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16. Abstract

Both a formal literature review and informal telephone inquiries of state departments of transportation in the region were performed to assess current roadside fire presuppression technology. Recommendations are presented for the Texas Department of Transportation's use in development of future roadside fire presuppression policy.

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Presuppression of Roadside Fires

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Research Report No. 902-7
Study 2-18-89-902
Roadside Vegetation Management Program

Sponsored by:
Texas Department of Transportation

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

October 1993

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

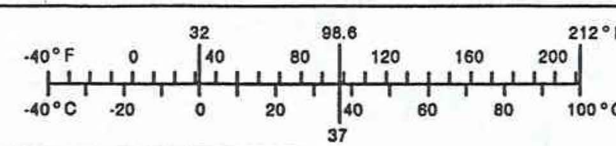
Note: Volumes greater than 1000 L shall be shown in m^3.

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Implementation Statement

This report contains the research findings and recommendations for TxDOT regarding presuppression of roadside fires. The contents of this report are for reference purposes only and require no implementation by TxDOT.

Disclaimer

The comments published in this report do not necessarily reflect the official views or concerns of TxDOT and do not constitute a standard, specification, or regulation. Further, this report is not intended for construction, bidding, or permit purposes. The authors are responsible for the accuracy of data in this report.

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Summary

Wildfires on roadsides place adjacent properties at risk. The Texas Department of Transportation (TxDOT) standard practice has been to blade or disk fire guards approximately twelve feet wide along corridor boundaries on request from adjacent property owners. Also, the United States Immigration and Naturalization Service uses fire guards maintained in bare condition as a deterrent to illegal entry along Texas' southwestern border.

Wildfires are defined as unplanned fires, regardless of ignition source. Most prevalent during hot, windy periods, over half of grass fires along roadsides originate from unknown ignition sources. Designated ignition categories include suspected incendiary activity, discarded smoking materials, contact with motor vehicles' catalytic converters, and lightning. A California study showed that seventy-four percent of fires in national forests originated within 10 feet of a roadway. Texas averages 3,586 reported grass fires on roadsides annually (equivalent to one fire per 21 centerline miles of roadway).

TxDOT's current mowing policy calls for the maintenance of safety strips along the pavement edge. These strips of close-cropped vegetation are slow to burn and do not carry fire well. It is more difficult for fires to gain significant velocity under these conditions than in the taller vegetation beyond the drainage channel.

Therefore, it is recommended that TxDOT discontinue its current fireguard practices and utilize both shoulder pavements and adjacent strip mowing as a managed fire break. These fire breaks of up to 23 feet in width will more effectively protect the ROW passive zone and adjacent properties. Mowing schedules and heights, routine maintenance, and the watershed effect of pavement combine to yield a belt of vegetation resistant to combustion.

Presuppression of Roadside Fires

The Problem

Wildfires on roadsides place adjacent properties at risk. The Texas Department of Transportation (TxDOT), in an effort to mitigate this risk, began blading or disking fire guards approximately 12 feet wide along the right-of-way (ROW) corridor boundary upon request of adjacent property owners beginning in 1950. Also, the U.S. Department of Immigration and Naturalization (INS) uses fire guards maintained in a bare condition along the Texas/Mexico border as an aid to enforcing regulations concerning illegal entry (Saenz 1993).

TxDOT curtailed construction of fire guards in 1973 because they were deemed to "create erosion problems within the ROW and are somewhat contrary to the current beautification program" (TxDOT 1992a). Recent developments include:

- In July 1991, the Maintenance Environmental Task Force of TxDOT recommended in a draft report that fire guards be eliminated. The reasons cited included a potential to increase erosion, an introduction of silt into water supplies, and a possibility of damage to the habitat of endangered species.
- There is some concern that fire guards may conflict with memoranda of understanding (MOUs) with the Texas Parks & Wildlife Department (TPWD) and Texas Water Commission (TWC).
- Survey comments from TxDOT districts show mixed reactions to current fire guard practices; a majority of the districts favor elimination of fire guards.
- Interpretation of "National Pollutant Discharge Elimination System" (NPDES) by the Environmental Protection Agency (EPA) indicates construction of fire guards will require permitting (TxDOT 1992b).
- When TxDOT proposed to cease the practice of constructing fire guards, it received a number of inquiries from individuals and elected officials expressing concern regarding cessation of this practice.

The conflict is whether TxDOT should continue the "good neighbor" practice of blading or disking fireguards given the recently imposed regulatory constraints. This report will review literature together with policies and practices of other agencies and state highway departments to determine present state-of-the-art fire technology.

Available Information

There is a wealth of information and research on fire, but mostly it is concerned with suppression, prescription burning, and statistics. These are valuable background sources on ignition materials, fuels, fire characteristics, and other pertinent topics with little or no mention of presuppression. The most comprehensive information on roadside fires is from California. A dense human population and highly flammable natural fuels adjacent to the ROW have led the California Department of Transportation (Caltrans) and the U.S. Forest Service to study and develop presuppression management techniques for especially southern California (Caltrans Division of Maintenance undated).

Fires are referred to as prescribed (also planned, applied, or controlled) or as wild (unplanned). Prescribed fire is used as a tool for management of forests, chaparral, grasslands, watersheds, and wildlife (Wright 1974). Many ecologists consider wildfire an environmental factor (Daubenmire 1959; Wright and Bailey 1980) which is responsible for the perpetuation of grassland. Native Americans used fire to facilitate the gathering of acorns and attract food animals to resulting fresh forage (Heady 1972).

