BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

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B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT

DETAILED ENVIRONMENTAL STUDIES
LAND RESOURCES SUBGROUP

PHYSICAL HABITAT AND RANGE VEGETATION REPORT

IMPACT ASSESSMENT
APPENDIX VOLUME

PREPARED BY:

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AND

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APPENDIX F

ASSESSMENT OF IMPACTS OF AIRBORNE EMISSIONS ON VEGETATION
PROPOSED HAT CREEK PROJECT
B.C. HYDRO AND POWER AUTHORITY

prepared by
V.C. Runeckles, Ph.D.

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PROLOGUE

"Secondary SO_2 standards could be set for averaging times of 1, 3 and 8 hours to be certain that all species of plants are protected from all types of ambient SO_2 patterns, whether from single sources with highly variable pollutant concentrations or from large areas of sources with less variable concentrations. If only a 3-hour SO_2 standard were used, a source could conceivably be operated so that several consecutive 3-hour concentrations were near to but did not exceed the standard and plants could be injured. The setting of 1 and 8 hour standards assures that plants will not be injured by these shorter and longer durations."[6]

"If laboratory experiments are to provide a realistic indication of the sensitivity of plants to SO_2 in the air, it is clear that attempts must be made in future work to ensure that fumigations are not carried out in conditions of air movement that are a great deal less than those normally prevailing out-of-doors."[20]

"Pollutants rarely exist alone; instead, the air environment consists of a complex mixture of phytotoxic gases ... The few available results suggest that the greater than additive, less than additive, and additive effects of pollutant combinations can make any attemps to set reasonable standards for individual toxicants very difficult."[102]

F1.0 INTRODUCTION AND DESCRIPTION OF PROJECT

This report is concerned with the assessment of the impact of airborne emissions from the proposed Hat Creek project of B.C. Hydro and Power Authority, including the thermal generating station, and its associated operations, on local and regional vegetation. While it focusses particularly upon the gaseous emissions (especially sulfur dioxide, SO_2) from the generating plant itself, it includes assessments of the airborne impacts from other operations such as the proposed cooling towers, and, in addition, provides an assessment of long distance effects upon regional vegetation.

The Hat Creek coal deposit which is to be mined to provide the fuel for the proposed 2000 Mw thermal generating station contains appreciable sulfur. The sulfur dioxide formed during its combustion represents the major stack emission of environmental concern. Other potentially harmful emissions to the atmosphere include oxides of nitrogen and fluorides, as well as a wide range of trace elements largely in the form of particulates[1].

For assessment purposes, the area surrounding the proposed Hat Creek operations is divided into a local zone of influence of 25 km radius centred on the proposed thermal generating station, and a regional zone of influence covered by a 100 km radius. Environmental Research & Technology, Inc. (ERT) has developed models of projected levels of SO_2 throughout the year for both local and regional zones[2]. These projections have formed the basis for the present assessments of injury to vegetation caused by SO_2, oxides of nitrogen (particularly nitrogen dioxide, NO_2) and fluorides (as hydrogen fluoride, HF). Similar modelling by ERT[3] has permitted assessment of the effects of cooling tower emissions.

Alternative strategies exist for the operation of thermal power generating stations, and also for the design of the station and its components[4]. For the present report, assessments of the impacts of emissions from an uncontrolled 366 m (1200 ft.) stack under base load conditions (2000 Mw) were developed first, and the assessment methodology was then applied to three alternative systems:

366 m stack with partial flue gas desulfurization,
366 m stack with meteorological control, and
244 m (800 ft.) stack with meteorological control.

The assessments of impact reported herein are based upon injury, whether expressed through visual symptoms or through modifications to plant growth. It must be emphasized, however, that the data presented are assessments and not measurements, since few of the plant species indigenous to the Hat Creek region have been studied in the context of air pollution effects. Even where reports of effects on individual species occur in the literature, in most cases these reports contain no quantitative information about severity or magnitude of impact. In the few cases where quantitative data exist, these in turn require cautious extrapolation to the conditions of Hat Creek. The first sections of this report are, therefore, devoted to describing the data bases available, and a discussion of the reasons for caution in their utilization, prior to a description of the actual approaches used in deriving the assessments presented. In the course of developing this methodology, extensive reviews of the scientific literature have been undertaken, which have involved over 380 published papers and reviews relating to vegetational effects of air pollutants exclusive of the photochemical oxidant group. Computer-assisted searches have also been undertaken. In general, the literature has been reviewed up to July 1978.

F2.0 CONTROL STRATEGIES AND DATA BASES

The three air quality control strategies for which assessments of impact on vegetation are presented below are described in detail elsewhere[4]. For the purposes of the present report, it is sufficient to describe them only briefly and to comment on features which have a direct bearing on the impact assessment methodology.

One strategy involves the use of partial Flue Gas Desulfurization (FGD). The system proposed involves the diversion of part of the flue gas through wet scrubbers, leading to an approximate halving of the emissions of SO_2. However, while the system reduces soluble constituents of the flue gas, it inevitably results in the increased discharge of water vapour. The present assessment of impact on vegetation is based upon an FGD system in conjunction with a 366 m (1200 ft.) stack.

The remaining two strategies involve Meteorological Control Systems (MCS). An MCS is a systematic sequence of defined procedures designed to result in a reduction in the rate of emission of airborne pollutants whenever meteorological forecasts indicate that high ground-level concentrations may occur. In the case of the Hat Creek project, evidence has been presented for two procedures by which MCS could operate: by load reduction, or by switching to low-sulfur fuel. The two MCS strategies for which assessments are presented are for the two stack heights: 366 m (1200 ft.) and 244 m (800 ft.).

For each control strategy and for the uncontrolled 366 m stack, local zone of influence modelling within a 25 km radius of the stack was carried out by ERT as described elsewhere[1,2]. The ERT projections were developed on a base of meteorological data obtained within the study area over a 12-month period, in conjunction with knowledge of the local topography. The Hat Creek model, a point-source Gaussian diffusion model, was used to predict hourly ground-level concentrations of SO_2 throughout the year at each of 128 receptor sites arranged in rows of eight, radiating from the stack in each of the 16 points of the compass (Figure F2-1, a fold-out at the end of this appendix).

The hourly projections obtained for the uncontrolled situation were used as the basis for preparing compilations of 3-hour, 8-hour, 24-hour, seasonal (3-month) and annual average SO_2 concentrations. After selecting appropriate threshold concentrations for each averaging period, the number of SO_2 excursions above threshold were computed for each receptor site and plotted as frequency isopleths. Such procedures, accompanied by information as to the maximum concentrations reached at each receptor site during the year, provide an initial overview of the probably magnitudes of ground level fumigations.

In order to obtain projections for the three control strategies, the base data for the uncontrolled situations were modified as follows. For MCS, appropriate action (whether load reduction or fuel switching) was presumed to be effective in meeting specified criteria. The 3-hour and 24-hour concentration criteria used were:

Averaging Time	SO_2 Concentration ($\mu g/m^3$)	Basis
3-hour	655	Afton Smelter permit
24-hour	260	B.C. PCB Level B

The same criteria were used in the FGD case, but here no intermittent action was invoked, the system simply being allowed to function with its scrubbers assumed to be continuously achieving 54 percent removal of SO_2 from the flue gas. The frequency isopleths (at a scale of 1:250,000) for the various averaging times for each strategy are reported elsewhere, together with the maximum predicted ground-level concentrations for each averaging time within the year[1].

While such a form of presentation of the data provides a general overview of the area within the local zone of influence which may receive concentrations of SO_2 above a given threshold, the assessment of vegetational injury requires a more detailed analysis of the projected concentrations, hour by hour, and receptor site by receptor site. Hence, recourse was made to PEAK programmes prepared by ERT, which provided a detailed print-out of 1-hour, 3-hour and 24-hour average concentrations for each of the three control strategy situations. For these PEAK programmes[3], the threshold selected for each averaging time was at or below the level of the most stringent B.C. Pollution Control Board standard[01]. Thus, the threshold for 1-hour averages was 225 $\mu g/m^3$, for 3-hour averages was 300 $\mu g/m^3$, and for 24-hour averages was 160 $\mu g/m^3$. The selection of the ultra-low 1-hour threshold was made in order to obtain information about the hour-by-hour concentration changes prior to and after the predicted occurrence of hourly peaks of significant magnitude, and in order to determine the temporal relationships of such peaks, both of which have an important bearing on injury to vegetation (see Section F4.0, below).

In order to provide quantitative assessments of injury to vegetation, recourse must be made to the published or available data on the response of individual species to specific pollutants at dosages comparable to those predicted. As pointed out in Section F4.0, a multitude of factors can influence the dose-response of any species to a given pollutant. Many of these are environmental factors which may or may not be controlled or even defined in many of the published reports. A particular problem is that the majority of such reports concern experimental data collected under "artificial" conditions. Hence, extrapolation to field conditions is fraught with difficulty. Nevertheless, for most species, such data are the only data which are available and, hence, have had to be used in the present injury assessments. Mention should also be made of the fact that, almost without exception, the published data concerned "acute" injury rather than "chronic" injury (see Section F4.1, below) and, hence, suffer further in their broad applicability to field situations..

F3.0 AIR QUALITY STANDARDS AND VEGETATIONAL IMPACT

Mention has already been made of air quality standards. Such standards are promulgated in order to prevent or minimize harmful effects on the environment, on public health, on materials, and on animals and plants. Available information on the effects of pollutant concentrations on plants forms part of the base on which standards are determined. However, it must be noted that there are important differences between compliance with standards on the one hand, and the determination of impact on the other. For example, all standards relate to the balance between risk and cost. The most stringent standards are those which are essentially at the risk threshold, and represent "safe" levels of contamination. Less stringent standards recognize that the costs of "safety" are excessive and, hence, knowingly permit a measure of risk. Biological impact on the other hand, whether it be of plants or animals, including humans, is not a matter of risk but of actual, quantifiable injury and impairment.

Standards are invariably both time- and concentration-dependent. In particular they are expressed in terms of average concentrations over a given time interval. As a result, they artificially impose a level of order on a situation which is rarely orderly and which is usually characterized by variability. Time-averaging may provide analytical and administrative convenience, but may also be misleading where injury assessment is concerned, since biological response is more dependent upon actual pollutant concentration and time of exposure than upon average concentration (see Section F4.2, below). Furthermore, present day standards are set in terms of individual pollutants, while it is well established that different pollutants may interact with each other with regard to biological response.

These comparisons between air quality standards and vegetational impact are summarized in Figure F3-1. It is important to recognize that full compliance with a given single standard might still result in vegetation injury, as has

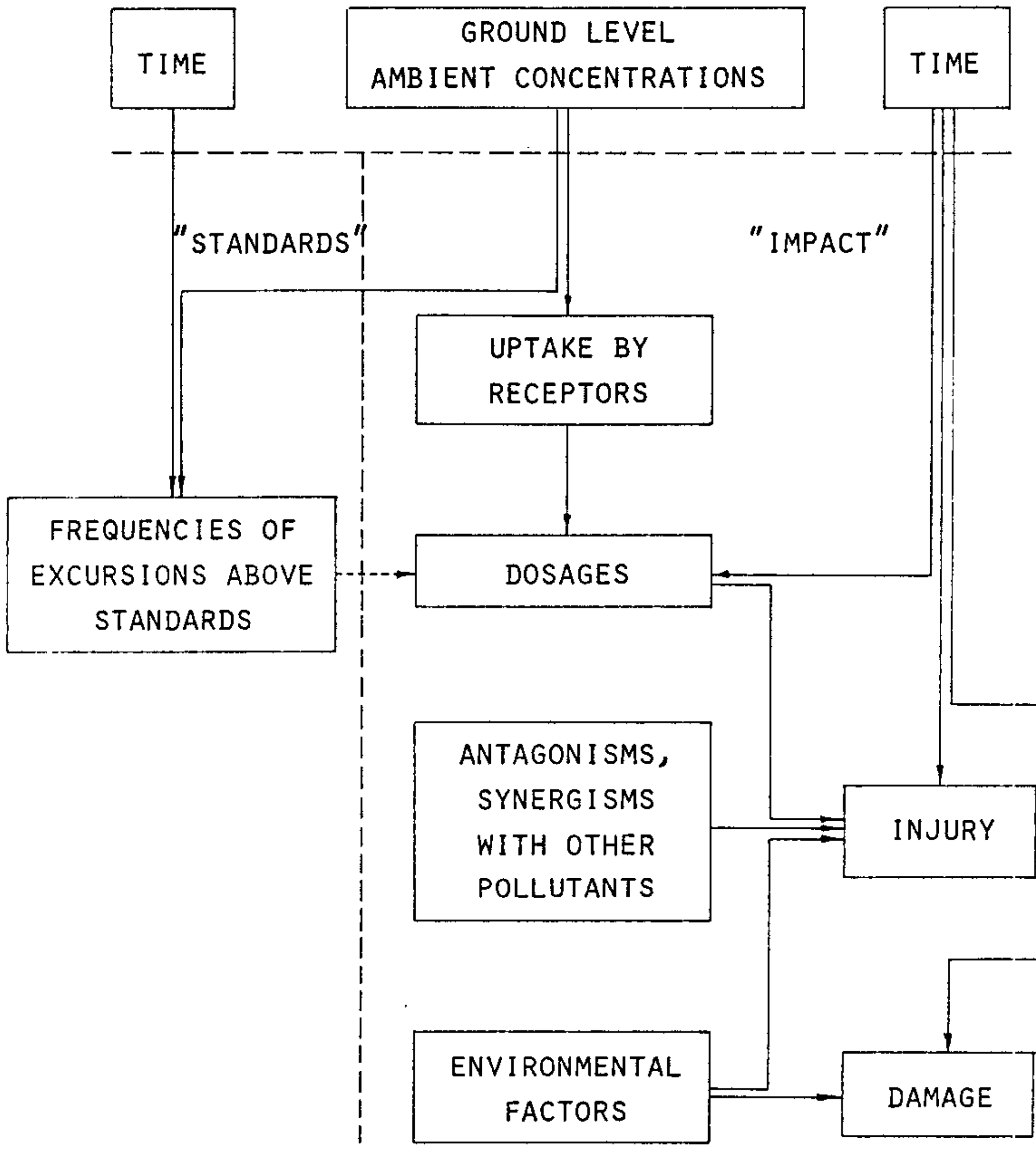


Figure F3-1

COMPARISON OF VEGETATIONAL IMPACT ASSESSMENT REQUIREMENTS AND AIR QUALITY STANDARDS

been pointed out by Jacobson in his report to the State of California Air Resources Board[5], particularly if the averaging time of the particular standard is several hours or more. Hence he has further pointed out that a single standard is insufficient and that compliance with several standards covering short-intermediate- and long-duration exposures is necessary in order to minimize the risk of injury. While such standards could be established for a wide range of exposure times, durations of 1 hour, 3 hours and 8 hours have been proposed specifically for SO_2 by Larsen and Heck[6].

F4.0 FACTORS AFFECTING THE IMPACT OF AIRBORNE EMISSIONS ON VEGETATION

This section provides an overview of the ways in which the responses of plants to air pollutants are or may be modified by a wide range of intrinsic and extrinsic factors. The subject has been reviewed extensively by various authors over the years[7, 8, 9]. Consequently, only those issues of particular relevance to the Hat Creek project and about which new information is appearing in the literature will be discussed here.

F4.1 INJURY AND DAMAGE TO VEGETATION

The terms "injury" and "damage" require definition, since, while they have in the past been used somewhat interchangeably, there is a need for precise terminology which differentiates between various types of impact. Guderian et al[10] first proposed in 1960 that the terms "injury" and "damage" should be ascribed specific definitions. This separation has become generally accepted and the term "injury" now is used to include all plant responses to air pollutant exposures, including reversible effects on metabolism, effects on physiological processes, necrosis, senescence and modifications of growth and development. "Damage" is reserved for those effects which clearly reduce the intended value or use of a plant, whether the reduction be in economic, ecologic or aesthetic terms.

Injury is, thus, a purely biological measure of impact, while damage introduces the concept of value or use. The bulk of the investigations into plant responses to air pollutants are concerned with injury. These include not only investigations into specific effects on individual species, but also general dose-response studies. Investigations focussing specifically upon damage have largely been restricted to field surveys and, in general, have been based more on subjective inputs than objective facts, as pointed out by Waddell and others[11]. However, recently Oshima *et al* have developed crop loss models for the effects of the oxidant air pollutant ozone on alfalfa[12]. Their approach will undoubtedly be extended to other species and pollutants

F4.2 RELATIONSHIP BETWEEN INJURY, AND CONCENTRATION AND DOSAGE OF AIR POLLUTANTS

Biological responses to air pollutants will only occur where there is actual impingement of the pollutant at the site of the biological receptor. Since such receptors are within the tissues and cells of the organism, any response implies the uptake of the pollutant into the cells and tissues, whether access to critical sites occurs by movement through or between the cells of the organisms from the location at which it first penetrates the epidermis. It is important to note, therefore, that response is a consequence of "effective" dosage in situ, and that this effective dose (and hence response) may or may not be related simply to ambient concentration or dosage[13]. Factors which affect the uptake of an air pollutant by the aerial parts of a plant may act independently of those factors which influence the tissue response *in situ*. These different influences on plant response are dealt with separately below (see Sections F4.4 and F4.5).

Figure F4-1 summarizes the important components of plant response to air pollutants. In particular it makes the point that, while concentration and time of exposure contribute to dosage, and hence to response, they are not equally important, particularly with respect to acute injury. Acute injury refers to the rapid response to a toxic agent. In the case of response to air pollutants, acute injury implies a response to one or two exposures to a pollutant lasting a few hours at concentrations sufficiently high to induce readily observable or measurable symptoms within a couple of days. In contrast, chronic injury implies a response over an extended period of time to repeated exposures to concentrations of pollutant which singly are insufficient to elicit acute symptoms.

