are also used to verify phase down acres and trading. The printouts from the database provide the staff assigned to enforce the regulations with information needed to conduct inspections. These inspections may be conducted unannounced and may target specific growers or fields.

The districts' ground inspection programs complement the ARB's inspection program which uses small planes to do aerial surveillance. Inspections are conducted during both fall and spring. The burning of crop residue other than rice straw is also monitored for compliance with burning regulations.

The workload of conducting inspections has increased because staff time must be allocated to checking the fields designated as no-burn as well as those burned. More information has been required from the growers, and, therefore, more staff time is required to process it. Because of the difficult fiscal circumstances in some counties, resources to support this program are often redirected from other aspects of the air pollution control program.

Administering field trading is one of the most costly parts of a district's program. Multiple contacts with rice growers are needed to: 1) explain the options to growers; 2) complete the data requirements; 3) make the availability of tradeable acres known to growers; and 4) to notify growers of new program requirements. Verifying that growers are meeting the phase down requirements becomes more complicated as trading activity increases. This process requires frequent modifications and double checking of databases to ensure that they are accurate.

Districts' staffs also verify inter-county trades by phone. For some districts, it is a full-time job for one or more staff members to contact the growers each burn day to

authorize burning of specific fields. Most districts have only one or two staff members working on the agricultural burning control program.

Impacts of the Phase Down Program, 1992-1996, on District Costs and Revenue

In most districts, the fees charged for agricultural burning permits during the last four years have not covered the districts' costs of operating the agricultural burning program, as shown in Table III-6. Cuts have been made in other programs at those districts to support the agricultural burning program.

Table III-5 shows how the fees charged for agricultural burning permits vary from district to district. Butte, Feather River (Sutter and Yuba Counties), Placer, and Sacramento Counties have fees that include yearly base (or registration) fees plus fees based on the acreage to be burned. The base component ranges from $25 in Butte and Feather River to $50 in Sacramento County. The acreage fee for rice straw burning varies from a low of $.25 per acre in Butte, to $1.75 per acre in Sacramento County.

Table III-5
Burning Program Fees

District	Burning Program Fees
Butte	$25 + $0.25 per acre
Colusa	$5 to $20 + $0.50 orchards, $0.75 field, $0.85 rice per acre
Feather River	$25 + $0.25/$0.50 per acre other/rice
Glenn	$15 to $255 based on acreage ranges
Placer	$35 + $0.50 per acre
Sacramento	$50 + $0.50 pruning, $3.50 orchards, $1.75 field crops per acre
Shasta	$30 per permit for land clearing
Tehama	$30 to $155 based on acreage ranges
Yolo-Solano	$30 + $0.85 orchards, $1 misc, $1.25 field, $1.50 rice per acre

Glenn and Tehama Counties have fees based categorically on the total acreage to be burned. Although the fee charges are supposed to cover the costs of the programs (including the rulemaking, computer time, inspection, and other costs), the districts have not raised their fees sufficiently to keep up with the costs of the variable acreage burning program and the phase down program.[1]

[1] Glenn County's fees have not changed, but are based on acreage *planted* instead of acreage burned.

Table III-6
Air Pollution Control Districts'
Burning Program Costs Compared to Fees

	1991/92		1992/93		1993/94		1994/95		1995/96		1996/97	
District	Costs	Fees	Costs	Fees	Costs	Fees	Costs	Fees	Costs	Fees	Costs	Fees
Butte	$25,772	$15,970	$26,244	$38,560	$38,170	$45,792	$28,365	$43,248	$65,000	$44,433	NA*	$45,000
Colusa	63,152	27,628	92,280	30,195	110,696	47,329	117,950	40,000	103,484	87,149	100,000	74,000
Feather River	85,500	65,500	100,000	79,500	129,500	88,400	117,000	83,000	124,000	94,200	121,800	69,200
Glenn	N.A*	N.A*	51,000	53,965	50,000	48,075	52,000	47,900	62,525	62,200	60,231	59,826
Placer	4,881	9,799	18,717	N.A*	25,841	8,733	7,044	7,379	10,611	6,287	28,781	7,274
Sacramento	59,310	16,517	55,913	17,602	67,998	16,849	65,000	15,163	61,251	31,310	65,000	31,670
Shasta	17,546	1,800	17,765	1,440	17,660	1,770	17,753	1,600	8,600	990	8,600	1,000
Tehama	11,432	11,250	20,550	13,520	19,797	18,930	17,700	17,890	21,035	19,975	19,815	19,500
Yolo-Solano	35,000	10,000	42,750	N.A*	55,760	N.A*	43,000	21,000	36,640	16,590	50,846	36,640

*N.A - Not Available

The additional requirements of administering the phase down and integrating this program with the other components of the agricultural burning program are compounding the districts' budget shortfalls. As fewer fields are burned (because of the phase down), less revenues are realized from fees. Fewer available revenue dollars from permit fees mean that districts can spend fewer resources on other aspects of the program. The increasing demands of the phase down will require additional workload and procedural adjustments each year.

C. METHODS USED TO MANAGE RICE STRAW

Controlled field burning has been the traditional method for eliminating rice straw and controlling diseases for more than 99 percent of the Sacramento Valley's rice acreage. Few growers used alternative methods before the implementation of the Act.

Currently, the only straw management option available to growers is some method of incorporation of the straw into the soil. Incorporation of rice straw into the soil can be done in many different ways, all necessitating additional labor and other costs. Various combinations of chopping, rolling, discing, and tilling, with or without subsequent flooding of the fields, are used.

The effectiveness of incorporation varies from place to place within the Sacramento Valley because of soil types and availability of water. Areas having poor drainage typically are found where soils are high in clay content. These heavy soils are difficult to work and require additional passes and more powerful tractors to mix the straw with the soil; early rains may make these soils unworkable. In addition, alkalis are prevalent in many of the high-percentage clay soils. With soils that have the lowest clay contents (higher percentages of sand or silt), incorporation has worked very well. Other factors affecting the ability to incorporate straw include cropping patterns and the ability to rotate crops to different areas.

The available, scientific evidence suggests that wet incorporation is more effective than dry incorporation because it results in more complete rice straw breakdown. Although the availability and price of water vary greatly around the valley, the east side generally has more water than the west. However, in drought years, water shortages are widespread.

Incorporation of rice straw is being studied by the University of California Cooperative Extension Service. Thirty-five rice fields representing a wide range of geographic locations, practices, soils, and tillage tools and choppers are being monitored for straw cover, straw decomposition, soil physio-chemical characteristics such as rice plant population, leaf nitrogen content, and disease incidence. Cost information is being obtained from grower cooperators. Much of the information available about incorporation stems from this work. The Cooperative Extension Service report, *Monitoring Rice Straw Management Practices,* covering the first three years of the study, is included in Appendix D.

Rice Diseases and Yields

Two major rice diseases occur in California--stem rot (*Sclerotium oryzae*) and aggregate sheath spot (*Rhizoctonia oryzae-sativae*.) Because residue straw is the primary means of re-infestation, open-field burning has been the traditional method of controlling these diseases. Removal of straw residue is considered a more satisfactory alternative than soil incorporation. Recent evidence from the Cooperative Extension suggests that stem rot and aggregate sheath spot are increasing in fields with repeated straw incorporation.

Rice blast, the most destructive disease of rice worldwide, was found on California rice for the first time in 1996. The blast fungus (*Pyricularia grisea*) can over-winter in diseased crop residue, seed, or weed hosts. Straw burning can be an important component of an overall control program although burning plays a different role with blast. Rice disease experts at the University of California, Davis, and the Cooperative Extension believe that the unusual meteorological conditions occurring last summer allowed the disease to reach problematic levels. Rice blast disease is favored by long periods of free moisture, high humidity (90%), little or no wind at night, and night temperatures between 63-73 degrees Fahrenheit. Typically, the dry summer climate in the Sacramento Valley is not favorable for rice blast. A Rice Blast Task Force has been established to identify and implement measures to control the disease.

After several years of no significant change, rice yields have decreased in the past two years. The average yields of the 1995 and 1996 crops decreased up to 15% over the 1994 average yield. It is not known to what extent repeated straw incorporation may be responsible for the yield decrease since fields which were burned also experienced a decrease in yield. Other factors such as yearly weather changes would also affect yields.

Rice Straw Management In Other Regions

The following examples of rice straw management are drawn largely from *Rice Straw and Stubble Management* by J.C. Flinn and V.P. Marciano. A matrix showing uses of rice straw prepared by A. Tanaka in 1973, appears in the article by Flinn and Marciano and is illustrated here as Table III-7. It depicts the favored uses of rice straw by country at that time. Dashed lines on the matrix show changes that might occur if growers choose to increase the use of the straw for composting.

Flinn and Marciano point out that in Japan, "in 1965, 95 percent of the rice crop was harvested by sickle and the crop threshed in a central place; assembling the straw for composting presented little difficulty." By comparison, Ezaki wrote in 1982 that by then, most of the crop was harvested by combine and that the straw was left in the field. Since direct incorporation could delay growth and reduce yields, field burning increased, prompting legislation to control this pollution source. As a result, scientists in Japan are also looking for ways to use or dispose of the rice straw.

In south Asia, where cattle and buffalo are common, the value of straw as cattle feed is considerable. In Nepal, many growers choose to grow long-straw varieties because they have "superior palatability as animal feed" (Flinn and Marciano, 1984).

In both the United States and Asia, the handling of straw is largely determined by local issues--i.e., it is location specific. As a local issue, climate is very important. Flinn and Marciano note "(particularly in cool climates and in poorly drained fields), incorporating straw may reduce yields" (Tanaka, 1978).

In the rice growing area of east Texas and the lower Mississippi Valley, the fall season is so warm and humid it enables the straw and stubble to decompose readily. Although some is fed to cattle, almost none of the straw is burned because of the dampness.

Rice production in Italy and Spain has many similarities to California. These two countries account for about 85 percent of western Europe rice production. The two countries grew about 640,000 acres of rice in 1995. The climate of the rice growing regions of these countries is similar to California. Many of the same varieties are grown there and were imported from California. The primary means of rice straw management in these countries is open-field burning during the months of September and October. No data are available as to how much is actually burned, left in the field, or removed for other uses. Some comments from Spanish growers indicate that open field burning eventually may be regulated.

Table III-7

From "Methods of Handling Rice Straw in Various Countries" (Tanaka 1973)
(in Flinn and Marciano, "Rice Straw and Stubble Management")

Country	Incorporation into soil	Compost	Burning	Feed or Animal Bedding	Mushroom Culture	Mulching for Orchard or Vegetable	Fuel of Household	Straw Products of Roofing	Manufacture of Paper
Korea		M <--	----------	--------- M	m	m		m	
Japan	m	M	m						
China		M <--	----------	--------- M	m	m		m	
Nepal		M <--	----------	--------- m			m		
Phillippines	M		M	m	m			m	m
Thailand			M	mS					
Indonesia	m		M		m				m
Malaysia	mS		M						
Burma			M(North)	M(South)				m	
Bangladesh			mS	M			m		
India			m	M			m	m	
Pakistan				M			m		m
Sri Lanka			m	M				m	

LEGEND: M = Major m = Minor S = Stubble

D. Recent Legislation Relating to Rice Straw Burning

Tax Credits for Purchasing Rice Straw

On September 26, 1996, Governor Wilson signed into law a bill which includes the granting of tax credits to purchasers of rice straw. Senate Bill 38 authorizes a tax credit of $15 for each ton California-grown rice straw purchased for each taxable year beginning January 1, 1997, and ending before December 1, 2008. The aggregate amount of tax credits granted to all taxpayers must not exceed $400,000 for each calendar year. The taxpayer receiving the tax credit must also be the "end user" of the rice straw. End user is defined as "...anyone who uses the rice straw for processing, generation of energy, manufacturing, export, prevention of erosion, or for any other purpose, exclusive of open burning, that consumes the rice straw." The CDFA is charged with administering this program, issuing certificates to the rice straw purchasers on a "first come, first served" basis, and providing a yearly informational report to the Legislature about the tax credit program including making recommendations on how the credits can be issued in a manner which will maximize the long term use of the California grown rice straw.

Rice Straw Bale Housing

On October 15, 1995, Governor Wilson signed into law Assembly Bill 1314. AB 1314 amended the State Building Standards Law to establish safety guidelines for the construction of structures, including single-family dwellings, that use baled rice straw as a loadbearing or nonloadbearing material. The bill specified that the safety guidelines would become effective within any city or county after the legislative body of the city or county made an express finding that the application of the guidelines within the city or county was reasonably necessary because of local conditions. As of August 1997, at least three counties--Colusa, Yolo, and Napa--have adopted the guidelines.