Prescribed Fire

Safety is a primary concern with prescribed fire. The construction of pre-burn fire guards as wide as 400 to 500 feet (120 to 150 m) in volatile fuels such as cedar (juniper) is used to contain applied fire to a prescribed area. Grassland normally is burned in early spring (Launchbaugh 1972; Vogl 1972; Wright 1974) using fire guards 100 to 300 feet (30 to 90 m) wide (Wright and Bailey 1982). Prescribed burns in grassland are ignited when 600 to 1,000 pounds per acre (660 to 1,100 kg per hectare) of fire fuel is present, fuel moisture ranges from 7 to 20%, air temperature is less than 80° F (27°C), a steady wind is less than 15 miles per hour (24 km per hour), and the soil is moist from recent rain. Other management objectives may alter these specifications (Wright and Bailey 1982), but prescription burning is an art which applies set conditions for burning based on anticipated results.

Wildfire

Wild (unplanned) fires, regardless of ignition source, are most prevalent during hot, windy periods when fuel is dry. Devastating prairie fires were a common threat to early settlers in the grasslands of the Great Plains (Sand 1993). Most documented wildfires in Western Texas during the 1880s have been traced to carelessness by cowboys and cooks of trail outfits (Wright and Bailey 1982). Bailey (1990) mentions the emotional impact on people from the terror of fire itself as well as the trauma of loss of life and personal possessions (1990).

At least 90% of the 240,000 wildfires which occurred in the United States during 1976 were man-caused and were either intentional or accidental (Wilson 1979). Forty-five percent (1,600) of the fires on national forests in southern California from 1950 through 1959 originated along roadsides (Johnson 1963). The study further found that, of fires occurring in the San Bernardino National Forest:

- 52% of man-caused fires occurred within 33 feet (9.9 m) of a road edge;
- 51% of man-caused fires which burned 100 ac (40 ha) or more before control started within the 33-foot (9.9-m) zone;
- about half the fires within the zone were traffic-associated, caused by smokers, overheated brakes, burning vehicles, or engine exhausts.

Another study completed in the same area found that 74% of the fires in national forests occurred within 10 feet (3 m) of a road edge (California Division of Forestry and USDA Forest Service 1968). Caltrans feels that a control strip 4 to 8 feet (1.2 to 2.4 m) wide along the pavement edge will control the incidence of fire (Caltrans Division of Maintenance undated). An average of 363 roadside fires burned annually from 1985 through 1989 in Northeastern California, and 246 roadside fires occurred per year during the same period in the remainder of Northern California. Estimates from New Jersey trace 75% of all forest fires during the period 1965 to 1975 to roadsides (Wilson 1979).

During the four-year period 1988-1991, an average of 3,586 grass fires on roadsides have been reported annually in Texas (Table 1). This is equivalent to one fire per 21 centerline miles (33.6 km) of roadway. Specific data on the distance between the point of ignition and the pavement edge, the exact character of the fuel, whether or not these fires burned into adjacent property, or whether specific areas are prone to burn are unavailable at the present time. However, these statistics do suggest the magnitude of the problem.

Fire in the median and along the roadside is a hazard to the highway users. Smoke from roadside fires reduces visibility and is a distinct traffic hazard, particularly on two-lane roads. In addition to the traffic hazards a roadside fire generates, there is also the threat of its spreading onto adjoining properties. However, TxDOT legal counsel holds that the State is not liable for fires originating on the ROW unless the fire was due to negligence by TxDOT personnel (TxDOT 1992a). It is not clear if discontinuing the practice of blading fire guards could be considered prima-facie evidence of negligence by TxDOT.

Fire Behavior

Many factors influence the ignition and spread of fires on the ROW, and the three most significant are fuel, weather, and topography (Oklahoma State University and International Fire Service Training Association 1982). Most fire starts on the ROW occur in fine fuels, vegetation less than one-eighth of an inch (3 mm) in diameter. Grasses, the predominant vegetative cover on ROWs in Texas, are classed as fine fuels. Also called flash fuels, fine fuels ignite easily and burn quickly. Although 600 to 1,000 pounds per acre (660 to 1,100 kg per hectare) of fuel is desired for ignition in prescribed burning (Wright and Bailey 1982), as little as 300 pounds per acre (330 kg per hectare) of drier fine fuel will carry a wildfire (Wink and Wright 1973; Britton and Ralphs 1979).

Fire managers and researchers generally agree that fires are circular in shape immediately after ignition, becoming elliptical with the influence of environmental factors such as wind, topography, and fuel type (Anderson 1983). Van Gelder (1976) developed a fire potential assessment model which determines the length to width ratio of the ellipse using slope, windspeed, and fuel characteristics. While an average fire burns an ellipse of 5:1 ratio (Hornby 1936), a grass fire's ellipse burns approximately 4:1 (Cheney and Bary 1969). McArthur and Mitchell (1966) state the stronger the wind, the more elongated and narrow the ellipse.

Although safety strips 5 to 15 feet (1.5 to 4.5 m) wide are mowed regularly, the remainder of the ROW is mowed only once during the dormant season (TxDOT 1993). Even vegetation on safety strips may fuel a fire under dry, windy conditions, but the rate of spread will be slower than in the taller unmowed grass (Wink and Wright 1973; Britton and Ralphs 1979). If the fuel on the mowed safety strip is leafy, it may dry and flare more quickly than taller grass on the outer roadside. If the taller grass contains enough moisture, there is a strong possibility it will not ignite. Taller grasses probably will ignite and burn in winds of 10 miles per hour (16 km per hour), but short grasses such as buffalograss/blue grama may require winds of 15 to 20 miles per hour (24 to 32 km per hour) to ignite and carry a fire. Common bermudagrass with a lower leaf-to-stem ratio, and King Ranch bluestem, which grows flat on the ground, are somewhat more resistant to ignition than is buffalograss (Wright 1993).