In terms of the literature, the bulk of the work reported on air pollutant

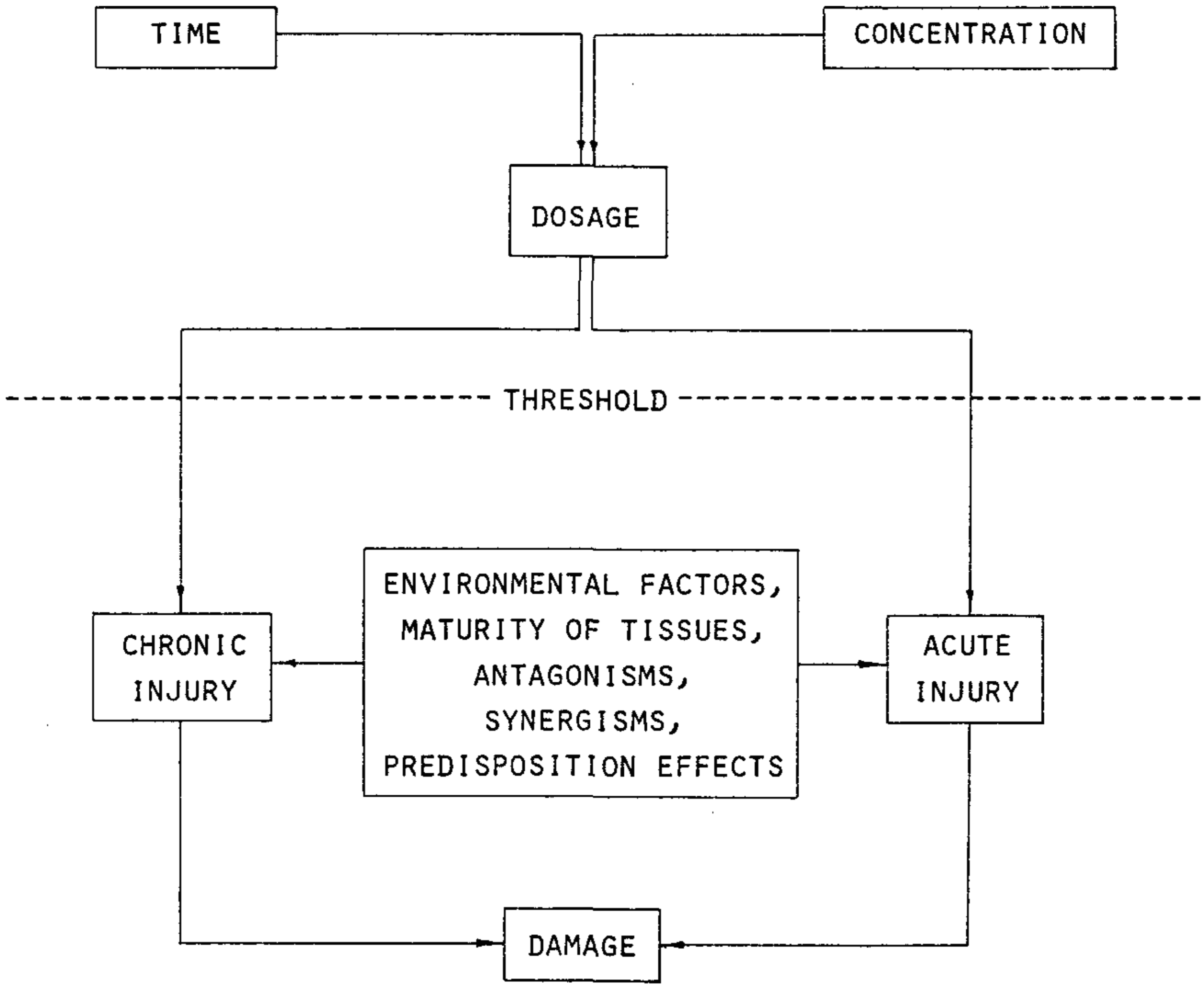


Figure F4-1

COMPONENTS OF VEGETATIONAL IMPACT OF AIR POLLUTANTS

effects on plants is concerned with acute responses, probably because experimentation with acutely injurious dosages is easier to undertake, is less time consuming and usually yields dramatic and unequivocal responses. While many workers tend to regard dose-response as a continuum, e.g. Jacosbson[5] , there is discontinuity between acute and chronic injury reponses, since they usually take visually or measurably distinct forms. Indeed, Swiss workers have recently proposed a reversed sigmoid form for the overall SO_2 threshold dose-response curve for time periods ranging from 30 mintues to 1 year[105]. Hence, extrapolations from acute injury studies to the chronic situation are of doubtful value, and the lack of specific information concerning the chronic response (Jacobson's opinion[5] notwithstanding) renders the assessment of injury in such situations doubly perilous.

F4.3 DOSE-RESPONSE MODELS

With regard to acute injury, several workers have explored the interrelationships of concentration and duration of exposure to individual pollutants. In almost all cases, however, emphasis has been on the mathematical definition of response at the acute injury threshold, with little attempt being made to include degree of injury as a variable. Hence, the models of O'Gara (as developed by Thomas and Hill[14]), of Zahn[15] and of Guderian *et al*[10] are of little value in predicting injury levels. All of these threshold response models show the expected inverse relationship between concentration of pollutant and duration of exposure. However, they differ from each other with regard to the mathematical form of the relationship, partly because of different weightings given to pollutant concentration as contrasted with length of exposure, and partly because of the introduction of terms to compensate for differences in susceptibility to acute injury casued by environmental factors and ontogeny. Such models have some use in establishing the general form of threshold-response curves, such as those depicted by Jacobson[5] and described by the U. S. Environmental Protection Agency[9] However, such curves are dependent upon the observed responses of different

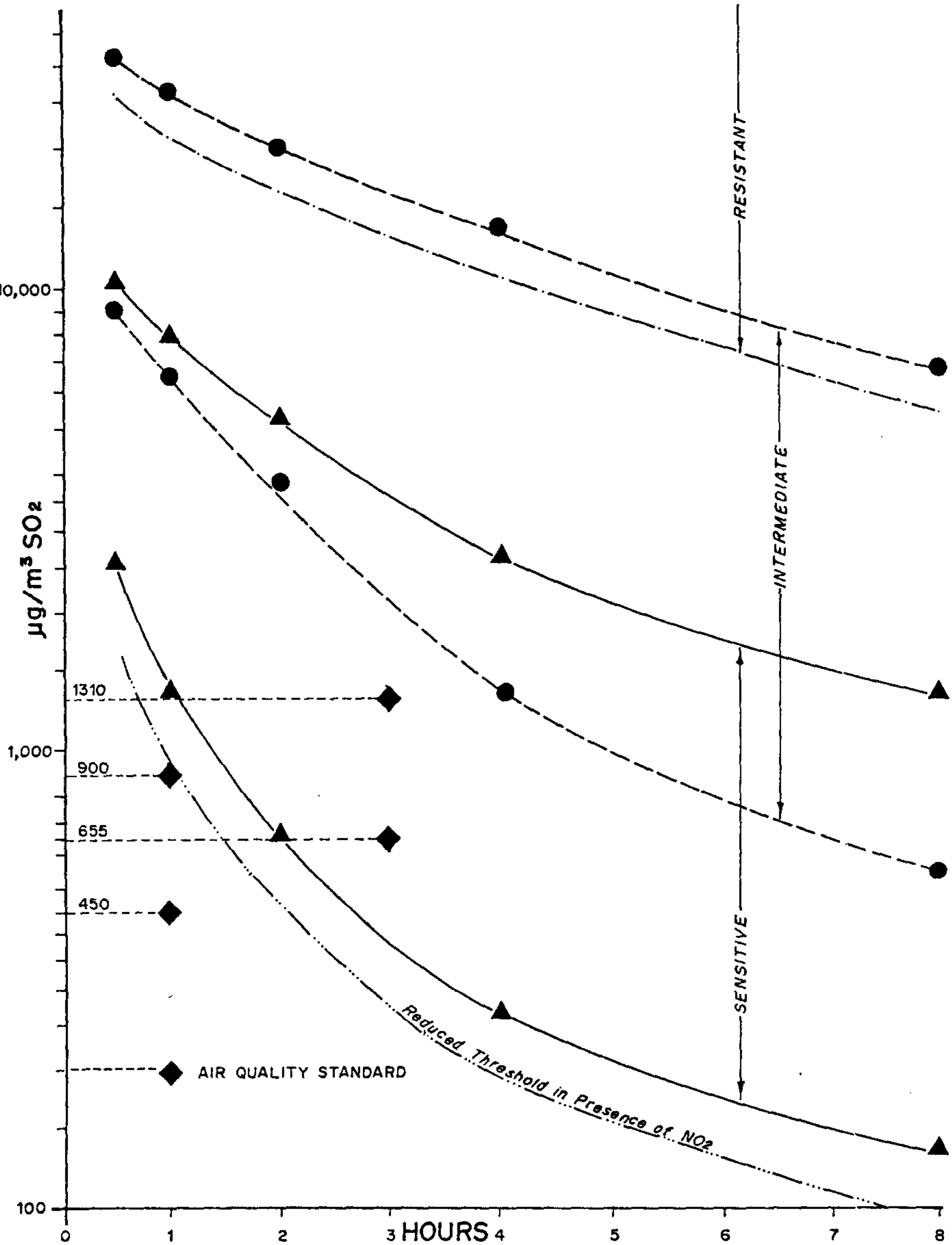


FIGURE F4-2

ZONES OF INJURY FOR SENSITIVE, INTERMEDIATE AND RESISTANT SPECIES IN RELATION TO SO_2 CONCENTRATIONS AND EXPOSURE TIMES species to different exposures, and rather than establishing universally applicable thresholds, they take the form of curvilinear zones relating to groups of plants with comparable sensitivities. In this form, the zones may be related to air quality standards.

Figure F4-2 presents such curves for SO_2 dervied from U. S. Environmental Protection Agency data[9], which in turn are derived from the actual experimentation of workers in many parts of the world. Species were grouped into classes: sensitive, intermediate, or resistant. The lower curve for each class depicts the approximate threshold dosage for acute injury for plants within that class when growing under those conditions which are most conducive to injury. No attempt has been made to extrapolate beyond the 8-hour exposure period. Included in the figure are four air quality standards: the B.C. Pollution Control 1-hour A and B levels (450 and 900 $\mu g/m^3$ respectively), the U. S. EPA 3-hour Secondary Standard (1300 $\mu g/m^3$), and the B.C. Pollution Control Board 3-hour level contained in the permit for Afton Mines (655 $\mu g/m^3$). Of these, it appears that both 1-hour levels are below the threshold for the most sensitive species (ignoring for the moment the reduced threshold in presence NO_2 curve). Both 3-hour levels, however, are within the zone in which sensitive species are likely to be injured. For 3-hour exposures, the maximum non-injurious concentration is interpolated at approximately 400 $\mu g/m^3$. A concentration of 655 $\mu g/m^3$ could thus last for approximately two hours followed or preceded by one hour at 0 $\mu g/m^3$ before reaching the 3-hour threshold while a concentration of 1310 $\mu g/m^3$ could only last for less than one hour, if the 3-hour threshold were not to be exceeded.

It should be reiterated, however, that the threshold values in Figure F4-2 are for sensitive species growing under conditions which enhance susceptibility for which data are available. In the context of the Hat Creek Project, the applicability of this threshold is not known since many of those species indigenous to the Hat Creek region are of unknown sensitivity to SO_2 (see Tables F5-4 to F5-9) inclusive). On the other hand, field conditions such as those occurring naturally in the Hat Creek region seem unlikely to elicit the greatest sensitivity, in the indigenous vegetation, although the evidence relating susceptibility in field vs greenhouse or fumigation chamber conditions is contradictory. (cf. Fig. 4-5 and text p. F4-5).

The data of Figure F4-2 differ somewhat from those presented by Jacobsen[5]. Specifically, his curves have a shallower form, as shown in Figure F4-3. Both sets of curves are based upon interpretations and assessments made by different individuals of essentially the same primary data; only the published work of Larsen and Heck[6] postades the EPA report; the data of Jones *et al*[16] and of Linzon[17] have been taken from unpublished material. How do such differences in interpretation arise? For many reasons, such as the differences in response observed for different species, or even different varieties, races or ecotypes of the same species; the different responses observed by different workers using the same species or varieties, which are probably largely attributable to differences in experimental facilities and procedures; and the degree of importance attributed to various factors which influence plant sensitivity and which may or may not have been controlled during the experiments in which response was measured. It would appear that Jacobson accepted a somewhat higher injury threshold criterion that those responsible for the EPA report.

Many of the factors influencing plant response will be dealt with in greater detail below (Section F4.5), but at this time it is pertinent to illustrate the magnitude of some of these effects and the influence they may have in terms of deriving a general threshold curve.

Figures F4-4, F4-5 and F4-6 present generalized depictions of response dervied from a wide range of sources. In Figure F4-4, the focus is upon variations in actue injury threshold between species, and the interrelationships between concentration, exposure time and dosage. Figure F4-4(a) illustrates both the differences in threshold concentration, and typical differences in the shapes of the dose-response curves for different species. In the case of species 4, the curve illustrates the condition in which low

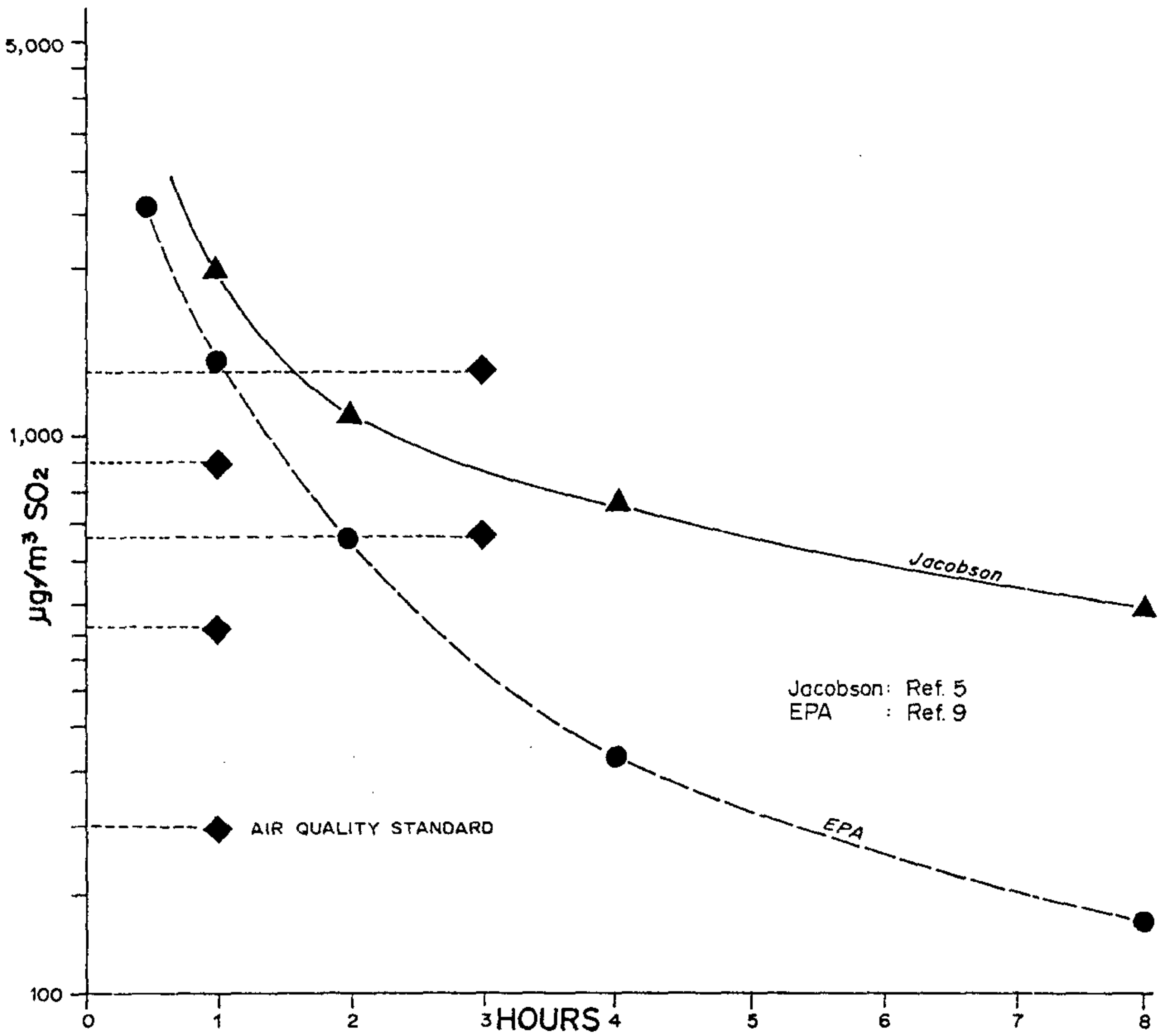
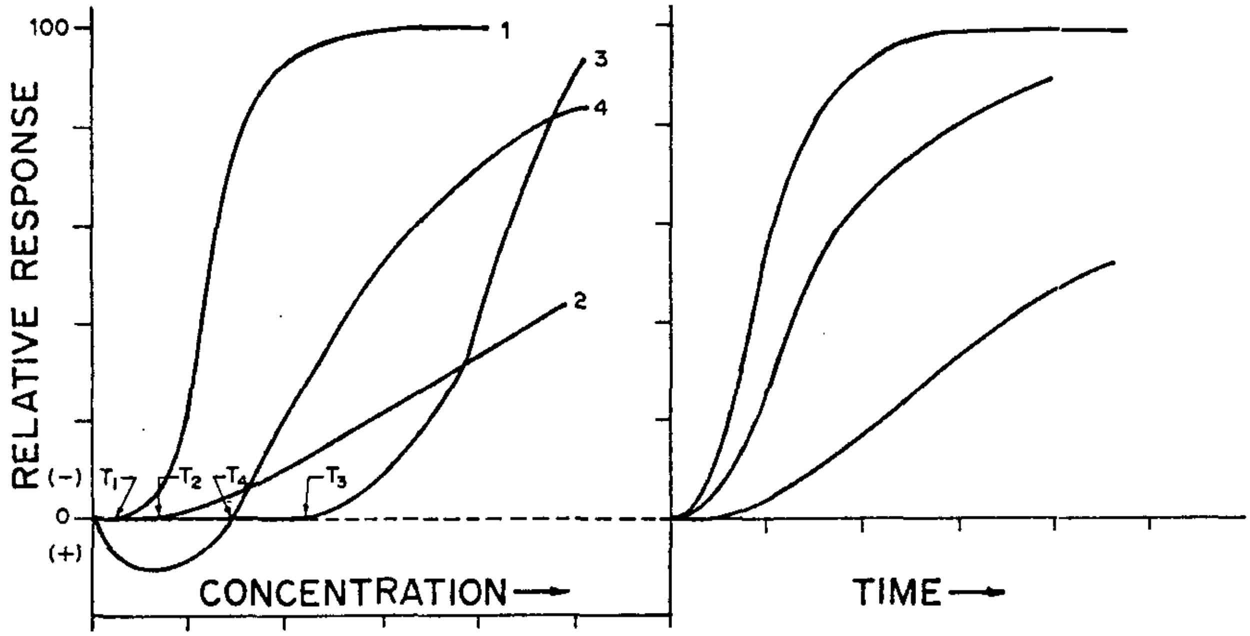


FIGURE F4-3

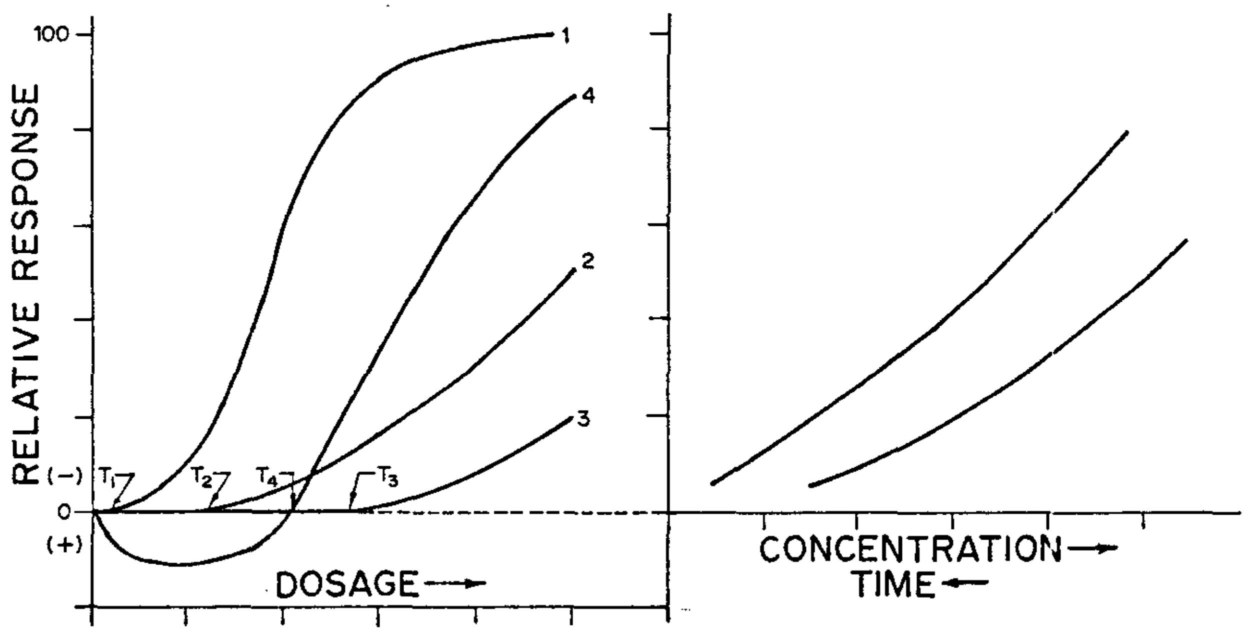
COMPARISON OF INJURY THRESHOLD DOSAGES
FOR SENSITIVE SPECIES IN RELATION TO VARIOUS 1 AND 3 HOUR
AIR QUALITY STANDARDS



(A) EFFECT OF CONCENTRATION ON DIFFERENT SPECIES, WITH SPECIES 4 SHOWING POSITIVE RESPONSE AT LOW CONCENTRATIONS

(B) EFFECT OF DURATION

T_1, T_2, T_3 AND T_4 = ACUTE RESPONSE THRESHOLDS FOR DIFFERENT SPECIES



(C) EFFECT OF DOSAGE ON DIFFERENT SPECIES, WITH SPECIES 4 SHOWING POSITIVE RESPONSE AT LOW DOSAGES

(D) EFFECT OF CONCENTRATION OR TIME AT CONSTANT DOSAGE

FIGURE F4-4

EFFECTS OF CONCENTRATION, TIME AND DOSAGE ON THRESHOLD AND PLANT RESPONSE concentrations of a pollutant such as SO_2 or NO_2 may be nutritionally useful and result in increased growth. In Figure F4-4(b), different species again respond differently to increasing exposure times, even though the concentration of pollutant is sufficiently great to cause a measurable response following a brief exposure. In Figure F4-4(c), concentration and time are combined, but marked differences in threshold dosage are still apparent. Again, the situation depicted for species 4 illustrates the condition in which low dosage of a pollutant such as SO_2 or NO_2 may be beneficial. Finally, Figure F4-4(d) shows that, even under constant dosage conditions, there is a greater effect of concentration than exposure time on response.

