2001 REPORT TO THE LEGISLATURE

PROGRESS REPORT ON THE PHASE-DOWN

AND THE 1998-2000 PAUSE IN THE PHASE-DOWN

OF RICE STRAW BURNING IN THE SACRAMENTO VALLEY AIR BASIN

Submitted by:
CALIFORNIA AIR RESOURCES BOARD
CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
AUGUST 2001

STATE OF CALIFORNIA

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ACKNOWLEDGMENTS

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Secretary of the Senate
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Dear Mssrs. Schmidt and Wilson:

This report responds to the Legislature's requirement to report on the phase down of rice straw burning in the Sacramento Valley Air Basin and for recommendations on achieving a diversion of 50 percent of the rice straw left on the fields after harvest. Health and Safety Code section 41865(n) requires the Air Resources Board (ARB or Board) and the California Department of Food and Agriculture (CDFA) to jointly prepare and submit this report every two years. Health and Safety Code section 41865(o) also requires the ARB to report on the air quality, public health, and economic impacts associated with the burning of rice straw during the years 1998 to 2000, when the phase-down schedule was paused at 200,000 acres. The "pause" report is incorporated in this 2001 biennial report.

The recommendations in this report were developed during a public process and reflect suggestions provided by rice growers, farm advisors, experts in the rice straw industry, and local air districts personnel. The Board considered the report and accompanying recommendations at a public hearing on June 26, 2001.

Subsequent to presentation of the report to the Board, the economic circumstances of the State of California have changed. We recognize that the Legislature will need to consider the current budget shortfall in reviewing the recommendations contained in the report.

Sincerely,

Alan C. Lloyd, Ph.D.
Chairman

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Website: http://www.arb.ca.gov.

Executive Summary

The purpose of this report is to provide an update on the status of the phase-down of rice straw burning in the Sacramento Valley. The report addresses progress in meeting the phase-down requirements, the status of alternatives to burning, environmental and ecological effects, and economic impacts. While the requirements of the phase-down have been met on schedule, the development of alternative uses for rice straw continues to be the major consideration.

The phase-down of rice straw burning in California's Sacramento Valley Air Basin has been in effect since 1992. 2001 is the final year of the phase-down. From this point forward, rice straw can be burned only for disease control purposes and will be limited to 125,000 acres or 25 percent of each individual grower's fields, whichever is less. The phase-down has met or exceeded the goals set forth in the program. This is due to the management of the Sacramento Valley's rice straw and smoke management program, which is administered by the Sacramento Valley Basinwide Air Pollution Control Council, along with the combined efforts of rice growers, rice industry representatives, and State officials. The amount of rice acreage burned in the Sacramento Valley has decreased from 303,000 acres in 1992 to 139,000 acres in 2000. Based on Air Resources Board (ARB) emission factors, this has resulted in a decrease in PM_{10} emissions from 2863 tons per year to 1313 tons per year.

Alternatives to burning continue to be slow to develop. In 1997 approximately 20,000 tons of rice straw, or about two percent of the available rice straw, was used off-field. This has not changed in the past four years. Table 1 shows current rice straw usage and our best projection for usage in 2005. Current usage was estimated by the California Department of Food and Agriculture (CDFA). The projected 2005 use is based on information provided by Rice Fund grant recipients, as well as estimates from rice industry representatives, university research sources, and non-Rice Fund end-users.

The Rice Fund, established in 1997, provides funding for demonstration and commercialization projects that use rice straw. These projects are designed to help establish commercial markets for rice straw and provide an alternative to both burning and soil incorporation. Most of these projects are still in the development and demonstration phase and have used little straw to date. However, a number of projects show promise and may increase straw usage substantially by 2005. The 2005 projected usage is primarily dependent on two categories, construction materials and export. Based on end-user projections of successful project development, this would achieve an approximate 40 percent diversion rate. However, even if successful, this would not meet the 50 percent diversion goal established in 1997. We will continue to track the progress of alternatives and promote their development through the ARB Rice Fund, the Rice Straw Utilization Tax Credit Program, and the forthcoming Agricultural Biomass Utilization Account grant program.

Table 1

Current and Projected Off-Field Rice Straw Usage

	2000[1] (tons)	2005[2] (tons)
Animal Bedding – domestic	2,034	2,000
Animal Feed – domestic	4,923	80,000
Compost/Fertilizer	2,400	50,000
Construction Materials	2,018	150,000
Erosion Control/Weed Suppression	4,742	15,000
Export		150,000
Estimated Total Usage	**24,176**	**447,000**

(1) Current estimates based on CDFA's Rice Straw Utilization Tax Credit Program multiplied by an adjustment factor of 1.50 (see Table 2)
(2) 2005 usage is the best projection based on current and anticipated usage.

Decreasing rice yields and prices, in addition to the higher costs of incorporation, have contributed to an adverse economic impact on Sacramento Valley rice growers. Grain yield per acre has decreased slightly and profits are down. Burning, the least costly rice straw management method, costs approximately $3 per acre. The incorporation of the straw back into the soil is the primary alternative to burning now available. The cost of incorporation has increased from previous estimates and now averages $43 per acre, reflecting increases in equipment and fuel and labor costs. Individual growers may experience higher or lower costs. Without a viable market for off-field uses of rice straw, removing the straw from the field is the most costly.

Impacts of the phase-down on the environment are mixed. Soil incorporation, with or without winter flooding, has both advantages and disadvantages. Increased chemical use is reported by some growers and decreased use by others. University researchers indicate that soil incorporation can provide many benefits if combined with winter flooding. These benefits include increased soil fertility and grain yield, increased rate of straw decomposition, increased waterfowl populations, and decreased incidence of weeds. Disadvantages include increased incidence of some weeds and diseases, increased water usage due to winter flooding that could lead to higher costs, and increased invertebrate populations (although these provide nourishment to migrating waterfowl).

A pause in the phase-down resulted from a 1997 amendment to the original schedule. These years, 1998, 1999, and 2000, limited annual burning to 200,000 acres, with a separate 90,000 acre limit in the fall. The total acreage burned in the fall and spring was similar to what would have been burned under the phase-down. Because the higher total acreage limits allowed during the pause were not reached, there has been limited impact on air quality, economics, public health,

or environmental and ecological issues. These impacts are addressed as part of our phase-down analysis.

In summary, the phase-down of rice straw burning in the Sacramento Valley has proceeded as scheduled and enters the final phase in September 2001. The availability of economically viable alternatives to burning continues to be the major concern, although projects are being developed that hold promise for 2005. End-user incentives exist, but the benefits have not been seen by the average rice grower, who continues to bear significant straw management costs.

Recommendations

In order to further encourage the development of alternatives to meet the goal of 50 percent diversion, we offer the following recommendations to the Legislature:

- Continue to provide financial and technical support to rice growers and end users for the utilization of rice straw for environmentally sound purposes through the use of grant programs, tax incentive programs, and the Rice Fund.

- Continue efforts to encourage State agencies to look to rice straw for erosion control, weed suppression efforts, sound mitigation, and other environmentally sound uses.

Background

The Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 (Act) requires the Air Resources Board (ARB or Board) and the California Department of Food and Agriculture (CDFA) to prepare and submit a report to the Legislature every two years on progress in reducing the amount of rice straw burned in the Sacramento Valley.[1] This report focuses on activities occurring since the 1999 report. The ARB is also required to submit a report presenting findings regarding the air quality, public health, and economic impacts associated with the burning of rice straw during the years 1998 to 2000, when the phase-down schedule was paused at 200,000 acres. The "pause" report is incorporated in this 2001 biennial report.

Rice is the most widely planted crop in the Sacramento Valley with approximately 500,000 acres grown annually. Open-field burning has been the traditional and most effective method of disposing of the rice straw and controlling rice disease. This burning can occur in the fall after harvest, or during the spring before planting. Historically, hundreds of thousands of acres of rice straw were burned during the fall, as burning during this time is most effective[2] for disease control purposes. In addition to disease management advantages, growers prefer burning in the fall to reduce their straw management burden in the spring when they are preparing to plant a new crop. Unfortunately, the fall can be an unfavorable time to burn as stagnant meteorological conditions often result in poor air quality. Smoke impacts can also be significant, especially on days when meteorological forecasts are not successful and smoke is transported over populated areas.

To improve air quality and reduce smoke impacts, the ARB began to regulate agricultural, rangeland, and forestland burning in 1971. The Sacramento Valley Agricultural Burning Program (Burn Program), a variable acreage burn program, was developed in 1981, tested in 1981 and 1982, and incorporated as regulation in 1983. The Burn Program determines the amount of burning that is allowed during the fall intensive burn season, as well as the rest of the year. However, continued public complaints about poor visibility and air quality resulted in the establishment of progressive reductions in rice straw burning beginning in 1992, pursuant to a schedule outlined in the Act. This timetable was modified in 1997 to limit burning to 200,000 acres annually for three burn seasons: 1998-1999, 1999-2000, and 2000-2001. This period was known as the "pause" in the phase-down. For these three years only, the law set a separate limit for fall burning. Up to 90,000 acres could be burned during the fall, subject to the acreage allocations of the Burn Program, with the total annual amount capped at 200,000

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[1] Assembly Bill No. 1378, Statutes of 1991, Chapter 787, Sec. 2; Health and Safety Code sections 41865-41866.

[2] Cintas, N.A., 1998. Relationship of *Sclerotium oryzae:* Inoculum levels, Stem Rot Incidence and Severity, Yield of Rice in California and Bacterial Populations Recovered from *S.oryzae* Sclerotia and Rice Stems under Different Rice Residue Management Practices. Dissertation, University of California, Davis.

acres. The final step of the phase-down begins September 2001, when the law will allow burning only for disease control under the Conditional Rice Straw Burning Regulation. The disease control burning will be limited to 25 percent of each grower's planted acres, up to an industrywide total of 125,000 acres.

The Act requires that the following topics be covered in the biennial reports:

- Alternatives to rice straw burning and recommendations from the Alternatives Advisory Committee;
- Progress toward achieving the 50 percent diversion goal for off-field uses of rice straw;
- Progress of the burning phase-down;
- Environmental and economic assessments; and
- Any related issues, including any recommendations.

Also required is a report on the impact of the pause in the phase-down. The impacts to be considered in this report include:

- Air quality;
- Public health; and
- Economics.

In preparing this report, the staff of ARB and CDFA reviewed current information on each of these topics. In addition, a workshop was held in Colusa on June 5, 2001. This workshop was attended by rice growers, rice industry representatives, rice straw users, and other stakeholders. The key issue continues to be the status of alternatives to rice straw burning. This report provides an update on the existing and promising new projects for use of rice straw. The primary current alternative to burning is soil incorporation, as was the case at the time of the previous reports.