Fuel volatility is a factor in rate of spread of fire. Many plants contain oils, waxes, terpenes, and fats which volatilize and ignite readily. Dead juniper is a high volatile fuel, but grass and hardwoods including mesquite are low-volatile fuels (Wright and Bailey 1982). In an operational mode, Wright (1993) considers any fuel which yields firebrands to be a volatile fuel. This includes shinnery oak/grass, sand sagebrush/grass, and running liveoak/grass vegetative types, commonly classed as moderately volatile (Wright and Bailey 1982). Oak leaves and dead juniper twigs readily become firebrands if relative humidity is less than 10% and wind is sufficient to carry them (Wright 1993).

Wind and fuel moisture content are factors in ignition and spread of wildfires. A green fine fuel or a dead fuel containing at least 33% moisture are difficult to ignite (Wright and Bailey 1982). Preferred atmospheric conditions for a prescribed burn in fine fuels are relative humidity of 25 to 40%, air temperature of 70° to 80° F (21° to 27° C), and winds of 8 to 15 miles per hour (13 to 24 km per hour). Drier, warmer conditions and/or higher winds make fire more difficult to control (Wright and Bailey 1980).

Winds dry fuels, fan flames, supply fresh air for combustion, and carry firebrands to start additional spot fires (Oklahoma State University and IFSTA 1982). In April 1974, a single fire buffeted by 55 miles per hour (88 km per hour) winds jumped three major highways before it was controlled. Under these wind conditions, fire control using traditional presuppression treatments would be difficult, and only an extensive cultivated acreage would serve as a satisfactory fireguard. Firewhirls often carry tumbleweeds or taller grass burning in fence rows and scatter sparks downwind some distance ahead of the firefront (Wright and Bailey 1982).

Wind roses for selected stations (Figure 2) and extreme wind velocities (Table 1) illustrate the impact this factor may play in wildfires on roadsides. The frequency and duration of winds shown in the wind roses suggest that a majority of wildfires would burn in a northerly direction off of east-west roads. This is not always the case, as wind direction may be conditioned by topography or atmospheric conditions.

ROW topography and cross section affect the burn rate. Highway ROWs are relatively narrow corridors containing two or more paved travel lanes and vegetated areas. Fire size and pavement width influence the likelihood of a wildfire crossing pavement. A fire burning up a steep slope on the ROW resembles a fire spreading before a strong wind. A fire burning up a slope of 5:1 or 2.5:1 will spread twice as fast as on level terrain (Wright and Bailey 1982). On fill slopes of the same grade, the firefront will travel only one-third as fast as on level terrain.

Features of the ROW representing increased fire hazard are culvert headwalls, turnouts, and other locations difficult to treat using a high-speed mower. Litter tends to collect around headwalls along with vegetation between treatments, presenting increased fuel for fire ignition and spread (U.S. Forest Service, California Division of Forestry and California Division of Highways 1950).

At-Risk Properties

When conditions exist favoring fire spread beyond ROW limits, adjacent properties are threatened. At-risk properties adjacent to the ROW can be segregated into three classes (Bailey, 1990):

- urban;
- wildland-urban; and
- wildland.

Urban properties adjoining highway facilities are maintained at a high level (*Vegetation Management Standards*). The risk of fire spreading from the highway is minimal because:

- fuel volume is low due to strict mowing standards;
- any fuel present likely has a relatively high moisture content, which retards burning;
- response time for suppression equipment is relatively short; and
- a volunteer force to suppress a fire can be assembled quickly.

Wildland-urban properties combine the natural and social amenities offered by suburban and rural living in a wildland setting (Bailey 1990). The combination of people, homes, flammable vegetation, and dry weather conditions brings new issues and problems to wildland fire managers. Wildland-urban properties often are unincorporated developments, clusters of homes near lakes and other recreational facilities, ranchettes, and weekend homes.

Wildlands include ROWs and thinly populated public and private lands such as parks, forests, grasslands for grazing or hay, and small-grain fields. Suppression forces usually are voluntary and often are based some distance from the fire site. In some areas, cultivation has reduced the geographic size attained by individual fires in wildlands; cultivated land breaks up the continuous grass cover of the prairie (Wright and Bailey 1980).

Texas Risk Area

The Southern Great Plains cover the northern two-thirds of Texas west of the main Cross Timbers belt (Wright and Bailey 1980). The Texas prairies are comprised of grasslands to the north with mixed grasslands invaded by mesquite and junipers extending into the central and southern portions of the state. Figure 1 shows those TxDOT districts with fire guards in place in 1991. It is apparent that these districts occur in the grassland portions of the state. Districts in the eastern forest and southern coastal portions of the state (shown shaded) did not blade fire guards at the time of the survey. They embrace the Pineywoods where suppression is active, the Post Oak belt, areas of intensive cultivation, and large metropolitan centers.

In addition to posing a threat to highway travel and adjoining property, ROW fires may damage safety hardware along the roadside. Further, fire temporarily removes the vegetative protection of roadside ditches and outer roadsides and alters wildlife habitat. Most range fires are not destructive to wildlife. The population densities of reptiles, vertebrates, and birds generally are affected by alteration of habitat rather than by direct mortality. Wildlife escape by fleeing the fire or by burrowing underground. They move back into the affected area immediately, especially if the burn is incomplete (Howard, Fenner and Childs 1959). Kruse and Higgins (1990) agree with this analysis and point out that wildlife is a product of the habitat, which in turn is a response to fire.

Sites on the Texas ROWs where fuel accumulation may cause greater than normal hazard include culvert headwalls and rodent burrows. Litter tends to collect around headwalls along with vegetation between treatments, presenting increased risk for fire ignition and spread (U.S. Forest Service, California Division of Forestry, and California Division of Highways 1950). Material collected at the ends of culverts may become firewhirls or firebrands, or the dense fuel may simply burn with more intensity. Burrowing animals such as armadillos often collect volatile fuels, which, if ignited, will function as firebrands (Wright 1993).