Figure F4-5 illustrates differences in the response to identical dosages administered under different experimental conditions[18] or to identical dosages administered following growth in standarized but different conditions[19]. In the first case, A, exposure under field conditions increased response significantly, as compared with exposure in chambers, while exposures following different growing conditions, B. resulted in reverse response.

In Figure F4-6, response is shown to be affected by the way in which a given dosage is administered. In Figure F4-6(a) a constant total dosage involving a constant total exposure time is divided into numbers of shorter exposure times. As the number of such exposures increases and, hence, their duration decreases, the response is diminished, indicating that partial recovery can occur between doses. In Figure F4-6(b), the size of the acute injury response is shown to be affected by the magnitude of sub-acute pretreatment doses. In curve X, the pretreatment doses (in this case determined largely by increased pretreatment concentrations), increasingly predispose the plant to subsequent acute injury; this is also true in curve & except that higher dosages ultimately diminish the predisposition because here the increase in pretreatment dosage reflects an increase in the duration of the pretreatments rather than their concentrations. In other words, the decline in response reflects a decrease in predisposition reflecting age and maturity

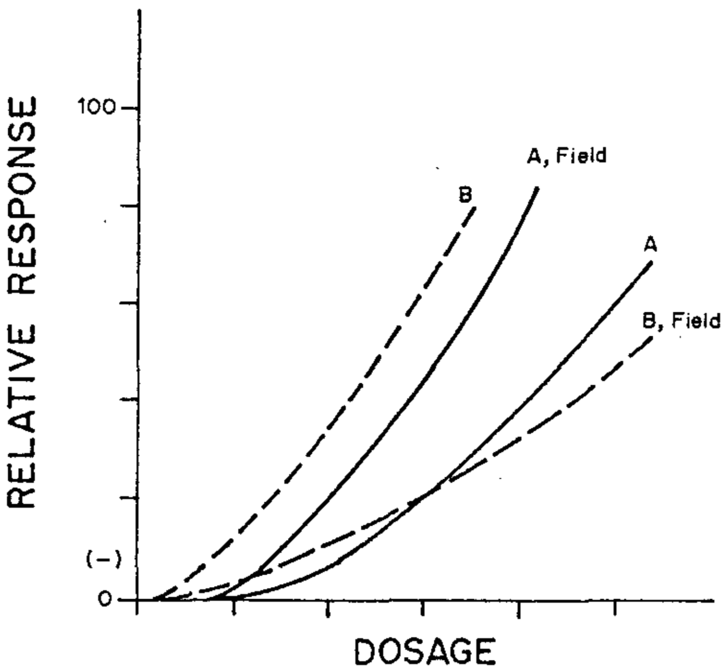


FIGURE F4-5

RELATIVE RESPONSE
TO

(A) STANDARD DOSAGES ADMINISTERED IN THE FIELD OR IN CHAMBERS

(B) STANDARD DOSAGES ADMINISTERED TO PLANTS GROWN UNDER FIELD CONDITIONS OR IN CHAMBERS

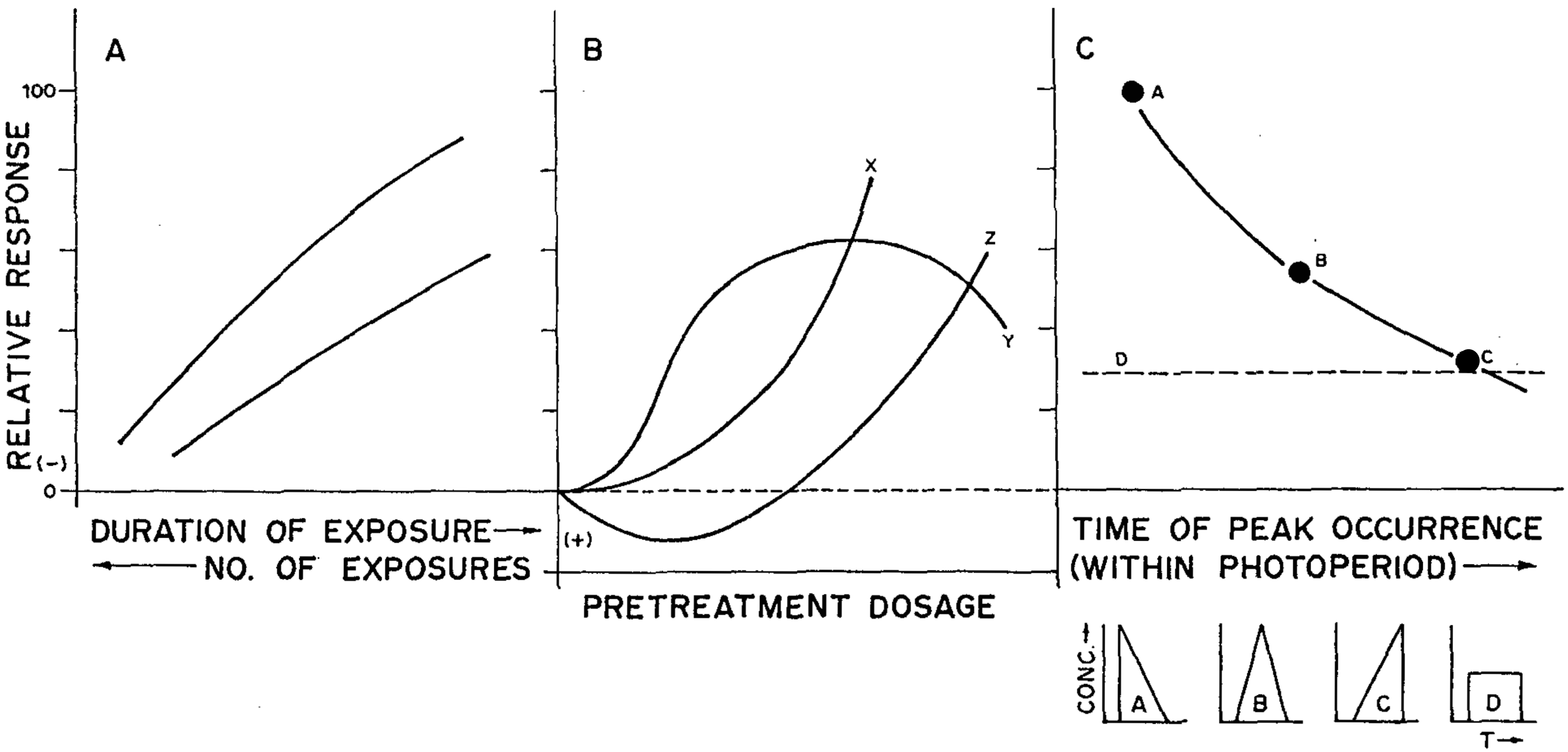


FIGURE F4-6

EFFECTS OF INTERMITTENT, CONSTANT AND VARIABLE DOSAGES ON RESPONSE

(A) INTERMITTENT DOSAGES WITH VARYING NUMBERS AND LENGTHS OF "RECOVERY TIME" BETWEEN INDIVIDUAL EXPOSURES

(B) EFFECTS OF SUB-ACUTE PRETREATMENT DOSAGES

(C) EFFECT OF TIME OF OCCURRENCE OF PEAK CONCENTRATION WITHIN PHOTOPERIOD, WITH CONSTANT TOTAL DOSAGE of the plant. In curve Z, pretreatment dosage initially decreases subsequent acute injury, i.e. exerts a "protective" effect. Figure F4-6(c) depicts the markedly different magnitudes of response which result from identical dosages administered in different ways, with the peak concentrations ranging from the beginning to the end of a photoperiod.

This sampling of causes of variability in plant response includes some effects which have been known for some time and others which have only recently been or are currently being investigated. However, it illustrates the variables which have to be considered in deriving threshold dose-response curves. It provides, in part, an explanation for the differences in opinion between different individuals, not only with regard to thresholds but also with regard to the magnitude of response to a given dosage. Perhaps of the greatest significance in this context is the fact that most of the available quantitative data on dose-response have been obtained in controlled environment or other chambers in which the environmental conditions may be considerably different from those prevalent in the field. A valid criticism of many of these data has been made by Ashenden and Mansfield[20], on the ground that the experimental facilities employed are such as to cause an overestimation of the concentrations of pollutant required to effect a given magnitude of response. Such an explanation may account for the observations of reduced thresholds for ozone injury to tobacco in field vs chamber experiments[18], which in turn could reduce the controversey on this subject. (cf. Fig. F4-5).

Even with the agreement over the level of the threshold curve for sensitive species for a single pollutant such as SO_2, the fact that the pollutants tend to occur in mixtures, the components of which may modify each others' effects, adds another level of complexity in determining "effective" threshold responses. The same variability in response caused by a variety of intrinsic and extrinsic factors which plagues the selection of threshold response curves also affects the assessment of the level of injury to the expected from dosages above the injury threshold. Few attempts have been made to introduce injury as a variable into dose-response equations. A notable exception is the work of Larsen and Heck[6], who developed a series of relationships essentially based upon the presumed lognormality of plant responses to air pollutants, analogous to the familiar lognormality of the response of organisms to toxins and drugs. Their equation 7,

$$C = M_{g\ hr} S_g^{\ z} t^p \quad ,$$

where C is pollutant concentration, $M_{g\ hr}$ is the geometric mean injury threshold concentration (in ppm) for a 1-hour exposure duration, S_g is the standard geometric deviation, z is the number of standard deviations that a particular percentage of leaf injury is from the median, t is the exposure duration in hours, and p is the slope of the log-log plot of concentration (ppm; ordinate) versus exposure time (hours; abscissa) for a given injury level, can be rearranged in order to predict z (and hence percentage of acute injury) from a knowledge of concentration and exposure time.

Rearrangement yields,

$$z = \log \left[\frac{C}{M_{g\ hr} t^p} \right] \Big/ \log S_g$$

From the limited SO_2 data provided by Larsen and Heck, the values of M_g observed for four species ranged from 5.6 to 54.0 ppm (for 1-hour exposures), S_g ranged from 1.2 to 2.48, and p from -0.25 to -1.86. This last observation (of a slope steeper than -1.0) is unique and is suggested[6] to be spurious, since all other slopes (p) fell far short of -1.0, indicating that equal dosages do not produce equal injuries (cf. Figures F4-4(d), F4-6(a) and F4-6(c)).

The Larson-Heck model is currently limited to its precise application to injury assessment to those species studies in the development of the model. The ranges of values quoted for $M_{g\ hr}$, S_g and p are quite broad, and, of the four species studied, Norway maple, ginkogo, pin oak and Chinese elm, the first three are rated as "tolerant" to SO_2, with Chinese elm rated as "sensitive" . Nevertheless, by assuming values for $M_{g\ hr}$ as high as 5.0 (i.e. 13100 $\mu g/m^3$ SO_2) with S_g = 1.5, and p = -0.4, levels of injury to sensitive species can be predicted for a wide range of 1- or 3-hour peak concentrations and frequenceies of occurrence. This approach has been used to assist in the assessment of injury to species in the Hat Creek region. It is somewhat reassuring to note that, given the assumptions which have to be made in the absence of specific information as to $M_{g\ hr}$ values for indi- vidiual species, the magnitude of the assessments derived from this model are in general agreement with those obtained by the more subjective procedures used in this report (described in Section F5.4) which take into account the numerous factors affecting plant response.

F4.4 FACTORS AFFECTING UPTAKE OF AIR POLLUTANTS BY VEGETATATION

Mention was made in Section F4.2 of the concept of "effective" rather than ambient concentration or dosage. Gaseous air pollutants behave in general in similar ways to other gases such as CO_2 , O_2 and water varpour, in terms of their movements into and out of plant leaves. Uptake is largely defined by the various resistances to diffusion present inside and outside the leaf. The three major resistances to gas movements are the boundary layer resistance within the air immediately surrounding the leaf, the stomatal diffusive resistance controlled by the condition of the stomata or pores on the leaf surfaces, and the mesophyll resistance within the leaf. These concepts are equally applicable to a canopy of leaves as to a single leaf in isolation. In canopy situations, the boundary layer resistance is more appropriately described as aerodynamic resistance, since its magnitude is dependent on the thickness of the boundary layer of relatively stagnant air surrounding the canopy, which in turn depends on the aerodynamic properites (e.g. roughness) of the canopy surface, and the turbulence and mixing induced by wind speed.

Recent publications[22, 23, 24, 25] have extended the earlier work of Hill and his associates [26, 27, 28]. The paper by O'Dell *et al*[22] provides a useful summary of the current "state of the art" and emphasizes that aerodynamic or boundary layer resistance is significant at wind speed below 1 m/s, that stomatal diffusive resistance usually exercises a major role in determining overall transfer, and that mesophyll resistance for SO_2 is usually of minor importance, because of the high solubility of the gas.

The importance of boundary layer resistance to the uptake of SO_2 is the focus of the previously mentioned criticism levelled by Ashenden and Mansfield at much of the experimental work on dose-response. Their work convincingly demonstrates that injury from a given concentration of SO_2 and exposure time can be markedly reduced in low wind-speed conditions, and that this in turn can lead to an overestimation of the ambient concentrations needed to cause a given level of injury. The study of Heagle *et al* [29] is singularly worthless in the context since none of the velocities used exceeded 0.32 m/s.

In the field, where wind velocities rarely drop below 1 m/s, the major regulation of uptake of pollutants will, therefore, be via stomatal action. The guard cells of stomata on the leaf epidermis which control stomatal aperture respond to light, humidity and CO_2 concentration as well as to the concentration of pollutants such as SO_2. Mansfield and Majernik [30, 106] observed in particular that since increases in CO_2 concentration frequently accompany levels of other pollutants derived from combustion processes, the CO_2 induced closure of stomata might in some species offer some potential protection to the leaf by increasing stomatal resistance to toxic gases. For one species at least (alfalfa), this protective effect of CO_2 has indeed been demonstrated[92].

Several workers have reported effects of SO_2 on stomatal aperture, but Mansfield and Majernik[30] were the first to determine that SO_2 caused stomatal closure of broad bean in low humidity conditions, but caused stomatal opening at humidities greater than 40 percent at 18°C (< 7 mm Hg water vapour deficit).

Under these latter conditions, the presence of SO_2 would therefore tend to decrease stomatal resistance, leading to increased uptake into the leaves.

Hence we have the potential for two effects occurring simultaneously: Stomatal closure induced by CO_2, and stomatal opening induced by SO_2. How generally widespread are these effects? The CO_2 induced closure is generally accepted, but is known to vary appreciably among species. Thus, while closure is almost complete in cereals, such as corn and sorghum and in soy bean subjected to 500 ppm CO_2 (an enrichment of approximately 170 ppm over normal background CO_2), the Stomata of tomato and cotton show little response even at concentrations up to and above 1000 ppm[107, 108] The published reports of effects of SO_2 on stomata are essentially confined to two species, broad bean [30, 106] and alfalfa[92]. However, recent, yet-to-be published studies at the University of Nottingham (M. Unsworth and V. Black) have shown that it is those species (e.g. broad bean, tobacco and sunflower), whose stomata respond to vapor pressure deficit, which show SO_2 induced closure below and opening above about 40% RH, while in those species (e.g. bush bean), whose stomatal response is independent of vapor pressure deficit SO_2 induced opening occurs regardless of ambient humidity. Thus the overall situation, based on our present knowledge, is probably best described by suggesting that elevated CO_2 levels are likely to counteract to some extent the effect of SO_2 in inducing stomatal opening, and that for this reason the same CO_2 levels may also reduce the impact of SO_2. Of possible relevance is the observation that elevated CO_2 levels reduce the adverse effects of low levels of a different sulphur-containing pollutant, hydrogen sulphide, on photosynthesis[109].

To relate these effects to the Hat Creek Project, however, it is first necessary to determine the levels of CO_2 enrichment which are likely to accompany projected levels of ambient, ground-level SO_2. Based on the ambient flue-gas composition:[110]

carbon dioxide	12%
oxygen	4%
Sulphur dioxide	0.06%

and assuming 1) that none of these gases undergoes chemical change within the plume, and 2) that all follow the same pattern of dispersion, the levels of CO_2 enrichment and O_2 depletion corresponding to various levels of SO_2 are as follows:

SO_2 μg/m^3	CO_2 (enrichment) (ppm)	O_2 (depletion (ppm)
2,096	+160	-227
1,572	+120	-170
1,310	+100	-142
1,048	+ 80	-113
786	+ 60	- 85
655	+ 50	- 71
524	+ 40	- 57
262	+ 20	- 28

The range of concentrations of CO_2 superimposed upon the 330 ppm in the diluent air is 40 - 120 ppm over the range of ambient, ground level SO_2 concentrations predicted to occur by ERT modelling[1]. Such levels of enrichment are considerably less than that used by Hou *et al*[92] to demonstrate reductions of SO_2 -induced injury and impaired photosynthesis in alfalfa (approx. 330 ppm above ambient). On the other hand, the higher concentrations (100 - 120 ppm above ambient) just fall within the range in which Pallas[107] observed reduced transpiration (attributed to stomatal closure) in CO_2 sensitive species such as corn, sorghum and soybean.

[The figures for oxygen depletion have been calculated because reduction in oxygen concentration has also been reported to affect stomatal response[111] However, the depletion of oxygen by the amounts indicated above is insignificant in light of the fact that the diluent air contains 210,000 ppm O_2 (21%).]

Effects of humidity on stomatal response to SO_2 have been mentioned above and considerations of the effect of humidity have also entered the modelling of the uptake SO_2 by forests[24]. Uptake of SO_2 is at a maximum in the mid to late morning, when stomatal resistance is approaching its lowest value. However, the maximum rate of uptake precedes the minimum stomatal resistance because mesophyll resistance is least at low night-time temperatures and reaches a maximum in the early afternoon because of the decrease in the temperature-dependent solubility of SO_2. This general observation is of importance in the context of the increased response to peak concentrations which occur early in the photo-period (Figure F4-6 (c)).

Other pollutants such as HF, with solubilities and diffusivities similar to SO_2 are predicted to be taken up by plants at comparable rates[23]. In the case of NO_2, its reduced diffusivity results in an increased mescphyll resistance, which effectively reduces the rate of uptake somewhat.