Senate Bill 318 - Amend the Phase Down Act

As of late August, legislation, Senate Bill 318 (Thompson), is pending in the California Legislature which would amend the Phase Down Act. SB 318 would change the phase down limits for five years, from 1998 through 2002. On an annual basis, 240,000 acres of rice straw could be burned in each of the five years. During the fall,

the bill would steadily decrease burning from 90,000 acres in 1998 to 60,000 acres in 2002. After this five year period, burning up to 25 percent of the acreage planted for disease management would be allowed. Administrative burning up to 2,000 acres would be excluded from the phase down.

In addition to changing the burn limits for five years, the bill would require the ARB to administer a demonstration program for the development of new rice straw technologies through the awarding of grants.

Rice Straw Products Preferences in State Contracts

As of late August, legislation, Assembly Bill 84 (Woods), is pending in the California Legislature which would require state agencies to give a purchase preference, not to exceed 10 percent, to products manufactured with rice straw. The bill would also require the Department of General Services to require the persons with whom they contract to use, to the maximum extent economically feasible in the performance of the contract work, these products made from rice straw. This purchasing preference is similar to the preference granted under existing law to recycled paper products containing post consumer and secondary materials. The California Integrated Waste Management Board would be required to implement a program, beginning July 1, 1998, for funding price preference claims. A maximum of $100,000 would be allowed for implementing the program.

CHAPTER IV

Environmental Assessment Of The Phase Down

This chapter assesses the impacts of the phase down on the environment of the Sacramento Valley as required by the Act. Section A examines emissions from rice straw burning and changes in emissions to date as a result of the phase down. Section B compares emissions from various rice straw removal processes. Section C focuses on air quality trends in the valley and examines air quality changes since the phase down. Section D examines the effects on public health. And, in Section E, other environmental concerns regarding soil, vegetation, water, and wildlife habitat in the Sacramento Valley are discussed.

A. Emissions From Rice Straw Burning

Shown in Table IV-1 are the emission factors, the calendar year 1996 annual emissions from rice straw burning, and a comparison of rice straw burning emissions to all emissions in the Sacramento Valley. The emission factors for the five listed pollutants are the result of recently completed work at University of California, Davis under ARB contract.[2] Although these emission factors are still being reviewed, they were used for the analyses in this chapter since they represent the best available data.

Table IV-1
Rice Straw Burning Emissions for Calendar Year 1996
in Sacramento Valley Air Basin

	PM_{10}	ROG	NOX	SOX	CO
Emission Factors (pounds/acre)	20.8	5.2	17	3.7	188
Annual Emissions (tons)	3,140	785	2,570	560	28,400
Annual Contribution To Total	4%	1%	8%	23%	12%

[2] *Atmospheric Pollutant Emission Factors From Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations,* ARB Contract No. A932-126, April 1996, B. M. Jenkins, Principal Investigator

On an annual basis, emissions from rice straw burning amounted to about four percent of total PM_{10} matter emissions in the valley during calendar year 1996. On a typical burn day, when 3,000 acres of rice straw are burned in the valley, agricultural burning produces about ten percent of the total PM_{10} emissions. And, on a major burn day, when 10,000 acres of rice straw may be burned in one day in the valley, the emissions would account for about 27 percent of the PM_{10} emitted that day. (The frequency of major burn days varies yearly, depending on existing air quality and meteorology. In the last five years there were twelve fall days in which 9,000 to 20,000 acres were burned in one day; in 1995 there were none, in 1996 there were four.) Table IV-2 summarizes these results.

Table IV-2
CY 1996 PM_{10} Emissions from Rice Straw Burning in Sacramento Valley Air Basin

	PM_{10}
Annual Emissions (tons)	3,140
Annual Relative Contribution	4%
3,000 Acre Burn Day Contribution	10%
10,000 Acre Burn Day Contribution	27%

Since the phase down has decreased total rice straw burning, PM_{10} emissions from burning have decreased (see Table IV-3) by about 30 percent since 1992. Shown in Table IV-3 are the PM_{10} emissions from burning rice straw for each burn year. Note that these would be different on a calendar year basis. (In *calendar* year 1996, 302,000 acres were burned; in *burn* year 1996, 211,000 acres were burned.)

Table IV-3
PM_{10} Emissions from Rice Straw Burning in Sacramento Valley Air Basin By Burn Year **(in tons)**

1992	1993	1994	1995	1996
3,150	3,180	3,050	2,790	2,200

Sources of PM_{10} Emissions

The figures below show the other sources of PM_{10} matter emissions in the Sacramento Valley for calendar year 1996, for three different scenarios: on an annual basis, on a 3,000 acre burn day in October (considered a typical burn day), and on a 10,000 acre day in October, considered a large burn day. On an annual basis, PM_{10} emissions from rice straw burning rank as the sixth major source following unpaved road dust, farming operations, paved road dust, construction and demolition, and residential fuel combustion categories. For the 3,000 acre typical burn day, rice straw burning emissions move up to rank four. And, on a 10,000 acre large burn day, rice straw burning is the largest source (27 percent) of PM_{10} emissions.

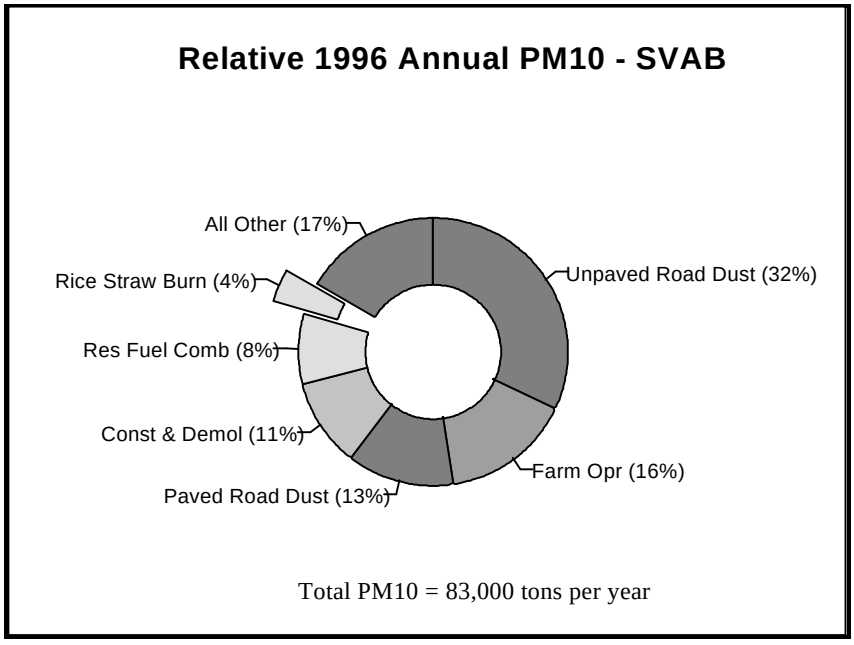


Figure IV-1

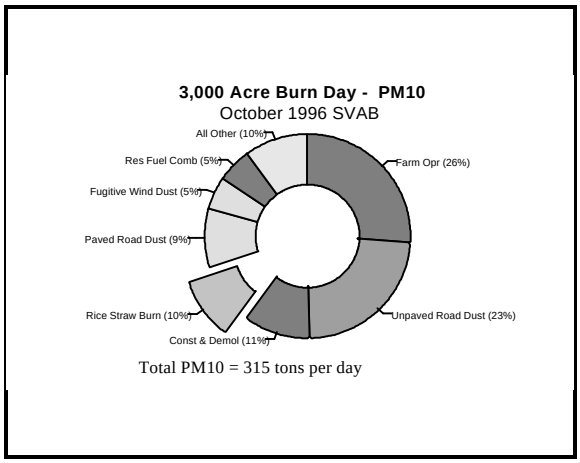


Figure IV-2

B. Comparison of Emissions from Various Rice Straw Removal Options

Current disposal options for rice straw include burning, incorporating the straw into the soil, and removing the straw from the field so it may be used for other purposes. This section compares the emissions produced by rice straw burning with those of straw incorporation and removal.

To compute emissions from the three management options cited above, it is necessary to account for all the emission-producing-operations for each option. Emissions from burning result primarily from the combustion of the rice straw. Emissions from straw incorporation result from farm equipment used to chop the straw and to work it into the soil; these emissions are due to dust and equipment engine exhaust. Emissions from hauling the straw offsite are due to activities in the field which also create dust, such as raking and baling, and exhaust emissions from motorized equipment.

These operations emit various types of pollutants. Straw burning produces combustion products such as particulate matter (PM_{10}), carbon monoxide (CO), reactive organic gases (ROG), oxides of nitrogen (NO_x), and oxides of sulfur (SO_x). The engine exhaust emissions from farming equipment (tractors, harvesters, etc.) includes PM_{10}, CO, ROG, NO_x, and SO_x. Equipment operation also creates airborne dust (PM_{10}) emissions. For this analysis, several representative straw removal scenarios were developed and their overall emissions calculated. The data are for comparison purposes only and should not be used beyond the scope of this report. Appendix E describes the emission estimation methodology.

Recent work at the University of California, Davis has quantified the NO_x and SO_x emissions from burning (17 lbs/acre for NO_x and 3.7 lbs/acre for SO_x), and has revised the emission factors for PM_{10} (from 24 to 20.8 lbs/acre) and CO (from 249 to 188 lbs/acre.) Some of the emission factors from equipment have also been reduced to reflect the benefits of California clean diesel fuel. These emission factor improvements are reflected in this analysis.

Six different scenarios and their respective emissions are shown in Table IV-4. Neither burning nor incorporation of rice straw is accomplished the same way by every grower; the burning and incorporation methods were divided into two and three scenarios, respectively. Scenario Burning 2 reflects rice harvested by a stripper header. The scenarios for each incorporation method depict techniques ranging from simple (Incorporation 1) to complex (Incorporation 3). Choppers are used to cut the straw into shorter, more manageable lengths. Rollers press the soil and straw closer together. Disc plows are used to cover the straw. Planing is done after tillage to smooth and level the

surface of the field. Removing the rice straw from the field by cutting, baling, and hauling comprises the sixth scenario. These scenarios may not depict any individual grower's specific practices, but represent a range of techniques used for managing rice straw.

The first column of Table IV-4 shows the operations of each scenario. The next two columns provide the estimated PM_{10} emissions caused by disturbing the soil (geological) and from burning and exhaust emissions, respectively. Geologic emissions tend to consist of larger and heavier particles which behave differently in the air from the fine particles (less than 2.5 microns) produced by straw burning and equipment exhaust. Geologic emissions are primarily composed of elements in the soil; combustion PM_{10} emissions are a complex mix of substances. The final columns in Table IV-4 summarize the emissions other than PM_{10} produced by burning and equipment exhaust for the listed operations. The emission estimates are approximate, and they are not indicative of actual emissions from any individual rice farm. The emission data should be used only for general comparisons and should not be used outside of this analysis.

Figure IV-4 illustrates PM_{10} emissions on a per acre basis for each scenario shown in Table IV-4. Figure IV-5 illustrates the total PM_{10} emissions for the 1995 and 1996 burn years for two scenarios: if there were no phase down and with the current phase down (burning scenario one and incorporation scenario two) in place.