Public Health Impacts

Fine particles in the air are generally characterized by the ambient concentration (in micrograms per cubic meter or $\mu g/m^3$) of particulate matter whose diameters are 10 micrometers (μm) or less (also known as PM_{10}). These particles are smaller than one-seventh the diameter of a human hair. These particles are small enough to be inhaled and can be especially harmful to people with existing vascular or respiratory illness, the aged, and the very young. The findings of recently published literature[3,4,5,6] have focused on the health consequences of

[3] Levy, J. I., Hammitt, J.K., and J.D. Spengler, 2000. Estimating the Mortality Impacts of Particulate Matter: What Can be Learned from Between-Study Variability? *Env.Health.Pers.* 108:109-117.

[4] Dockery, D.W., Pope, C.A. III, Xu, X., Spenger, J.D., Ware, J.H., Fay, M.E., Ferris, B.G. Jr., and F.E. Speizer, 1993. An Association Between Air Pollution and Mortality in Six U.S. Cities. *N.Engl.Med.* 329:1753-1759.

PM_{10} and smaller size fractions. These studies indicate that when particle levels increase, adverse health effects increase as well.

A recent report by the Health Effects Institute[7] concluded that there is an adverse relationship between increases in PM_{10} and mortality and hospitalization. This study, an analysis of mortality, hospital admissions, and air quality data from urban areas across the United States, concluded that an approximate average of 0.5 percent increase in total mortality was associated with each 10 $\mu g/m^3$ increase in PM_{10}. Cardiovascular-related hospitalization admissions for the elderly (ages 65 and above) increased by one percent. A two percent increase was noted for pneumonia and chronic obstructive pulmonary disease for every PM_{10} increase of 10 $\mu g/m^3$. It should be noted that this analysis, and many other additional studies on air quality and health, was limited to monitoring in urban areas. The specific effects of exposure to short-term agricultural burning is still being investigated but the data support the benefits of a well-managed air quality program which includes a well-managed burn program that allows for burning on days which limit public exposure to particulate matter.

Over 97 percent of the particles directly emitted from the burning of rice straw are less than 10 micrometers in size (PM_{10}).[8] The ARB is sponsoring on-going clinical studies to look at the specific health effects of burning rice straw and other agricultural residues[9]. These studies are proceeding on schedule and results will be released when available. It is important to move forward with additional research efforts focused on:

- Improving our knowledge of the levels of smoke to which people are exposed; and
- Better characterizing and, if possible, quantifying how people of varying health status (healthy or diseased) respond to smoke.

Alternatives to Rice Straw Burning

The development of alternatives to burning is critical to the long-term success of the phase-down and agricultural prosperity. Although recent developments hold promise for the longer-term, in the near term most of the rice straw that is not burned will be incorporated into the soil. Off-field uses of rice straw could

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[5] Pope III, C.A. and D.W. Dockery, 1999. "Epidemiology of Particle Effects", in Air Pollution and Health, Academic Press, pp.675-705.

[6] Pope III, C.A., 2000. Review: Epidemiological Basis for Particulate Air Pollution Health Standards. *Aer.Sci.Tech.* 108:125-133.

[7] Samet, J.M., Dominici, F., Zeger, S.L., Schwartz, J. and D.W. Dockery, 2000. National Morbidity, Mortality, and Air Pollution Study. HEI Research Report No. 94, May 2000, Health Effects Institute, Cambridge, MA.

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

[9] Solomon, C. and J. Barnes, The Effects of Smoke from Burning Vegetative Residues on Airway Inflammation and Pulmonary Function in Healthy, Asthmatic and Allergic Individuals, ARB Contract No. 97-322

increase to about 40 percent by 2005, but soil incorporation will likely remain the primary alternative to burning for the next few years.

Stakeholders agree that additional financial incentives, such as grants and loan guarantees, are needed to speed the development of commercial uses for rice straw. Many of these financial incentives have been recommended in previous biennial progress reports[10], reports of the Alternatives Advisory Committee[11], the Rice Straw Supply report[12], the Rice Straw Diversion Plan[13], and the annual reports submitted by CDFA on the Rice Straw Utilization Tax Credit Program[14].

Programs such as the Rice Straw Demonstration Project Grant Fund[15], the Rice Straw Utilization Tax Credit Program[16], and the Agricultural Biomass Utilization Account[17] provide increasing incentives to the end-user, thereby increasing the market potential for rice straw. However, funding amounts are still low and the amount of rice straw used off-field is still well below the hoped for 50 percent as outlined in the 1998 *Rice Straw Diversion Plan*.

In this section, we present an update of off-field usage of rice straw, including

- A description and update of the Rice Straw Diversion Plan;
- Tax and grant programs available for users of rice straw;
- An update of the Rice Straw Demonstration Project Grant Fund;
- A brief description of alternative uses of rice straw and their estimated usage;
- A description of the Rice Straw Supply report; and
- The recommendations of the Advisory Committee on Alternatives to Burning.

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[10] California Air Resources Board [CARB], 1995, *Report to the Legislature - Progress Report on the Phase-down of Rice Straw Burning in the Sacramento Valley Air Basin, 1992-1994*, Sacramento, CA; CARB, 1997, *1997 Report to the Legislature - Progress Report on the Phase-down of Rice Straw Burning in the Sacramento Air Valley Air Basin, 1995-1996*, Sacramento, CA; CARB, 2000, *1999 Report to the Legislature - Progress Report on the Phase-down of Rice Straw Burning in the Sacramento Valley Air Basin*, Sacramento, CA.

[11] Advisory Committee on Alternatives to Rice Straw Burning, 1995, *Report of the Advisory Committee on Alternatives to Rice Straw Burning*, Sacramento, CA; Advisory Committee on Alternatives to Rice Straw Burning, 1997, *Report of the Advisory Committee on Alternatives to Rice Straw Burning*, Sacramento, CA

[12] CARB, 2001, *Draft Report to the Legislature - Recommendations for Rice Straw Supply*, Sacramento, CA

[13] CARB, 1998, *Rice Straw Diversion Plan,* Sacramento, CA

[14] California Department of Food and Agriculture [CDFA], 1998, *Report to the Legislature - rice Straw Utilization Tax Credit Program*, Sacramento, CA; CDFA, 1999, *Report to the Legislature - Rice Straw Utilization Tax Credit Program*, Sacramento, CA; CDFA, 2000, *Report to the Legislature - Rice Straw Utilization Tax Credit Program*, Sacramento, CA

[15] Established by Senate Bill 318, Statutes of 1997, Chapter 745; California Health and Safety code sections 39750 to 39753.

[16] Established by Senate Bill 38, Statutes of 1996, Chapter 954; State Revenue and Taxation Code section 17052.10.

[17] Established by Assembly Bill 2514, Statutes of 2000, Chapter 1017; California Health and Safety Code sections 39760 to 39763.

Off-Field Usage

Rice Straw Diversion Plan

Senate Bill 318[18] directed the ARB to develop an implementation plan and schedule to find off-field uses for 50 percent of the rice straw by the year 2000. In December 1998, the ARB released *The Rice Straw Diversion Plan* (the Plan), which outlines measures that could be taken to achieve the 50 percent goal.

The Plan recommended that resources be appropriated to address the issues of developing a rice straw infrastructure since these issues are common to most potential uses of rice straw. The recommendations included providing financial resources, such as low-interest loans, accelerated capital depreciation, or tax credits, toward building storage facilities so that rice straw would be available on a year-round basis. Some of these issues are addressed in a recent report to the Legislature on the supply of rice straw for cost-effective uses[19].

Progress toward the goal of 50 percent diversion has been slow. In particular, two of the major anticipated users of rice straw – ethanol and particleboard manufacturing – have suffered delays. The anticipated construction of plants converting rice straw to ethanol has been delayed and the current projected date for the BCI-Gridley project to be operational is 2004. Both particleboard facilities funded by the Rice Straw Demonstration Project Grant Fund have encountered technical difficulties, but are now installed and anticipate full operation within a year. A non-Rice Fund particleboard project is planned near Willows and is anticipated to be in operation by the end of 2002. In addition:

- Progress has been made toward opening the rice straw export market to Japan, but no rice straw has been used for this effort at this time;
- Activities to export straw to Taiwan are expected to start in 2001, with an anticipated 30,000 tons of straw being exported each year for the next five years;
- Rice straw as an erosion control material is showing steady market expansion; and
- Rice straw used as animal bedding and feed should continue as a small but consistent market with the assistance of the Rice Straw Utilization Tax Credit Program.

To date, rice growers in the Sacramento Valley have seen no significant increases in rice straw usage resulting from these activities. Although ARB staff anticipates increased rice straw usage in the near future, these projects are all in various stages of development and are subject to changes in market conditions.

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[18] Senate Bill 318, Statutes of 1997, Chapter 745; California Health and Safety code section 41865.

[19] CARB, 2001, *op. cit.*

Tax Credit/Grant Programs

Several programs exist in the State of California to financially assist rice straw end-users and to provide further incentive toward the off-field use of rice straw. These programs range from tax credit programs to grant programs. Not all of these programs have been used to their full potential nor are all of these programs restricted to rice straw use.

- *Agricultural Biomass Utilization Account.*
  This program provides grants of at least $20 per ton of rice straw for uses that include processing, energy generation, manufacture, export, or any other environmentally sound purpose. The program is administered by CDFA and is currently budgeted for $2 million .

- *Agricultural Biomass-to-Energy Incentive Grant Program.*
  This program provides incentive payments of $10 per ton of qualified agricultural biomass to facilities that convert the biomass to energy. The Trade and Commerce Agency administers the program. Since rice straw is not singled out in this program, it is unlikely, given the competition from more traditional and more technically-viable biomass[20], that rice straw users will be able to take advantage of this program.

- *Rice Straw Utilization Tax Credit Program*
  This program provides tax credits of $15 per ton of rice straw used for off-field purposes. This program is administered by CDFA and is limited to $400,000 a year.

- *Rice Straw Demonstration Project Grant Fund*
  This program provides grants to aid in the development of commercial uses for rice straw. This program is administered by ARB and is discussed in further detail in the next section.

Rice Straw Demonstration Project Grant Fund

The Rice Straw Demonstration Project Grant Fund (Rice Fund), created in 1997[21], and administered by the ARB, provides grants for developing commercial uses for rice straw. The Rice Fund has awarded $5 million in grants and an additional $1 million is in the current 2001-2002 fiscal year budget.

Criteria for evaluating applications were developed with the University of California, the Trade and Commerce Agency, and the CDFA. The Board

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[20] Jenkins, B.M., R.R. Baker, R.B. Williams, R. Bakker-Dhaliwal, M.D. Summers, H. Lee, L.G. Bernheim, W. Huisman, L.L. Yan, P. Andrade-Sanchez and M. Yore. 2000. Commercial Feasibility of Utilizing Rice Straw in Power Generation, Proceedings, Bioenergy 2000 (submitted).

[21] Senate Bill 318, Statutes of 1997, Chapter 745; California Health and Safety Code sections 39750 to 39753.

adopted these criteria at its January 29, 1998, public meeting. The applications were reviewed by a panel of experts from the University of California, Davis, the United States Department of Agriculture (USDA), the Trade and Commerce Agency, the rice industry, and staff from the ARB and CDFA. In total, 12 projects have been approved for grants to date.