Within the leaf, the ultimate sinks for gases such as SO_2 and NO_2 are metabolic. In either case, the dissolved gas, or its ionic forms in solution, can enter the metabolic pathways of the leaf cells and be reduced to sulphydryl and amino groups respectively, which can be incorporated into amino acids, proteins and other biochemical constituents. In the case of SO_2 , both oxidation and reduction may occur, and increased levels of sulfate are frequently detected in plant leaves subject to SO_2 fumigation. Without describing the detailed biochemisty involved, suffice to say that a simplistic explanation for the onset of acute injury symptoms of SO_2 and NO_2 is that the leaf's ability to utilize the dissolved gases has been exceeded, possibly because of their effect in reducing pH at critical sites within the cell.

F4.5 FACTORS AFFECTING RESPONSES OF VEGETATION

Once within the plant tissue, pollutant gases elicit typical syptoms of injury[31]. The severity of such injury can be modified by a wide range of factors. Those factors which are important in the context of Hat Creek are discussed briefly in the following sections.

(a) Season of Year

Since pollutants must enter the tissues of the plant to have effect and since during the winter months in a location such as Hat Creek the stomatal resistance of evergreens is high, while the deciduous and annual species are without foliage, there is relatively little uptake of gaseous pollutants by higher plants. Exposed mosses and lichens which lack stomata), however, may take up significant amounts of gases such as SO_2 and HF during the winter, and may be injured by the accumulation. The reduced impact of SO_2 during the winter months on several tree and shrub species has been documented by Katz[32] and others[33, 34], and is in general attributed to the low level of physiological activity within the leaves resulting from the low prevailing temperatures. However, even at such low levels of activity, conifers may be injured, especially in areas with higher concentration during winter months . Recently, Huttunen[112] has reported significant injury to *Pinus sylvestris* and *Picea abies* (two coniferous species in the forests of central Finland) caused by winter deposition of SO_2 at times when the seasonal SO_2 concentration averages 30 $\mu g/m^3$ and at which the needles may be covered with snow or frost. The injury may be severe and result in considerable necrosis and needle loss, but only becomes visible in the spring with the onset of temperatures above freezing. A similar phenomen has been observed with ryegrass in northern England, where deposition of SO_2 the winter months (when the seasonal average may reach 150 $\mu g/m^3$), in the absence of snow cover, causes appreciable decrease in yield during the following growing season[113].

Season is also related indirectly to susceptibility to injury from air pollutants because of the variations in sensitivity shown by plants or plant tissues at different stages of development throughout the growing season (see Section F4.5(c), below).

(b) Time of Day

Because the primary route of gas movement to the interior of plant leaves is via the stomata, the normal diurnal rhythm of stomatal opening during the photoperiod provides greater accessibility and, hence, greater potential for injury during daylight hours. The many observations on stomatal aperture and its relationship to the uptake of gaseous pollutants have been utilized in models such as that developed by O'Dell *et al* [22].

In spite of the controlling influence of stomata on pollutant uptake, there may nevertheless be appreciable uptake or deposition of gases such as SO_2 during the night, reaching about one-third of the daytime values [35]. Independently of effects of stomata, light sensity (the most important environmental variable associated with time of day) may also influence the effect of gaseous pollutants once they are within the leaf.

In general, a positive correlation exists between light intensity and injury to SO_2 and other pollutants [33]. However, plant sensitivity may still show a diurnal increase even under conditions of constant light intensity, temperature and humidity [34], and it has been shown that under field conditons injury to SO_2 is greatest when exposures occur in mid morning, in spite of the fact that the rate of SO_2 uptake usually reaches a maximum just before midday and is still appreciable even at midnight. This situation is analogous to currently unpublished work from the author's laboratory, summarized in Figure F4-6(c), in which the effects of ozone when peak concentrations are administered early in the photoperiod are found to be much greater than when the peak occurs later in the photoperiod.

(c) Stage of Development of Vegetation

The stage of development of the whole plant as well as the age of individual leaves influence the magnitude of the injury response to air pollutants. In the case of sensitivity to SO_2, this is generally greatest in the spring and summer for woody species, partly because of the factors referred to above (Section F4.5(a)) with regard to time of year, and partly because, in general, leaves which are reaching the stage of full expansion are the most susceptible[9, 35]. Perhaps contrary to expectation, pollutants such as hydrogen fluoride, on the other hand, tend to show syptoms of injury in very young, expanding leaves[31].

In annual and biennial species, sensitivity to SO_2 is least during the initial seedling stages of growth and usually reaches a maximum just prior to flowering[31, 35]. In the case of woody perennials and trees, Wenzel (as reported by Guderian[35]) has shown that "a certain sensitivity of conifers begins in the late stage at the time of cumulative growth and remains until early maturity. Injury during this time can lead to severe reductions in growth and an opening of entire forest stands".

In all cases, the most sensitive plant organs are the leaves, although other parts of a plant may be affected secondarily as a consequence of leaf injury and the resulting impairment of the assimilatory machinery. Leaf sensitivity to acute injury is usually different from sensitivity to chronic injury. Thus, while in general the leaves most susceptible to acute SO_2 injury are those of "middle age" chronic injury symptoms usually appear first on the oldest leaves. SO_2 concentrations also dictates (to some extent) which leaves will be acutely injured, with progressively younger leaves being affected by higher concentrations above the acute injury threshold[35].

(d) Genetic Variability

Species, varities, cultivars and even individual plants react differently to a given air pollutant, independently of any of external, environmental factors which may affect susceptibility. Levitt has classified responses to stress in terms of "stress avoidance and tolerance" components[36]. In the context of air pollution, stress avoidance mechanisms include responses which reduce pollutant uptake or increase detoxification, for example the closure of stomata. Stress tolerance on the other hand includes mechanisms which modify the capacity of the plant to withstand the effects of the pollutants. Pollutant uptake can be reduced by specific morphological, anatomical and physiological modifications, which in many cases are genetically controlled. Similarly, tolerance is genetically controlled in many cases, based upon the wide and consistent variation in response of different species which may be shown by subsequent analysis to have accumulated comparable amounts of a given pollutant, or in which even an inverse relationship between injury and accumulation may be demonstrated [37].

While most information about genetic differences in susceptibility derives from work on cultivated plants, increasing numbers of studies are being reported on genetic variability in natural populations ranging from trees[38, 39] to herbaceous species[9]. The reasons for these differences in susceptibility between individuals of different species or within a single species are not of concern in this report. However, the fact that such genetic variability is readily demonstrated in almost all species which have been studied argues that it may well be a widespread phenomenon. Hence, in the context of the Hat Creek project, one may expect that species such as Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus controta*) will show such variability and that certain individuals will be more highly susceptible to pollutants such as SO_2 than others regardless of environmental influences. Indeed, such differences may account for the apparent contradiction between Katz[32] and Scheffer and Hedgcock[40] in terms of their ratings of the susceptibility of several coniferous tree species to SO_2, in both cases based upon observations of trees affected by emissions from the smelter at Trail, B.C.

Genetic variability poses one of the major problems with regard to the assessment of injury from air pollutants in locations such as Hat Creek. In few instances does the literature provide data about particular native species which may be prevalent in a given location. Extrapolation from the reported sensitivities of related species or from varieties or cultivars is hence best avoided since it is highly speculative in nature. On the other hand, it is frequently the only method available.

Genetic variability may also make hazardous the prediction of actual injury thresholds for those species whose sensitivities to air pollutants have been studied. Together with the variability among species, it explains the thickness of the zones of sensitivity depicted in Figure F4-2. Nevertheless, it is possible to think of an "absolute" threshold concentration of a pollutant below which even the most susceptible species will show no adverse effects. In the case of SO_2, this threshold for short-term exposure (approximately 2 to 3 hours) appears to be approximately 530 $\mu g/m^3$, while for long-term (several weeks) exposures it approximates 53 $\mu g/m^3$ as a mean value[41]. However, a constant concentration of 53 $\mu g/m^3$ in an extended exposure is not the same in its effects as a mean concentration of 53 g/m^3 made up of fluctuating concentrations[41]. This is the chronic situation analogous to the acute injury response summarized in Figure F4-6(c). On the other hand, gases such as SO_2 and NO_2 which are capable of being metabolized and entering the sulfur and nitrogen pools within the plant, at concentrations below the injury threshold, may be beneficial and give rise to increases in growth, as depicted earlier in Figures F4-4 and F4-6(b). In the chronic case, this was indeed shown to occur to individuals of eastern white pine (*Pinus strobus*) in the Sudbury region, following 10 years of exposure to low SO_2 levels averaging 21 $\mu g/m^3$, with a total of 29 half-hour excursions >655 $\mu g/m^3$ and one >1310 $\mu g/m^3$, during the ten six-month growing season, as a result of which Linzon[9, 42] reported a 1.6% increase in growth. In contrast, trees subjected to an annual concentration of 45 $\mu g/m^3$ over ten years, with 86 half-hour excursions >655 $\mu g/m^3$, ten 1310 $\mu g/m^3$ and one >2620 $\mu g/m^3$ resulted in 0.6 percent less radial growth.

One of the consequences of genetic variability within a given species is ecological in nature and leads to changes in plant community structure. Such ecological changes are discussed more fully below (Section F4.5 (h)).

(e) Edaphic Factors

The availabilities of soil moisture and nutrients play important roles in determining susceptibility and resistance. With regard to soil moisture, it has been a general and widespread finding that susceptibility decreases with declining water availability and that resistance of otherwise susceptible plants is maximal at the wilting point or close to it. Guderian has summarized the evidence[35] and also points out that the effects of soil moisture availability are closely similar to those of atmospheric moisture (humidity), and appear to be largely mediated through effects on stomatal pore size which influence uptake of gaseous pollutants. Hence, the limited rainfall of the Hat Creek region might be expected to result in an overall decrease in plant sensitivity.

The supply of nutrients has been shown to influence plant response to air pollutants in a variety of ways. Some of the reports are contradictory, but for the most part, overall nutrient deficiency usually results in increased sensitivity[35]. However, Leone and Brennan have reported the reverse effect on tobacco and tomatoe subjected to SO_2, in which injury increased with sulfur nutrition[43]. Zahn generalized that dicots became less susceptible to SO_2 with increased availability of fertilizer nitrogen, while, of the monocots tested, barley showed no effect of N and became more sensitive as N-fertility increased[44]. Sensitivity of both red clover and winter barley increased with increasing levels of fertilizer phosphate but decreased with increasing levels of fertilizer potassium[35]. N-deficient bean plants are much more susceptible to NO_2 than those receiving adequate fertilizer nitrogen[45]; Norway spruce (*Picea abies*) shows a similar response with regard to sensitivity to hydrogen flouride[35]. Thus, the most usual response to increased soil fertility is a reduction in susceptibility to a range of air pollutants, although in some cases reduced fertility leads to reduced sensitivity. In the Hat Creek region, major nutrients are unlikely to be limiting (with the possible exception of phosphorous in the alkaline soils) except that their availability will be limited somewhat by the lack of precipitation.

(f) Effects of Mixtures of Air Pollutants

Gaseous air pollutants rarely occur in isolation. All combustion processes lead to the formation of quantities of oxides of nitrogen; in the case of coal which contains sulphur, the oxides of nitrogen are discharged into the air together with surphur dioxide, and other impurities. While air quality standards are expressed in terms of single pollutants, and most of the observations of the effects of pollutants on plants made in the past concern individual gases, there has been a growing concern over the effects of combinations of pollutants. This has come about because of various reports that combinations of gases such as SO_2 and ozone, and SO_2 and NO_2 may act synergistically and result in greater injury than that resulting from either pollutant alone. The observation of symptoms of SO_2 injury in the field at ambient levels of SO_2 less than the accepted threshold levels based upon laboratory studies has been attributed to enhancement or synergism with oxides of nitrogen[9]. The results of various studies of the effects of simultaneous exposures to SO_2 and NO_2 are summarized in Table F4-1. Only those data for exposures in which the concentrations of SO_2 were in the range of those predicted to occur in the Hat Creek region by ERT modelling of the uncontrolled emissions[1], and in which the concentrations of SO_2 were in excess of those of NO_2, have been included. This latter criterion was adopted since the SO_2/NO_2 ratios predicted by ERT are 1:0.37 (local zone of impact) and 1:0.59 (regional zone of impact). Rationales for the calculation of these ratios have been presented by ERT elsewhere[2]. From Table F4-1 it can be seen that the effects, both acute and chronic, of simultaneous exposure to SO_2 and NO_2 range from zero to a many-fold increase in impact over that due to exposure to SO_2 alone. There are no examples of antagonism between the two gases, resulting in decreased impact. However, it should also be noted that some of the synergistic effects on acute injury reported in the published literature appear to be quite variable in magnitude and have not been confirmed by subsequent experimentation, as pointed out by Tingey *et al*[115]. Nevertheless, overall it appears that a reduction in the SO_2 threshold and an increase in injury over that caused by SO_2 alone is likely to be caused by concument exposures to both SO_2 and NO_2 , at concentrations relevant to Hat Creek. The greatest magnitude of these effects would on average appear to be a 25% reduction in SO_2 threshold and a 50% increase in impact for the most sensitive species and conditions. The former situation is that depicted in Figure F4-2 as the curve labelled, "Reduced Threshold in Presence of NO ". It should be noted that the specific NO_2 concentrations predicted for the Hat Creek region are considerably below the injury threshold for NO_2 alone. Thus NO_2 concentrations between 3.7 and 18.8 mg/m^3 are needed for acute injury to occur although physiological effects such as reduction in photosynthesis and reductions in yield may result from exposures as low as 940 μg/m^3 NO_2 However, the writer has observed stimulatory growth effects on the growth of beans, wheat and radish from daily exposures to 188 μg/m^3 for 3 hours extending over several weeks[115].

The only other combinations of gaseous pollutants which have been studied extensively are SO_2 and ozone. Reinert *et al* have reviewed these studies in detail[51] and conclude that the effects are mostly additive or synergistic, with a few cases of less than additive responses. In contrast, combinations of SO_2 and hydrogen floride have received scant attention. The only report of possible relevance to Hat Creek of which the author is aware is that of Mandl *et al*[52] who found that 7-day exposures of barley and sweet corn to 393 μg/m^3 SO_2 and 0.5 μg/m^3 HF yielded injury and symptoms indentical to those from SO alone. However, exposure to 217 μg/m^3 SO_2 and 0.6 μg/m^3 HF for 27 days showed a synergistic response, since the concentration of HF employed caused no injury when present alone. The emissions of gaseous florides predicted for the Hat Creek generating station are only one-thousandth of the emission of SO_2[1] . Although the evidence is scanty, there appears to be no reason to believe that the gaseous HF emissions from the Hat Creek generating station stack will dramatically influence the effects of SO_2 or SO_2/NO_2 emissions.

TABLE F4-1

EFFECTS OF SO_2/NO_2 COMBINATIONS ON PLANT INJURY

IN RELATION TO RESPONSE TO SO ALONE

Species	Conentration of SO_2/NO_2 ($\mu g/m^3$)	Duration of Exposure	Effect of (% Injury, of Reduction of Photosynthesis, PS, or Reduction of Growth, G)	SO Threshold ($\mu g/m^3$)	Reduction of Threshold (T) or Increase In Effect	Reference
Agropyron Smithii	1572/0	4	0	2000	-	115
	1572/188	4	3	<1572	-25% (T)	115
Artemisia frigida	1572/0	4	0	2000	-	115
	1572/188	4	0	2000	0	115
Avena sativa	655/94	4	3	1310	50%	46
	262/188	4	27	1310	>80%	46
	655/282	4	0	1310	0	46
	524/376	4	10	1310	>60%	46
	1965/1410	1	Threshold	2620	-25% (T)	47
Beta vulgaris	1965/1410	1	Threshold	2620	-25% (T)	47
Bouteloua gracilis	1572/0	4	0	1572	-	115
	1572/188	4	0	1572	0	115
Dactylis glomerata	178/0	20 wk	40 (G)	<178	-	117
	178/128	20 wk	78 (G)	<178	2-fold	117
Glycine max	131/94	4	2	1310	90%	46
	524/94	4	6	1310	60%	46
	655/94	4	7	1310	50%	46
	262/188	4	35	1310	>>80%	46
	655/282	4	1	1310	50%	46
	524/376	4	9	1310	60%	46
Koeleria cristata	2358/0	4	0	<2358	-	115
	2358/188	4	0	<2358	0	115
Lolium multiflorum	178/0	20 wk	5 (g)	178	-	117
	178/128	20 wk	52 (g)	178	10-fold	117

TABLE F-4 Continued

Species	Concentration of SO_2 / NO_2 (g/m)	Duration of Exposure (h)	Effect of (% Injury, of Reduction of Photosynthesis, PS, or Reduction of Growth, G)	SO_2 Threshold (g/m)	Reduction of Threshold (T) or Increase in Effect	Reference
Lycopersicon esculentum	655/94	4	1	1310	50%	46
	262/188	4	1	1310	80%	46
	655/282	4	0	1210	0	46
Medicago sativa	655/0	1	2-3 (PS)	629	-	48
	655/470	1	9 (PS)	629	3-4-fold	48
	917/0	1	8 (PS)	629	-	48
	917/564	1	16 (PS)	629	2-fold	48
	393/282	1	7 (PS)	629	-60% (T)	48
Nicotiana tabacum	262/188	4	26	1310	80%	46
	655/470	4	68	1310	50%	46
	1310/470	4	100	1310		46
Phaseolus vulgaris	262/188	4	11	1310	80%	46
	655/282	4	4	1310	50%	46
	524/376	4	16	1310	60%	46
Phleum pratense	178/0	20 wk	51 (G)	178	-	117
	178/128	20 wk	86 (G)	178	70%	117
Pisum sativum	1965/1410	1	Threshold	2620	-25% (T)	47
Poa pratensis	178/0	20 wk	46 (G)	178	-	117
Raphanus sativus	262/188	44	27	1310	80%	46
	655/282	4	4	1310	50%	46
	1310/940	1	Threshold	1965	33%	47
	1965/0	3	0.5	1965	-	47
	1965/1410	3	2.5	1965	5-fold	47
	1965/0	3	0.8	1965	-	47
	1965/1410	3	12.8	1965	15-fold	47

TABLE F4-1 Continued

Species	Concentration of SO_2 /NO_2 ($\mu g/m^3$)	Duration of Exposure	Effect of (% Injury, of Reduction of Photosynthesis, PS, or Reduction of Growth, G)	SO_2 Threshold (μg/m)	Reduction of Threshold (T) or Increase In Effect	Reference
Stipa comata	3144/0	4	0	3144	-	115
	3144/188	4	0	3144	0	115
Triticum aestivum	2358/0	4	1	2358	-	115
	2358/188	4	1	2358	0	115
7 species (unspecified ; desert vegetation)	1310-26200/ 263-5280	2	0	5240(?)	0	79

Mention has already been made in Section F4.4 of the role of elevated CO_2 levels in counteracting SO_2 induced stomatal opening of humidities between 40 and 60%. While such an effect might be expected to reduce the uptake of SO_2 where CO_2 is also present at higher than normal concentrations, and hence reduce the magnitude of impact, to the writer's knowledge there is only the single reference to the literature of SO_2 effects, *viz* Hou *et al*[92], which presents experimental evidence for a reduction in SO_2-induced injury, although several workers have speculated upon the potential "protection" offered by concomitant exposure to the elevated CO_2 concentrations [30, 106].

(g) Combined Effects of Gaseous and Other Pollutants

Little information is available about the interactions between gaseous air pollutants and other pollutants such as particulates in general, or heavy metals, aerosols, trace elements, etc. Krause and Kaiser[103] observed that exposure of lettuce, millet, radish and *Tagetes* to 210 $\mu g/m^3$ SO_2 for 28 days in the presence of dusts containing the oxides of cadmium, lead, copper and manganese resulted in enhancement of the injury caused by the heavy metals. While each of these elements is projected to be present in the particulate emissions from the Hat Creek generating station[1], the surface concentrations of oxides (1.3, 122, 10.2 and 18.2 µg, Cd, Pb, Cu and Mn respectively) used in these studies are several orders of magnitude higher than those expected to be deposited in either the local or regional zones of influence, based upon ERT predictions for deposition of particulates and trace elements[52] The author is unaware of any other studies of SO_2 and heavy metals, although heavy metal interactions with ozone have been reported[53, 54].