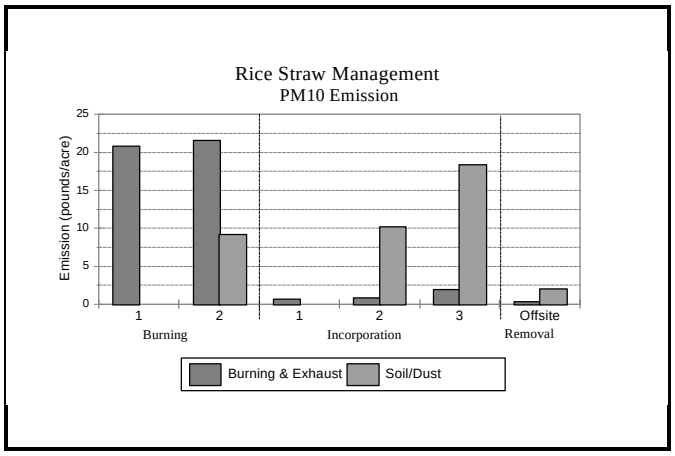


Figure IV-4

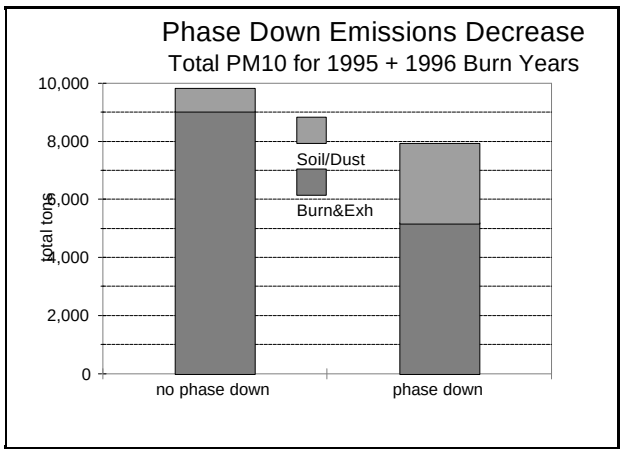


Figure IV-5

Table IV-4
Rice Straw Removal Emission Estimates
(estimated pounds/acre)

Straw Removal Scenarios	Soil PM_{10}	Burning & Exhaust PM_{10}	ROG	NO_x	SO_x	CO
Burning 1						
Burn		20.8	5.2	17	3.7	188
Burning 2						
Chop 1x	5.1*	0.31	0.57	3.7	0.06	1.4
Burn		20.8	5.2	17	3.7	188
Disc 1x	4.1	0.31	0.57	3.7	0.06	1.4
Total	***9.2****	***21.4***	**6.3**	**24.4**	**3.8**	**191**
Incorporation 1						
Roll (wet) 2x		0.62	1.1	7.4	0.12	2.8
Incorporation 2						
Chop During Harvest 1x	2*	no additional exhaust				
Disc 2x	8.2	.62	1.1	7.4	0.12	2.8
Total	***10.2****	***.78***	**1.1**	**7.4**	**0.12**	**2.8**
Incorporation 3						
Chop 1x	5.1*	.31	0.57	3.7	0.06	1.4
Disc 2x	8.2	.62	1.1	7.4	0.12	2.8
Roll 1x	1*	.31	0.57	3.7	0.06	1.4
Plane 1x (extra spring planing run)	4.1	.31	0.57	3.7	0.06	1.4
Total	***18.4****	***1.9***	**2.8**	**18.5**	**0.3**	**7**
Offsite Removal						
Cut, Bale, Haul, etc.	***2****	***.31***	**0.57**	**3.7**	**0.06**	**1.4**

* Emissions values marked with "*" are derived from emission factors extrapolated to the listed process from published emission factors. The "*" factors were estimated using engineering judgement from rice growers, agricultural scientists, and emission inventory personnel.

Particle Size and Behavior

So far, this analysis has focused on the quantities of emissions. Particle size is a third factor in evaluating particulate matter emissions. Smaller particles stay in the air longer and are carried farther from the emission source than larger particles.

Emissions of particulate matter may be classified into these categories: particles that are larger than 10 microns (um) in diameter; particles that are 10 um or less in size (PM_{10}); and particles that are 2.5 um or less in size ($PM_{2.5}$).

Burning emissions and exhaust emissions include higher percentages of fine particles than dust created by straw tilling and discing operations. Table IV-5 summarizes these differences.

Table IV-5
Particulate Matter Size Fractions for Straw Removal Operations

	< 2.5 um	< 10 um	> 10 um
Straw Burning Smoke	85%	88%	12%
Diesel Exhaust	94%	96%	4%
Tilling/Discing Dust	10%	45%	55%

Modeling analysis shows that the $PM_{2.5}$ particles from burning, which are lofted high into the air, stay airborne for days and travel over 300 miles under normal conditions (assuming average 1 meter/second winds). $PM_{2.5}$ particles from diesel exhaust, which do not rise as high as burning emissions, may stay airborne for several hours and travel about eight to ten miles. Dust from soil preparation operations, which is predominantly particles larger than 2.5 um, generally stays airborne for less than an hour and travels about a mile under fairly calm conditions. Table IV-6 summarizes these approximations.

Table IV-6
Particle Time Aloft and Distance Traveled

	Typical Release Height	Typical Time Aloft	Particle Travel Distance (assuming steady 1m/s winds)
Straw Smoke ($PM_{2.5}$)	230m	170 hrs	610 km (379 mi)
Diesel Exhaust ($PM_{2.5}$)	5m	3.7 hrs	13 km (8 mi)
Tilling Dust (PM_{10})	5m	0.3 hrs	1 km (0.7 mi)

All values in Table IV-6---release height, time aloft, and travel distance--are approximate. They are provided to allow rough comparisons of how far particles from different operations might travel. The approximations do not reflect all of the complexities that occur, both meteorologically and within the straw removal processes.

Results and Conclusions

The results in Table IV-4 show that rice burning produces more PM_{10} emissions than straw incorporation options. All three soil incorporation scenarios produce less PM_{10} emissions than burning. However, based on the incorporation practices employed, there is a scenario shown (Incorporation 3) in which particulate matter from straw incorporation can approach that of burning. In evaluating relative PM_{10} emissions, it is important to note that the types of particulates caused by burning and incorporation are different. Burning produces very small particles which may remain in the air for a long time and may penetrate deeper into the lung. Soil emissions due to straw incorporation activities will have a greater proportion of large particles which will not remain airborne as long. Like burning, PM_{10} from equipment exhaust emissions consists of small particles.

The quantity of gaseous pollutants created by straw burning are much greater than the additional exhaust emissions resulting from equipment usage for straw incorporation. In particular, reactive organic gas (ROG) and carbon monoxide (CO) emissions are much higher for burning. Equipment exhaust produces relatively small amounts of NO_x and SO_x. As Table IV-4 shows, burning rice straw produces NO_x and SO_x emissions substantially larger than diesel exhaust emissions.

Where sufficient water is available, wet incorporation produces the lowest overall emissions. It is also possible that gathering and removing the straw from the fields may produce fairly low emissions although good emissions data are not available for these activities. Also, additional emissions may be produced as the straw is processed off-site for other uses.

These results are rough estimates generated using the advice of rice growers, agricultural scientists, and emission inventory personnel. For several relevant processes, published emission data were not available and had to be extrapolated from published data. The results are general estimates.

In evaluating the relative contributions of various emissions, it may be necessary to consider the types of pollutants and their behavior. For example, soil dust, rice straw smoke, and diesel exhaust emissions might not be of equivalent concern to public health. Also, soil emissions might remain more localized, whereas tractor exhaust and especially straw smoke will be lofted and may affect larger areas and stay in the air longer. The various gaseous pollutants could be evaluated in terms of their ozone production potential and their contribution to greenhouse gasses.

C. Air Quality

The primary purpose of the Phase Down Act is to improve air quality by phasing down the burning of rice straw. An analysis was done to determine any existing air quality trends and to assess the effects of the phase down on air quality. The results of this analysis are presented in this section following some background information. The description of the methodology used for this analysis is included as Appendix F.

For this analysis, the effects of all agricultural burning on air quality were considered. Although rice straw burning represents the majority -- about 80 percent -- of all agricultural burning done in the Sacramento Valley, other agricultural burning has similar air quality effects and was included. For this analysis, the time period for fall includes the months of September, October and November, and the time period for spring includes March, April and May.

Air Quality Indicators

There were four types of indicators used to assess the air quality related to agricultural burning and the impacts of smoke on the public:

- **PM_{10},** particulate matter less than ten microns in diameter, is the primary pollutant of concern in the burning of rice straw. The state standard for PM_{10} is 50 micrograms per cubic meter (50 ug/m^3) averaged over 24 hours.

- **Coefficient of haze** (COH) is a measure of the Soiling Index.

- **Visibility is** measured as a percentage of smoky hours at valley airports.

- **Smoke complaints**, about agricultural burning, received from the public.

Particulate Matter Sampling

Eighteen monitoring sites in the Sacramento Valley monitor PM_{10} using size selective inlet (SSI), high volume samplers. The PM_{10} samples are collected over a 24-hour period every sixth day throughout the year. During the fall intensive burning season in the valley, the sampling is done every third day at most of the sites. Eight Tapered Element Oscillating Microbalance (TEOM) monitors record PM_{10} concentrations on an hourly basis. For most of the analysis in this section, the SSI data were used.

The Coefficient of Haze (COH), also known as the soiling index, is collected at 11 sites in the valley where it is collected every two or three hours on a continuous basis. The samplers use the absorption of light passing through a sampling tape to measure the particulates deposited onto the tape when ambient air is passed through the tape for two or three hours. The particles can be of any size that will blow through a sampling tube and be caught by the fiber of the tape. The COH data include smoke and larger particles such as road dust and dust from the tilling of fields. COH data are especially useful because the data are available very quickly and do not require expensive laboratory work. Data are available for guiding decisions in two hour time steps within minutes after the two hour sampling period is complete. A COH value less than 1.0 indicates relatively clean air, while higher values represent a higher concentration of particulates.

Laboratory measurements of total particulate matter mass and the mass of potassium ion in samples have been used to indicate days with an especially large amount of particles attributable to the burning of vegetative material. The critical level is a potassium ion to total mass ratio of one part in one hundred (one per cent potassium ion). However, the potassium ion*fingerprint* is common to all biomass burning. Not only rice straw burning, all agricultural burning, residential wood fire burning, field burning, tule burns, forest fires and other wildfires produce potassium. Analysis of potassium ion concentrations in ambient PM_{10} data suggests that total biomass burning (including the burning of rice straw) contributed about 4 to 5 percent on average and 11 percent maximum for the 1995 fall and 1996 spring months analyzed.

Air Quality Trends

How does the air quality vary from month to month? Figure IV-6 shows the monthly variation in average PM_{10} and COH readings, averaged over the period 1992 through 1996. It can be seen that PM_{10} concentrations are highest from September through November. COH also shows a similar pattern. This is primarily due to meteorological conditions. In the spring there is better vertical and horizontal mixing of the atmosphere which enables the particulate matter and smoke to be dispersed and diluted more completely. Figure IV-7 shows a similar pattern for frequency of exceedances of the State PM_{10} standard. Basin exceedance days were defined as days in which any one site had an exceedance. As Figure IV-7 shows the 24-hour state standard for PM_{10} is more often exceeded in the fall, about 50 percent of days, than the spring, less than about 10 percent.

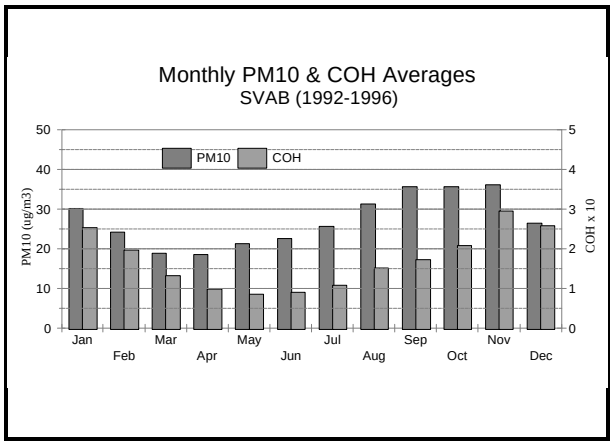


Figure IV-6

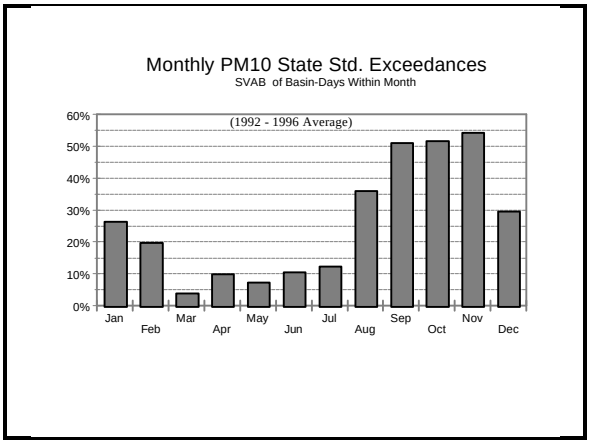


Figure IV-7

What has been the trend in air quality over the years? The next four figures show the average PM_{10} concentrations, COH readings, and PM_{10} exceedances of the State PM_{10} standard during the past 10 years for fall and spring. The trend in the Sacramento Valley is higher values of PM_{10} concentrations, COH readings, and more frequent exceedances during the fall than the spring from 1987 through 1996. These figures show no discernable change in air quality between 1987 and 1996 for either spring or fall.