Several projects have not yielded the anticipated results. Other projects are proceeding on schedule and at anticipated levels. The grants awarded to date, should they become successful, would not be sufficient to meet the goal of 50 percent diversion of rice straw by 2005.

Projects Awarded

A summary of the projects funded by the Rice Fund can be found at the ARB's web site at:

http://www.arb.ca.gov/smp/rice/rice.htm.

An abbreviated summary of grants awarded since the program's inception, presented by fiscal year, follows:

1997-1998

- Anderson Hay & Grain Co., Inc., $500,000, *Preprocessing of Rice Straw for Multiple Products.* Final Report submitted September 2000.

  Status: Anderson Hay & Grain submitted the final report for this project in September 2000. Harvest techniques have been analyzed and the results have contributed greatly to increasing the efficiency and economics of straw harvesting, baling, and transporting for various end uses. Rice straw is being supplied to companies manufacturing erosion materials and continuing progress is being made on the opening of the rice straw market to Japan.

  Primary issues: Development of a disease treatment protocol acceptable to the Japanese government.

  Rice straw usage to date: 14,000 tons.

- FiberTech USA, Inc., $750,000, *Bioboard Plant for Colusa, California.*

  Status: Fibertech submitted the final report for this project in May 2000. Despite technical difficulties, which have hampered efforts,

limited production has begun and full production is anticipated in late 2001.

Primary issues: Development of a commercial market for the product.

Rice straw usage to date: 25,000 tons.

- MBI International, $820,000, *Production of Fermented Animal Feeds from Sacramento Valley Rice Straw: Prototype and Commercial Pilot.*

  Status: Initial outside funding for this project is complete. Cattle feed trials are scheduled to begin in fall of 2001.

  Primary issues: Farmer acceptance of animal feed; potential impact of rising energy costs.

  Rice straw usage to date: 40 tons

1998-1999

- Agriboard Industries L.C., $665,000, *Phase One Development of the Agriboard Industries L.C. Rice Fiber Based Structural Panel Plant in Sacramento Valley, California.*

  Status: Withdrew from program.

- Louisiana-Pacific Corporation, $565,753, *Medium Density Fiberboard Manufactured from Sacramento Valley Rice Straw Residuals.*

  Status: Withdrew from program.

- Enviro Board Corporation, Inc., $500,000, *Colusa Rice Straw Project.*

  Status: Funding for this project is complete and the plant has been established in Colusa. Production of fiberboard is expected to begin in July 2001.

  Primary issues: Additional funding needs to be secured; market acceptance of product is unclear.

  Rice straw usage to date: minimal.

- Arkenol Holdings, L.L.C., $519,247, *Production of Citric Acid From Sacramento Valley Rice Straw*

  Status: Arkenol submitted the final report for this project in March 2000. Project is fully funded.

  Primary issues: Not cost competitive at current market prices.

  Rice straw usage to date: minimal.

1999-2000

- Rice Straw Cooperative, $380,000, *Evaluation and Delivery of Rice Straw Needed for Gridley Ethanol Plant's Startup Year of Operation.*

  Status: No Rice Fund monies expended to date. Testing on rice storage will begin in fall of 2001. Timeline for BCI Gridley ethanol plant to begin operation is uncertain.

  Primary issues: Ethanol plant financial backing is uncertain; future of fuel oxygenate market in California is also uncertain.

  Rice straw usage to date: none.

- Broken Box Ranch, $297,589, *Development of a Commercial Scale Composting Plant in Colusa County.*

  Status: This project is operational as of fall 2000.

  Primary issues: Development of market and product familiarity.

  Rice straw usage to date: 900 tons.

- Kuhn Hay, $402,311, *Rice Straw Export Project.*

  Status: Minimal expenses have been incurred to date. Kuhn Hay is still working to develop a disease treatment protocol to satisfy Japanese government.

  Primary issues: Development of disease treatment protocols.

  Rice straw usage to date: none.

- Smith Ranches, $50,100, *Rice Straw Silage Production for Cattle Feed.*

  Status: The demonstration of rice straw silage as viable animal feed has been completed. Testing of nutritional properties of feed is underway.

  Primary issues: Technical problems with mold formation.

  Rice straw usage to date: minimal.

- Arkenol Holdings, L.L.C., $100,000, *Production of Ethanol from Rice Straw.*

  Status: Project completion is very uncertain. Pilot plant is under development in Japan. California plant construction is not yet underway. No Rice Fund monies have been expended to date.

  Primary issues: Economic viability is uncertain.

  Rice straw usage to date: none.

2000-2001

No grants awarded due to lack of funding.

2001-2002

SB 1794 extended the Rice Fund to 2003[22]. The ARB expects to award grants totaling $1 million for the fiscal year 2001-2002. ARB staff anticipate issuing an Invitation for Grant Requests in the summer of 2001.

Alternative Uses

Using an estimate of 2.25 tons of harvested rice straw per acre, the 521,000 acres of rice planted in 2000 could have yielded a potential of 1.17 million tons of rice straw. The 50 percent diversion goal would therefore require 586,000 tons to be used off-field.

Table 2 lists the basic categories of off-field usage of rice straw for several years. These uses include animal feed and bedding, compost and fertilizer, erosion control, particleboard manufacturing, and straw bale construction. The information for this table came from two primary sources: the 1995 *Report of the*

[22] Senate Bill 1794, Statutes of 2000, Chapter 1019; California Health and Safety Code sections 39751 and 39752.

Advisory Committee on Alternatives to Rice Straw Burning and the Rice Straw Utilization Tax Credit Program reports to the Legislature which cover the years 1997-2000. These numbers do not reflect complete usage. Not all end-users will utilize the tax credit program. The figures in the table have been adjusted by the factor noted in the table and reflect best estimates of actual use.

Table 2

Documented and Estimated Off-field Usage of Rice Straw[1] (tons)

Types of Use	**1997**	1998	1999	**2000 (est.)**
Animal Bedding - domestic	2,967	2,530	1,250	2,034
Animal Feed - domestic	1,646	1,688	3,207	4,923
Compost/Fertilizer	1,264			2,400
Construction Materials	50		19,450	2,018
Erosion Control/Weed Suppression	107	1,672	1,714	4,742
Export				
Total	**6,034**	**5,891**	**25,621**	**16,117**
Adjustment Factor[2]	***3.3***	***4.0***	***2***	***1.50***
Estimated Actual Usage	***20,113***	***23,564***	***51,000***	***24,176***

(1) 1997-1999 data from CDFA Reports of the Rice Straw Utilization Tax Credit Program; 2000 data is preliminary information from CDFA.
(2) Adjustment factors were taken from CDFA Reports of the Rice Straw Utilization Tax Credit Program and are the best estimates of rice industry experts and university researchers.

Table 3 indicates potential usage in the year 2005, using estimates from current and past Rice Fund grant recipients, as well as estimates obtained from rice growers, rice straw harvesters, researchers, and end-users. It is also assumed that a continuing use will exist due to the presence of the CDFA Rice Straw Utilization Tax Credit Program and the four years of data from this program have been extrapolated to 2005 to account for this continued usage. The establishment of an export market to Japan and a viable construction material manufacturing industry would account for almost 70 percent of projected use in 2005.

Estimates of rice straw use in 2005 are subject to several key assumptions. One is the opening of the export market to Japan. Trade barrier obstacles exist and unless these are eased this use will not increase. Two Rice Fund grant recipients, Anderson Hay & Grain and Kuhn Hay, are working closely with the National Hay Association to alleviate these barriers. A concerted effort by the United States Department of Agriculture would greatly aid in the development of this alternative to burning.

Table 3

2005 Potential
Off-field Usage of Rice Straw
(tons)

Types of Use	Tax Credit Program	Rice Fund Program[1]	Private Business Venture[2]	Combined Estimate[3]
Animal Bedding - domestic	2,000			2,000
Animal Feed - domestic	10,000	80,000		80,000
Compost/Fertilizer	900	50,000		50,000
Construction Materials	5,400	50,000	100,000	150,000
Erosion Control/Weed Suppression	15,000	3,000		15,000
Export		150,000	30,000	150,000
Total	**33,300**	**333,000**	**131,000**	**447,000**

(1) The stated output for 2005 that was provided by Rice Fund recipients has been analyzed by ARB staff, CDFA staff, Energy Commission staff, researchers, and rice industry experts and adjusted accordingly.
(2) These estimates are from communication with officials in the bale construction industry, straw balers, and Agriboard, a particleboard manufacturer.
(3) Duplication may exist in these numbers; it is assumed that the tax credit program will be the most likely to be duplicated and are therefore not added to the combined estimates if other estimates exist.

Ethanol

Because the viability of a rice-based ethanol market is highly uncertain, ethanol was not included in the projected 2005 usage. In addition, estimates are based on current projects and the rice straw ethanol industry has not yet been established. However, the establishment of an expanded ethanol market in California and the subsequent construction of ethanol plants in the Sacramento Valley would greatly increase the off-field use of rice straw.

A biomass-to-ethanol plant could use 150,000 tons of rice straw and produce 20 million gallons per year of ethanol. This would represent about 15 percent of the total rice straw available and a few of these plants could substantially contribute to the 50 percent diversion goal. Two Rice Fund grants awarded in 2000, to Arkenol Holdings and the Rice Straw Cooperative, specifically targeted this industry. However, the likelihood of this industry contributing to the 2005 diversion goals is unlikely as neither the Arkenol plant, nor the plant supplied by the Rice Straw Cooperative, BCI Gridley, have begun construction of processing facilities.

The phase out of methyl tertiary butyl ether (MTBE) in California's gasoline could generate the need for significant quantities of ethanol as a substitute for fuel oxygenate requirements. California Phase 3 reformulated gasoline (CaRFG3) could establish a near term (2003) ethanol market of about 580 million to

710 million gallons a year[23]. The U.S. Environmental Protection Agency's recent decision denying California's request for a waiver from the federal oxygenates mandate may spur the California rice straw ethanol industry. At this date, however, construction of new ethanol manufacturing plants has not begun and financing is still uncertain.

Challenges facing the California ethanol industry include[24,25]:

- Competition with traditional suppliers in the Midwest;
- Transportation economics, which make it cheaper to ship ethanol by rail from the Midwest than by truck from Northern California;
- Feedstock technical barriers, such as the high silica content of the straw which makes it difficult to process; and
- Lack of facilities available to store a seasonal crop throughout the year.