(h) Effects on Mixed Vegetation

While most investigations of the effects of air pollutants on plants have been concerned with the responses of individual species or cultivars, ecological impacts and effects on competition and succession are being increasingly studied. These studies range from synthetic, simple simulations of competition, frequently using species of agricultural importance, to analytical studies of ecological change, either *ex post facto* following the operation of an industrial enterprise or utility, or by field studies in which an anticipated pollution situation can be simulated on a small scale under field conditions.

The synthetic approach has been used by Guderian[55] and Bennett and Runeckles[56] to demonstrate that pollutants cause changes in interspecific competition. Sensitive species are progressively affected so that they lose ability to compete for environmental resources and eventually disappear. However, the more tolerant species may then exploit this lack of competition and become dominant, with the result that no overall loss in biomass occurs. However, changes in nutritional quality of the vegetation, for example as forage, may be significant, particularly where, leguminous species decline within a community[35].

However, it should also be pointed out that the rankings of susceptibility or tolerance of species based upon their growth in isolation may not indicate their performance under the combined stresses of an air pollutant and interspecific competition. Thus, the writer has observed that crimson clover (*Trifolium incarnatum*) survives in mixture with barley (*Hordeum vulgare*), flax (*Linum usitatissimum*) and radish (*Raphanus sativus*) under conditions of ozone exposure in which it is unable to survive alone, presumably because of the contribution of the other species to the overall plant canopy and the effects of canopy structure on the flux of the pollutant through the canopy[57].

Analytical studies of the effects of pollutants on natural vegetation communities are numerous and include reports of the ecological changes at Wawa[58] and Sudbury[59, 60], Ontario, and Anyox[61] and Trail[32, 40], British Columbia, to quote some Canadian examples. Other North American and European studies are described by Miller and McBride[62]. In all cases observations were made after several years' emissions of pollutants (usually SO_2, occasionally HF), leading to the identification of zones of injury, ranging in severity from complete denudation close to the source and downwind from it, through a transition zone with a few hardy survivors, a scrub zone, and a zone of dying trees, to a distant boundary zone of foliar effects. Distance from the source is generally reflected in increased species diversity, with species tolerant to the pollutant(s) becoming locally dominant[58]. In some instances, species which are of minor occurrence or significance emerge as dominants under severe pollutant stress. For example, the lichens *Lecanora conizaeoides, L. dispersa* and *Stereocaulon pileatum* are typically able to survive relatively high SO_2 concentrations and have moved and continued to spread into many urban locations in Europe and North America, although their occurrence in undisturbed habitats is extremely limited[63].

More recently, investigations have been undertaken prior to the start up of operations which will result in pollutant emissions. Such investigations start with "baseline" studies which are intended to provide a description of the existing ecology, in varying degrees of thoroughness, to act as a point of reference on which to base projections of impact. Such studies also frequently include attempts at simulating possible projected pollutant conditions in order to obtain locally relevant data on the effects on particular species for which no impact data are available or on indigenous species occurring in particular habitats and growingly subjected to the environmental conditions peculiar to the region in question. While several baseline studies have been undertaken with respect to proposed mining, smelting and energy generation and distribution developments, of particular relevance to the Hat Creek proposal are the studies being undertaken at Colstrip, Montana, funded by the U.S. Environmental Protection Agency. These have been reported on in progress reports for the years 1974[64], 1975[65], and 1976[118], and include investigations into the flora and fauna of the region, its soils and hydrology. In addition, some of the predominant plant species have been studied in the laboratory with respect to their sensitivity to SO_2[65,115]. Of particular interest are the studies using the Zonal Air Pollution System (ZAPS) in which SO_2 is released at different rates over 0.62 ha plots of native rangeland vegetation[67]. Under the natural conditions of dispersal of the gas released through ports at 3 m intervals along a tubing manifold supported 0.75 m above the ground, exposures to arithmetic mean SO_2 concentrations of 26, 71, 168 and 267 $\mu g/m^3$ were obtained over four plots during the 1976 growing season (April - October inclusive). In addition, the frequency distributions of 8-minute median concentrations were found to be lognormal, so that the geometric mean (GM) values and standard geometric deviations (SGD) have been used as a measurement of dose. The observed GM and SGD values fall within the ranges of values observed for several U.S. locations, with GM values of 29, 58, 102 and 170 $\mu g/m^3$ SO_2 for the four plots in 1976. Studies of the impact of these dosages on the dominant grass species, *Agropyron smithii* and *Koeleria cristata* and upon forbs and shrubs have been reported for the 1975, 1976 and part of the 1977 growing seasons by Dodd et al[68]. The studies to date have shown that there are considerable differences in response from year to year and from site to site. Thus, in 1975 and 1976, net production of the important grasses was inversely related to SO_2 concentration on one site (ZAPS I) but the pattern was not repeated in 1976 on another site (ZAPS II). In contrast, the forbs on ZAPS I appeared to be most productive in the high SO_2 plot in both 1975 and 1976, but the reverse was true for ZAPS II in 1976. Hence, on the basis of the existing data, no clear indications have emerged as to whether, under the field conditions of the study, the injurious or beneficial effects of SO_2 are predominating. Similarly, the below ground plant biomass dynamics show few consistent treatment effects, although rhizome biomass of the important grasses appears to have been reduced by SO_2 treatment over the years 1975, 1976 and 1977. On the other hand, significant reductions due to SO_2 treatment in the levels of crude protein in the major grasses occured over two years. A similar decrease in dry matter digestibility was observed, although no specific differences in crude cell wall constituents were observed. Furthermore, there was evidence from 1975 and 1976 that SO_2 fumigations stimulated leaf growth of *Agropyron smithii*, by increasing the number of leaves rather than their size. However, 1977 studies have shown that this appears to be related to increased rates of senescence induced by SO_2.

This increase in the growth of a grass in response to chronic SO_2 stress is similar to the author's findings with annual ryegrass[69] and winter wheat[57] under ozone stress, in which increased senescence occurs and leads to increased rates of top dry matter production, although root growth is impaired. In the case of perennial grasses such as *Agropyron smithii* and *Koeleria cristata*, any effect of increased senescence and "replacement" of aerial growth may divert assimilates away from storage in below-ground perennating organs such as rhizomes, and hence place the subsequent year's growth in jeopardy, with consequent shifts in competitive ability and ultimately in the distribution of species.

The results obtained from the ZAPS plots at Colstrip point out clearly the utmost importance to be placed upon continuing such studies over several seasons, in order to obtain unequivocal information about impact, partly in order to determine season-to-season variability in response, and partly in order to be able to determine long-term subtle effects on growth which may influence species survival and community composition.

F5.0 APPROACHES USED IN THE ASSESSMENT OF THE IMPACT OF AIRBORNE EMISSIONS ON VEGETATION IN THE HAT CREEK PROJECT AREA

This section provides descriptions of the approaches used in deriving quantitative assessments of the impact of airborne emissions on existing vegetation and possible agricultural crops in the Hat Creek region. It deals with emissions from the proposed generating station and cooling towers separately. It details the various data bases used, the computed data derived therefrom, and the assumptions made in interpreting the data.

F5.1 GENERATING STATION EMISSIONS

The local and regional impacts of airborne emissions from the generating station have been assessed for the three strategies: 366 m stack with FGD, 366 m stack with MCS, and 244 m stack with MCS (see Section F2.0). For each case, projected levels and frequencies of SO_2 concentrations, computed by ERT[1, 3] form the prime data base. The magnitudes of the impacts of these projected SO_2 concentrations have then been derived in the light of the various factors, environmental and temporal, discussed in Section F4.0 on plant response. Major emphasis has been placed upon the impact of SO_2, the predominant gaseous emission.

(a) Local Impact

The local impact of the generating station emissions covers the circular area of 25 km radius centred on the stack, close to Harry Lake. The ERT projections are presented as they relate to 128 receptor sites arranged radially in rows of eight along axes at 22.5^0 intervals around the stack. The individual sites are located 4 km from the stack and subsequently at 3 km intervals out to 25 km. The sites are numbered outwards from the stack commencing with the axis facing south, and thence in sequence in a clockwise direction (Figure F2-1, at end of report). The factors related to the locations of the individiual receptor sites, to the extent and nature of the vegetational cover present around each site, and to the vegetational response itself are dealt with separately in the following sections.

(i) Factors Related to ERT Receptor Sites

The impact of projected ambient SO_2 concentrations is dependent upon certain site-related factors. The ERT projections are site-specific, and relate to a particular elevation and location. The actual vegetational area which is "summarized" in a single receptor site increases in size as one progresses outwards from the stack. For purposes of assessing impact, each receptor site has been assumed to be located at the centre of an annual region extending 1.5 km along the radial axis in either direction, and occupying 22.5^{0} arc. The areas of the annualar sectors and the distances of their central receptor sites from the stack are summarized in Table F5-1.

Since the topography of the Hat Creek region is highly variable, the elevational ranges within each vegetational annular sector have been noted and related to that selected by ERT for each receptor site. As would be expected, the greatest ranges in elevation and the greatest difference from the ERT receptor site elevation occur in the outmost annular sectors. Elevation partly dictates vegetation association through its influence on climatic factors such as mean temperature and length of frost-free season. In general, vegetation growing at the highest elevations will be dormant for a greater part of the year than that at lower elevations, and hence is expected to be less affected in the spring and fall by elevated SO_2 levels. However, it may be affected in the spring by deposition of SO_2 occurring during the winter months.

A further site-related factor is the mixing depth used in the ERT modelling. This has a relationship to possible impact in that it provides an indication of the range of elevations around that of a given receptor site within which a projected concentration might be expected to occur as a result of simple transport from the stack.

TABLE F5-1

AREAS OF ANNULAR SECTORS
COVERED BY VEGETATIONAL ANALYSIS
IN RELATION TO DISTANCE FROM STACK SITE

Distance of Receptor Sites (km)	Receptor Site Nos.*	Area of Annular Sector (km^2)
4	1,9,17,25,33,41,49,57,65, 73,81,89,97,105,113,121	4.7
7	2,10,18,26,34,42,50,58,66, 74,82,90,98,106,114,122	8.2
10	3,11,19,27,35,43,51,59,67, 75,83,91,99,107,115,123	11.8
13	4,12,20,28,36,44,52,60,68, 76,84,92,100,108,116,124	15.3
16	5,13,21,29,37,45,53,61,69, 77,85,93,101,109,117,125	18.8
19	6,14,22,30,38,46,54,62,70, 78,86,94,102,110,118,126	22.4
22	7,15,23,31,39,47,55,63,71, 79,87,95,103,111,119,127	25.9
25	8,16,24,32,40,48,56,64,72, 80,88,96,104,112,120,128	29.4

*As used in ERT Peak Programme. Sites 1 to 8 are arranged in a line due south of the stack. Sites 9 to 16 lie in south south-west direction. The subsequent lines of sites are arranged clockwise at 22.5^0 angles coincident with the remaining 14 compass points.

(ii) Extent of Vegetational Cover

Within each annular sector, the extent of individual vegetation associations was estimated from the 1:50,000 vegetation cover maps of the local zone of impact prepared by The TERA Environmental Resource Analyst Limited. The associations used for this assessment are coded as shown in Table F5-2. The estimates of associations per annular sector are presented in Table F5-3. It should be noted that the TERA mapping does not extend throughout the sectors associated with receptor sites 7, 8, 16, 24, 31, 32, 39, 40 47, 48, 56, 64, 71, 72, 80, 95, 96, 103, 104, 112 and 128. The association composition of these sectors was therefore assumed to be the same as a neighbouring sector, as indicated in Table F5-3. The basis for selection of an appropriate sector for this purpose was largely topographic.

From the estimates of the vegetation associations present in the annular sectors, further estimates of the cover contributed by individual species were made, using the cover data provided by Tera Consultants Ltd. Vegetation Tables based upon vegetation plots in the area. The actual cover for each species for which the mean cover per association exceeded 1 percent was calculated for each association present within an annual sector, and summed to give the total cover provided by these species within the sector. These estimates of cover are presented in Addendum A, and in the individual tables for each receptor site's estimated impact.

An assessment of impact has been provided for all species which were estimated to comprise at least 0.1 km of cover within a potentially impacted sector and for which impact data are available in the literature. No impact data are available for the majority of the plant species which may be exposed to SO_2 and NO_2 emissions from the Hat Creek powerplant. Species which are deemed to be significant were also included in the injury assessment tables in order to draw attention to important data gaps. Species deemed significant were:

(a) All tree species,

TABLE F5-2

VEGETATION ASSOCIATIONS AND CODES

	Association	Code
Alpine:		
	Mountain Avens - Sedge	A
Grassland:		
	Highland Grassland (>1830 m)	B
Engelmann Spruce - Subalpine Fir:		
	Engelmann Spruce - Grouseberry	C
	Engelmann Spruce - Grouseberry - Pinegrass	D
	Engelmann Spruce - Grouseberry - White Rhododendron	E
	Engelmann Spruce - Willow - Red Heather Parkland	F
	Engelmann Spruce - Grouseberry - Lupines	G
Interior Douglas-fir:		
	Douglas-fir - Pinegrass	H
	Douglas-fir - Bunchgrass	J
	Douglas-fir - Spiraea - Bearberry	K
	Douglas-fir - Bunchgrass - Pinegrass	M
Ponderosa Pine:		
	Ponderosa Pine - Bunchgrass	N
Intrazonal:		
	Riparian	P
	Engelmann Spruce - Horsetail	Q
Grassland:		
	Saline Depression	S
	Kentucky Bluegrass	U
	Big Sage - Bunchgrass	V
Intrazonal:		
	Willow - Sedge Bog	W
Grassland:		
	Bunchgrass - Kentucky Bluegrass	X
	Sagebrush - Bluebunch Wheatgrass	Y
Other:		
	Rock	R
	Cultivated Fields	T

TABLE F5-3

ESTIMATES OF EXTENT OF VEGETATION ASSOCIATIONS OCCURING WITHIN ANNULAR SECTORS RELATED TO RECEPTOR SITES (Percentages of area)

Receptor Site No.	Vegetation Association (%)
1	B: 10: D: 20; H: 45; U: 15
2	B: 5; D: 40; H: 40; U: 15
3	D: 40; H: 35; W: 5; X: 15
4	D: 55; H: 20; M: 5; U: 10; W: 5; X: 5
5	D: 25; H: 45; M: 15; T: 3; U: 5; W: 5; X: 2
6	B: 1; D: 40; H: 29; K/M: 20; W: 5; X: 5
7	(Assumed to be the same as site 15)
8	(Assumed to be the same as site 15)
9	H: 13; M: 35; U: 50; X: 2
10	H: 5; M: 10; Q: 2; S: 3; U: 30; X: 50
11	H: 5; M: 15; T: 10; X/S: 15; X: 55
12	H: 20; M: 5; T: 25; X/S: 20; X: 30
13	C: 10; D: 15; G: 4; H: 25; M: 3; T: 15; U:2 W: 1; X/S: 20; X: 5
14	C: 20; D: 20; G: 20; H: 20; T: 10; X/S: 5; X: 5
15	A/B: 25; C: 17; D: 20; F: 5; G: 20; H: 10; R: 3
16	(Assumed to be the same as site 15)
17	M: 60; P: 3; T: 10; U: 15; X: 10; Y: 2
18	H: 5; M: 15; P: 3; T: 3; X/S: 40; X: 30; Y: 4
19	D: 8; H: 45; P: 2; T: 5; X/S: 40
20	C: 15; D: 50; H: 30; T: 3; W: 2
21	B: 5; C: 48; D: 15; F: 19; G: 10; R: 2; W: 1
22	A/B: 35; C: 38; F: 10; G: 10; H: 5; W: 2
23	A/B: 15; C: 40; F: 8; G: 20; H: 15; R: 1; U: 1
24	(Assumed to be the same as site 23)
25	J: 8; M: 35; P: 5; T: 2; U: 20; X: 15; Y: 15
26	H: 38; J: 15; U: 2; X/S: 25; Y: 20
27	C: 5; D: 40; H: 45; H/M: 8; W: 2
28	B: 10; C: 40; D: 5; G: 20; H/M: 20; W: 5
29	A/B: 20; C: 15; F: 35; G: 20; R: 5; W: 5
30	B: 10; C: 40; G: 15; H: 25; R: 5; U: 5
31	(Assumed to be the same as site 23)
32	(Assumed to be the same as site 23)

TABLE F5-3 (Continued)

33	J: 5; M: 60; U: 20; Y: 15
34	H: 40; J: 10; M: 10; U: 15; Y: 25
35	D: 45; H: 55
36	C: 70; D: 17; R: 3; W: 10
37	B: 10; C: 70; H: 10; M: 5; W: 5
38	C: 25; H: 25; K/M: 25; M: 25
39	(Assumed to be the same as site 31)
40	(Assumed to be the same as site 31)
41	M: 70; P: 10; U: 20
42	H: 30; J/K: 40; K/M: 25; R: 5
43	C: 15; H: 70; J: 5; R: 5; X: 5
44	C: 45; H: 10; K/J: 20; K/T: 5; R: 10; W: 5; X: 5
45	B: 3; C: 45; H: 34; J: 8; K/T: 6; R: 3; X: 1
46	B: 5; C: 35; H: 45; J: 15
47	(Assumed to be the same as site 46)
48	(Assumed to be the same as site 31)
49	H: 50; J: 15; P: 30; U: 5
50	H: 35; J: 30; M: 5; Q: 20
51	E: 10; H: 80; R: 5; W: 5
52	C: 5; E: 45; H: 30; K/T: 5; M: 10; W: 5
53	C: 30; D: 15; E: 20; J: 15; K/J: 10; K/T: 3; R: 2; W: 5
54	C: 15; D: 15; G: 5; H: 20; J: 25; Q: 5; R: 5; X: 5; Y: 5
55	B: 3; C: 20; H: 10; J: 20; M: 5; P: 2; R: 5; T: 12; U: 20; X: 2; Y: 1
56	(Assumed to be the same as site 55)
57	H: 80; J: 5; P: 5; U: 10
58	J: 80; P: 10; U: 10
59	H: 90; Q: 3; R: 2; U: 5
60	E: 8; H: 85; W: 2
61	E: 80; H: 15; R: 5
62	C: 5; D: 10; E: 60; G: 5; M: 15; R: 5
63	C: 12; D: 10; E: 60; G: 10; W: 3
64	(Assumed to be the same as site 63)

TABLE F5-3 (Continued)

65	H: 60; M: 20; U: 20
66	H: 45; J: 20; M: 15; U: 20
67	H: 80; J: 10; P/U: 10
68	H: 80; J: 15; M: 5
69	E: 9; H: 85; Q: 15; W: 1
70	H: 70; M: 28; U: 2
71	(Assumed to be the same as site 70)
72	(Assumed to be the same as site 70)
73	H: 100
74	H: 85; M: 10; U: 5
75	H: 95; U: 5
76	H: 10; J: 70; M: 5; U/P: 15
77	H: 20; J: 35; M: 20; T: 5; U: 5; V: 15
78	H: 30; M: 25; N: 5; T: 5; U: 5; V: 30
79	H: 35; J/K: 10; M: 20; P: 5; V: 25; X: 5
80	(Assumed to be the same as site 79)
81	D: 90; H: 10
82	H: 95; Q: 5
83	H: 90; V: 5; X: 5
84	H: 20; N: 15; P: 8; T: 15; U: 2; V: 35; X: 5
85	H: 30; J/K: 5; M: 25; N: 15; T: 10; V: 15
86	C: 10; D: 25; H: 40; M: 20; N: 5
87	D: 50; H: 45; Q: 3; W: 2
88	D: 55; H: 43; W: 2
89	D: 100
90	D: 3; H: 70; U: 25; W: 2
91	H: 85; P: 2; U: 8; V: 5
92	H: 10; M: 5; N: 5; T: 10; V: 68; X: 2
93	M: 45; N: 3; P: 5; T: 5; V: 40; X: 2
94	C: 8; D: 20; H: 10; J: 20; M: 15; P: 5; V: 20; X: 2
95	(Assumed to be the same as site 94)
96	(Assumed to be the same as site 94)
97	H: 90; U: 10
98	H: 85; U: 15
99	H: 80; U: 20
100	H: 60; N: 5; U: 5; V: 30
101	P: 3; T: 17; V: 80
102	T: 10; V: 90
103	(Assumed to be the same as site 102)
104	(Assumed to be the same as site 102)

TABLE F5-3 (Continued)

105	H: 80; U: 20
106	D: 50; H: 50
107	D: 30; H: 50; M: 20
108	H: 10; M: 75; U: 5; V: 10
109	M: 2; T: 18; V: 80
110	T: 20; V: 70; Townsite: 10
111	(Assumed to be the same as site 119)
112	(Assumed to be the same as site 119)
113	D: 60; H: 40
114	C: 5; D: 95
115	D: 75; H: 5; M: 20
116	M: 60; T: 5; V: 35
117	M: 10; S: 2; T: 8; V: 80
118	M: 20; N: 10; S: 5; T: 10; V: 55
119	M: 5; N: 5; T: 10; V: 80
120	M: 15; N: 20; R: 5; V: 60
121	B: 5; D: 60; H: 30; U: 5
122	B: 10; D: 90
123	B: 15; D: 65; F: 10; G: 10
124	B: 20; D: 15; G: 5; H: 25; M: 30; U: 5
125	H: 30; M: 50; T: 5; U: 5; V: 5; X: 5
126	B: 10; C: 5; D: 35; H: 25; M: 20; X: 5
127	D: 40; H: 25; M: 20; V: 5; X: 10
128	(Assumed to be the same as site 127)

(b) Major ecosystem components. The value of 0.5 km of cover was arbitrarily selected as the cut-off value. This value corresponds to 10.6 percent of smallest sectors and 1.7 percent of the largest sectors.