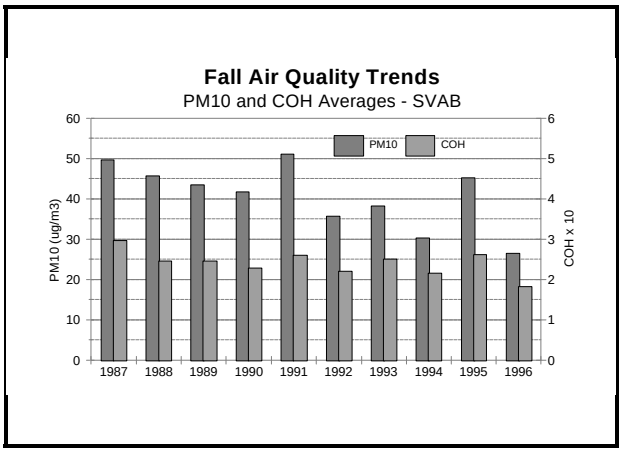
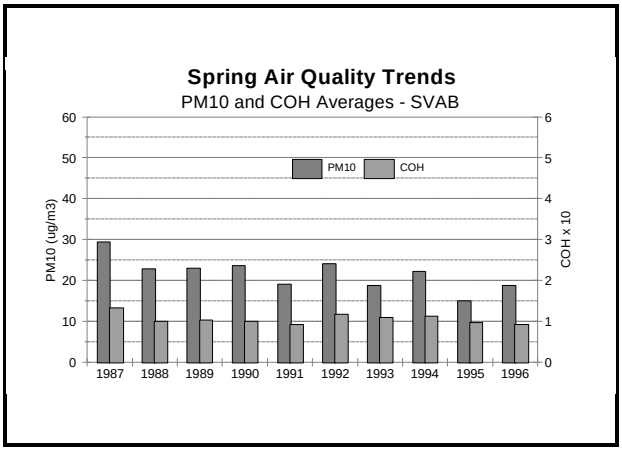


Figure IV-8



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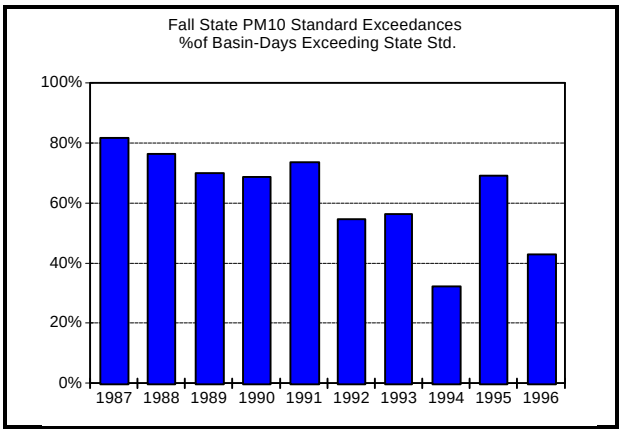

Figure IV-10

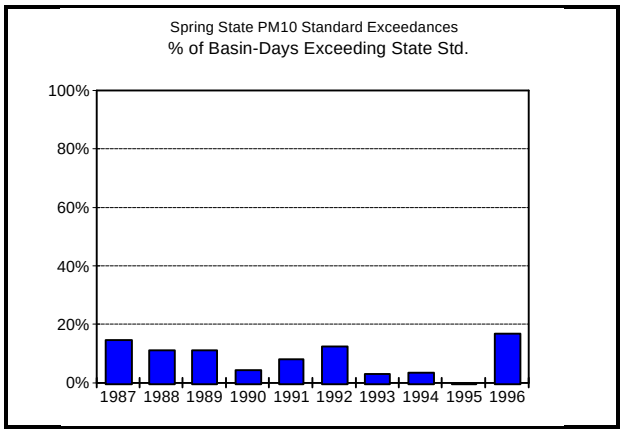

Figure IV-11

Air Quality on Burn versus No-burn Days

How does the air quality differ on burn and no-burn days? Table IV-7 is based on the days monitored (normally, every sixth day), not the number of calendar days in the study period. The study period was September-November 1995 and March-April 1996 (May 1996 was not included since burn data were not available). There were 42 days of data for the 90-day fall period and 16 days of data for the 60-day spring period due to the sampling schedule of PM_{10}. If any burning occurred in the basin during one day, the day was defined to be a *burn* day. Otherwise, it was a no-burn day. If any monitoring station in the basin recorded a PM_{10} observation greater than 50 ug/m^3 in a day (exceeding the state 24-hour standard), the day was defined to be a *basin exceedance* day.

Table IV - 7
Air Quality by Season and by Burn Category

	Type of Day	Fall 1995	Spring 1996
Avg PM_{10} (ug/m^3)	Burn	42.4	16.9
	No Burn	51.5	13.7
Avg COH (COH x 10)	Burn	2.28	0.96
	No Burn	3.72	0.86

As indicated in Table IV-7, air quality was better on burn days than on no-burn days in the fall. While this may seem counterintuitive, this is the expected result because of the way the Agricultural Burning Program is designed to work. Under the burn program, consideration is given to the existing air quality when deciding whether to allow burning. Thus, most of the intensive burning takes place during the fall season on days when the air is cleaner and the atmosphere's capacity to dissipate smoke is the greatest. In the spring the situation is reversed, air quality was better on no-burn days than on burn days although both types of days in the spring are much better than the fall.

PM_{10} Hourly Concentrations on a Smoke Impact Day

Although the state PM_{10} standard is based on a 24-hour average concentration, hourly PM_{10} concentrations can be much higher, especially on days that experience smoke impacts. The worst smoke impact day in recent years occurred on November 1, 1994, when a sudden change in weather conditions caused smoke to inundate the Sacramento urban area. Figure IV-12 shows the hourly variation of PM_{10} at four sites in Sacramento County during the smoke episode of November 1, 1994. These data are from the Tapered Element Oscillating Microbalance (TEOM) monitors which record PM_{10} concentrations on an hourly basis. The corresponding 24-hour averages for the four TEOM sites are also shown. As Figure IV-12 shows, the maximum reading at the Sacramento T Street Site was 223 ug/m^3 while the 24-hour average at that site was 59 ug/m^3. Because the smoke impacts of this episode at the monitoring sites lasted for about six hours, the peak concentration had only small impacts on the 24-hour PM_{10} measurements.

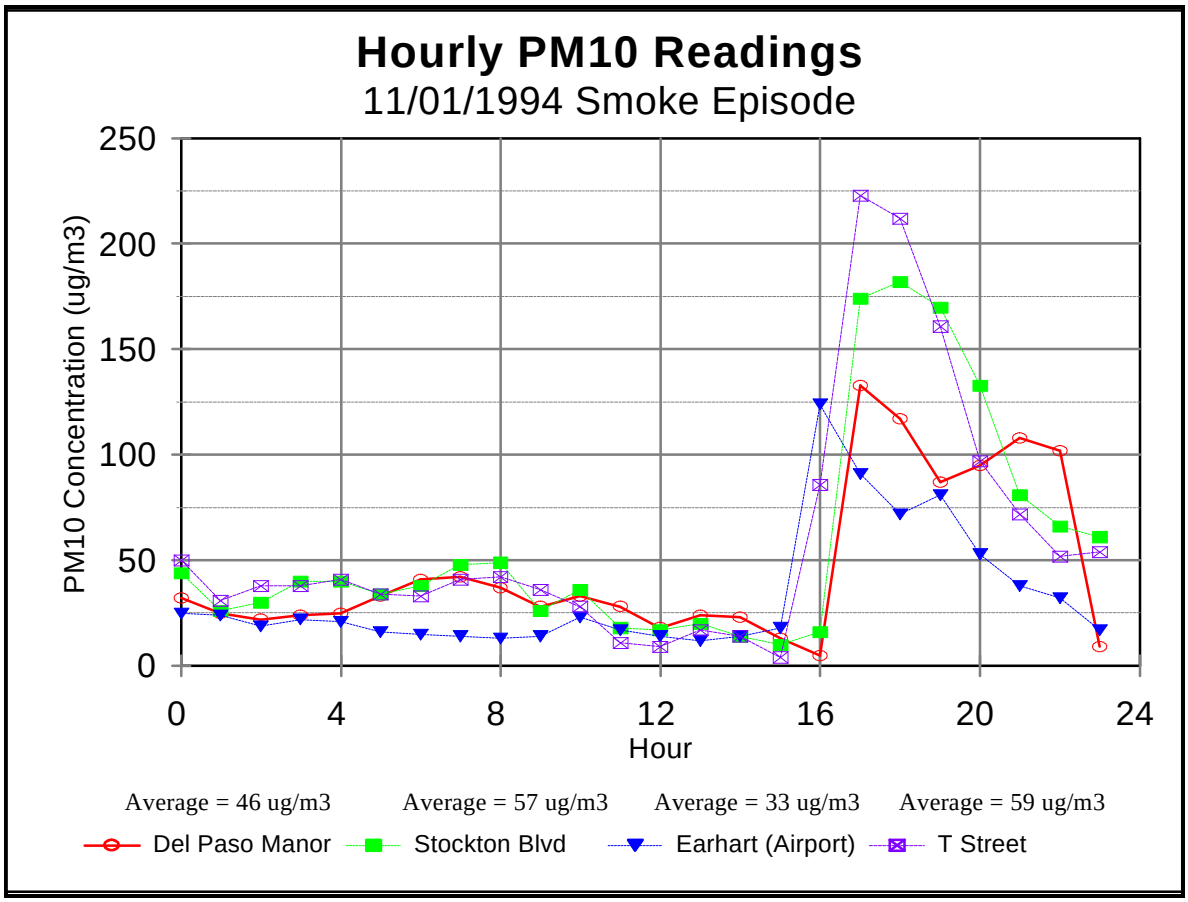

Figure IV-12

Air Quality - Visibility Effects

The smoke resulting from burning is not only harmful to public health if present in sufficient concentrations, but is aesthetically unpleasant due to the resulting degradation of visibility. Weather observations from professionally trained weather observers include prevailing visibility measurements. Visibility restrictions under seven miles are noted in each hourly observation. A common statistic which is indicative of the visual impact of smoke is the frequency of observed smoke at Sacramento Valley airports from 10:00 a.m. to midnight for the 46-day period between October 1 and November 15. Figure IV-13 shows smoke frequency for the period from 1980-1996. The years from 1987-89 had the worst visibility as measured by the amount of smoke observed during this 46-day period. The average was approximately 16 minutes per day per site for the entire 17-year period shown, while over the last five years, the average was approximately 9 minutes. The valley airports included Red Bluff, Chico, Marysville, Sacramento Metropolitan, and Sacramento Executive Airports.

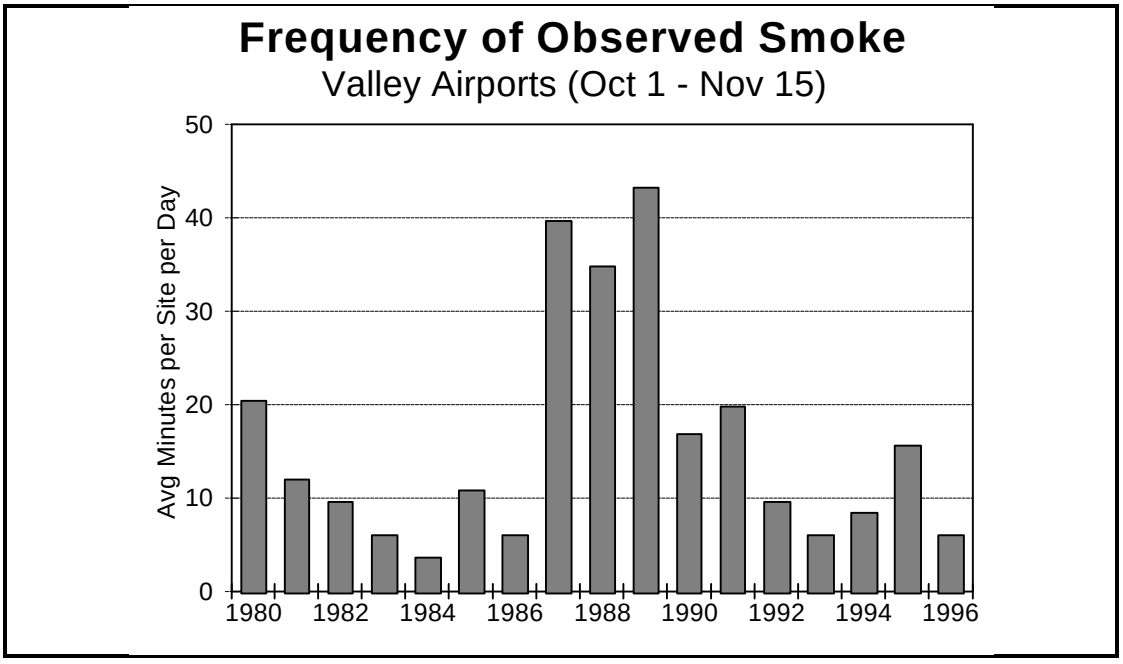

Figure IV-13

Air Quality - Smoke Complaints

The frequency of complaints from the public about smoke from agricultural burning is one indicator of the extent to which the public is subjected to impacts of smoke. The ARB and air pollution control districts track the number of smoke complaints during the fall intensive burn period. Complaints are received at the ARB's complaint hot-line (1-800-952-5588), the ARB's Meteorology Section, ARB's Public Information Office, and the air pollution control districts. Those received at the ARB are all referred to the Compliance Division, and the complaints are immediately phoned or faxed to the air district of origin for investigation and response. Complaints of a general nature, such as "I am calling to complain about agricultural burning" or, "the air quality is poor today" are not generally forwarded to the district. During the fall intensive burn season, a copy of each complaint from the Sacramento Valley is sent to the Meteorology Duty Desk. At 8 a.m. each morning, the total number of smoke complaints received by the Compliance Division during the previous 24 hours is relayed to Meteorology and to the Basin Control Council to be listed in the daily update of the Intensive Burn Season Statistics computer program, which is available to all the valley districts.