In its recent evaluation of the costs and benefits of a biomass-to-ethanol production industry in California[26], the CEC reiterated these challenges, finding that:

- 2004-2005 is the earliest that biomass-to-ethanol production facilities could be in place;
  - Only two small ethanol plants are operating in California and several biomass-to-ethanol construction projects are being considered, but no firm commitments are known at the time of the report;
- The technology that converts cellulosic biomass (which includes rice straw) to ethanol has not been commercially demonstrated;
- Federal and other State financial and non-financial incentives have been effective in stimulating the corn-to-ethanol production industry and could aid in the biomass-to-ethanol industry as well;
- The benefits of a California ethanol production industry could be greater than the cost of State support[27] in terms of:
  - increased employment,
  - decreased air pollution from decreased burning,
  - increased forest health,
  - increased use of rice straw,
  - diversion of waste from landfills, and

[23] California Energy Commission, 2001. *Costs and Benefits of a Biomass-to-Ethanol Production Industry in California*, Sacramento, CA, March 2001.
[24] California Energy Commission, 1999. *Evaluation of Biomass-to-Ethanol Fuel Potential*, Sacramento, CA, December 1999.
[25] ARB staff analysis.
[26] California Energy Commission, 2001. *Costs and Benefits of a Biomass-to-Ethanol Production Industry in California*, Sacramento, CA, March 2001.
[27] Ibid. The 2001 CEC Report estimated economic benefits of $1 billion over a 20-year period assuming State support of $500 million for a 200 million gallon a year ethanol industry.

- decreased reliance on out-of-state fuel components.

The report recommended that the State should provide technical and financial support for biomass-to-ethanol production projects; fund activities to help establish the availability and quality of the feedstock for ethanol production; and develop and implement a market incentive program to increase the market certainty of California produced ethanol. In addition, the State should direct the Energy Commission to analyze means of increasing ethanol import options and limit ethanol price fluctuations.

ARB will continue to monitor the progress of ethanol issues in California and support the use of rice straw based ethanol.

Rice Straw Supply Report

SB 1186[28] directed the ARB to submit recommendations to the Legislature that would ensure the consistency and predictability in the supply of rice straw for cost-effective uses. These recommendations were to include methods of harvesting, storing, and distributing rice straw for off-field uses. Completed in consultation with CDFA and with the cooperation of the California Energy Commission and the California Integrated Waste Management Board, the recommendations include:

- Implementing fiscal measures designed to offset harvest, storage, and distribution costs;
- Developing funding to support collaborative research to improve the efficiency of methods to harvest, store, and distribute rice straw; and
- Altering the Rice Straw Utilization Tax Credit Program to include a storage tax credit component to enable the construction of new storage facilities.

The recommendations in this report were based on input from rice growers, rice straw experts in the harvesting, baling, storage, and transportation industries, University of California researchers, farm advisors, and air district staff in the Sacramento Valley Air Basin during an extended public process.

Printed copies of the report[29] can be obtained from the ARB or can be found in electronic format on the ARB website at:

http://www.arb.ca.gov/smp/rice/supply/supply.htm.

Release of the final report is expected in late 2001.

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[28] Senate Bill 1186, Statutes of 1999, Chapter 640; California Health and Safety Code section 41865.5.

[29] California Air Resources Board, 2001. *Draft 2001 Report to the Legislature - Recommendations for Ensuring the Consistency and Predictability in the Supply of Rice Straw for Cost-Effective Uses*, Sacramento, CA, February 2001.

Advisory Committee on Alternatives to Rice Straw Burning

The Advisory Committee on Alternatives to Rice Straw Burning (Alternatives Committee) has identified numerous commercial uses for rice straw and has discussed the technical and economic barriers for each. Recommendations designed to increase the commercial uses of rice straw were made. The Committee noted that without financial incentives, alternative uses would be slow to develop. These recommendations were previously made in the *Rice Straw Diversion Plan* in 1998, the 1999 *Biennial Report to the Legislature on the Progress of the Phase-down of Rice Straw Burning*, and the report on *Rice Straw Supply* in 2001.

The Committee is finalizing its most recent report and anticipates its release in summer of 2001. This report will provide a summary of changes and progress since the last report as well as a more detailed discussion of the status of the rice straw marketing infrastructure in California. The Committee's recommendations are designed to speed the development of alternative uses of rice straw.

The Committee's past recommendations include:

- Providing financial incentives, such as loans and grants for rice straw projects;
- Conducting studies on straw infrastructure;
- Supporting rice straw research;
- Increasing the rice straw tax credit limit;
- Encouraging State agencies to use and promote rice straw products where appropriate;
- Encouraging the State to undertake building code testing and standardization for straw bale housing; and
- Investigating a tax credit program, such as the one used in Oregon, to stimulate construction of storage barns for rice straw in California.

Many of these recommendations are being addressed through current programs. The ARB and the CDFA support the Committee's recommendations as necessary and appropriate to stimulate the alternative uses of rice straw.

Progress of the Phase-down

Phase-down Compliance

The Act limits the acres of rice straw that can be burned each year. The original 1991 phase-down schedule is presented in Table 4. A burn year is defined as September 1 through August 31, while the intensive fall burn season is September 1 to December 31.

Table 4

1991 Original Rice Straw Burning Phase-down Schedule

Burn Year	Maximum Acres Allowed To Be Burned
1992	90% of Planted Acres
1993	80% of Planted Acres
1994	70% of Planted Acres
1995	60% of Planted Acres
1996	50% of Planted Acres
1997	38% of Planted Acres
1998	25% of Planted Acres
1999	25% of Planted Acres
Starting 2000 Only for Disease Control	The lesser of: 25% of Planted Acres or 125,000 Acres

When the Act was modified in 1997, as shown in Table 5, the Phase-down Act distinguished between fall and spring burning. Previously, only the total yearly burn acreage, as a percentage of acres planted, was required to be phased down. The 1997 amendments specified an annual burn limit of 200,000 acres including a fall burn limit of 90,000 acres for three years (the Pause) starting in 1998. The pause began in September 1998 and will continue to the end of August 2001.

The phase-down has been achieved by primarily decreasing burning in the spring, as opposed to the fall. Unfortunately, atmospheric conditions in the fall do not allow the smoke to be easily dispersed. However, fall burning is considered to be more effective for disease control. In addition, some soil types take a long time to dry in the spring, delaying burning and subsequent crop planting. Because of these reasons, growers like to accomplish as much burning as possible from September 1 until the winter rainy season begins. The intensive fall burning season is strictly controlled under the Burn Program to minimize adverse air quality impacts.

Table 5

1997 Modified Rice Straw Burning Phase-down Schedule

Burn Year	Maximum Acres Allowed To Be Burned	
	Annual Limit	Fall Limit
1992	90% of Planted Acres	No Separate Limit
1993	80% of Planted Acres	No Separate Limit
1994	70% of Planted Acres	No Separate Limit
1995	60% of Planted Acres	No Separate Limit
1996	50% of Planted Acres	No Separate Limit
1997	38% of Planted Acres	No Separate Limit
1998	200,000 Acres	90,000 Acres
1999	200,000 Acres	90,000 Acres
2000	200,000 Acres	90,000 Acres
Starting 2001 Only for Disease Control	The lesser of: 25% of Planted Acres or 125,000 Acres	No Separate Limit

Table 6 shows the maximum percent of acres allowed to be burned under the Act and the percentages reported as burned from 1998 to 2000, the years known as the "pause" in the phase-down.

Table 6

Compliance with the Phase-down Schedule: 1998 - 2000

Burn Year:	1998	1999	2000
Allowable Burned	200,000 acres	200,000 acres	200,000 acres
Actual Burned	29%	26%	27%
Acres Planted	490,625	535,949	521,000
Acres Burned: Total	**140,627**	**137,930**	**138,825***
Fall	89,418	79,974	85,364
Spring	51,209	57,956	53,461*

Note: These data represent the best estimate of acres burned. The actual burn numbers may be lower in some years.
* Preliminary data - expected to change after end of Spring Burn Season (May 31)

Figure 1 shows the maximum rice acreage that could have been burned under the original 1991 phase-down schedule and the adjusted 1997 phase-down schedule, which introduced the pause for the years 1998 to 2000. The actual acreage burned since 1992 is also indicated in the figure. While the acreage burned in 1998 and 2000 slightly exceeded what would have been allowed before the pause, in 1999, the acreage was almost equivalent to levels that would have occurred without the pause.

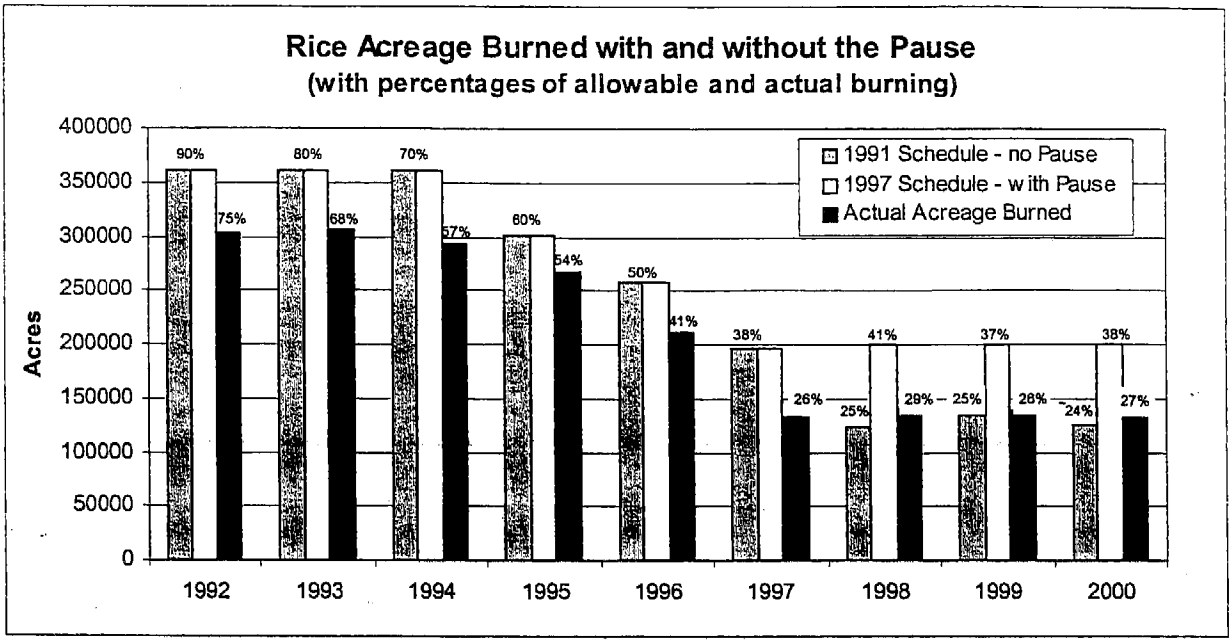

Figure 1

During the last three years, the percentage burned annually (29 percent in 1998; 26 percent in 1999; and 27 percent in 2000) has approached the original scheduled burn limits of 25 percent for 1998 and 1999. 2000 would have been the first year of burning for disease control purposes only (now starting in 2001) and estimates by rice industry officials indicate that less than the 25 percent allowable acreage will likely be burned. Individual rice growers have indicated that the fields they weren't able to burn during the intensive fall burn season were plowed to avoid delay in spring planting, further reducing spring burn acreage over the last several years. Early fall rains, poor air quality, and unfavorable atmospheric dispersion all contributed to actual burn acres not meeting allocated burn acres.