Texas Commission on Fire Protection (TCFP) data, compiled from reports by volunteer fire departments, list over half of roadside grass fires to be of unknown ignition source (Table 1). Other ignition categories, in order of decreasing occurrence, are miscellaneous, suspected incendiary activity, discarded smoking materials, and contact with vehicles' catalytic converters. Lightning, which is known to ignite wildfires, is not listed as an ignition source. The various ignition categories remain fairly constant from year to year.

Suppression of ROW fires usually falls under the jurisdiction of volunteer fire departments. The time required for mobilization and the lengthy travel time to many rural fire sites combine to increase the response time and make identification of the ignition source difficult.

The California Division of Forestry and the USDA Forest Service cite suspected incendiary activity/arson, burning tire fragments, and exhaust from vehicles in faulty mechanical condition as major ignition sources north of San Francisco. In some cases, fire ignition from catalytic converters of vehicles pulled off the shoulder onto vegetated areas may incorrectly be categorized as arson because of the difficulty in tracing fire to this specific occurrence. Cigarettes are considered to be the least likely cause of ROW fire in California.

Presuppression

Literature regarding presuppression of wildfires is scarce. Literature regarding fire suppression is plentiful, and, while interesting, lends little to a discussion of effective fire presuppression practices and programs.

Presuppression strategies vary from vegetation-free zones to mowing. Many states do not have active programs.

- California (Caltrans undated) and Washington (WSDOT 1993) maintain vegetation-free zones up to 12 feet wide along the pavement edge using chemical or mechanical treatment.
- Arizona uses preemergent herbicides to control infestations of mustards and other volatile fuels. Also, a strip 10 feet wide is mowed along the pavement edge (and raked if biomass production is sufficient to create a fire hazard) (Taylor 1993).
- Oklahoma disks fire guards of varying widths on occasion near the ROW boundary. If an urban area is extremely dry, it may be selected by motor patrol to be scalped (Maloy 1993).
- New Mexico (Roybal 1993), South Dakota (Holzworth 1993), Wyoming (Powell 1993), and Nebraska (Gray 1993) may have bladed fire guards previously, but felt the low fire incidence did not justify a presuppression strategy.

Lincolnshire County, England revised and lowered standards of maintenance in 1975 for roadsides along trunk roads and motorways. In 1976, there were many fires on trunk road verges, some of which spread to adjoining property. All fires presented traffic hazards by reducing visibility (Cox 1977).

Wildfire Mitigation

Curtailing the risk of wildfire on the ROW involves the dual strategies of fuel management and ignition risk reduction. Fuel management is a measurable task employing physical or chemical methods to reduce the risk of ignition and/or spread of fire. Risk reduction is based on educating the public concerning the hazards and effects of wildfires starting on the ROW.

Fuel Management

Fire guards have long been used in presuppression to interrupt the movement of a firefront during a prescribed burn or as a suppression strategy to control wildfire. Traditionally, fire guards have been disked or bladed to expose a belt of mineral soil. The NPDES regulations of EPA allow newly constructed fire guards to remain unvegetated only for 21 days and prescribe the installation of silt fences to direct the water flow and control siltation.

The regulatory requirements of NPDES require that the blading of fire guards as currently practiced must be modified or discontinued. Adjacent property owners have asked TxDOT not to discontinue presuppression. A fire guard should not be considered the ultimate device in the containment of wildfires. If fire guards are a maintenance objective, the following mitigative actions will render them more effective:

- Combine the paved shoulder (if present) and the safety strip along the pavement edge as a fire guard.
    1. The U.S. Forest Service, in its *Highway Hazard Reduction Guide* (1950) questions the placement of fire guards at any location other than immediately adjacent to the pavement edge. Washington (WSDOT 1992) and California (Boyd 1993) maintain a clear strip at the pavement edge for fire protection. The clear strip reduces the risk of ignition from burning objects or catalytic converters.
    2. Vegetation management strategies should favor bermudagrass and King Ranch bluestem (or Caucasian bluestem in the Panhandle) which resist ignition and spread of ROW fire.

- Mowing schedules for safety strips doubling as fire guards must favor fire presuppression.
    1. The initial cycle of mowing should be accomplished before a significant amount of biomass has accumulated. A mat of mowed grass is more easily ignited than unmowed grass. Fire in mowed grass also generates more smoke than standing grass, which interferes with driver vision (Jones & Stokes 1992).
    2. Mowing height can be used to favor common bermudagrass and King Ranch bluestem which resist ignition.

- Apply integrated pest management, which includes the use of chemicals to control weeds and volatile fuels in the fire guard.

- The Texas Forest Service and others use greenstripping to stabilize fire guards. However, their needs for fire guards are during early spring, whereas the dangerous part of the year for ROW fires is mid- to late summer. Hot, windy conditions during mid-summer hasten the "curing" of grasses and increase their flammability. Mid-summer also is outside the planting time specified by TxDOT, as a new stand of grass is nearly impossible to establish. Consequently, greenstripping is not considered a viable option.

- Chemical suppression of vegetative growth on a fire guard is not considered a viable option at this time. Plant growth regulators (PGRs) tend to be specific for individual plant species and must be applied when plants are actively growing. Continued use of

PGRs weakens the existing plant stand, permitting the establishment of weeds and less desirable vegetation for presuppression of fire on the ROW.

- Construction of fire guards using prescribed fire is not a usable option. This method is labor-intensive, entails a high risk to wildlife cover on the outer ROW, and delays traffic.

- Routine maintenance will reduce the probability of fire ignition and spread.
    1. Systematic maintenance of areas of fuel accumulation, as around culvert ends and headwalls, will reduce ignition risk.
    2. Open armadillo burrows on the ROW should be plugged. These animals prefer liveoak leaves for lining their nests. Liveoak leaves are a volatile fuel and generate firebrands.
    3. Juniper (cedar), pine, and liveoak trimmings should be removed from the ROW. In a wildfire, these materials will generate firebrands.