Complaints about specific, significant smoke impacts on urban areas are usually reviewed at meetings of districts' and ARB's staffs, who work directly with agricultural burning. In most years, there is usually one of these meetings a day or two after the significant smoke impact. The meteorological conditions that were present at the time of the smoke impact day are studied in detail by the ARB meteorologists to determine the probable cause(s) of reported smoky condition, and whether the weather forecast or the burn allocation decision contributed to the perceived smoke problems. Significant complaints are also reviewed by the ARB and districts' staffs at the end of the fall intensive burn season. Table IV-8 shows the total number of such complaints received during each fall intensive burn season, for the first five years of the phase down.

Table IV-8
Smoke Complaints During the Phase Down Years
Intensive Fall Burn Season

1992	1993	1994	1995	1996
57	101	336	138	124

Note: Table IV-8 lists total complaints for the entire intensive fall burn season, which starts on September 15 and ends when the winter rains curtail burning. The last day of the intensive fall burn season for the last five years is shown in Table III-8.

Table IV-9 shows the total number of complaints during the 46-day period of October 1 through November 15 for each year since 1980. This 46-day subset of the entire intensive fall burn period is used for comparative purposes since the length of each year's intensive fall burn period varies. As shown in the table, the number of complaints has been quite variable and not necessarily related to the numbers of acres burned during the period. However, a high number of complaints may not necessarily mean that the season as a whole was bad. For instance, the
46-day period in 1994 recorded the most complaints (301), but 71 percent of these complaints were about the smoke impact on one day, November 1. On that day alone, 215 complaints were received.

Table IV-9
Smoke Complaints (October 1 - November 15) - 46-day Period

Year	No. of Complaints	%Days with Complaints	%Days > 5 Complaints	Acres Burned
1980	218	N/A*	N/A*	220,000
1981	24	24.4	2.4	152,000
1982	32	26.1	2.2	225,000
1983	75	39.0	2.4	212,000
1984	174	67.5	25.0	203,000
1985	132	76.1	21.7	205,000
1986	101	67.4	21.7	221,000
1987	31	39.1	2.2	179,000
1988	57	41.3	2.2	163,000
1989	13	13.0	2.2	106,000
1990	188	56.5	21.7	100,000
1991	68	47.8	4.3	100,000
1992	40	34.8	2.2	101,000
1993	56	34.8	6.5	68,000
1994	301	36.6	12.2	87,500
1995	92	45.7	8.7	46,706
1996	103	52.2	13.0	96,915

* Not Available

Shown in Table IV-10 is a listing for the 1995 and 1996 fall intensive burn seasons of the days when more than five complaints were received. Note that the days with the highest number of complaints are not necessarily the days with the most acres burned in the valley. On October 16, 1995, the day with the greatest number of complaints (28) that year, only 1,896 acres were burned. Similarly, on September 30, 1996, the day with the greatest number of complaints (30) that year, 2,560 acres were burned. The day with the largest number of acres burned (7,256) in 1995 was December 1 with five complaints received. The day with the largest number of acres burned (15,224) in 1996 was November 16 with no complaints received. The total acres burned (all agricultural) for the fall burn season were 100,588 acres in 1995 and 128,380 acres in 1996.

Table IV-10
Smoke Complaints >5
and Acres Burned During
Entire Fall Intensive Burn Season
1995 and 1996

Date	No. of Complaints	Acres Burned
10/16/95	28	1,896
10/30/95	11	1,765
11/1/95	6	1,682
11/10/95	8	2,880
11/27/95	16	2,366
9/30/96	30	2,560
10/1/96	12	1,154
10/14/96	11	3,205
10/16/96	6	1,929
10/17/96	18	1,929
10/21/96	8	3,599
10/23/96	7	3,210
10/24/96	6	11,847

Conclusions

The preceding discussion indicates that most adverse air quality impacts from agricultural burning occur in the fall because PM_{10} concentrations are much greater in the fall than in the spring. This is primarily due to meteorological conditions. In the spring there is better vertical and horizontal mixing of the atmosphere, and this enables the particulate matter emissions and smoke to be dispersed and diluted more completely. Analysis of potassium ion concentrations in particulate samples indicates that biomass burning contributes about four to five percent to PM_{10}.

Figures IV-15 through IV-18 illustrate the yearly changes in four air quality indicators relating to agricultural burning in the fall (since the rice straw burning phase down started in 1992): average PM_{10} concentrations, exceedances of the 24-hour PM_{10} state standard, smoky hours at valley airports, and smoke complaints from the public. To present how the changes in these four indicators relate to the agricultural burning, Figure IV-14 is included to show the acres of rice straw and all agricultural acres burned each year.

As these figures show, the yearly variation in each of the four air quality indicators does not necessarily correlate to the number of acres burned each year. Fall PM_{10} concentrations, PM_{10} exceedances, and observed smoke at valley airports were highest in 1995 when the fewest number of acres were burned. In 1992, when the greatest number of acreage was burned, smoke complaints from the public were at the lowest. In summary, the overall fall air quality appears to be primarily a result of existing meteorological conditions' ability to disperse particulates from all emission sources. In years when fall meteorological conditions are more stagnant than usual, the effectiveness of the burn program is crucial to not contributing to the existing air quality problem.

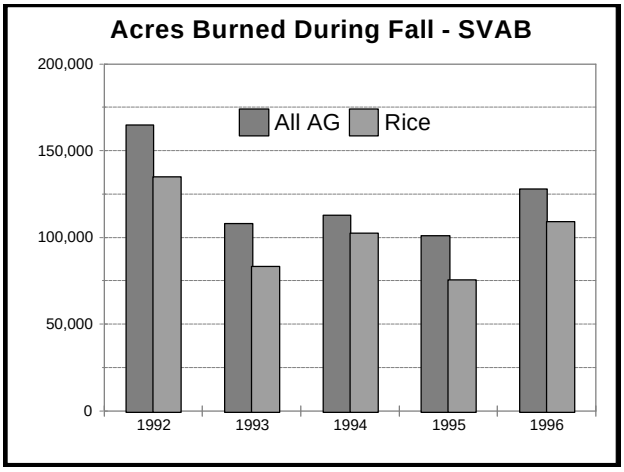

Figure IV-14

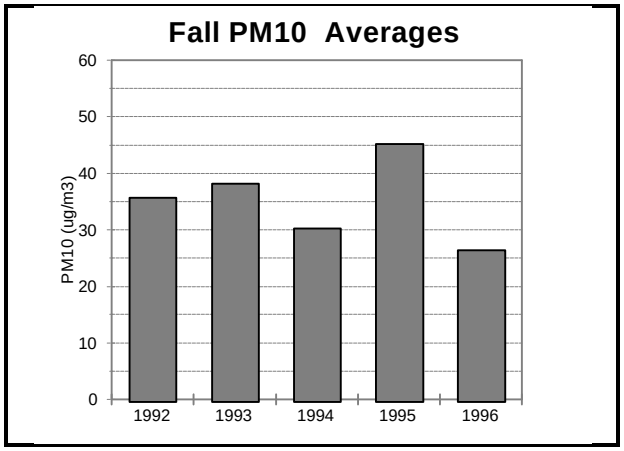

Figure IV-15

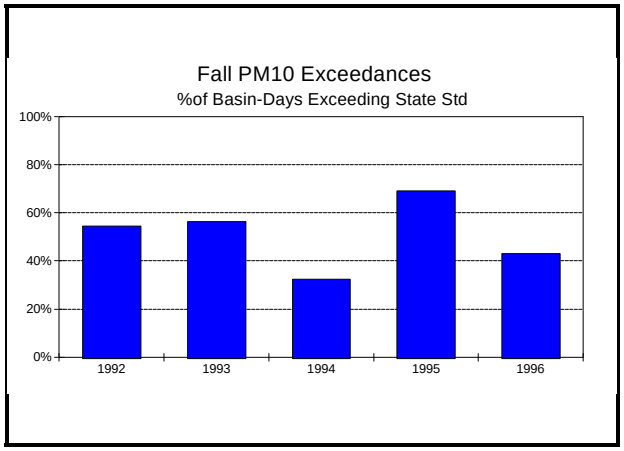

Figure IV-16

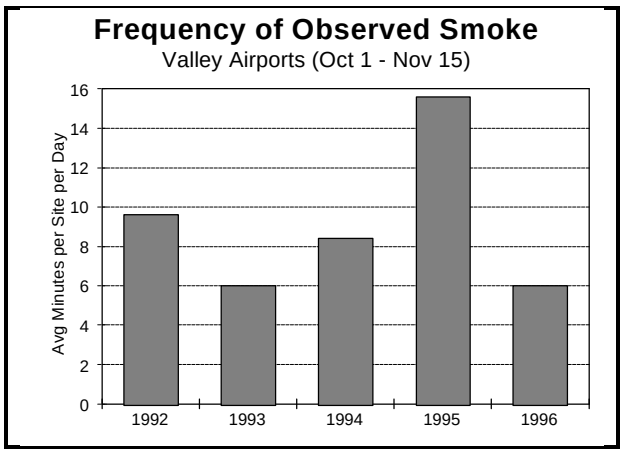

Figure IV-17

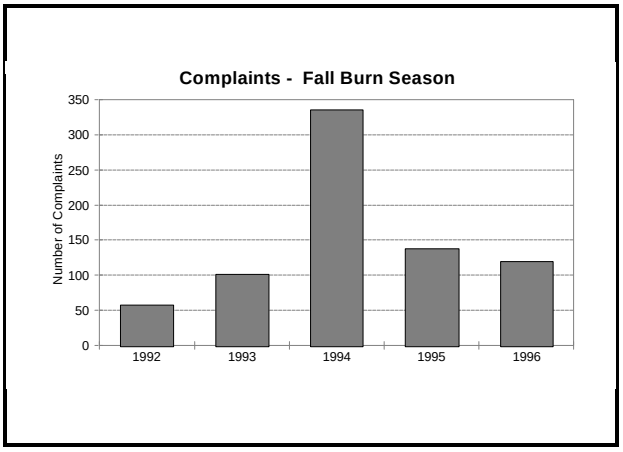

Figure IV-18

D. Effects of the Phase Down on Public Health

The practice of open-field burning of rice straw and harvest residues releases large quantities of particles and gases into the air. These airborne pollutants have been recognized as both harmful and annoying to people. Smoke is associated with adverse health effects, particularly among persons with respiratory disabilities, is irritating, its smell is distinctive, and it reduces visibility. Because of this, public complaints rise dramatically when the Sacramento Valley area skies are smoky. Burn control, based on daily meteorology and cultural practice, was instituted in the early 1970's to reduce and disperse the amounts of smoke generated and to reduce the likelihood that people would be exposed to harmful airborne pollutants. Control practices have been enhanced over the years to the extent that people who now reside in rice burning regions of the state are largely protected from the routine smoke episodes that occurred in the past.

However, exposures still occur, and, when they do, people with existing respiratory illnesses often suffer health impacts. There are numerous reports from area physicians stating that people with asthma, allergies, and bronchitis are made more ill during smoky periods. While current control practices are well implemented, as the urban population in the region has expanded into agricultural areas, it remains a challenge to manage smoke emissions to achieve a satisfactory compromise between the public and rice growers.

The primary components of rice smoke that concern public health are directly emitted particles, particles secondarily formed from precursor materials, organic gaseous compounds, and vapor-phase materials. While there is no direct, toxicological information that specifically explains how rice residue smoke impacts health, there is a great deal of information on how the constituents of smoke, in general, can worsen existing illnesses. There is also evidence that prolonged exposures to smoke may cause permanent health effects.

Particles that are small enough to be inhaled (smaller than 15 microns in diameter) can be harmful, especially to people with existing vascular or respiratory illness, the aged, and the very young. Exposure to such particles may worsen existing disease conditions. They can produce symptoms ranging from breathing difficulties to increased respiratory infections and even death. Observations of a clear association between ambient fine particle levels and these effects have been reported in numerous studies performed in cities across the nation and the world. These reports form the basis of State and federal ambient air quality standards.

These standards currently focus on reducing exposure to particles smaller than 10 microns (PM_{10}). While exposure to fine particulate matter air pollution has been linked to a variety of health effects in humans, questions remain regarding the mechanism leading to these effects and how particle size and chemical composition may effect health impacts. Fine particles, those less than 2.5 microns ($PM_{2.5}$) in size, may be more harmful than larger particles. Existing evidence, however, is insufficient to conclusively support this finding. Evidence that tends to support this idea is that products of both combustion and atmospheric transformations are found in the smaller fractions and are dominated by components that show potential for adverse effects, such as acids, organics, metals, and sulfates. Resolution of the issue will require considerable research, including epidemiological studies where size fractions of ambient PM are determined and controlled laboratory studies where exposures can be carefully characterized.