(c) Species which are of particular importance to wildlife or livestock grazing.

Because of the dearth of impact data on the majority of the shrubs, gramin-aceous and herbaceous species, lichens and mosses, many of the species present are therefore not included in the assessment. Information on the cover provided by these species is, however, presented separately by receptor site in order to provide a complete picture of the nature of the cover present. In addition, the information provides a useful indication of those species deserving attention with regard to future studies of impact.

(iii) Factors Related to Vegetational Response

In addition to factors related to receptor sites and their associated vegeta-tion, the numerous factors which influence plant response and have been described in Section 4.0 have to be incorporated into the overall assessment of impact. The various weighting factors used in these incorporations are described later in this section. However, one group of factors related to the timing of exposures to SO_2 within the year, within the day, and within the daylight hours, and the sequences of concentrations experienced at any given receptor site, are of particular significance with regard to the assessment of impact, as described above in Section F4.5. Accordingly, an initial detailed inspection was made of the PEAK programme data provided by ERT for the 366 m uncontrolled stack, as described below.

A. Analysis of ERT PEAK Programme Data for Uncontrolled Base-Load 366 m Stack Emissions of SO_2

The PEAK programme SO_2 data provided by ERT for the uncontrolled 366 m stack with the generating station operating under base-load conditions comprised three sets: excursions above 450 $\mu g/m^3$ for 1-hour; excursions above 633 $\mu g/m^3$ averaged over 3 hours; and excursions above 260 $\mu g/m^3$ averaged over 24 hours. In the case of the latter two averages it should be noted that these are averages for defined 3-hour and 24-hour intervals, i.e. 3-hour averages commencing at hours 1, 4, 7, 10, 13, 16, 19 and 22, and 24-hour averages commencing at hour 1. In other words, they do not necessarily inlcude the highest average levels reached over all 3-hour and 24-hour averaging periods throughout the year.

The importance to injury assessment of SO_2 concentration, duration of exposure, interval between exposures, time of day of exposure, and time of year of exposure, has been described above. In order to determine the overall pattern of exposures, the 1-hour PEAK data for selected sites was studied in detail. As an example of the pattern of exposures predicted, Figure F5-1 shows the data for Receptor Site 14 for the period April 1 to October 31. This period was selected as being the average growing season for the local region (see section F5.1(a)(iii)B, below). With the cut-off at 450 $\mu g/m^3$ SO_2, no data are available for many of the days within the growing season, although it is probable that on many occasions SO_2 levels greater than zero would have occurred. Nevertheless, the figure provides a visual image of the types of exposure possible. For example, on days 96 and 97, the only excursions were during the night; on day 116, the single excursion occurred shortly after daybreak; and on day 223, there were fumigations lasting several hours in the morning and the evening, followed two days later by a similar pattern; on several other occasions there were isolated 1-hour peaks.

It should be borne in mind that this example is taken from the uncontrolled stack PEAK programme and is presented merely to demonstrate the somewhat random nature of occurrence of peak SO_2 concentrations. While it should also be understood that the uncontrolled stack data are of largely academic interest since, in operation, the Hat Creek Generating Station would be operated with controls at least to ensure compliance with a maximum 3-hour

SO_2 average concentration objective of 655 $\mu g/m^3$, these data were the only ones available in the early stages of impact assessment, and hence were used to develop methodology. Thus the frequency isopleths presented by ERT at a scale of 1:250,000 were found to provide too general an overview of the ambient SO_2 picture throughout the year. In order to assess the actual impact of SO_2 concentrations and frequencies, it is necessary to relate isopleths to the locations of specific sites and their associated vegetation. The combination of maps showing isopleths of peak concentrations and isopleths of frequencies was found to provide more useful information than one based on frequency isopleths of excursions above several thresholds. Hence the PEAK programme data was used to prepare detailed maps of both frequences of excursions above a single selected threshold, and the maximum average concentrations attained both throughout the year and within the growing season, for each averaging time. Examples of such maps are presented later in this report, in the sections dealing with each of the three alternative control stragegies. (Section F6-1, F6-2 and F6-3).

The detailed studies of the uncontrolled stack data led to the identification of those sites areound which the vegetational impact was likely to be greatest. These observations were then used as the basis for selecting the sites which were subjected to further analysis with regard to time of day of peak occurrence, as depicted for site 14 in Figure F5-1. This analysis[70] revealed that of a total of 620 excursions greater than 450 $\mu g/m^3$ SO_2 which occurred at the 12 most affected sites, 58.1 percent occurred between one hour after sunrise and the hour of sunset. Furthermore, the peak concentrations reached during daylight hours averaged 88.9 percent of the maxima predicted for the days in question. Of the daylight maxima, 20 percent occurred in the hours immediately following sunrise, at which time they would be expected to exercise a maximum effect (see Section F4.5 (b)).

The data for site 14 depicted in Figure F5-1 fall within these overall relationships. Thus, while daytime peaks occurred on 18 out of a total of 23 days on which peaks occurred within the growing season, only 43 of a total of 69 1-hour excursions occurred during daylight hours (62 percent).

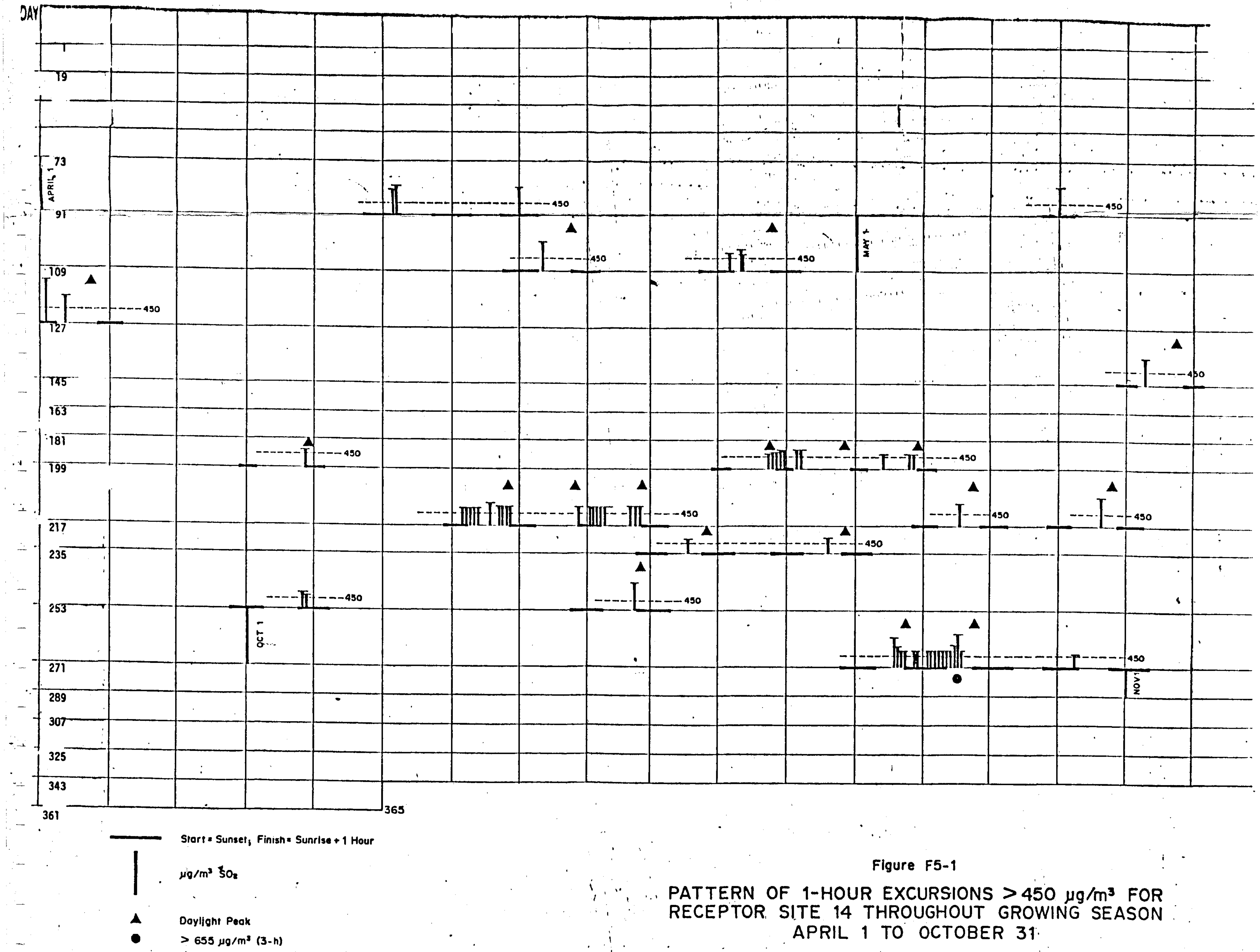


Figure F5-1

PATTERN OF 1-HOUR EXCURSIONS > 450 µg/m³ FOR RECEPTOR SITE 14 THROUGHOUT GROWING SEASON APRIL 1 TO OCTOBER 31

Although the data subjected to this analysis all related to the uncontrolled stack emissions, perusal of the comparable PEAK programmes for the various control strategies indicated that similar relationships between peak occurrences and time of day occurred in those cases (see Sections F6.1, F6.2 and F6.3).

B. Weighting Factors Used in Assessing Vegetational Impact

The final assessment of impact of emissions from the proposed Hat Creek generating station has been made in the light of currently available information on the response of individual species to specific emissions, particularly SO_2 and NO_2, and current knowledge of the variables which influence these reponses, described above in Section F4.0.

With regard to the dose-response of individual species, original data were compiled wherever available for those species occurring within the vegetation of the Hat Creek area. However, exhaustive searches of the literature failed to reveal dose-response data for the majority of the species present including some of major importance. In some cases, the only information available appears to be subjective, and in the form of rankings of sensitivity[21], which while of general use, provide no basis for a quantitative assessment of impact. In a few cases, data from different sources yielded widely different dose-response information for a given species. In these cases, detailed perusal of the original reports occasionally yielded clues as to the reasons for the disparity; as a result judgment was used to determine which data would be most applicable to the Hat Creek situation. In some cases, where experimental details as to how the dose-response data were obtained were lacking, these data were discounted. In most cases where relevant data exist, it should be borne in mind that the data were probably obtained in laboratory rather than field situations, and that there is considerable likelihood that the plants studied were in a more susceptible state than would be in the case of nature.

In the case of the important tree species present in the Hat Creek area, dose-response information was generated by extrapolation from the few isolated data in the literature for individual species, together with the subjective observations of numerous workers as to the relative susceptibilities of these and other species to SO_2. These subjective assessments are summarized as follows) ranked in order of increasing tolerance):

Pinus strobus = *P. ponderosa*[71]

P. strobus = *P. ponderosa* = *Pseudotsuga menziesii* < *Pinus contorta*[72]

Abies lasiocarpa < *Ps. menziesii* < *P. contorta* < *Picea engelmanni* < *P. ponderosa*[40]

A. lasiocarpa < *Ps. menziesii* < *P. monticola* < *P. ponderosa* < *P. contorta* < *P. engelmannii*[40]

Ps. menziesii < *P. ponderosa* < *P. engelmannii* < *P. monticola* < *P. contorta*

Ps. menziesii < *P. ponderosa* < *P. strobus* < *P. contorta*[34]

P. strobus = *P. resinosa* = *P. bankisana* < *Ps. menziesii* = *P. contorta* = *P. ponderosa* = *P. monticola* = *P. engelmannii*[21]

The three pines, *P. strobus, P. resinosa and P. banksiana* described as "sensitive" by Davis and Wilhour[21] were included in the dose-response data obtained under field conditions by Dreisinger and McGovern[60], as follows:

Maximum average concentrations ($\mu g/m^3$) of SO_2 causing 10 percent injury

	1h	2h	4h	8h
P. strobus	1179	917	655	880
P. resionosa	2043	1809	1153	786
P. banksiana	1362	1153	760	524
Mean	1528	1293	856	620

Treshow reports that young *Pseudotsuga menziesii* trees were marked by 2040 $\mu g/m^3$ SO_2 in 8 h. All of these data were interrelated by assigning the following numerical values of tolerance relative to *Ps. menziesii:*

P. bankisana, P. strobus, P. resinosa:	0.3
A. lasiocarpa:	0.8
Ps. menziesii:	1.0
P. contorta, P. ponderosa, P. engelmannii:	1.2

Dose-response data for *A. lasiocarpa, Ps. menziesii, P. contorta, P. ponderosa* and *P. engelmanni* were then generated by proportion to the mean data for the sensitive pine species (*P. strobus, P. resinosa,* and *P. banksiana)* and to the 8-h datum for *Ps. menziesii.*

This procedure admittedly provides only a best estimate of the dose-response characteristics of the important tree species, but is considered to be justified on the basis of the numerous subjective reports of relative susceptibilities and the desirability of providing a quantitative assessment for these species. However, for no other types of vegetation are there such extensive subjective assessments, and hence the procedure has not been applied to other species.

Where dose-response data are available for individual species, the assessment of response has been based upon considerations of the following modifying factors:

(1) Where tree and shrub-layers are dominant within an association, the impact on the lower vegetation has been reduced because of the likelihood of their exposure to concentrations less than those predicted as a consequence of deposition in the upper storeys[23, 24]

(2) Enhanced impact has been attributed to exposures occurring during the early hours of daylight;

(3) Enchanced impact on exposed species has been assumed relative to data generated in laboratory or chamber experiments in which low wind velocities were employed[20], except where the species are protected by upper stories of vegetation;

(4) In general, species have been assumed to be less sensitive when growing under natural conditions in the field than when grown in growth chambers and greenhouses[19];

(5) Increased growth has been assessed where sequential exposures have been predicted to occur, or where several peaks occur within a single daylight period, regardless of whether they are consecutive or intermittent;

(6) Impact of SO_2 has been considered to be enhanced 50 percent and thresholds have been considered to be reduced 25 percent by the simultaneous fumigation with NO_2 at SO_2/NO_2 ratios expected for the Hat Creek generating station emissions (see Table F4-1). As pointed out in the discussion of Table F4-1, there is some controversy as to the magnitude of the effects of adding NO to SO fumigations, and some reported observations have not been repeatable. On the other hand, other reports or additive or synergistic effects appear to be both unquestionable and dramatic.

(7) Impact of SO_2 has been considered to be reduced by the concomitant presence of elevated levels of CO_2. Since there appears to be no information available as to the combined effects of SO_2 and CO_2 on tree and shrub species, and in the light of the relatively low levels of CO_2 enrichment likely to occur (see Section F4.4), a 25% reduction of impact has been used for such species. On the other hand a 50% reduction has been applied to assessments of impact on graminaceous and herbaceous species. Such reductions are admittedly conservative in light of reports of "protections" against SO to alfalfa[92] and broad bean[106] but appear to be realistic in the light of scanty data available on the subject, and the general view that changes in ambient CO_2 concentration greater than 50 ppm are necessary to cause significant changes in stomatal aperature[119]. From the data presented on p. F4-12, it can been seen that such changes in CO_2 concentration will only be exceeded in conjunction with SO_2 levels greater than 655 $\mu g/m^3$.

(8) Impact on tree and shrub species has been assumed to be increased 25% because of the likelihood of injury resulting from the deposition

of SO_2 during the winter months (outside the growing season). In the table of impact assessment presented later in this report, the greatest emphasis has been placed on exposures April 1 - October 31 growing season (the period over which the mean monthly temperature in Hat Creek is above ^oC). However, the limited data available[112] require that an adjustment be made for winter deposition.

One of these modifying factors (SO_2/NO_2 interaction) has been incorporated directly into the tables of sensitivities of individiual species to airborne emissions presented below in Section F5.3. Two others (CO_2 and winter deposition) have been incorporated directly into the cumulative dose-response curves used to estimate injury, presented below in Section F5.4.

In addition to the above factors, several other considerations have been borne in mind with regard to the quantitative assessment of injury. Firstly, the ERT modelling[2] is described as probably being accurate to a factor of 2, Furthermore, the database used by ERT is limited to a single calendar year. The year-to-year and season-to-season variations in the meteorology of the Hat Creek area, which undoubtedly occur, will add another level of uncertainty as to the precise ground level SO_2 concentrations which may occur. However, the conservatism already built into the ERT modelling suggests that its use, coupled with the various weighting factors described above, will lead to fair assessments of the most probable impacts of the emissions from the Hat Creek generating station for the three control strategies proposed. The use of "average" and "worst" case situations is frequently adopted in impact assessment studies[74] in order to accommodate uncertainties in the modelling procedures used. However the present context, if a "worst" case exists, it is unlikely to lead to impacts more than about 10% greater than the average case because of the randomness with which the modelling errors would be distributed.

Perhaps the greatest uncertainties of all, however, relate to the long-term effects of fumigations occurring season after season. It has already been pointed out on several occasions that the data available in the literature regarding long-term chronic injury responses are even scarcer than those dealing with short-term acute responses. And yet such long-term chronic responses undoubtedly occur. Indeed examples are cited in various reviews[9, 31, 80], and specific reference has been made to Linzon's study of *Pinus strobus* in the Sudbury region[42]. In addition such effects on trees, and other perennial species, for example the grasses, may show little visible signs of injury or reduction in yield in the short term, but reduction of photosynthesis (whether by loss of photosynthetic tissue through necrosis, or by impairment of the photosynthetic process) may lead to serious reduction in the amounts of assimilates stored in the roots and crowns, which in turn may lead to progressive declines in productivity over the years, if not the death of individual plants with inadequate reserves for overwintering. Data relevant to such effects are expected to come from the ZAPS plots in the EPA Colstrip study, to date, the study has not progressed far enough to draw any clear conclusions[68].