Risk Reduction

Another means of presuppression of ROW fires is risk reduction, altering the behavior of those who start fires. A public education campaign increases the effectiveness of any fire presuppression program for the ROW. Several techniques are available for implementing this strategy:

- Public service announcements on radio and television can be targeted to a specific area when fire danger is high.
- It is likely that a professional society such as *Society for Range Management* would cooperate in producing a tape targeting elementary school children.
- The U.S. National Weather Service is responsible for providing weather support to federal, state, and private land managers in support of presuppression of wildfires (Goens 1990).
- Either permanent or temporary signage, modeled after international road signs, are easy to see and comprehend (Folkman 1963). These signs were found to be equally or more effective after six years of use (Folkman 1973). In some national forests in the eastern United States, signs are used to inform motorists that a road or highway is patrolled by aircraft to prevent fires (Wilson 1979).

Recommendations

Based upon the research analyzed previously, the following course of action by TxDOT is recommended for consideration in public hearings:

1. Combine the paved shoulder (if present) and the mowed safety strip as a fire guard and relocate it adjacent to the main travelway. This will utilize as much as 8 feet of shoulder

pavement with 5 to 15 feet of safety strip to intercept ignition materials. This fire guard will satisfy the following conditions:

- The safety strip will continue to be mowed relatively short. Sections scheduled for use as a fire guard can be mowed at a height to stimulate bermudagrass and King Ranch bluestem, yet not so short that mower-thrown objects (MTOs) are launched. Panhandle sections support buffalograss, blue grama, Western wheatgrass, and Caucasian bluestem as the major fuels. Again, mowing heights should be prudent but not so short that the desired grasses react adversely or MTOs become airborne.
- The watershed effect of pavement offers greenstripping with runoff from showers. Grass in the green strip will contain enough moisture to resist combustion.
- TxDOT should retain a favorable "good neighbor" rating with this relocated fire guard. Protection of the passive zone of the ROW and adjacent properties from fire will be enhanced.
- No permitting is required from regulatory agencies; storm water quality will be maintained without disturbance.
- If TxDOT and INS can reach agreement, patrol vehicles could travel on pavement and eliminate rutting and potential erosion.
- This strategy does not involve any extra effort except to manage mowing to favor grasses having a relatively low ignition risk.
- Systematic cleanups of culvert headwall areas, turnouts, and other areas needing trimming should be scheduled to reduce fuel loads and source materials for firewhirls and firebrands.

2. TCFP should be encouraged to collect more detail in ROW wildfire reports. The following additional statistics would be useful for information and planning:
   - Estimated point of fire origin by route and reference marker, ultimately by TxDOT's Texas Reference Marker (TRM) system.
   - Distance from point of origin to pavement edge.
   - Whether or not ROW fires burn onto adjacent property.

3. Pertinent research topics should include the following:
   - Evaluate the need for fire retardant chemical use on road sections with a tendency for fire starts.
   - Test fuels to determine a relative ignition tendency. These materials could be emphasized in designing planting mixtures for the active zone.
   - Devise a water management procedure to utilize incident precipitation.
   - Formulate visually enhanced materials for television spots and youth education. Compose audio spots for both television and radio.
   - Establish a relationship with the National Weather Service for predicting hazardous fire danger weather for signage and public service announcements.

Table 1. ROW Grass Fires in Texas

Year	1988	1989	1990	1991
Total ROW Grass Fires	3687	3585	3644	3427
Ignition Sources				
Catalytic converter - Auto	2	8	14	15
Catalytic converter - Truck	9	9	0	0
Smoking materials	385 (10%)	370 (10%)	366 (9%)	310 (9%)
Incendiary	455 (11%)	476 (13%)	482 (13%)	714 (21%)
Other Miscellaneous	862 (21%)	520 (15%)	734 (19%)	523 (15%)
Unknown	2321 (58%)	2202 (62%)	2248 (59%)	1865 (55%)