The findings of the recently published literature, which have focused on the health consequences of PM_{10} and other PM fractions, indicate that when particle levels increase health effects increase as well. For example, when 24-hour PM_{10} values increase by 50 ug/m^3 above a base value, total daily mortality rates increase by approximately one extra death per million people. Most of these deaths occur two or three days following the episode. More than half of these deaths occur in people over 65 years of age. Most deaths are due to cardiovascular and respiratory causes. Should high ambient concentrations persist for several days, mortality increases over these several days may be as high as 1.5 deaths per day, per million people. Hospital admission rates have also been found to increase following increases in PM_{10} and $PM_{2.5}$ levels. Approximately two admissions per day, per million people (due to respiratory conditions) are predicted per 50 ug/m^3 increase above 24-hour average baseline PM_{10} levels.

Particles directly emitted from rice straw combustion include soil material entrained in the smoke plume and products from the combustion of the rice straw itself. Soil particles are fairly large in size, mostly in the fraction above $PM_{2.5}$. The directly emitted combustion particles include partially burned residues which may be quite large, but include substantial amounts of small particles. The smaller particles are largely made up of the organic remains of the straw that did not burn completely.

In addition to these organic remains, rice straw smoke contains considerable non-combustible silica. Concerns emerged that this silica could potentially pose asbestos-like effects. Investigations have been performed over the past decade to determine the nature and possible health consequences of this airborne silica. In summary, exposure to airborne silica does not resemble asbestos exposure, and furthermore, silica emissions from rice straw do not appear to present a major health threat.

Particles originating from the gaseous products of combustion are a result of condensation and chemical processes. Complex organic compounds are formed in this process, along with some sulfates and nitrates. Known and suspected human carcinogens as well as mutagenic compounds have also been found in these particles. These fine particles are capable of being transported considerable distances from the site of combustion (see Table IV-6).

A study of rice growers has been performed to evaluate how their occupational exposures might relate to possible adverse health effects. (An assumption was that growers might be exposed to elevated levels of smoke). In this study, air samples were taken during several phases of rice growing practices, including preplanting cultivation, harvest, and burning. Exposures to silica were found to be higher during the non-burn operations. The authors of the study found the 464 subjects studied had lower percentages of both smoking and smoking-related symptoms than the population as a whole. The rice growers as a group, also had normal or above-normal readings in tests of lung function. The researchers speculated that this, in part, could be due to more active lifestyles. However, in the study, authors did document chest X-ray observations that are consistent with dust or fiber exposure, and evidence that suggests rice field preparation activities may be related to development of asthma. It is important to note that no conclusions were reached regarding rice straw smoke exposures or its health impacts.

Vapor or gas phase materials are released in large quantities by open-field rice straw combustion. The list of components is very large, but the dominant ones include carbon monoxide, carbon dioxide, nitrogen dioxide, sulfur dioxide, and numerous organic substances. The extent to which these materials from rice straw combustion impact ambient air quality is not well studied, but most are harmful to health when present at elevated levels. The organic substances include known human and animal carcinogens as well as mutagenic materials. Some of the organic vapors may serve as precursors of ozone.

For several reasons it is not possible to calculate or quantify the adverse health impacts of rice straw combustion. The specific contribution of a given amount of field combustion to changes in ambient air quality is not available. Calculations of the contribution of smoke to urban, ambient, particulate pollution levels have not been made, and it is unclear how this unique source of particulate pollution might resemble the PM_{10} from other sources. In addition, we have in place a typically well managed prescribed burning program that significantly reduces widespread public exposure to rice straw. Finally, actual human exposure levels to rice smoke and/or other particulate material are difficult to determine. Although it may be difficult to make quantitative

estimates of the health effects of rice straw smoke exposures, it has become clear that smoke exposures elicit adverse health consequences in people. While not quantifiable, reductions in exposures to rice straw smoke will benefit public health.

Definitive studies regarding the health consequences of rice straw smoke exposure would be helpful but they are difficult to perform successfully. Epidemiological studies of how people are affected by rice straw smoke exposures are complex and are of limited value with respect to open-field burning practices. The regulatory programs of the ARB, the districts, and the growers are very effective in reducing routine public exposures to smoke. Smoke typically becomes a problem only when weather forecasts turn out to be wrong or when violations of burn permit conditions occur. The frequency at which these incidents occur is low (see Table IV-8 and Figure IV-13 for the number of complaints and smoky hours each fall season as an index of frequency of smoky days); therefore large numbers of people are only occasionally exposed to high levels of smoke. In addition, during the fall and early winter months when rice straw is burned and climatic conditions are often adverse, many other sources contribute to elevated particulate loadings in the Sacramento Valley. While there are methods to differentiate the impacts of different types and sources of pollutants on ambient air quality, and chemical *fingerprints* are available for many of these sources, it has been a challenge to identify a fingerprint for rice straw smoke that is unique from other kinds of vegetative burning such as wood (fireplace) smoke, another common fall/winter source of particulates. Finally, ambient air monitoring for particulate pollutants is fairly sparse in the Valley. It is very difficult to determine overall PM_{10} or $PM_{2.5}$ exposure levels for populated areas. These factors make it impossible, at this time, to perform population based studies which may attribute adverse impacts of rice straw burning as it now exists or in various phase-down scenarios.

In summary, the practice of open-field burning of rice straw impacts ambient air quality and people who breathe the resulting smoke. Presently, we cannot quantify the extent to which these effects now occur or may occur in the future. In light of this it is important to move forward with research efforts focused on: 1) improving our knowledge of the levels of smoke to which people are exposed; and 2) better characterizing and, if possible, quantifying how people of varying health status (healthy or diseased) respond to smoke. To assist in addressing these questions, controlled clinical studies are planned by the ARB that include exposing people to controlled, quantified levels of smoke from rice straw and other vegetative materials. Subjects will be recruited from the general population as well as from groups that are likely to be sensitive to smoke, such as asthmatics and bronchitics. The level of lung function and symptom change following brief to multi-hour periods of various levels of smoke exposure will be documented. These studies will provide information needed to begin

establishing how and to what extent smoke from these sources of vegetative burning impacts human health. The effects of burning controls put into practice over the past decades have resulted in a marked reduction in smoke impacts and should serve to reduce the potential for adverse health effects and nuisance problems. However, because accidental or unplanned incidents appear to remain a source of smoky days during the fall months, it is imperative to implement means to assure they occur at the lowest possible levels.

E. Other Environmental Concerns

The phase down has forced many changes in cultural practices for disposing of rice straw. In burn year 1996, about 295,000 acres (885,000 tons) of rice straw were not burned but incorporated into the soil. Very little research has focused on the broader impacts on soil, water, air, and wildlife in the Sacramento Valley. This section addresses some of these concerns.

Increase of Methane Gas

Incorporation of rice straw can increase methane emissions from the soil. Flooded rice fields have decomposition products that include methane which increase in production as rice straw is incorporated into the soil. Bubbling of gases from the soil occurs even when straw is not incorporated because of roots and stem material near the ground. With emission estimates of 33-46 grams per square meter during a season, the California rice acreage of about 450,000 acres could emit about 75,000 tons of methane per year, or about 0.05 percent of the global emissions from rice fields (Schutz *et al.*, 1990; IPCC, 1992; Yagi and Minami, 1990; Itoh and Iimura, 1990; Cicerone and Shetter, 1981), and approximately 0.01 percent of the total global methane emissions (Khalil and Rasmussen, 1983). Incorporating 450,000 acres of rice straw would approximately double or triple methane production from California rice land (Yagi and Minami, 1990). Methane does not contribute to an identified air pollution problem but is considered to be a gas that could contribute to global warming.

Increase of Diesel Fuel Use

The amount of diesel fuel used per acre by rice growers varies with incorporation practices, type of soil, soil moisture, and equipment used. Incorporating rice straw consumes approximately 2.1 gallons of diesel fuel per acre of land worked. This amounts to 600,000 gallons of additional diesel fuel used to incorporate rice straw in the 1996 burn year and represents about 3 percent of the total diesel fuel burned for agricultural operation and on-road motor vehicles. However, as described in Chapter IV, Section B, *Comparison*

of Emissions from Various Rice Straw Removal Options, particulate emissions from using diesel-fueled equipment for soil incorporation are much lower than from burning rice straw. PM_{10} exhaust emissions from soil incorporation range from 0.62 to 1.9 ug/m^3 compared to 20.8 ug/m^3 from burning.

Effects on Wildlife

Changes in rice straw management may affect birds and animals accustomed to feeding on the rice dropped during the harvest. The residue rice is estimated to be one or two hundred pounds per acre but, may be as much as four hundred pounds per acre. A study on bird use of the winter flooded fields was sponsored recently by Ducks Unlimited Inc.[3] The data, which have not been formally published yet, will appear soon in some environmental journals. The study notes that fields are flooded to different depths which would benefit different birds depending on the water depth.

Upland game such as pheasant are not able to feed on the flooded fields, and this may be affecting bird populations in locations such as Glenn County. Some pheasant hunting clubs have reported much poorer pheasant habitat and smaller bird populations because of the efforts to flood the fields to promote decomposition of the straw.

One observer noted the question of balance for the different bird and animal populations. Flooding may reduce population of rodents and other small animals feeding on the fallen grain. Fewer of these animals may affect the raptor populations that winter in the valley. A 1992 study done by the California Waterfowl Association, "Assessments of Rice Fields as Habitats for Ducks Wintering in California," found that invertebrate densities were highest in burned fields and lowest in rolled fields in comparing the following flooded, post-harvested treatments: burned, rolled, and non-treated. The report suggested that a variety of post-harvest farming practices may be the best strategy for providing maximum waterfowl benefits.

Comments received from rice growers and others regarding possible environmental impacts of the phase down are summarized in Table IV-11.

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[3] *Wetland Management on Private Lands: Effects of the "Ricelands/Habitat Project" On Aquatic Birds,* Research report submitted to Ducks Unlimited Inc., September 1996, Chris S. Elphick and Lewis W. Oring, University of Nevada, Reno

Table IV-11
Growers' Concerns About Potential Environmental Impacts of the Phase Down

WILDLIFE

- Incorporation decreases the amount of seed available for waterfowl.
- Wet incorporation decreases the invertebrate productivity of many wetland habitats.
- Wet incorporation decreases the amount of pheasant habitat.
- Geese prefer to feed in burned or non-flooded fields.
- There is a concern that the number of unhunted but flooded acres will increase so much that ducks will move to the unhunted acres. If this happens, fewer people will pay to hunt, and the revenues used to maintain restored natural habitat (e.g., Gray Lodge) will decline significantly.

WATER RESOURCES

- Wet incorporation uses more water during the fall and winter periods.
- Fall flooding keeps the ditches from getting the maintenance that they need; cleaning and sometimes cement work are needed for flood control. For this reason, some flood control districts will need to limit the number of acres that can be flooded (e.g., in Sutter County there is a district that lets only about 5-6 percent of the available acres be flooded).
- With rice paddies flooded during the winter, the ground is saturated and the paddies cannot hold any more water. When heavy rains occur, the water just runs off. This doesn't help flood control and may have contributed to urban flooding in 1995.
- During the floods of 1995, loose straw was observed jamming culverts and drains, making the water back up. This caused local flooding. The straw was probably from unincorporated, unbaled, and unburned fields.

AIR

- There are increased emissions of methane, nitrogen oxides, and hydrogen sulfide as well as greater use of diesel fuel needed for incorporating rice straw.

SOIL

- Incorporation ties up nitrogen, produces gases which may be toxic to rice, and changes the salinity of the soil.
- The more the fields are worked, the more compaction, rutting, disease build-up, weed seed build-up, and changes to water holding capacity will occur.

OTHER

- Particulate emissions from diesel fuel usage for incorporation are considered toxic.
- With total reliance on soil incorporation, more pesticides and herbicides are being used in rice fields.

CHAPTER V

Economic Assessment Of The Phase Down

This section evaluates the economic impacts of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 (the Act) during the 1995 and 1996 seasons. The purpose of this analysis is to estimate the financial impacts on typical growers who operate under various farm conditions and practices and to assess the regional economic impacts on rice-growing counties in the Sacramento Valley.

Despite existence of a number of technologies that show good potential for the creation of markets for rice straw, during the past five years over 99 percent of the straw that was not burned was incorporated into the soil. During the past two years, many growers have experienced substantial yield reductions, but conclusive evidence has not been found on what caused these yield reductions. This economic assessment of the program to date will concentrate on the economic impacts of soil incorporation.