Because of the additional uncertainties related to long-term effects, the estimation of chronic injury is more difficult than the estimation of injury of the acute type. Nevertheless, the assessments presented later in this report have attempted to recognize the impacts of both types of response.

(b) Regional Impact

The regional impact of the generating station emissions covers an area bounded by a 100 km radius centered on the stack. ERT projections[1] of ground-level concentrations of SO_2, NO, NO_2 and particulates within the regional area beyond the local zone of impact are extremely low except in close proximity to the edge of the local model in certain directions. For example, for the most part SO_2 levels are in the range 0.5 to 2.0 $\mu g/m^3$ from the uncontrolled 366 m stack, which is well below the level likely to induce injury in any species. Furthermore, the other present or proposed sources of SO_2 emissions within the region have been suggested as giving rise to regional SO_2 levels 1.5 to 2.0 times greater than those emanating from the Hat Creek generation station[1]. However, the combined emissions of SO_2 are still extremely low and no impact on vegetation is likely. Indeed, it is possible that the ground-level SO_2 concentrations predicted could be generally mildly advantageous to the regional vegetation as a source of nutrient sulfur.

However, while the low ambient concentrations of SO_2 predicted for the region should not give rise to any direct injury to vegetation, indirect effects are possible, particularly following long range oxidation to SO_2 and the possible effect which either form of oxide would have on the pH of rainwater, i.e. the occurence of acid rain. NO_2 in the gaseous emissions would also contribute to the acidification of rain. The impact of acid rain on vegetation in general has been reviewed elsewhere[75]. In the Hat Creek context, calculated rainfall acidities ranged fom pH 3.7 to 5.5, depending upon the specific assumptions made with regard to buffering capacity of neutralization by NH_3[75]. However, pH values less than 4.3 appear to be extremely unlikely. Such values are at or above the threshold for direct injury to most vegetation, even the most susceptible pines[76], and are greater than those which significantly modify plant host-parasite relations[77]. Hence it appears that no directly injurious effects on vegetation will occur.

F5.2 COOLING TOWER EMISSIONS

The cooling towers associated with the generating station will utilize water from the Thompson River. Evaporative cooling in such towers inevitably results in the entrainment of droplets of cooling water containing dissolved solids, particularly salts, in the stream of air and water vapour which they emit. Condensation of this water results in visible plumes, containing saline aerosols whose chemical composition reflects that of the cooling water used and whose deposition occurs around the site of the cooling towers. ERT has provided an assessment of the atmospheric effects and deposition isopleths for four alternative cooling tower designs[3]. The projected maxmimum deposition rates are:[3]

Four round mechanical draft towers:	51,400 $kg/km^2/year$;
Four rectangular mechanical draft towers:	24,150 $kg/km^2/year$;
Two natural draft towers:	4,717 $kg/km^2/year$;
Four natural draft towers:	8,760 $kg/km^2/year$.

In all cases the deposition rate drops to 560 $kg/km^2/year$ within 3 km of the towers.

McCune *et al*[78] have studied the effects of saline aerosols on a range of plant species. The aerosols which they used consisted 47.9 percent of chloride ion, in comparison with the 6 percent chloride content of the Thompson River water. This wide discrepancy makes precise assessment impossible since there is no information offered as to the particular sensitivities of the species tested to specific ions within the aerosol. However, the range of susceptibilities includes "sensitive" species such as hemlock (injured by 6 hours' treatment with deposition rate equivalent to 636 $kg/km^2/year$) and "resistant" species such as witchhazel (injured by 6 hours treatment with a deposition rate equivalent to 46,500 $kg/km^2/year$). Curtis[120] recently reported the results of several years' studies of simulated cooling tower aerosol deposition on a range of plant species. He concluded that the effects were negligible.

This range of responses to such long and short term exposures makes it unlikely that many species of vegetation in the Hat Creek region will be adversely affected by aerosol deposition occurring throughout the year, regardless of the choice of cooling towers. However, within a distance of approximately 1 km from the towers, some injury to some species may occur as a consequence of continued deposition. The quantitative assessment of such injury is not possible in the absence of specific information as to the effects of the particular mixture of salts typical of Thompson River water, applied to vegetation in aerosol form. Indeed, the presence of sulfate and calcium as two of the major ions may be of some nutritional benefit.

It should also be noted that, because of the water vapour content of the plumes from the cooling towers, impact on elevated terrain such as Cornwall Peak will result in conditions in local high humidity. If the impingement of the cooling tower plume coincides with that of the generating station stack, the locally high humidity will increase the probable impact of SO_2/NO_2 in the latter's emissions, through the effect of humidity on stomatal aperature[30].

F5.3 SENSITIVITIES OF INDIVIDUAL SPECIES TO AIRBORNE EMISSIONS

The quantitative assessment of impact on vegetation of the airborne emissions from the proposed Hat Creek project is finally based on consideration of the responses of individual species to the predicted dosages of the different components of the emissions, in the light of the various factors which modify response and which have been weighted accordingly, as described in Section F5.1. Because the dose-response of individual species is a major component of the assessment, the injury responses of individual species to ambient SO_2 concentrations relevant to the Hat Creek situation, as modified by NO_2 CO_2 and winter deposition, have been tabulated and are presented in Tables F5-4 and F5-9. Those species of particular importance to forestry, agriculture, rangeland and wildlife use and of ethnobotanical interest have been included in these tables, although perusal will reveal that data are lacking for over 60% of these species, including several highly important species, e.g. the primary range grass, *Agropyron spicatum* (bluebunch wheatgrass). Because the major impact on vegetation is likely to be caused by the SO_2/NO interaction, the tables are confined to responses to these pollutants. The predicted concentrations of NO_2 are in themselves below the threshold for injury, as discussed previously in Section F4.5(f). The same is true for gaseous fluoride emissions, at least as regards short-term effects.

Based upon a 1.60×10^{-3} ratio of gaseous fluoride to SO_2 emissions , the range of fluoride concentrations (as HF) corresponding to various SO_2 levels is as follows:

$\mu g/m^3$ HF:	1.59	1.27	1.06	0.85	0.64	0.42	0.21	0.11	0.05
$\mu g/m^3$ SO_2:	1500	1200	1000	800	600	400	200	100	50

Exposures to levels such as 0.4 and 1.5 g/m^3 HF for over 65 days are necessary for injury to occur on *Pinus ponderosa*[97] and *Pseudotsuga menziesii*[98] respectively, while 16 days of exposure to 0.6 g/m^3 HF were required to injure the sensitive tulip cultivar Paris[35]. No short-term dosages of this magnitude are predicted in the Hat Creek region. However, since fluorides

TABLE F5-4

SENSITIVITIES OF TREE SPECIES TO SO_2 IN THE PRESENCE OF NO_2 (SO_2/NO_2 RATIO 3:1) *CONCENTRATIONS LISTED ARE NECESSARY TO INDUCE 1 - 10% FOLIAR INJURY FOLLOWING* SINGLE EXPOSURES FOR THE TIMES INDICATED

Species	Concentration ($\mu g/m^3$) of SO_2 for					Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	
*Abies lasiocarpa***	(3020)	(2560)	(2100)	(1690)	(1230)	
Abies lasiocarpa	-	<19650	-	-	-	Reference *79*
Alnus rubra	-	-	-	-	-	No information
*Picea engelmannii***	(4530)	(3840)	(3050)	(2540)	(1840)	
Pinus albicaulis	-	-	-	-	-	No information
*Pinus contorta***	(4530)	(3840)	(3050)	(2540)	(1840)	
*Pinus ponderosa***	(4530)	(3840)	(3050)	(2540)	(1840)	
Pinus ponderosa	-	<19650	-	-	-	Reference *79*
*Pseudotsuga menziesii***	(3780)	(3200)	(2600)	(2120)	(1530)	
Populus tremuloides	825	770	(683)	-	-	Reference *60*
Populus tremuloides	-	-	(683)	-	-	Reference *38*
Populus trichocarpa	(3780)	(3200)	(2600)	(2120)	(1530)	Assumed to be as sensitive as *Pseudotsuga menziesii* (Reference *21*)

* 3-hour values obtained by interpolation from curves based on 1, 2, 4, and 8-hour data.

** Data in parentheses obtained from intercomparison of reported susceptibilities of coniferous species[17, 21, 40, 60, 71, 73] and comparison of data for *Pseudotsuga menziesii*[18] with those for "sensitive" *Pinus spp.*[60]. See Section F5.1(a)(iii)B.

< Published data are probably too high because of low air velocities during fumigations.

TABLE F5-5

SENSITIVITIES OF IMPORTANT SHRUB SPECIES TO SO_2 IN THE PRESENCE OF NO_2 (SO_2/NO_2 RATIO 3:1). CONCENTRATIONS LISTED ARE NECESSARY TO INDUCE 1 - 10% FOLIAR INJURY FOLLOWING SINGLE EXPOSURES FOR THE TIMES INDICATED

Species	Concentration ($\mu g/m^3$) of SO_2 for					Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	
Acer glabrum	-	-	-	-	-	"Intermediate" (Reference *21*)
Alnus incana	-	-	-	-	-	No information
Amelanchier alnifolia	-	<1970	(<1680)	-	-	Assumed to be as sensitive as *Amelanchier utahensis* (References *21, 66*)
Arctostaphylos uva-ursi	-	-	-	-	-	"Tolerant" (Reference *21*)
Artemisia dracunculus	-	-	-	-	-	No information
Artemisia frigida	-	-	(2370)	1965	-	Reference *66*
Artemisia ludoviciana	-	<11790	(<10060)	-	-	Reference *79*
Artemisia tridentata	-	<7860	(<6700)	-	-	Reference *79*
Betula glandulosa	-	-	-	-	-	No information
Chrysothamnus nauseosus	-	(<11790)	(<10060)	-	-	Reference *79*
Cornus stolonifera	-	-	-	-	-	"Intermediate" (Reference *21*)
Empetrum nigrum	-	-	-	-	-	No information
Juniperus communis	-	-	-	-	-	"Tolerant" (Reference *21*)
Juniperus scopulorum	-	<19650	(<16760)	-	-	Reference *79*
Kalmia microphylla	-	-	-	-	-	No information
Lonicera involucrata	-	-	-	-	-	No information
Pachystima myrsinites	-	∞	-	-	-	Reference *79*
Populus tremuloides - See Table F5-4						
Ribes spp.	-	-	-	-	-	No information
Rosa spp.	-	-	-	-	-	No information
Rosa woodsii	-	<3930	(<3350)	-	-	Reference *79*
Rubus idaeus	-	-	-	-	-	No information
Salix sp.	806	747	(690)	649	590	Reference *60*
Shepherdia canadensis	-	-	-	-	-	No information
Spiraea douglassii	-	-	-	-	-	No information
Symphoricarpos albus	-	-	-	-	-	No information
Symphoricarpos oreophitus	-	<1970	(<1680)	-	-	Reference *79*
Vaccinium spp.	-	-	-	-	-	No information

* 3-hour values obtained by interpolation from curves based on 1, 2, 4, and 8-hour data where available, or by computation from 2 or 4-hour values.

< Published data are probably too high because of low air velocities during fumigations.

TABLE F5-6

SENSITIVITY OF IMPORTANT GRASSES, RUSHES AND SEDGES TO SO_2 IN THE PRESENCE OF NO_2 (SO_2/NO_2 RATIO 3:1). CONCENTRATIONS LISTED ARE NECESSARY TO INDUCE 1 - 10% FOLIAR INJURY FOLLOWING SINGLE EXPOSURES FOR THE TIMES INDICATED

Species	Concentration ($\mu g/m^3$) of SO_2 for					Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	
Agropyron caninum	-	<15720	(<13410)	-	-	Reference *79*
Agropyron smithii	-	-	(2370)	1960	-	Reference *66*
Agropyron spp.	-	-	-	-	-	No information
Agrostis spp.	-	-	-	-	-	No information
Bromus ciliatus	-	<7860	(<6700)	-	-	Reference *79*
Bromus inermis	-	<19650	(<16760)	-	-	Reference *79*
Bromus tectorum	-	<19650	(<16760)	-	-	Reference *79*
Calamagrostis spp.	-	-	-	-	-	No information
Carex spp.	-	-	-	-	-	No information
Danthonia intermedia	-	-	-	-	-	No information
Distichlis stricta	-	-	-	-	-	No information
Eleocharis palustris	-	-	-	-	-	No information
Elymus cinereus	-	-	-	-	-	No information
Eriophorum viridia-rinatum	-	-	-	-	-	No information
Festuca spp.	-	-	-	-	-	No information
Festuca idahoensis	-	-	(3560)	2950	-	Reference *66*
Hordeum jubatum	-	-	-	-	-	No information
Juncus spp.	-	-	-	-	-	No information
Koeleria cristata	-	-	(4745)	3930	-	Reference *66*
Luzula spp.	-	-	-	-	-	No information
Muhlenbergia sylvatica	-	-	-	-	-	No information
Oryzopsis hymenoides	-	<1965	(<1675)	-	-	Reference *79*
Phleum alpinum	-	-	-	-	-	No information
Phleum pratense	1300	1060	(900)	785	415	Reference *60*
Poa pratensis	-	395	(335)	-	-	Reference *82*
Poa pratensis	-	-	(<4740)	<3930	-	Reference *81*
Poa pratensis	-	<11790	(<10060)	-	-	Reference *79*
Poa spp.	-	-	-	-	-	No information
Spartina gracilis	-	-	-	-	-	No information
Sporobolus cryptandrus	-	∞	-	-	-	Reference *79*
Stipa comata	-	-	(3560)	2950	-	Reference *66*
Stipa occidentalis	-	<15720	(<13460)	-	-	Reference *79*
Stipa richardsonii	-	-	-	-	-	No information
Trisetum spicatum	-	<11790	(<10060)	-	-	Reference *79*

* 3-hour values obtained by interpolation from curves based on 1, 2, 4, and 8-hour data where available, or by computation from 2 or 4-hour values.

* Published data are probably too high because of low air velocities during fumigations.

TABLE F5-7

SENSITIVITIES OF IMPORTANT HERBACEOUS SPECIES TO SO_2 IN THE PRESENCE OF NO_2 (SO_2/NO_2 RATIO 3:1). CONCENTRATIONS LISTED ARE NECESSARY TO INDUCE 1 - 10% FOLIAR INJURY FOLLOWING SINGLE EXPOSURES FOR THE TIMES INDICATED

Species	Concentration (μg/m³) of SO_2 for					Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	
Achillea millefolium	-	<11790	(<10060)	-	-	Reference 79
Allium carnuum	-	-	-	-	-	No information
Antennaria spp.	-	∞	-	-	-	Reference 79
Arnica spp.	-	-	-	-	-	No information
Aster spp.	-	-	-	-	-	No information
Astragalus spp.	-	-	-	-	-	No information
Astragalus utahensis	-	<1965	(<1675)	-	-	Reference 79
Balsamorhiza sagittata	-	-	-	-	-	No information
Castilleja miniata	-	-	-	-	-	No information
Cornus canadensis	-	-	-	-	-	No information
Epilobium augustifolium	-	-	-	-	-	No information
Equisetum spp.	-	∞	-	-	-	Reference 79
Erigeron speciosus	-	-	-	-	-	No information
Eriogonum spp.	-	-	-	-	-	No information
Fragaria glauca	-	-	-	-	-	No information
Fritillaria pudica	-	-	-	-	-	No information
Geranium viscosissimum	-	-	-	-	-	No information
Hedysarum boreale	-	-	-	-	-	No information
Lathyrus ochroleucus	-	-	-	-	-	No information
Lewisia rediviva	-	-	-	-	-	No information
Linnaea borealis	-	-	-	-	-	No information
Lupinus lepidus	-	-	-	-	-	No information
Medicago lupulina	-	-	-	-	-	No information
Melilotus alba	-	-	-	-	-	No information
Opuntia fragilis	-	-	-	-	-	No information
Opuntia sp.	-	∞	-	-	-	Reference 79
Pedicularis racemosa	-	-	-	-	-	No information
Penstemon spp.	-	-	-	-	-	No information
Polygonum viviparum	-	-	-	-	-	No information
Potentilla spp.	-	-	-	-	-	No information
Salsola kali	-	<7860	(<6700)	-	-	Reference 79
Sanecio triangularis	-	-	-	-	-	No information
Taraxacum officinale	-	-	(<4740)	<3930	-	Reference 81
Thallictrum occidentalis	-	-	-	-	-	No information
Trifolium repens	-	-	-	-	-	No information
Valeriana sitchensis	-	-	-	-	-	No information

* 3-hour values obtained by computation from 2 or 4-hour values.

< Published data are probably too high because of low air velocities during fumigations.

TABLE F5-8

SENSITIVITIES OF LICHENS AND MOSSES TO SO_2. CONCENTRATIONS LISTED ARE INJURY THRESHOLDS (SHORT TERM) OR THRESHOLDS FOR SURVIVAL (ANNUAL)

Species	Concentration ($\mu g/m^3$) of SO_2 for 1 hr.	3 hr.	24 hr.	Annual	Notes
Alectoria jubata (Alectoria fuscescens)	-	-	-	26.2 - 52.4	Reference 83
Alectoria spp.	-	-	-	-	No information
Alectoria americana	-	-	-	13.1 - 26.2	Reference 84
Cladonia (Cladina) rangiferina	3900	2000	550	14	Reference 85
Cladonia spp.	-	-	-	-	No information
Letharia vulpina	-	-	-	-	No information
Peltigera spp.	-	-	-	-	No information
Stereocaulon alpinum	-	-	-	-	No information
Abietinella abietina	-	-	-	-	No information
Aulacomnium spp.	-	-	-	-	No information
Brachythecium uncinatus	-	-	-	-	Zone $\geq$III, Reference 86
Brachythecium sytabulum	-	-	-	10.5 - 52	Reference 87
Dicranum scoparium	-	-	-	-	Zone $\geq$IV, Reference 86
Dicranum spp.	-	-	-	-	No information
Ditrichum flexicaule	-	-	-	-	No information
Drepanocladus uncinatus	-	-	-	-	Zone $\geq$II, Reference 86
Eurynchimum pulchellum	-	-	-	-	No information
Halocomium splendens	-	-	-	-	No information
Hypnum revolutum	-	-	-	-	No information
Hypnum upressiforme	-	-	-	52 - 105	Reference 87
Leptobryum pyriforme	-	-	-	-	No information
Mnium insigne	-	-	-	-	No information
Pleurozium schreberi	-	-	-	-	Zone V, Reference 86
Pohlia nutans	-	-	-	-	Zone $\geq$III, Reference 86
Pohlia cruda	-	-	-	105 - 131	Reference 87
Polytrichum spp.	-	-	-	-	No information
Timmia austriacea	-	-	-	-	No information
Tomenthypnum nitens	-	-	-	-	No information
Tortula ruralis	-	-	-	-	No information
Tortula princeps	-	-	-	10.5 - 105	Reference 87

TABLE F5-9

SENSITIVITIES OF IMPORTANT OR POTENTIAL AGRICULTURAL CROPS TO SO_2 IN THE PRESENCE OF NO_2 (SO_2/NO_2 RATIO 3:1). CONCENTRATIONS LISTED ARE NECESSARY TO INDUCE 1 - 10% FOLIAR INJURY, TO REDUCE PHOTOSYNTHESIS 1 - 10% (PS), OR TO REDUCE GROWTH (GR) FOLLOWING EXPOSURES FOR THE TIMES INDICATED