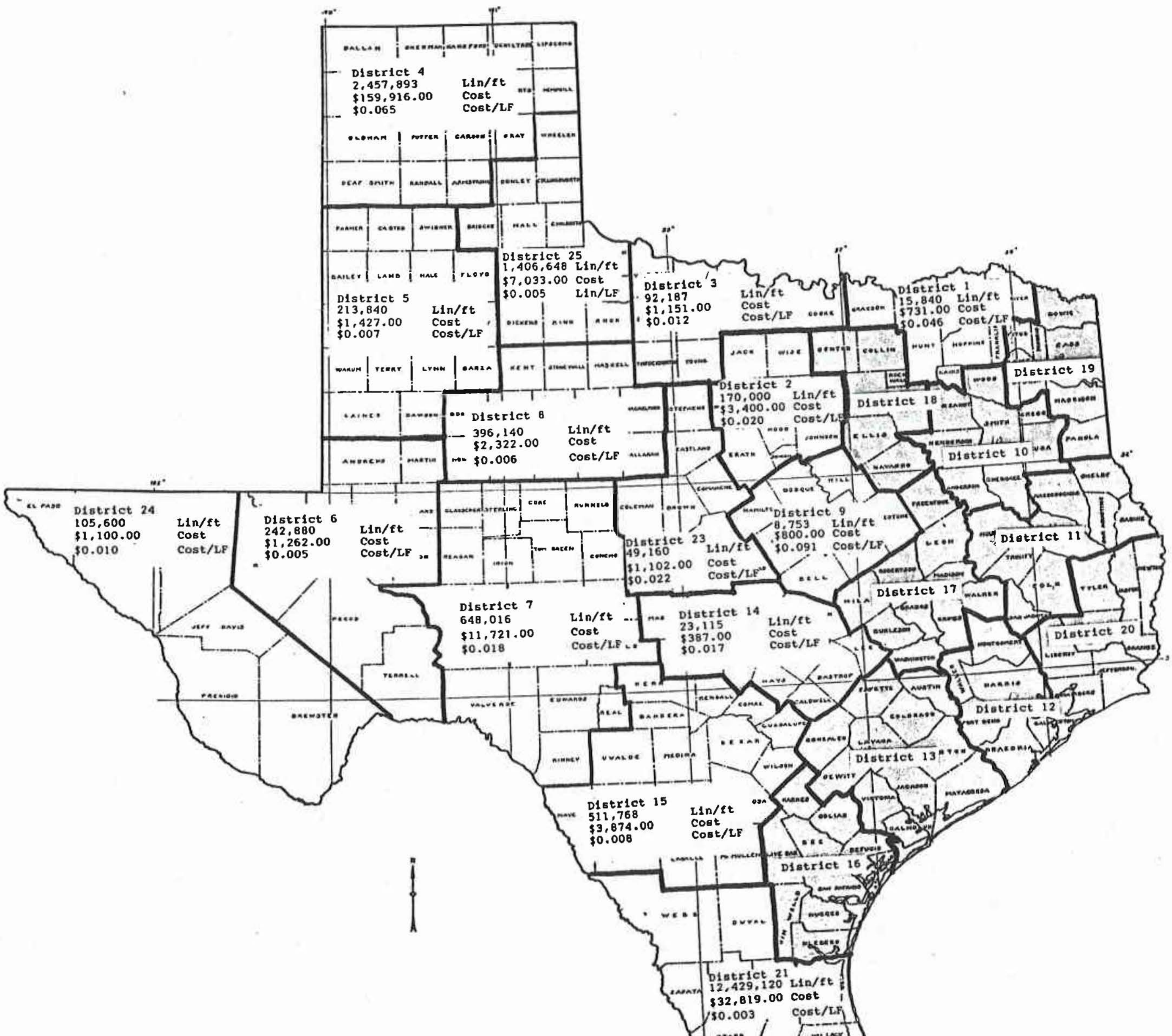
Source: Jean Mitchell of the Texas Commission on Fire Protection (TCFP). Data compiled from reports by volunteer fire departments throughout the state.

Table 2. Maximum Wind Speeds for Selected Cities
July/August 1989-1991

City	Maximum Speed in miles/hr (km/hr)	Direction
Abilene	41 (66)	East
Amarillo	62 (100)	East
Austin	40 (64)	Northwest
Brownsville	40 (64)	Southeast
Dallas/Fort Worth	45 (72)	Northwest
El Paso	53 (85)	Northwest
Lubbock	59 (95)	Northwest
Midland	45 (72)	Northwest, Southeast
San Angelo	38 (61)	Northwest
San Antonio	36 (58)	North
Waco	40 (64)	Northwest
Wichita Falls	56 (90)	South

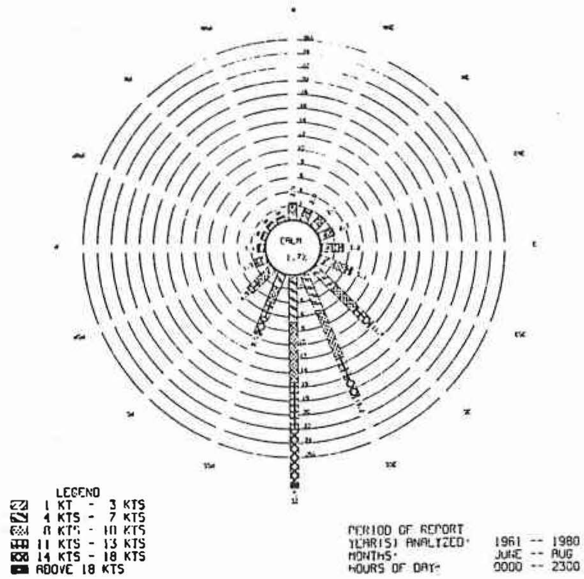
Source: National Oceanic Atmospheric Administration (NOAA) *Local Climatological Data, Monthly Summary.*

Figure 1. TxDOT Districts with Fire Guards in Place, 1991 (shown unshaded)