Conditional Rice Straw Burning Program

Beginning in 2001, State law allows burning only for disease control purposes. Growers will then be allowed to burn up to the lesser of 25 percent of each grower's planted acreage or 125,000 total acres in the Sacramento Valley Air Basin (SVAB or Basin). There is no ability for growers to trade burn credits under this program.

State law also requires the ARB to adopt a regulation for the issuance of conditional rice straw burning permits for disease control (Health and Safety Code section 41865). The air districts issue permits at the local level in the Basin. Such permits may be granted only for fields with rice disease in amounts

likely to cause a quantifiable and significant reduction in rice yield in the current or upcoming growing season. This level has been established through ARB's regulation, adopted in September 2000. This program was developed in cooperation with the rice industry.

The regulation requires the Sacramento Valley Basinwide Air Pollution Control Council (Basinwide Council), which consists of representatives from the air districts in the Basin, to adopt and submit to ARB a program that contains the elements specified in the statute and the ARB regulation. These elements include confirmation of disease by the county agricultural commissioner, use of specified significance thresholds for disease, procedures for field inspection, annual reporting, and certification of rice disease inspectors. The Basinwide Council submitted its program to ARB on April 16, 2001, and it was approved by ARB's Executive Officer on June 1, 2001.

The Conditional Rice Straw Burning Advisory Group, created under State law to assist in development of this regulation, provided recommendations on a local program administration role by the Basinwide Council. The Advisory Group also put forth program elements, including provisions for an inspector training program to delegate inspection authority. The ARB accepted the vast majority of the Advisory Group's recommendations.

Environmental Assessment of the Phase-down

Emissions

Rice Straw Burning Emissions

The most significant air pollution impact of rice straw burning is the emission of fine particles (i.e., less than 10 μm in diameter) in the combustion products that make up smoke. On an annual basis, rice straw burning accounts for only 2 percent of PM_{10} emissions in the Sacramento Valley Air Basin. However, on a typical October day when 3,000 acres of rice straw are burned, 9 percent of emissions are attributable to rice straw burning, rising to 23 percent during a 9,000-acre burn day[30]. It should be noted that the agricultural industry complies with the daily restrictions of the Sacramento Valley Burn Program. This Program is designed to allocate burning only on days when air quality problems from the burning are not anticipated.

Rice straw burning also emits other pollutants including carbon monoxide and precursors to ozone (i.e., oxides of nitrogen) and secondary particulate formation, which is particulate matter formed in the atmosphere by substances released from the burning.

[30] California Air Resources Board, 2000. *1999 Report to the Legislature - Progress Report on the Phase-down of Rice Straw Burning in the Sacramento Valley Air Basin*, Sacramento, CA.

Emissions from Alternatives

Currently available disposal alternatives to rice straw burning are incorporation into the soil or removal from the field. Typically, removal is done to harvest the straw for some off-field use.

Emissions from burning result from the combustion of the rice straw. Emissions from straw incorporation come from farm equipment used to chop the straw and work it into the soil; these emissions are due to dust and equipment engine exhaust. Emissions from removal of the straw to an off-site location are due to activities in the field, which also create dust, such as raking and baling, and the exhaust emissions from motorized equipment.

Straw burning produces combustion products such as PM_{10}, carbon monoxide (CO), reactive organic gases (ROG), nitrogen oxides (NO_X), and sulfur oxides (SO_X). The engine exhaust emissions from farming equipment, such as tractors and harvesters, include PM_{10}, CO, ROG, NO_X, and SO_X. The ARB has identified particulate matter from diesel-fueled engines as a toxic air contaminant. Equipment operation also creates airborne dust, which includes PM_{10} emissions, shown in Table 7 as *Soil PM_{10}*.

Every grower does not accomplish incorporation of rice straw the same way. The emission estimates shown here for soil incorporation represent the most common method used by growers: chopping, discing, flooding, then rolling.

As shown in Table 7, emissions on a per acre basis are much higher for burning rice straw, compared with incorporation and offsite removal. Table 8 shows the amount of PM_{10} emitted by rice straw burning since 1992.

Table 7

Rice Straw Incorporation and Removal Emission Factor Estimates
(pounds/acre)

Straw Removal Scenarios	Soil PM_{10}	Burning & Exhaust PM_{10}	ROG	NO_x	SO_x	CO
Burning		18.9	14.1	15.6	3.3	172.2
Incorporation	9.2	0.9	1.7	11	0.2	4
Offsite Removal	2	0.3	0.6	4	0.1	1

Note: Some of the factors used here were estimated using engineering judgement from rice growers, agricultural scientists, and emission inventory specialists.

Table 8

PM_{10} Emissions from Rice Straw Burning (1992-2000)

Burn Year	PM_{10} Emissions (tons)
1992	2,863
1993	2,889
1994	2,771
1995	2,535
1996	1,997
1997	1,263
1998	1,329
1999	1,303
2000	1,312

Particle size is another important consideration for evaluating the impact of particulate matter emissions. Atmospheric simulation modeling shows that smaller particles stay in the air longer and are carried farther from the emission source than are larger particles[31]. They are also believed to be of greater health significance.

Agricultural burning and exhaust emissions include higher percentages of extremely fine ($PM_{2.5}$) particles, while dust created by straw tilling and discing operations is comprised mostly of larger particles as shown in Table 9.

Table 9

Relative Emissions of $PM_{2.5}$ and PM_{10} for Rice Straw Removal Activities

Operation	< 2.5 μm	< 10 μm	> 10 μm
Straw Burning Smoke	92%	97.6%	2.4%
Diesel Exhaust	94%	96%	4%
Tilling/Discing Dust	10%	45%	55%

Overall, fine particulate emissions are greater from burning than soil incorporation or offsite removal. While diesel exhaust emissions result from offsite removal, from a fine particulate standpoint, the emissions are relatively small compared to those from burning. However, from the toxics standpoint, diesel particulate is a concern. The Board has listed particulate emissions from diesel-fueled engines as a toxic air contaminant and reducing the health risk from diesel-fueled engines is a high priority.

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[31] Servin, A., 1995. *Evaluation of Dust Particulate Matter Suspension Time and Travel Distance in Ambient Air*, Draft ARB Report, January 13, 1995, Sacramento, CA.

PM_{10} Concentrations in the Sacramento Valley Air Basin

Seasonal average PM_{10} concentration exceedances for the Sacramento Valley Air Basin are averaged from 1992 to 1999 and are shown in Figure 2. PM_{10} emissions can result from a wide variety of sources, the most common in the Sacramento Valley are road dust (both from paved and unpaved roads) and dust contributed by farming operations. The Statewide average exceedances are also shown.

PM_{10} samples are collected every 6th day for 24-hours (and every 3rd day in the fall), so it should be noted that these figures represent exceedances that occurred on sampled days and not all possible exceedances. There are approximately 60-sample days in a year.

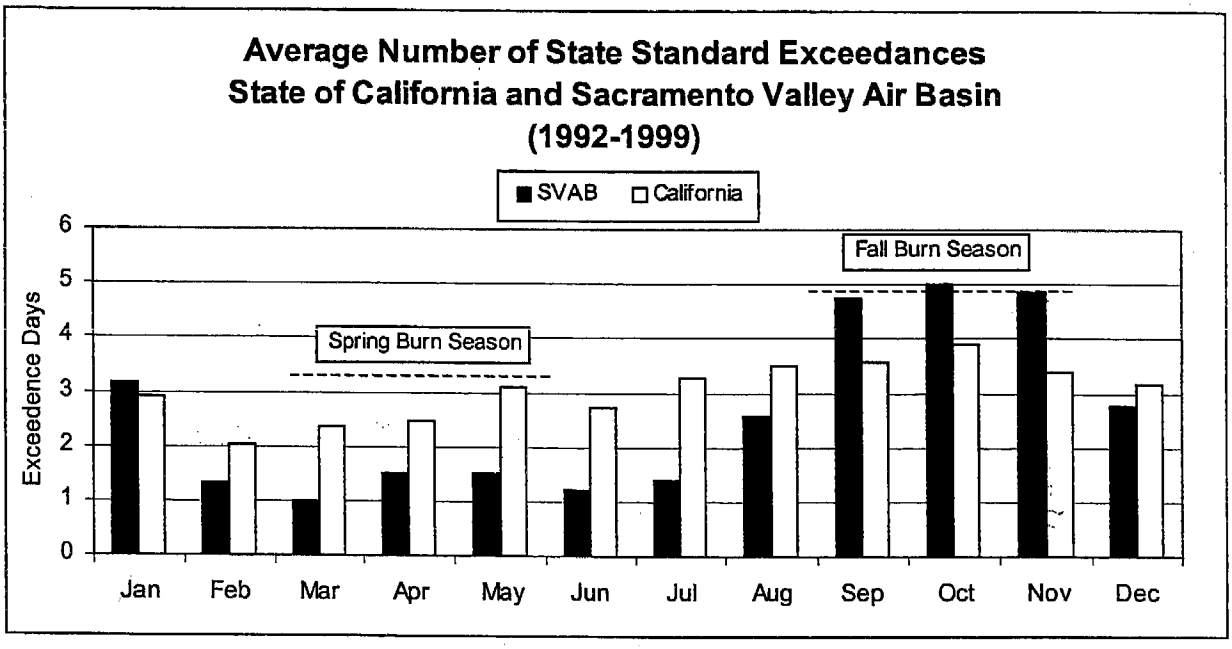

Figure 2

Monthly average PM_{10} concentrations in the Sacramento Valley begin to increase in early summer, with the highest levels occurring September through November. January and February are also relatively high, after which levels begin to decline until summer. This is primarily because fall and winter meteorology in the Sacramento Valley is not as conducive to good dispersion of pollutants as it is in the spring. Fall and winter meteorological conditions are also more conducive to secondary particulate formation; that is, PM formed in the atmosphere *after* being emitted from a source such as particulate sulfates and nitrates. In spring, better vertical and horizontal mixing of the atmosphere enables particulate matter and smoke to be dispersed and diluted more completely as indicated in Figure 3.

Rice straw burning is generally done in the fall months of September, October, and November, and is strictly regulated by the Sacramento Valley Burn Program. The Burn Program 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 depends upon prevailing meteorological and air quality conditions. The Program allows more acres to be burned on days with good ventilation, 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. The Program's goal is to avoid public exposure to smoke, prevent significant deterioration of existing air quality, and ensure burning does not cause or contribute to violations of the State ambient air quality standards. The Burn Program has resulted in substantial reductions in smoke impacts in the fall.

Figures 3 and 4 show, for the spring and fall, respectively, the number of basin exceedance days of the State 24-hour PM_{10} standard in the Sacramento Valley during the phase-down. These figures further illustrate the seasonal nature of the State standard exceedances. Although there has been a small improvement in spring air quality during the phase-down, the number of exceedances during the spring are limited due to meteorological conditions that are conducive to smoke dispersion.

The number of exceedances in the fall varies substantially from year to year. This is influenced by variations in meteorology and other source impacts, such as numerous wildfires that occurred during 1999. However, the phase-down, Burn Program, and other controls have contributed to reducing fall impacts.