Methodology

The economic impacts of the phase down are estimated in the following manner. First, the direct costs of the phase down to the rice growers in the Sacramento Valley were estimated. Second, the direct costs were reduced to net costs by subtracting in-field burning. Finally, output, income, and employment multipliers were applied to these net costs to estimate the phase down's indirect impacts on the Valley.

The direct costs associated with soil incorporation were estimated for each of the eight rice-growing counties in the Sacramento Valley. The estimates for burn years 1995-96 were based on the percentage of acres required to be no-burn by the Act, and on the costs of rice straw incorporation estimated by the University of California Cooperative Extension Service which range from a low of $7.70 to a high of $76.54 per acre, with a mean of $36.31 per acre. This wide variation in costs is due to differences in farm size and ownership, straw management practices, soil type, cost of equipment, cost of water, cost of labor, and other inputs.

The costs to bale and transport rice straw to a site 25 miles away were estimated to range from $96 to $108 per acre, with an average of $102. These costs vary depending on farm location, soil conditions, and the weather.

The costs of burning were estimated to be between $1 and $3.50 per acre, with an average of about $2 per acre. The variation in these costs is due to differences in the district fees and the field conditions.

The economic impact of the phase down was estimated for each rice-growing county in the Sacramento Valley using multipliers from the United States Department of Agriculture Forest Service's IMpact analysis for PLANning input/output system (IMPLAN). The total economic impact, including the direct and indirect costs of the phase down, are determined by multiplying the direct costs by these multipliers.

Increased costs associated with the phase down reduce income from rice farming, thereby inducing a contraction of economic activity. The ripple effects on the regional economy are tied directly to whether supplies, materials, and labor are obtained locally or from other areas. The greater the interdependence in the regional economy, the larger the ripple effects will be. Thus, the size of a multiplier indicates the extent of self sufficiency of the local economy. Three multipliers were used to estimate the impacts of the phase down on jobs, income, and output. The industries most affected by the rice straw burning phase down are those that supply equipment, materials, and services to rice growers and those who purchase rice output from growers.

Phase Down Costs

The phase down costs were estimated for each county in the Sacramento Valley for both soil incorporation and offsite removal for the past three years. Over 99 percent of rice straw from all acres required to be *no-burn* was worked back into the soil, with the balance being baled and transported off the fields. The direct phase down costs were estimated by multiplying the per acre costs for the no-burn alternatives from the University of California Cooperative Extension Service by the rice acreage not burned, and subtracting the costs of the in-field burning that was not done.

Table V-1 presents the average direct costs of the phase down (net of the burning costs), by county, from 1992 through 1996. As shown in the table, the annual costs associated with the phase down have been rising over time because the rice acreage that could be burned has been decreasing.

Table V-1
Average Direct Costs of the Phase Down Per County by Burn Year
(Thousand of Dollars)

County	1992	1993	1994	1995	1996
Butte	$ 286	$ 617	$1,056	$1,292	$2,043
Colusa	327	773	1,273	1,772	2,590
Glenn	220	499	814	1,118	1,580
Placer	41	82	136	242	301
Sacramento	28	66	110	145	174
Sutter	245	543	905	1,334	2,004
Tehama	5	11	18	35	20
Yolo/Solano	64	143	268	320	625
Yuba	106	210	342	515	734
Total	$1,322	$2,944	$4,922	$6,773	$10,071

Table V-2 provides the ranges of direct phase down costs for all affected counties in 1996. Each county's range is based on costs of soil incorporation as well as costs of straw collection and transportation for use or disposal. As shown in the table, the annual costs of not burning rice straw throughout the Valley during the 1996 burn year are estimated to be between $2.2 million and $21.1 million, with an average of about $10 million. The four northern counties---Butte, Colusa, Glenn, and Sutter---accounted for over 80 percent of the direct phase down costs in 1996.

Table V-2
Ranges of Direct Costs of Phase Down Per County in 1996
(Thousands of Dollars)

County	Low	Average	High	%Total
Butte	$ 443	$2,043	$4,286	20
Colusa	562	2,590	5,433	26
Glenn	342	1,580	3,315	16
Placer	65	301	631	3
Sacramento	38	174	365	2
Sutter	435	2,004	4,204	20
Tehama	4	20	43	0
Yolo/Solano	135	625	1,310	6
Yuba	159	733	1,540	7
Total	$2,184	$10,071	$21,127	100

Economic Impacts of the Phase Down in 1996 Assuming No Yield Reduction

The economies of rice-growing counties in the Sacramento Valley are affected by increased production costs associated with the phase down through many complex interactions. Although it is difficult to fully quantify these interactions, many of them are estimated using economic multipliers. The multipliers used in this analysis were intended to capture both direct and indirect effects of industry and consumer spending on the county-level economies in the rice-growing counties of the Sacramento Valley.

The multipliers should be viewed with caution because they tend to overestimate indirect costs of the phase down. First, multipliers are based on the assumption that production patterns of growers are fixed. This assumption implies that rice growers cut production, lose income, and lay off workers in proportion to the increase in production costs. To the extent that some growers adapt to changing conditions by either switching to alternative crops, reducing production costs, or a combination of both, the impacts on the regional economy would be less. Second, much of the increased spending by growers on straw management practices is captured by local suppliers such as custom straw management services and those who sell and service equipment used for incorporation. To the extent that local industries attract the increased spending by growers, the cumulative impacts on the regional economy are less than indicated by this analysis, that is, any positive impacts of increased spending on local industries were not captured by this impact analysis. Although the impacts are likely overestimated for the two reasons given, they are still small.

Table V-3 shows the economic impacts induced by the phase down by county in 1996, assuming no yield changes are due to the phase down. As shown in the table, the increase in costs induced by the phase down had relatively minor impacts on the economies of rice-growing counties in the Sacramento Valley. The phase down appears to have reduced the output of goods and services produced in the region by about $16.4 million, accounting for about 0.05 percent of the Gross Valley Product (GVP). The associated losses in income and jobs were estimated to be around $17.2 million and 376 jobs, respectively, accounting for about 0.05 and 0.04 percent of the Valley's total personal income and employment. However, the impact was more significant in the northern counties in the Valley, which have larger rice bases and smaller economies, than in the southern counties. The impacts on Colusa County were most significant.

Table V-3
Economic Impacts of the Phase Down in 1996

County	Reduction in (Millions of Dollars)			As a Percentage of		
	Output	Income	Jobs	GCP*	Personal Income	Employment
Butte	3.9	3.9	111	0.12	0.12	0.13
Colusa	3.7	4.2	66	1.03	1.16	0.79
Glenn	2.2	2.2	35	0.55	0.55	0.32
Placer	0.5	0.4	15	0.01	0.01	0.01
Sacramento	0.3	0.3	7	0.001	0.001	0.001
Sutter	3.6	3.9	93	0.27	0.26	0.29
Tehama	0.03	0.03	1	0.004	0.004	0.005
Yolo/Solano	1.1	1.2	23	0.04	0.04	0.02
Yuba	1.1	1.1	25	0.13	0.12	0.10
Total	16.4	17.2	376	0.05	0.05	0.04

* Gross County Product

Potential Rice Revenue Changes If Yields Decline

The incorporation of rice straw into the soil could result in reduced crop yields due to increased incidence of diseases or changes in crop nutrients. So far, efforts to establish whether the phase down has contributed to yield reductions have been inconclusive. Some growers reported higher yields or no yield changes during the past two years, and others reported yield reductions of up to fifteen percent. These reductions could have been caused by usually warm and humid weather. However, yield reductions could occur as the phase down progresses and disease problems build up. The purpose of this analysis is to estimate the potential range of revenue decreases if yields decline.

The changes in the rice revenue estimates were based on data collected through telephone surveys from county agricultural commissioners and growers' rice cooperatives. For cost and yield comparisons: 1 ton equals 20 hundred weight (cwt), and 1 sack equals 1 cwt. The rice yields varied from county to county in 1996, ranging from a low of 3.40 tons per acre (68.0 cwt/ac) in Tehama County to a high of 3.90 tons

per acre (78.0 cwt/ac) in Sacramento County, with an average of 3.70 tons per acre (74.0 cwt/ac). The average revenue for rice was about $225 per ton ($11.24 per cwt) in 1996.

Table V-4 shows the changes in rice revenues per county which would be induced by yield losses of five, ten and fifteen percent. As shown in the table, the northern counties of Butte, Colusa, Glenn, and Sutter would sustain over 80 percent of such reductions in rice revenues if uniform yield reductions should occur Valley wide. Note that this table does not indicate that reductions in rice yields of five, ten or fifteen percent are expected, but it estimates what impacts those *yield reductions* would have on revenue if they did occur.

Table V-4
Potential Revenue Reduction at Three Yield Loss Levels
(1996 Thousands of Dollars)

County	5%	10%	15%
Butte	$2,498	$4,996	$7,494
Colusa	3,083	6,167	9,250
Glenn	1,932	3,863	5,795
Placer	358	716	1,074
Sacramento	219	437	656
Sutter	2,450	4,900	7,350
Tehama	22	44	67
Yolo/Solano	743	1,487	2,230
Yuba	897	1,795	2,692
Total	$12,202	$24,405	$36,608

Financial Impact

The per acre rice revenue varies widely from grower to grower depending on crop prices, yields, and production costs. For the 1996 crop, California growers received, on average, $7.75 to $8.50 per hundred-weight (cwt) for their rice crop. In the same year, growers also received, on average, $2.16 per cwt, or about $162 per acre, in transitional payments from Agricultural Market Transitional Program subsidies. The program,

established by the Federal Agricultural Improvement and Reform (FAIR) Act of 1996, provides for seven annual transitional payments. The program also greatly reduced restrictions on the acreage uses. Growers are now able to plant any crop on contract acres, except fruits and vegetables, to receive the payments. They are not required to idle a certain percentage of their base acreage, and the contract acreage must be kept in agricultural uses. Unlike the previous program, the payments are fixed and are not linked to current market prices. These payments will be available to growers on 85 percent of base acres under a "production flexibility contract" multiplied by historical yields. Thus, the total, average income for rice was estimated to be about $9.91 to $10.66 per cwt in 1996. Given the variation of yield of about 74 to 78 cwt per acre in 1996, California rice growers were estimated to have realized total revenues of between $733 to $831 per acre, with an average of about $782 per acre.

Total production costs exclusive of costs to implement the phase down were estimated to be around $782 to $793 per acre. These costs reflect true resource costs, both explicit and implicit. The explicit (cash) costs include variable and fixed cash expenses. Variable expenses are payments for fertilizer, labor, seed, pesticides, irrigation, custom operations, fuel, electricity, repairs, and technical services. Fixed expenses are payments for general farm overhead, taxes, insurance, and capital replacement. Implicit (noncash) costs include the imputed cost of capital invested in land, equipment and unpaid labor. As mentioned earlier, the straw incorporation costs were estimated to range from $7.70 to $76.54 per acre, and the burning costs from $1 to $3.50 per acre. When spread over all of the acres, the net increase in costs due to the phase down in 1996 (when the phase down was 50 percent) would be around $3 to $37 per acre. These additional costs would increase the total production costs to around $785 to $830, with an average of about $808 per acre in 1996.

Based upon these figures, a typical California rice grower operating under various farm practices and conditions is estimated to have lost, on average, about $26 per acre in 1996, with some losing up to $52 per acre and others earning up to $1 per acre in 1996. These profit or loss levels reflect economic returns to management and risk. It accounts for both explicit costs paid by growers and implicit (opportunity) costs of labor, capital, and land that growers contribute to the production process. This profit (loss) represents the residual after all payments are made including any salary drawn by the grower. At least in the short-term, growers continue to operate as long as their revenue from operations exceeds their explicit costs. In other words, growers have positive cash flow from operations. In 1996, this cash flow was around $200 per acre. This indicates that rice farming is still economical for the majority of growers in the Sacramento Valley despite the increase in production costs. In the 1995 and 1996

seasons, many growers have experienced yield reductions of ten percent or more. Any further reduction in yield without a corresponding increase in the market price for rice would have serious consequences for rice growers and the economy of the region.

Economic Forecasts

Forecasts of the income per acre of rice production from 1997 to 2000 are provided in Table V-5. The forecasts are calculated assuming a market price of $8.50 per cwt and a yield of 80 cwt per acre. This represents the most likely scenario based on recent history, including historical yields. Growers' revenue also include transitional payments. These payments have already been determined by the Congress and vary from year to year. However, they are subject to annual Congressional appropriation. The changes in the revenue per acre over the forecast period reflect the changes in these payments.