Source: TxDOT Survey, 1991

Figure 2. Representative Wind Roses for Selected Cities
June/August 1961-1980



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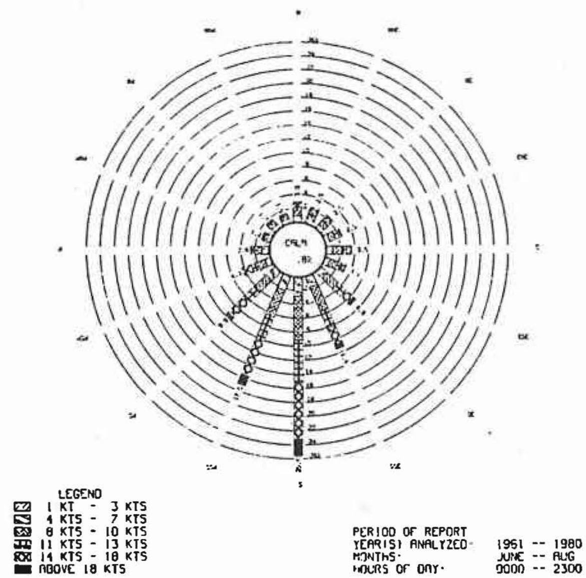
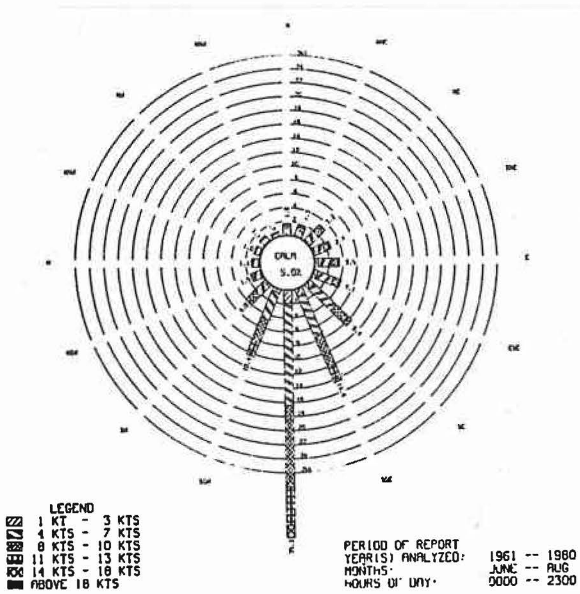
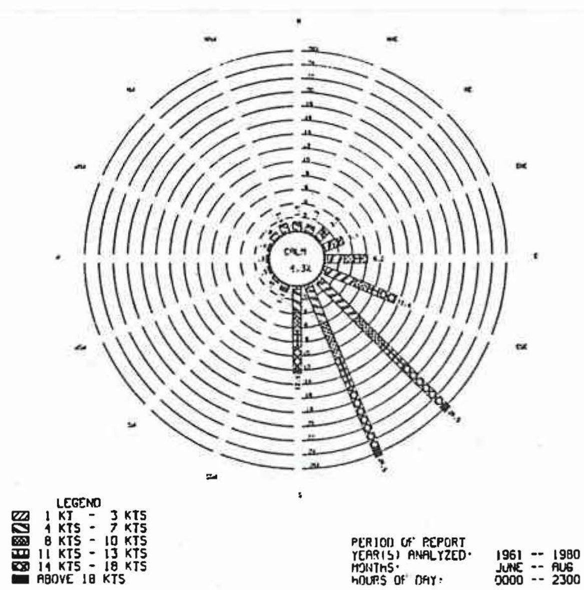


AMARILLO



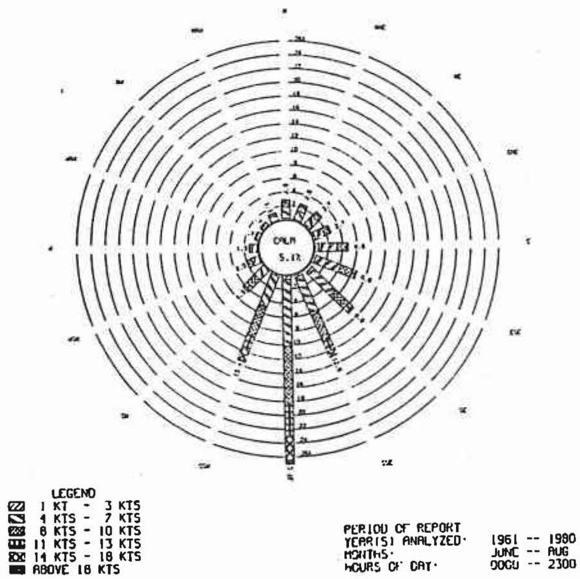
AUSTIN



BROWNSVILLE

Source: *Climatic Atlas of Texas*, 1983

Figure 2. Representative Wind Roses for Selected Cities (Continued)



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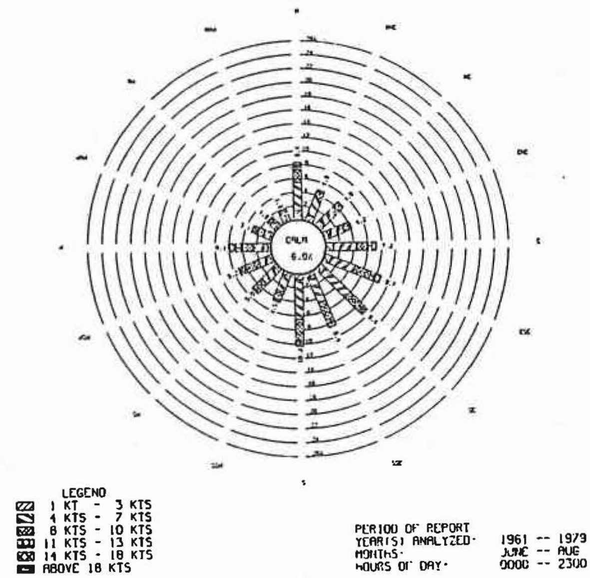

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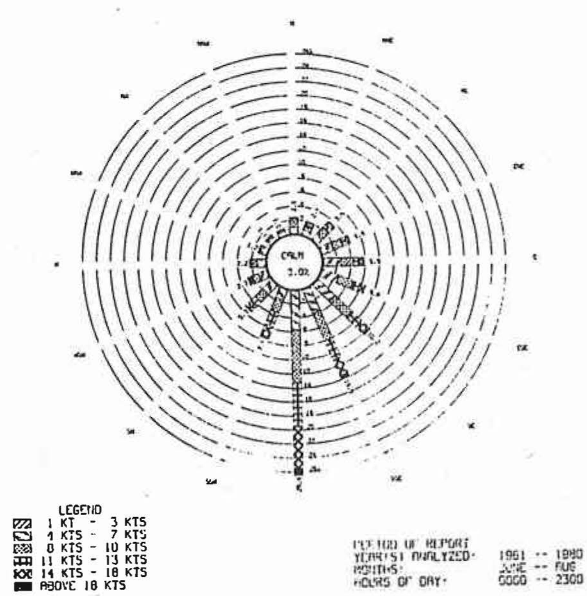