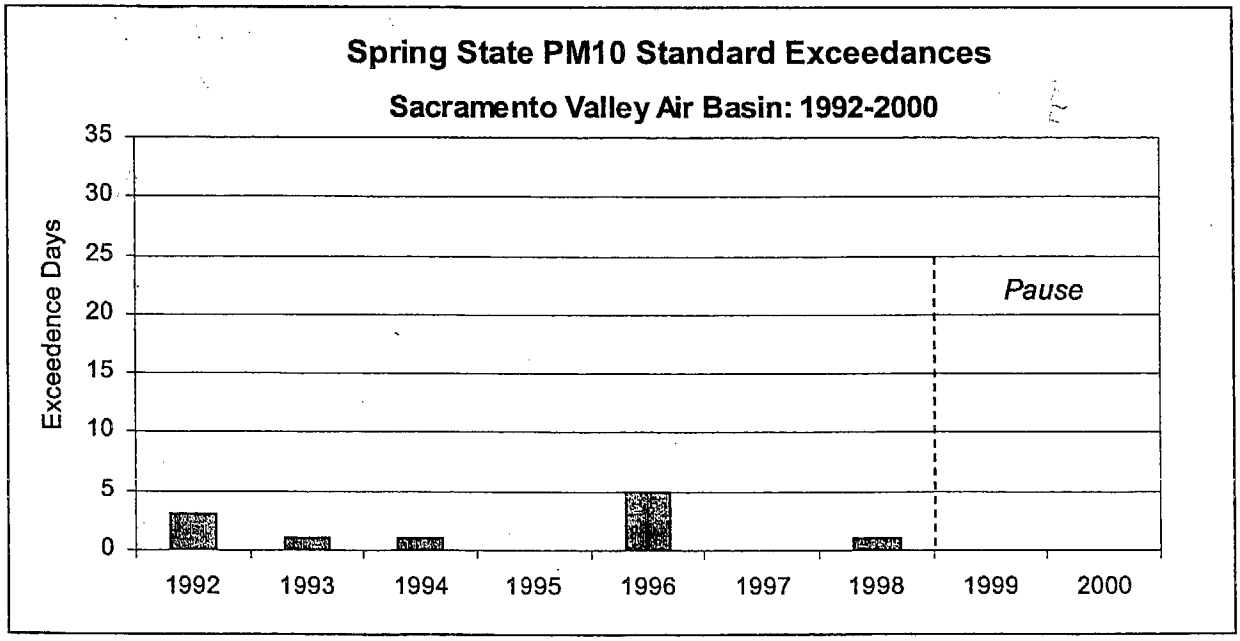

Figure 3

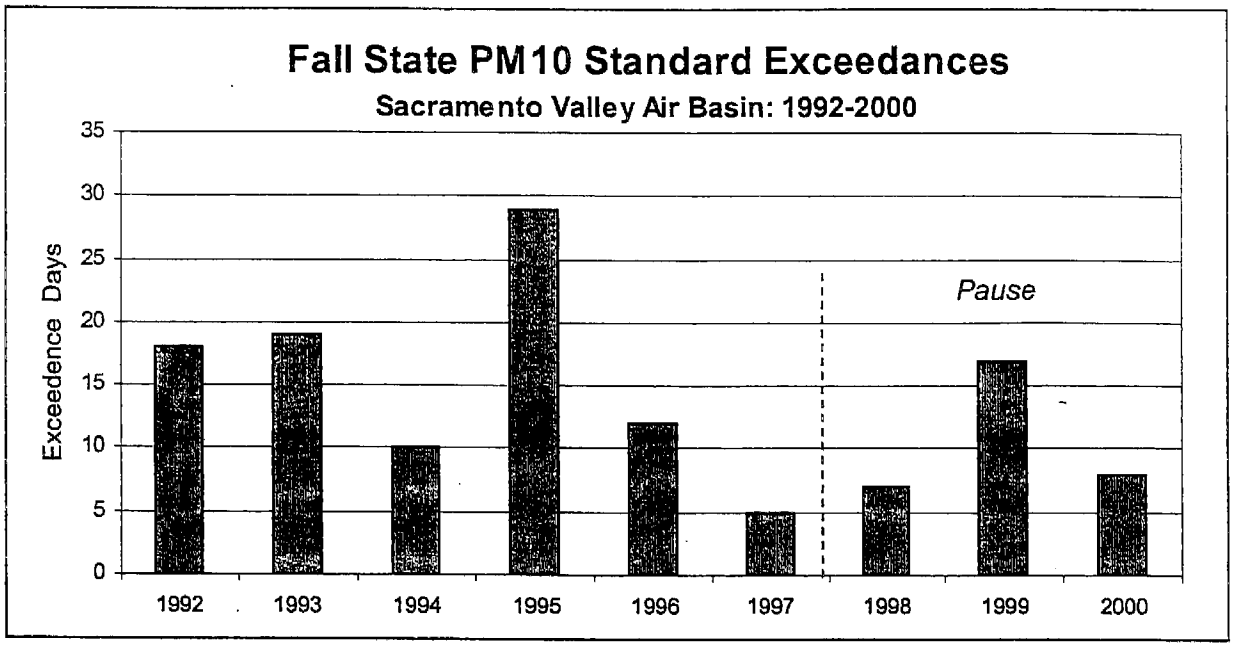

Figure 4

As previously noted, rice straw burning, which is conducted during the fall season, is estimated to contribute approximately 2 percent of the PM_{10} emissions in the Sacramento Valley on an annual basis. A 3,000-acre burn day can increase this to nine percent. A 9,000-acre burn day would increase the contribution to 23 percent. On average, as shown in Table 10, 1,100 acres of rice straw are burned in a typical day during the fall intensive burn season. In 1998, three days saw over 3,000-acres of rice straw burned in the Sacramento Valley, none over 9,000 acres. In 1999, there were three days with over 3,000 acres of rice straw being burned, and one day was over 9,000 acres. In 2000, there were no 9,000-acre burn days, but there were five days where over 3,000 acres of rice straw were burned.

Table 10

Average Acreage Burned During the Fall During the Phase-down Pause (1998-2000)

Pause Year	Average Daily Allocation	Rice Acreage	All Agricultural Acreage
1998	2,981	1,255	1,530
1999	2,254	918	1,156
2000	3,172	1,139	1,377
AVERAGE	2,815	1,109	1,348

The daily rice acreage burned and the days on which exceedances of the State PM_{10} standard occurred are shown in Figures 5, 6 and 7, for the fall of 1998, 1999, and 2000, respectively. A bold bar indicates a burn day on which exceedances of the State PM_{10} standard occurred. A starred day indicates a "no burn day", declared either by the ARB or the local air district, on which State PM_{10} exceedances occurred.