The cost per acre is projected using historical data from 1975 to 1991. Costs are divided into explicit (cash) expenses, implicit (noncash) expenses and incorporation costs. The sum of these costs are defined as total economic costs. Economic costs are a reasonable indicator of the long-run profitability of rice farming while explicit expenses are a good measure of the short-run profitability. Explicit expenses including incorporation costs are expected to rise by about 9 percent from 1997 to 2000, about one percent more than the expected increase in total economic costs. The incorporation costs net of the burning costs are projected assuming average incorporation costs of $36 per acre, burning costs of $2 per acre, and the phase-down requirements of 62 percent in 1997 and 75 percent thereafter.

Cash flows from rice growing operations are expected to be positive over the next four years. In 1997, the cash flows per acre are projected to be around $260, a significant improvement over the 1996 cash flow of $200. In 1998, the cash flows are projected to stay at the 1997 level. Thereafter, growers will continue to generate positive cash flows but at slightly lower levels.

Economic Profits (losses) are payments to management and risk. They represent the difference between economic costs and revenues. The economic profit per acre is projected to be about $6 per acre in 1997, declining to a loss of about $63 per acre in 2000. In the absence of an improvement in revenue above our projections due to either an increase in yield or prices, many growers would be severely squeezed in the next few years.

Table V-5
Projected Economic Profit (Loss) Per Acre of Planted Rice, 1997-2000

	1997	1998	1999	2000
Price/cwt	$8.50	$8.50	$8.50	$8.50
Transitional Payment/cwt	$1.99	$2.15	$2.07	$1.91
Yield/Acre (cwt)	80	80	80	80
Revenue/Acre	$839.20	$852.00	$845.60	$832.80
Incorporation Costs Net of Burning Costs	$21	$26	$26	$26
Explicit (Cash) Costs	$579.35	$592.42	$605.48	$618.55
Cash Flows	**$259.85**	**$259.58**	**$240.12**	**$214.25**
Implicit (Noncash) Costs	$232.98	$239.14	$245.30	$251.45
Economic Profit (Loss)	**$5.87**	**($5.56)**	**($31.18)**	**($63.20)**

Conclusion

The implementation of the Act appears to have a small, overall impact on the economy of rice-growing counties in the Sacramento Valley during the first five years of its operation. However, the implementation costs of the Act continue to increase. We have no evidence that the phase down has forced any rice grower out of business. The economies of the smaller northern counties, those with larger rice bases, were affected more than the southern counties. The impacts, however, have not been large enough to cause a reduction in rice acreage during the past five years. Many growers have experienced substantial yield losses in the past two years. Should no significant alternative to soil incorporation of straw be developed and yield losses begin to result, it would have a significant effect on growers' incomes. The federal government has embarked on a program to eliminate the federal subsidy program in seven years. Some marginal growers with slim profit margins would not find it profitable to continue to grow rice.

CHAPTER VI

Public Comments on Preliminary Draft Report

On July 9, 1997, about 250 copies of the preliminary draft report were mailed out for public comment. In response, eleven comment letters were received. These letters are included as Appendix G. In addition to comments on the phase down and the preliminary draft report, some letters included suggestions for changing the agricultural burning program. Key comments presented in the letters are summarized and addressed below by subject. A number of technical revisions and corrections have been made in the report as a result of these comment letters.

- **Burning Phase Down:**

  Several letters included the recommendation that rice straw burning should be phased out completely. The Sierra Club advocated a firm deadline to phase out rice straw burning in order to create market conditions that would encourage the development of alternatives to burning. Placer Bikeways and Trails Partnership urged that the phase down "stay on track." Ms. Margaret C. Felts advocated the selection of a point in time when burning agricultural fields will no longer be allowed. While the Phase Down Act restricts the burning of rice straw, the California Health and Safety Code, section 41850, specifies that agricultural burning not be prohibited. The Act phases down rice straw burning until the 2000 burn year, after which up to 25 percent may be burned, under specific circumstances that include a finding that disease has caused a significant, quantifiable reduction in yield, for disease management.

  Some letter writers were concerned that the number of acres burned during the fall, when emissions from rice straw burning are most problematic, has not declined very much. Some said that the rice straw burning phase down should be extended to cover all agricultural burning throughout the state.

  Several letter writers stated that the costs of enforcing the burn program, real-time PM_{10} monitoring, and complaint investigation should be fully covered by raising fees on burning.

- **Smoke Complaints:**

  The significance of the number of smoke complaints received by the public was interpreted in two contrasting ways. Some writers stated that each complaint received represents many more people affected by smoke from burning who did not call to complain; while others stated that the number of complaints was small compared to the large population of the Sacramento Valley.

  Ms. Felts wrote about the problems she found with the smoke complaint procedures and suggested that the telephone number for making complaints should be more easily accessible. In response to this suggestion, the smoke complaint phone number has been added to the ARB Internet Web page on agricultural burning (http://www.arb.ca.gov/agburn/burn.htm). Also, the draft report was revised to better describe how complaints are currently handled (see page III-4).

  The Sierra Club made several suggestions for improving the procedures for investigating complaints. The expanded description of how complaints are handled shows that some of the Sierra Club's suggestions are already being implemented. The Sierra Club noted that since complaints (and presumably health impacts) were more frequent on days when a small number of acres have been authorized, eliminating these marginal burn days would reduce health impacts at relatively little inconvenience to the growers. The ARB staff will be testing the effectiveness of stricter limits on marginal days during the 1997 fall burn season.

- **Emissions from Rice Straw Burning:**

  Dr. Howard Carnahan rightly noted that the emission factors for the field burning of rice straw are different than those in the 1995 Report to the Legislature. As stated in the preliminary draft report, the new emission factors are the result of recently completed work at the University of California, Davis under ARB contract. Previous to this contract, the nitrogen oxides (NO_x) and oxides of sulfur (SO_x) emission factors for rice straw burning were unavailable and, were, therefore, not included in the 1995 report. This did not mean that emissions of NO_x and SO_x were zero as Dr. Carnahan assumed, but merely that these emission factors were not quantified when the 1995 report was written.

  Dr. Bryan Jenkins, Professor at UC Davis, pointed out an error in the draft report for the new NO_x emission factor for rice straw burning. The correct value is 17 pounds per acre burned, not the 26 pounds per acre listed in the preliminary draft report.

Professor Jenkins was the principal investigator of the study that estimated the new emission factors for burning. The emission factor table and related calculations and graphs have been corrected in the final report.

Mr. Ed Romano, Air Pollution Control Officer of Glenn County, stated that, when rice straw is burned during the fall, the entire standing portion of the plants is not burned, which, Mr. Romano concludes, would result in the estimated emissions being overstated by 20 to 40 percent. We would welcome any documentation supporting his assertion. It is possible that incomplete combustion with higher levels of smoldering (in the 20 to 40 percent of rice straw that is unburned) might result in higher emissions.

- **Environmental Assessment of the Phase Down:**

Mr. Romano correctly pointed out that the estimated emission contributions from rice straw burning shown on pages IV-2 and IV-3 of the draft report did not agree with ARB's previous estimates of the contribution of burning determined using ambient sampling data. PM_{10} emissions from rice straw burning in the Valley account for about 4 percent of the total PM_{10} emissions when averaged over the entire year and about 27 percent on a large burn day (10,000 acres burned in the Valley). Analysis of ambient PM_{10} data suggests that total biomass burning (including the burning of rice straw) contributed about 4 to 5 percent on average and 11 percent maximum for the 1995 fall and 1996 spring months analyzed. Atmospheric chemical reactions, location of monitors relative to burning, and wind dispersion account for the difference in the results of the two methods. Although 11 percent of the concentration of PM_{10} may seem like a minor contribution, it is the visibility of the smoke that makes this emission source so readily identifiable.

Some letter writers objected to the report's finding that to-date the phase down has reduced the burning of rice straw primarily during the spring, but that the phase down has not yet improved fall air quality. The California Rice Industry Association (CRIA) noted that average fall burning during the first five years of the phase down (98,000 acres) was less than the average during the previous five years (165,400 acres). While fall burning has been reduced during the past 16 years, the Sacramento Valley Agricultural Burning Plan, not the phase down, has been responsible. The phase down neither limits nor discourages burning during the fall, but, instead, limits burning on an annual basis. CRIA went on to say, "If such a large reduction in burning has not improved air quality, one can only conclude that burning of straw wasn't a significant contributor to poor air quality in the first place..." The report

shows the four air quality indicators used to assess the air quality related to agricultural burning and the impacts of smoke on the public. The graphs of PM_{10} concentrations and exceedances on page IV-12 do not show discernable changes in air quality during the last ten years for spring or fall. The figures on page IV-20 display the fall acreages burned along with the air quality indicators for each of the five years of the phase down. As stated in the conclusions on page IV-19, the overall, fall air quality appears to be primarily a product of existing meteorological conditions' ability to disperse particulates from all emission sources. In years when fall meteorological conditions are more stagnant than usual, the effectiveness of the burn program is crucial to minimizing air quality problems. While the contribution of straw burning may not appear to be a significant contributor to poor air quality overall, it is very significant in terms of smoke impacts on the public.

Ms. Felts made several recommendations. She suggested that we should reconsider the "burning paradigm" of burning only on the days which would otherwise be the "...crispest, clearest, most enjoyable days in Northern California...turning the best days into the worst days." This recommendation would require that burning be done on the days less able to disperse the smoke which would result in severe smoke and fine particulate matter impacts on the population.

- **Health Issues:**

Several letter writers stated that the report was deficient in its analysis of the health impacts of rice straw burning. While there is considerable recent epidemiologic information suggesting the significant and far reaching health impacts of particulate matter exposure, this document is intended to serve as a report to the Legislature on the phase down of rice straw burning, not to provide an extensive assessment of the potential health impacts of particulate matter air pollution. We do, however, recognize that there is limited data specifically addressing the health impacts of smoke from rice straw burning, and in light of this we would like to note that the ARB is conducting a three-year research project to examine the "Health Impacts of Smoke from Rice Residues and Other Vegetative Burning". Unfortunately, since this work has only recently been funded, results from this work will not be available for inclusion in this report.

The Sierra Club suggested that a better PM_{10} monitoring program be established to assess the exposure potential from rice straw burning in each season and to estimate impacts on urban and suburban populations. The ARB does carry out some PM_{10} continuous monitoring on a real time basis (TEOMs) as well as enhanced monitoring

of PM_{10} during the intensive fall agricultural burn season. The new Federal requirements for $PM_{2.5}$ monitoring in support of the new Federal fine particle standards may prove helpful in enhancing existing monitoring efforts.

Professor Bryan Jenkins pointed out that smoke complaints generally reflect visible or odor impacts associated with acute conditions, and the chronic exposures to lower concentrations may be equally or more severely damaging to human health. We agree, and believe that chronic effects of PM exposure have not been adequately addressed to date. We also believe that long term PM exposure may greatly impact the health of many Californians. The ARB is currently conducting a ten year study that will address the long-term effects of air pollution, including PM, on the health of children in the Los Angeles Basin. However, long term exposure studies such as these are extremely expensive to carry out. Because of this, we are not now considering a study of this magnitude for the Sacramento area. If resources became available and the Board felt it was desirable, we would reconsider conducting such a study in the Sacramento area.

Mr. Romano objected to a statement in the report that there have been reports from area physicians stating that people with respiratory illnesses are made more ill during smoky periods. It is correct that we have not documented increased hospital admissions which we can directly attribute to smoke exposure from rice straw burning in the Sacramento area. However, this is not surprising, and furthermore, not necessarily indicative of the potential health impacts of rice smoke exposure. The ARB has for many years carefully implemented a well designed agricultural burning program which has minimized the number, severity and duration of smoke episodes that impact Sacramento residents. As a result, there are few episodes of record that can be examined in conjunction with hospital admissions data. This essentially means, statistically speaking, that there isn't enough data using epidemiologic tools to draw a conclusion one way or the other regarding rice smoke exposure and human health in the Sacramento area. However, the ARB continues to believe that inhalation of particulate matter air pollution, including smoke from rice straw and other vegetative burning, is harmful to human health and that the use of controlled laboratory exposure studies might prove more helpful in assessing the specific effects of rice smoke. In light of this we are conducting the three year research project mentioned earlier.

Dr. Carnahan suggested that a new section be added to the report describing the beneficial effects of rice growing on people. While there are significant ecological benefits from growing all kinds of photosynthetic species, including rice, it is not

known how the benefits of growing rice compare with any other crop or even natural vegetation.

- **New Federal $PM_{2.5}$ Standard:**

  The American Lung Association wrote that, considering the recently established federal $PM_{2.5}$ standard, the report overlooked the "shift in attainment and maintenance strategies that will occur and the impacts this shift will have on the rice straw burning program." Although smoke from straw burning is mainly $PM_{2.5}$ particles, at this time it is unknown how the promulgation of the fine particle $PM_{2.5}$ standard will affect rice straw burning restrictions.

  As previously mentioned, one of the effects of the new Federal $PM_{2.5}$ standard may be to enhance existing monitoring efforts in the Sacramento Valley.