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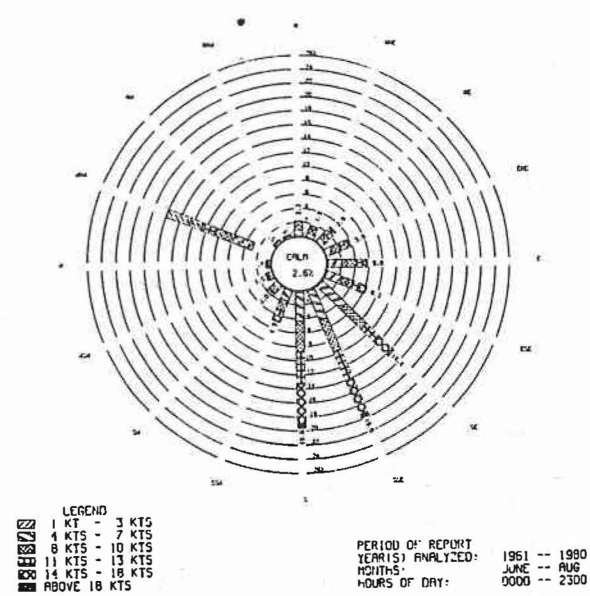
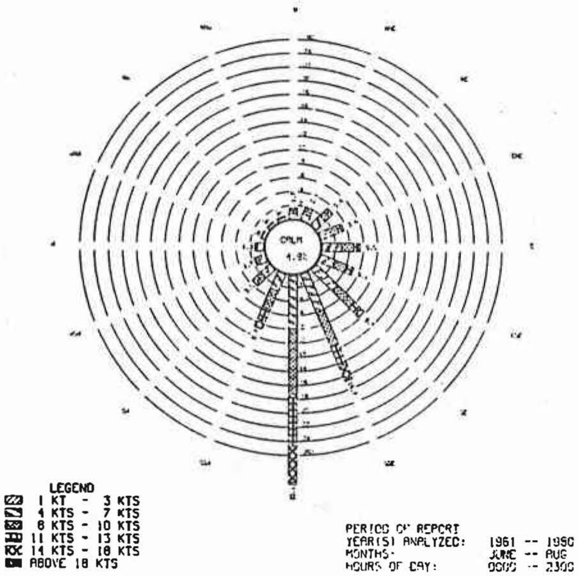


MIDLAND

Figure 2. Representative Wind Roses for Selected Cities (Continued)



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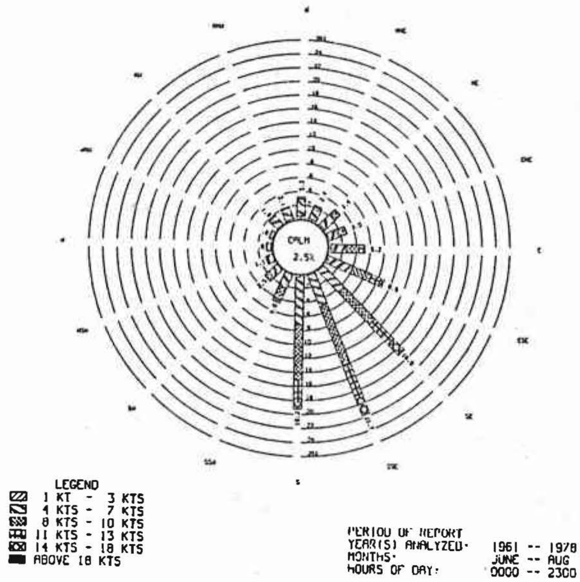

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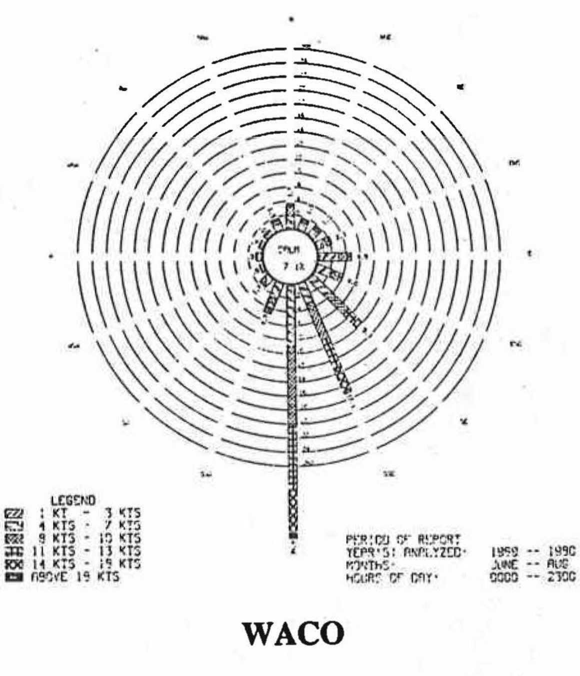
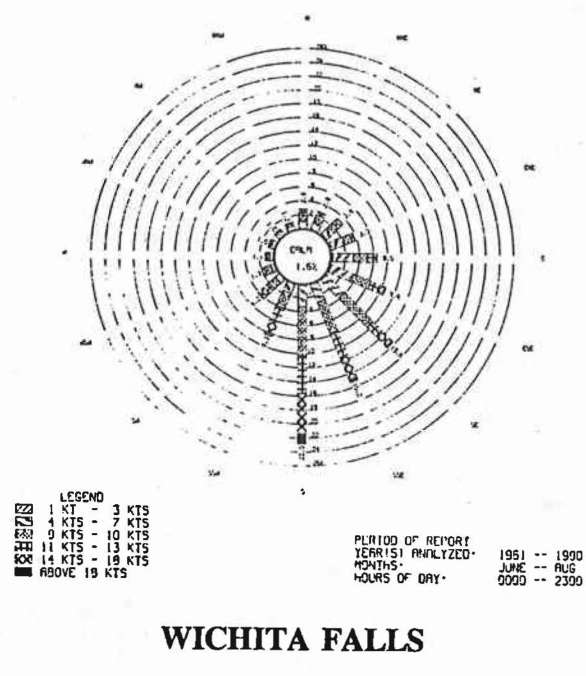


WACO



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