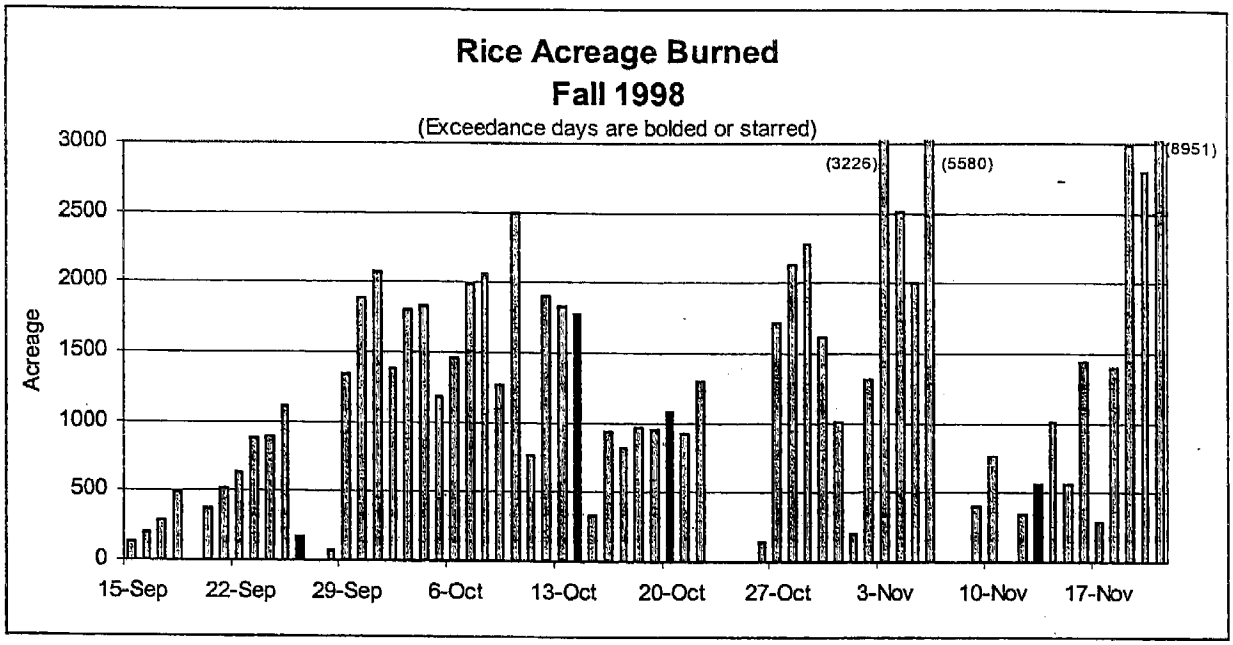

Figure 5

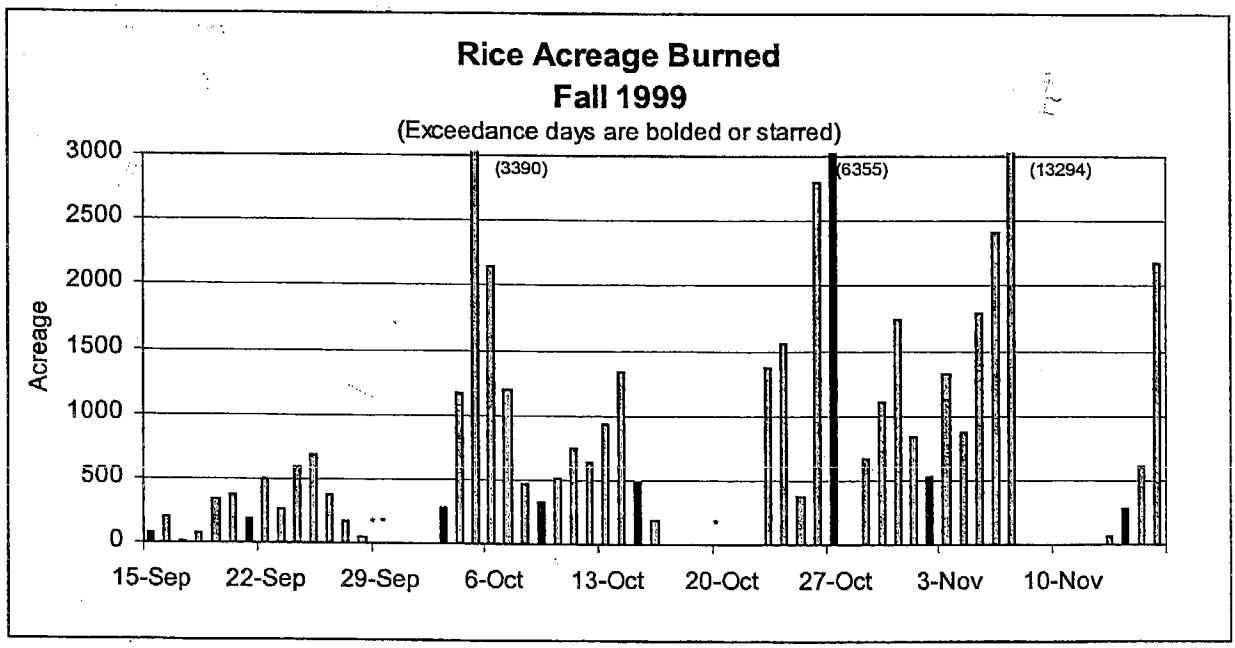

Figure 6

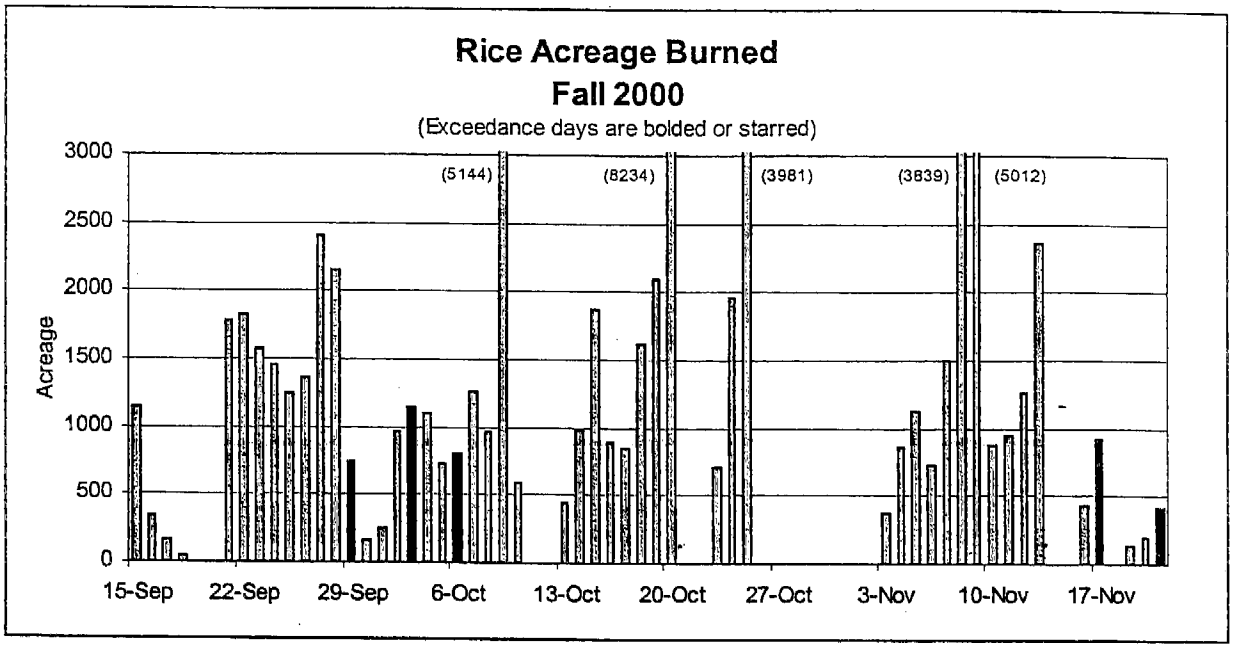

Figure 7

Many sources contribute to the exceedances noted here, not just rice straw burning. While the Burn Program generally keeps exceedances from occurring, and keeps air quality below the State standards on a large acreage allocation day, rice straw burning contributed to some exceedance days as noted in Figures 5 through 7.

Air Quality - Smoke Complaints

The frequency of complaints from the public about smoke from agricultural burning is sometimes used as an indicator of the extent to which the public is subjected to impacts of smoke. While complaints may not be a true representation of smoke impacts, they can provide useful information about the smoke management program. The ARB and the 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, the ARB's Public Information Office, and the districts. Complaints received at the ARB are all referred to the Compliance Division, and they are immediately transmitted to the district of jurisdiction for investigation and response.

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 that the Compliance Division receives during the previous 24 hours is relayed to the ARB Meteorology Section

and to the Basinwide Control Council. The complaints are then listed in the daily update of the intensive burn season statistics computer program, which is available to all the Sacramento Valley districts.

Complaints about specific, significant smoke impacts on urban areas are reviewed at meetings of the ARB and district staff that have direct responsibility for agricultural burning. There is usually one of these meetings a day or two following each significant smoke impact. The ARB meteorologists conduct a detailed study of the meteorological conditions that were present at the time of the smoke impact to determine the probable cause(s) of reported smoky conditions, and whether the weather forecast or the burn allocation decision contributed to the smoke problems. Significant complaints are also reviewed by the ARB and districts' staff at the end of the fall intensive burn season.

Table 11 shows the number of such complaints received during each fall intensive burn season, from 1992 to 2000.

Table 11

Smoke Complaints During the Phase-down Years
Intensive Fall Burn Season

Year	Complaints Received		Total
	ARB	Air Districts	
1992	24	35	59
1993	36	65	101
1994	94	241	335
1995	33	100	133
1996	17	124	141
1997	19	61	80
1998	2	40	42
1999	1	14	15
2000	4	34	38

Data from ARB Meteorology Section and Fife Environmental.

Ecological Assessment of the Pause and Phase-Down

The effect of the phase-down and the pause in the phase-down on environmental and ecological issues other than air quality is not easily determined. A myriad of options exist for rice growers to manage straw left on the field after harvest, each one contributing to a complex interaction that is being intensely studied. Some growers will choose to burn 25 percent of their acreage if disease levels warrant burning. Others will choose to burn only part or none of the 25 percent given the

same level of disease. The remaining rice straw may be chopped, flooded and rolled, removed from the field, or a combination of all of these.

Differing straw management techniques have varying impacts on weed, pest, and disease infestations. Early results indicate that removal of the straw from the field is the best way, aside from burning, to decrease these infestations. Unfortunately, as previously noted, the market for rice straw has not developed as hoped, leaving growers with little alternative other than to incorporate the straw back into the soil.

Increased incorporation, or chopping and discing, of the straw into the soil after harvest of the grain can lead to increased weed and pest concerns, as well as increased incidence of rice disease. For many growers, this entails an increased use of chemicals (fertilizers, herbicides, insecticides, and fungicides), to maintain grain yield in current and future harvests. Although many of these products break down quickly, the potential cumulative environmental effect is unknown, although efforts to investigate these issues are underway by university researchers, State and local agencies, and the rice industry. Rice growers are required to hold water on their fields for 28 days after the last pesticide application so that water bodies are not adversely impacted by the release of pesticide residues.

An additional detriment to soil incorporation is the increased methane emissions that result[32]. These emissions are estimated to double, on a per acre basis, when the straw is incorporated into the soil[33]. Although methane does not contribute to an identified air pollution problem, it is considered to be a gas that could contribute to global warming. As the amount of rice straw diverted off-field increases, the amount of methane emissions from flooded fields will decrease on a valley-wide basis.

A workshop on rice straw management issues was held in Yuba City, California on March 6, 2001. The University of California at Davis sponsored this workshop, with support from the California Rice Commission and the Rice Producers of California[34]. Research indicates that winter flooding of rice fields after incorporation in the fall results in a great number of benefits, both for the individual grower and for society at large. The disadvantages of soil incorporation are reiterated below in Table 12. The advantages of soil incorporation when combined with winter flooding are also shown. It should be noted that winter flooding would increase grower costs due to increased need for water.

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[32] van Kessel, C. and W. Horwath, 2001. *Managing Rice Straw: Research Shows Many Advantages of Winter Flooding* (in Proceedings: Rice Straw Management in California) University of California at Davis, Yuba City, California, March 6, 2001, p. 7.

[33] Analysis by ARB Emissions Inventory staff, 1999

[34] *Proceedings: Rice Straw Management in California*, University of California at Davis, Yuba City, California, March 6, 2001.

Table 12

Soil Incorporation of Rice Straw - Advantages and Disadvantages

Impacts of Soil Incorporation
➢ Increased weed and pest concerns ➢ Increased incidence of disease ➢ Increased use of chemicals
Soil Incorporation With Winter Flooding Reduces the Impacts Above and Provides Additional Benefits
➢ Increased grain yield in subsequent harvests ➢ Increased straw decomposition ➢ Increased soil sequestration of carbon (a global warming issue) ➢ Increased winter habitat for migrating waterfowl ➢ Retention of nitrogen and potassium

Increased methane gas production from flooded fields and increased mosquito populations and associated diseases are also of concern. Weed pressures may be increasing, however, confounding factors, including loss of use of some herbicides, herbicide resistance in some weed species, and meteorology must also be considered. In addition, rising fuel and water costs may make winter flooding less than attractive for some growers.

The Alternatives Committee in its most recent draft report, slated for release in summer 2001, stated that complete reliance on a single method of managing rice straw is not recommended. Incorporation, baling and removal, and burning are all desirable and should remain available. Burning, however, is no longer an option for other than disease control and alternatives for off-field use have not developed as quickly as anticipated. Incorporation will, therefore, remain the main alternative to burning.

Water Usage

Winter flooding of incorporated fields increases water usage in the Sacramento Valley by an estimated additional 0.5 million acre-feet (MAF). Rice cultivation in the Sacramento Valley uses approximately 3.1 million acre-feet (MAF) per year during the regular growing season (using a base figure of 5.5 acre-feet per acre and the 2000 planted rice acreage of 565,000 acres)[35].

[35] CH2MHill, 1996, *Environmental and Conservation Balance Sheet for the California Rice Industry*, a report prepared for the California Rice Promotion Board, Sacramento, CA, August 1996.

In the Sacramento River Hydrologic Region, the additional usage entailed by winter flooding amounts to roughly 6 percent of the 8.1 MAF used for all agricultural purposes and about 3 percent of the total water use (urban, agricultural, and environmental) of 14.7 MAF. Approximately 24 percent of the Statewide agricultural water use of 33.8 MAF is in the Sacramento River Hydrologic Region[36]. Not all of this water is lost, as an estimated 25 to 35 percent of the water used for rice cultivation is returned to the Hydrologic Region[37] where it can be used for other purposes.

Effect of Fallow Fields

The phase down has increased the cost of straw management, including soil incorporation and straw harvesting and baling. This, in turn, contributes to the high cost of production and is part of the economic decision made when rice growers decide whether or not to cultivate a field or allow it to lie fallow. Rice growers may choose to sell the water rights to those fields as a way of recouping losses, although this is not a common practice in normal water years. Some of these fields may lie fallow, but others may be planted with non-irrigated crops [38]. In some areas of the Sacramento Valley, however, rice is the only suitable crop[39] and these fields cannot be planted with an alternative. Although the reasons for fallowing are primarily economic, they are also related to the availability of water in the area being farmed. Some growers are subject to cutbacks by their hydrologic district and so do not gain economically by not cultivating rice.

The majority of fields, if allowed to lie fallow, are tilled at least once and often more than once, to avoid increasing weed pressure[40]. The nature of the soil, climate, and geographic location of the field, will help determine whether or not this practice contributes to increases of particulate matter due to equipment exhaust and the increase of dust and dirt in the atmosphere.

One benefit to allowing fields to go fallow is an increase in nesting habitats for birds. These habitats are short-term enough to allow nesting, but not long-term enough for predators to establish themselves[41].

Wildlife

Rice cultivation in the Sacramento Valley contributes significant environmental benefits, especially with regard to habitat for many wetland dependent species. The California Rice Commission notes that over 141 species of birds, 28 species

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[36] *The California Water Plan Update*, Bulletin 160-98, Department of Water Resources, Sacramento, CA, 1998

[37] CH2mHill, *op.cit.*

[38] Jack Williams, University of California Cooperative Extension, personal communication, July 9, 2001

[39] CH2mHill, *op.cit.*

[40] Jack Williams, University of California Cooperative Extension, personal communication, July 6, 2001

[41] Paul Buttner, California Rice Commission, personal communication, July 2, 2001

of mammals and 24 species of amphibians and reptiles consider California rice fields home[42]. Many of these species are listed as endangered or threatened under federal and/or State endangered species acts[43]. The impact of the phase-down on wildlife in the Central Valley has been intensely studied. Most studies have focused on the impact on waterfowl. The impacts of development have significantly reduced wetland habitat areas for waterfowl populations in California. As a result, numbers have declined from an estimated 10-12 million in the mid-1970's to a current estimate of 3-6 million[44] due, in part, to this decline in natural wetland habitat. The use of winter flooded harvested rice fields in conjunction with restored wetlands is seen by some as "critical to waterfowl survival and recruitment[45]."

Flooded rice fields are especially important for Northern Pintail, American Wigeon, Green-winged Teal, Mallard, and Northern Shoveler. Since more than 95% of natural wetlands have been drained, these alternative habitats are crucial[46]. Given this relationship, the California Department of Fish and Game, as well as officials from Ducks Unlimited and the California Waterfowl Association, recognize that a significant reduction in planted rice acreage could have devastating effects on the waterfowl populations[47].

Attracting waterfowl to flooded rice fields has the additional benefit of increasing the rate of decomposition of the straw, a direct benefit to the grower. Waterfowl will tramp the straw into the soil and some geese and swans are particularly fond of the straw roots, pulling them up to get at the tender morsels and increasing the turnover of the straw in the field.

Unfortunately, mosquito-breeding populations also benefit from winter flooding of rice fields. Studies performed by researchers in the Department of Entomology at the University of California at Davis indicate increased mosquito populations in test rice fields. These results are preliminary and expansion of these studies into commercial rice fields is underway

Economic Assessment of the Phase-down

This economic assessment provides estimates of revenues and production costs of a hypothetical rice grower using typical rice farming practices[48,49]. This

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42 California Rice Commission, 2001. http://www.calrice.org/environment/environment.htm

43 Resource Management International, Inc., 1997. *Special Status Wildlife Species Use of Rice Cultivation Lands in California's Central Valley*, a report prepared for the California Rice Commission, Sacramento, CA.

44 Reid, F.A. and M.E. Heitmeyer, 1995. *Waterfowl and Rice in California's Central Valley*, California Agriculture, 49:6 pp.62.

45 Ibid.

46 Personal communication, June 8, 2001, Ducks Unlimited.

47 Personal communication, April 17, 2001, ARB waterfowl and rice meeting

48 *Sample Costs to Produce Rice, 1998, Rice Only Rotation*, Department of Agricultural Economics, University of California Cooperative Extension, 1998.

assessment focuses on the cost of the primary alternative to burning, soil incorporation, as a result of the phase-down.

The average rice grower in the Sacramento Valley actually uses more than one method of soil incorporation that would include some burning, some winter flooding, and some rain-fed management. Additional variations of chopping, discing, rolling, etc., also exist. The costs associated with incorporation will, therefore, vary widely. In determining the average cost of incorporation, the following options were investigated:

Table 12

Straw Management Methods

Option	Percent of Acreage	Method
1	15% 50% 35%	Burning Chop/Flood/Roll Chop/Disc (twice)
2	100% 100%	Chop/Stubble Disc (once) Winter Flood
3	100%	Chop/Chisel/Stubble Disc (once)
4	100% 100%	Chop/Chisel/Stubble Disc (once) Winter Flood

Assumptions and sources for determination of incorporation costs were made by the University of California Cooperative Extension and were:

- Primary cost information was obtained from *Sample Cost to Produce Rice, Sacramento Valley, 2001;*
- Options 2 and 4 represent the most popular methods of straw management, as estimates are that on average only 15 percent of the Sacramento Valley individual grower's rice acreage will be burned;
- Costs include cash overhead, noncash overhead, and operating expenses as defined in *Sample Costs to Produce Rice, Sacramento Valley, 2001*; and
- Expenses for presumed yield loss or spring straw management are not included.

Based on the four options in Table 10, the estimated cost of incorporation ranges from $31 to $47 per incorporated acre within the Sacramento Valley. The

[49] *Sample Costs to Produce Rice, 1998, Multiple Crop Rotation.*, Department of Agricultural Economics, University of California Cooperative Extension, 1998.

average of two most popular options, $43, is utilized to develop an economic assessment of the phase-down. Individual growers, however, may experience costs significantly different than those noted here. The costs can range throughout the Sacramento Valley from approximately $20 to $80 an acre[50]. The estimated cost of incorporation has increased in the past two years and was calculated based on acres allowed to be burned (at $3 per acre) and acres which cannot be burned (at $43 per acre)[51].

Based on estimates provided by the University of California Cooperative Extension and calculated by ARB staff, the hypothetical rice grower is estimated to have a cash profit, on average, of about $254 per acre in 1997, $274 in 1998, and $210 in 1999. Cash profits (average gain plus non-cash costs, such as the grower's own labor) represent short-term profitability. A decrease in the market price of rice[52] has resulted in a decrease in cash profits from 1998 to 1999. The result is an average decrease in net grower profit of about 10 percent. This should not be confused with the potential yield loss of 10 percent discussed later in this section.

On a regional basis, the phase-down has cost growers about $15 million in direct costs due to soil incorporation in 1999. The phase-down appears to have reduced the output of goods and services produced in the region by about $25 million, with an estimate of 571 jobs lost. This represents about 0.05 percent of the Gross Valley Product and about 0.06 percent of the Valley's total employment. The impacts on Colusa County were most significant, since rice growing is a major part of the county's economy, representing somewhat less than 2 percent of the Gross County Product.

Rice yield, when averaged over all counties in the Sacramento Valley, declined from 83 hundred-weight (cwt) per acre in 1997 to 68 cwt in 1998, 73 cwt in 1999, and 79 cwt in 2000[53]. Over the period of the phase-down, a general trend to lesser yields has been documented and is indicated in Figure 9.

Many factors can affect rice yield, particularly meteorology, rice variety, soil type, and basic farm management techniques. It is not conclusively known to what degree each of these contribute to yield variations. ARB staff, in an effort to develop general estimates of yield loss, estimated the economic effects for a potential yield loss of ten percent. The potential revenue reduction of such a yield loss was estimated at about $19 million valley-wide. Colusa County would suffer the greatest loss at almost $5 million. This potential loss, if averaged over

[50] Blank, S.C., Jetter, K., Wick, C.M. and J.F. Williams, 1993. Incorporating Rice Straw into Soil May Become Disposal Option for Growers. *Cal.Agric.*, 47:8-12.

[51] While growers burned less that allowed by the Act, acres allowed to be burned and acres required to be not burned was used to calculate the direct financial impact of the law.

[52] National Agricultural Statistics Service, Published Estimates Database, United States Department of Agriculture, data download 5/14/01 from www.nass.usda.gov/ipedb

[53] California Agricultural Statistics Service, 2001, *California Rice: Acreage, Yield and Production by Counties, 1998-99 Revised*, Sacramento, CA, March 2001.

the estimated number of incorporated acres in the Sacramento Valley, would result in an average $51 per acre decrease in revenue.

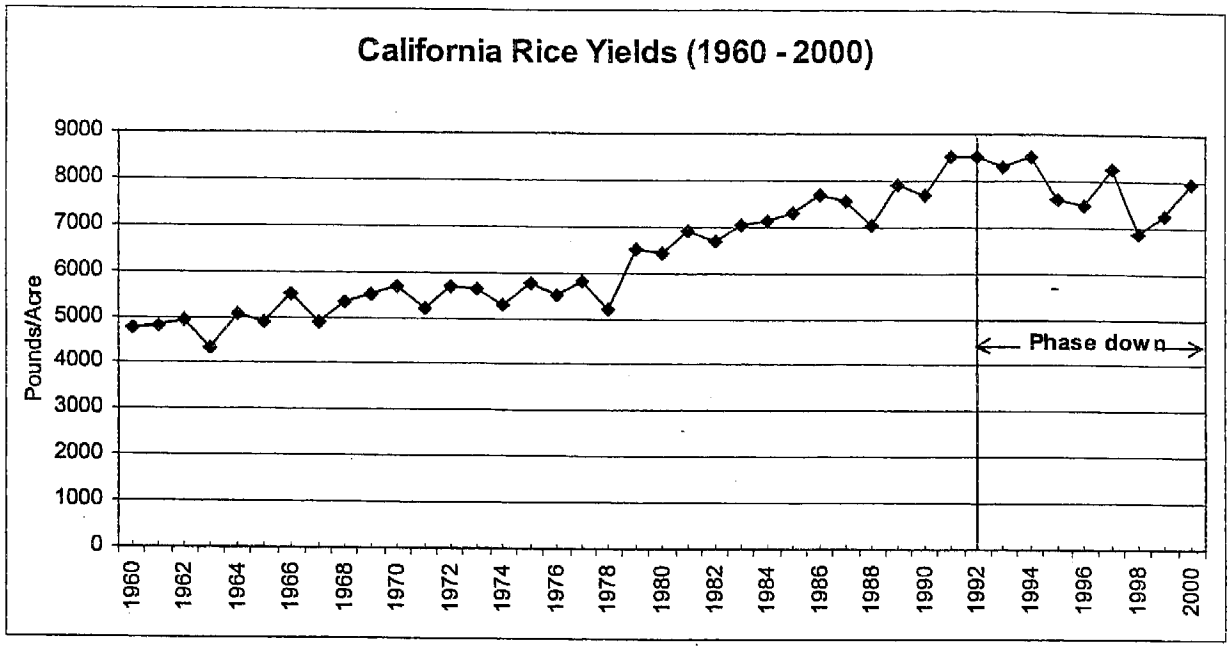

Figure 9