Species	Concentration ($\mu g/m^3$) of SO_2 for						Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	>8 hr.	
Alfalfa							
(Medicago sativa)	400 PS	-	-	-	-	-	Reference *48*
	490 PS	1570	(1340)	-	-	-	Reference *89*
	1475 PS	-	-	-	-	-	Reference *47*
	-	-	<2100 PS	-	-	-	Reference *92*
	1475	-	885	-	-	-	Reference *16*
	-	-	(1780)	1475.	-	-	Reference *96*
	-	-	-	-	-	131 GR	8h/d-4wks Reference *95*
	-	-	-	-	-	262 GR	7h/d-cont. Reference *94*
	2193	1387	(1130)	983	772	-	Reference *60*
Alsike Clover *(Trifolium hybridum)*	-	-	-	-	<1870	-	Reference *35*
White Clover *(Trifolium repens)*	-	-	-	-	-	-	No information
Bromegrass							
(Bromus arvensis)	-	-	-	-	-	-	No information
(Bromus inermis)	-	15720	(<13410)	-	-	-	Reference *79*
	-	-	(< 3160)	<<2620	-	-	Reference *96*
Crested Wheatgrass *(Agropyron cristatum)*	-	-	-	-	-	-	No information
Orchard Grass *(Dactylis glomerata)*	-	-	-	-	-	178 GR	20 wks Reference *117*
						-	"Sensitive" Reference
Perennial Ryegrass *(Lolium perenne)*	-	-	-	-	-	191 GR	26 wks. Reference *88*
	-	-	-	-	-	131 GR	1 yr. Reference *90*
	-	-	-	-	-	-	"Sensitive" Reference
Reed Canarygrass *(Phalaris arundinacea)*	-	-	-	-	-		No information

TABLE F5-9 Continued

Species	Concentration ($\mu g/m^3$) of SO_2 for						Notes
	1 hr.	2 hr.	3 hr.*	4 hr.	8 hr.	> 8 hr.	
Timothy	-	-	-	-	1870 GR		Reference *35*
(Phleum pratense)	1300	1060	(900)	786	413		Reference *60*
	-	-	-	-	-	178 GR	20 wks. Reference *117*
Corn *(Zea mays)*	∞	∞	(∞)	∞	∞	-	Reference *60*
	-	-	-	-	-	<786 GR	5h/d-2wks Reference *93*
	-	-	-	-	-	890 GR	8h/d-1wk Reference *51*
	-	-	-	-	-	157 GR	8h/d-2wks Reference *51*
	-	-	-	-	-	-	"Resistant" Reference *9*
Oats *(Avena sativa)*	-	393	(260)	130	-	-	Reference *46*
	1240	1160	(850)	670	335	-	Reference *60*
	>980	-	>790	-	-	-	Reference *91*
Rye *(Secale cereale)*	-	-	-	-	-	-	"Sensitive" Reference *9*
Faba Bean	-	-	-	-	-	<745 GR	48h.Ref. *35*
(Vicia faba)	-	-	-	-	-	<786 GR	5h/d-2 wks Reference *93*
Potato	1260	1100	(970)	845	745	-	Reference *60*
(Solanum tuberosum)	-	-	-	-	-	-	"Intermediate" Reference *9*
Tomato	1260	1100	(970)	845	745	-	Reference *60*
(Lycopersicon	-	-	(<4740)	<3930	-	-	Reference *43*
esculentum)	-	-	(1580)	1310	-	-	Reference *96*
	-	-	(790)	695	-	-	Reference *47*
	-	-	(315)	262	-	-	Reference *46*

* 3-hour values in parentheses obtained by interpolation from curves based on 1, 2, 4, and 8-hour data where available, or by computation from 2 or 4-hour values.

< Published data are probably too high because of low air velocities during fumigations.

are cumulative, non-metabolizable toxicants, chronic fluoride injury may occur on sensitive vegetation at sites subjected to repeated fumigations. For example, *P. ponderosa* has been reported[99] to be injured by exposures to average concentrations as low as 0.06 $\mu g/m^3$. The only species likely to be affected by fluorides in the Hat Creek region are trees such as *P. ponderosa*, and an assessment of impact on these species is provided in the Hat Creek Detailed Environmential Studies, Forestry Report.

No plant injury is anticipated from the levels of particulates predicted to be deposited from the emissions from the generating station stack. Based upon the ERT projections for annual average SO_2 concentrations[1], the proposed 0.12 ratio of particulate/SO_2 emissions and a deposition velocity of 0.1 cm/sec, the greatest predicted annual deposition fluxes for particulates are:

366 m stack/FGD	17.0 mg/m^2/year
366 m stack/MCS	26.5 mg/m^2/year
244 m stack/MCS	35.2 mg/m^2/year

There is no evidence to suggest that vegetation will be affected by particulates deposited at such rates or by the specific trace elements present within them[100].

F5.4 SPECIFIC METHODOLOGY - IMPACT OF ASSESSMENT OF SO_2/NO_2

(a) Site-by-Site Analysis of Peak Occurrences

Data from the ERT PEAK programmes for each control strategy were as outlined above (Section F5.1(a)(iii)A). Tables were drawn up listing the 1-hour, 3-hour and 23-hour peaks projected to occur throughout the year for each receptor site around which it was considered likely that impact would be discernible. The assembled data were then subdivided into a) those pertaining to the April-October growing season, and b) those relating to daylight hours. For each site, the maximum predicted concentration occurring during the daylight hours of the growing season was noted (C_{max}) and the total number of peaks within the daylight hours of the growing season which were 80% or more of this maximum was calculated (n). The selection of 80% of the maximum peak concentration per site as the lower limit is admittedly arbitrary. In terms of the complete PEAK Programme data for each control strategy, however, the range 80-100% included approximately one half of the peaks above the threshold selected for the particular PEAK Programme output, in the case of the highest peak values (1500 - 1800 $\mu g/m^3$), and an increasing proportion as the value for the highest peak value decreased. Hence, while it may be argued that the product $C_{max}.n_s$ would inflate the value for cumulative dose, there is the counter-argument that an approximately equal number of lesser peak concentrations which might also elicit an effect, depending upon their absolute magnitude, have been excluded from the computation of cummulative dose. The 80% level is thus a compromise.

Where peaks occurred within 3 hours of daybreak, their impact was weighted by multiplying their number by 1.5, to account for their greater potential for injury (see Section F4.5). The products of C_{max} and the weighted number of peak occurrences just described (n_s for the growing season), i.e. $C_{max}.n_s$ were used as an initial approximation of cumulative growing season dose for each site. These dose values were then interpreted as injury by reference to cumulative dose-response curves for the different species, developed as described in the next section.

(b) Cumulative Dose-Response Curve

As outlined above (Section F4.2 and F4.3), concentration - response curves of plants to air pollutants, where the duration of exposure is constant, show a rough direct proportionality above the response threshold. When dosage is kept constant (by changing concentration and duration in inverse proportionality), response is usually greater when high concentrations are involved. In the case of intermittent exposures to high concentrations, the response is frequently, but not invariably, less than would be the case if the same concentrations were maintained without break for the same total length of time. Each of these aspects of dose-response has been documented for certain species, but no overall integration of these effects (in the sense of a mathematical model) has yet been proposed because of the lack of commonality in the available data. Nevertheless, for quantitative assessment of impact, some form of integration is essential.

In the present report, a simplistic approach has been taken to meet this need, based upon the knowledge that increasing dosage *per se* elicits an increased response, above the response threshold, and that, as response, i.e. injury, accumulates, there is a decline in the rate of response, because less tissue is available to respond (e.g. see Fig. F4-4(c)). The data for sensitivity of species presented in Tables F5-4, F5-5, F5-6, F5-7, F5-8 and F5-9 were used as the basis for the cumulative dose-response curves depicted in Figure F5-2.

The curves are limited to those species relevant to the Hat Creek region for which dose-response data of any kind exist in the literature. The shapes and slopes of the curves are in large measure based upon judgment rather than observation, because, as has been pointed out above (Section F4.3) few data exist for the actual dose-response of individual species.

The values for the abscissa in Figure F5-2 are for SO_2 dose, modified to take into account the concomitant presence of NO_2, as was the case for the data in the above-mentioned tables. The curves also incorporate the reductions in impact discussed in Sections F4.4, F4.5 and F5.1 (a)(iii)(b)) to accommodate the probable effects of localized CO_2 enrichment. They furthermore take into account the increased injury likely to occur to tree and shrub species resulting from the deposition of SO_2 during the winter season discussed in Sections F4.5(a) and F5.1(a)(iii)B. This "winter deposition" correction was applied to the dose-response curves rather than to the site-specific assessments, based on calculated cumulative dose for the April-October season, because of the general consistency in the relationships observed for the peak distributions for all sites between the growing season

FIGURE F5-2

CUMULATIVE DOSE-RESPONSE CURVES (GROWING SEASON BASIS) FOR MAJOR SPECIES IN THE HAT CREEK LOCAL REGION

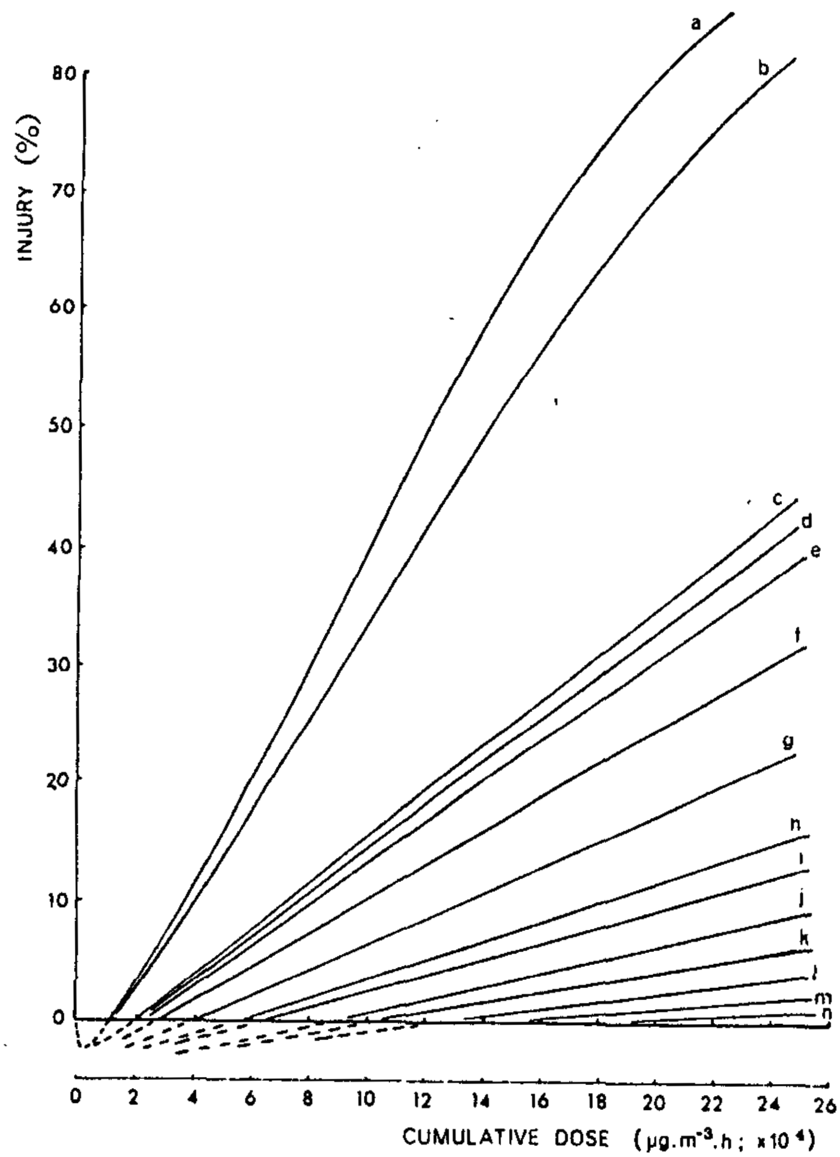


FIGURE F5-2

LEGEND

Curves:

a. *Salix spp.*

b. *Populus tremuloides*

c. *Lycopersicon esculentum, Phleum pratense, Solanum tuberosum*

d. *Avena sativa*

e. *Medicago sativa*

f. *Poa pratensis*

g. *Abies lasiocarpa*

h. *Pleurozium schreberi, Pseudotsuga menziesii*

i. *Amelanchier alnifolia, Picea engelmannii, Pinus contorta, P. ponderosa*

j. *Alectoria jubata, Bromus inermis, Oryzopis hymenoides, Trifolium hybridum*

k. *Agropyron Smithii, Artemisia frigida*

l. *Artemisia tridentata, Drepanocladus uncinatus*

m. *Bromus ciliatus, Koeleria cristata, Stipa comata*

n. *Achillea millefolium, Stipa occidentalis, Taraxacum officinale, Trisetum spicatum* and the total year, as discussed in Section F5.1(a)(iii)A.

The dose response curves in Figure F5-2 contain negative values for injury at the lowest doses, and reveal various thresholds of injury response. The precise form of the negative parts of the curves is unknown, because of the almost total lack of specific data. This depiction of sub-threshold responses is merely intended to indicate that possible beneficial effects could occur over this range of doses.

(c) Site-by-Site Assessment of Impact

The cumulative seasonal doses for the receptor sectors of interest, computed as described in Section F5.4(a), were used to estimate cumulative injury or beneficial effect by reference to the dose-response curves of Figure F5-2. These preliminary estimates were then further refined in the light of the other site-specific modifying factors described above in Section F5.1(a)(iii)B, i.e. plant cover distribution, altitudinal range, mixing depth, etc. The resulting final estimates of impact are those presented in Sections F6.1, F6-2 and F6-3, below.

(d) Comparison of Impact Assessment Methodologies

Mention has been made in Section F4.3 by the Larsen-Heck model of dose response[6] as the only existing model which incorporates degree of injury as a variable. Although the database for the model is extremely limited for SO_2, it was nevertheless of interest to compare the assessments of injury derived from the somewhat subjective procedures used in the present study, with those obtained by use of the Larsen-Heck model. A random selection of species and receptor sites was used for this comparison. By assuming certain values for the model's individual parameters which are within the range of those observed for the species studied in its development, an approximate value for injury can be obtained from the rearranged equation(p. F4-8):

$$z = \log \left(\frac{C}{M_{ghr} t^{p}}\right) / \log S_g, \quad \text{------------------------------(1)}$$

where Z is the number of standard deviations that a particular percentage of leaf injury is from the median (50% injury), C is the concentration of SO_2, M_{ghr} is the geometric mean concentration for a 1-hour exposure which induces 50% injury median, t is the exposure duration (hours) p is the slope of the concentration (ordinate) vs duration (abscissa) line on log-log paper for any given degree of injury, and S_g is the standard geometric deviation of the response of a particular species.

Assuming an injury threshold of 1% for concentration, C_t, and using mean values from Larsen and Heck's data for S_g and p of 1.5 and -0.4 respectively, $M_{g\ hr}$ values can be calculated (for 50% injury) from

$$C_t = M_{g\ hr} . t^{p} . s_g^{z},$$

rearranged to:

$$M_{g\ hr} = \frac{C_t}{t^{p} . s_g^{z}}, \quad \text{--(2)}$$

for any value of C_t, where Z = -2.33 standard deviations from the median (50% injury). If the values for C_t, based on 1-hour exposure durations are used in Equation 2, the concentrations required to induce 50% injury (M_{ghr}) are related to C_t according to

$$M_{g\ hr} = 2.57\ C_t \text{ (1-hour)}$$

The value of the coefficient (2.57) compares well with the mean value of 2.67

for the injury ratios quoted by Larsen and Heck for three of the four species which they studied[6]. The difference is attributable to the selection of average values S_g and p. For threshold values based on 2-, 3-, 4- or 8-hour exposure durations, the coefficients are 3.39, 3.99, 4.48 or 5.91 respectively. These coefficients were used to calculate mean $M_{g\,hr}$ values for a selection of the species included in Tables F5-4, F5-5, F5-6 and F5-9; these values for $M_{g\,hr}$ are presented in Table F5-10, and were used in Equation 1 to compute expected injury levels for various combinations of peak concentrations and frequencies, selected from the receptor site analysis described above in Section F5.4(a). Each peak was assumed to have a 1-hour duration, the impact of which (in number of standard deviations from the median) was transformed to percent injury, and multiplied by the number of peaks (n_s) to yield a value for cumulative injury for the season. The values were in turn adjusted for CO_2 enrichment and winter deposition as described in Section F5.1(a)(iii)B. No adjustment was made for concomitant NO_2, since this adjustment is already included in the tables of sensitivity.

A sampling of such values is presented in Table F5-11, together with assessments obtained by the simpler but more subjective procedures of Section F5.4(b) and (c). In the light of the range of species, the range of concentrations and frequencies, and the various assumptions made in both the subjective procedure and the use of the Larsen-Heck model, the agreements revealed in Table F5-11 are reassuring.

(e) Accuracy of Assessments

It will be obvious from all the foregoing that the assessments derived from the procedures used must be associated with appreciable errors in the statistical sense. The many contributory factors relating to the variability in plant response have been detailed in Section F4. The various assumptions made and their uncertainties, relating both to the impact of ambient CO_2 concentrations on vegetation, and to the projected values for ambient

TABLE F5-10

MEAN VALUES OF $M_{g\,hr}$ FOR SELECTED SPECIES, CALCULATED FROM EQUATION 2. FOR ASSUMPTIONS MADE IN THE CALCULATIONS SEE TEXT

Species	M_{ghr} ($\mu g/m^3$)	
Abies lasiocarpa	7,810	
Picea engelmannii	11,560	
Pinus spp.	11,560	
Pseudotsuga menziesii	9,710	
Populus tremuloides	4,140	*
Artemisia frigida	8,800	
Salix sp.	4,150	*
Koeleria cristata	18,940	
Poa pratensis	5,030	**
(Alfalfa)	4,430	**
(Oats)	2,850	
(Potato)	3,840	
(Tomato)	3,840	

* Threshold concentrations used are twice those in Tables F5-4 and F5-5 for these species, since those data refer to highly sensitive clones.

** Based on geometric means of threshold concentrations reported by different observers, presented in Tables F5-6 or F5-9.

TABLE F5-11

COMPARISON OF INJURY ASSESSMENTS MADE BY SUBJECTIVE PROCEDURES WITH THOSE BASED UPON THE LARSEN - HECK MODEL, FOR VARIOUS SPECIES AND PROJECTED EXPOSURES TO AMBIENT SO_2

Species	C_{max} (μg/m³)	n_s (hours)	Estimated injury (%)	
			Subjective	Larsen-Heck
Salix sp.	723	28	3	<1
	1565	49	28	40
	1644	40	23	45
Pseudotsuga menziesii	1730	61	3	2
Picea engelmannii	723	28	0(+)	<1
	1565	49	0	<1
	1644	40	0	<1
Artemisia frigida	1565	49	0	1
Poa pratensis	1565	49	7	5
	1644	40	5	6

(+) Indicates possible beneficial effect.

concentrations have been discussed in earlier parts of Section F5. What then are the likely ranges of variability associated with specific injury assessments? Rather than assigning a value, which would probably be almost meaningless, since some component errors will be additive while others tend to cancel each other, suffice it to say that the assessments quoted are best estimates, which attempt to provide a view of the most likely consequences of the operations of the Hat Creek generating station throughout a particular year. Several of the component inputs have built-in conservatism, including the ERT modelling, yet this is based on a single year's meteorological data. On the other hand, the biological component has tended to emphasize the most highly susceptible species in conditions which favour their susceptibility to injury. While this may be unjustified for populations of different species as a whole, the fact remains that individual plants within those populations are going to be more susceptible than others, as a result of both genetic and environmental differences, and that these individuals are going to respond more dramatically.

All things considered, however, it seems reasonable to suggest that while there is a distinct possibility that the impact of the Hat Creek generating station could be greater than that suggested by the assessments of injury, regardless of the control strategy employed, there is a greater likelihood that it will be somewhat less.

F6.0 ASSESSMENT OF IMPACTS OF GENERATING STATION EMISSIONS ON VEGETATION

The following assessments of the impacts of generating station emissions are presented separately for the three control strategies. In each case, separate assessments are provided for the local and regional zones of impact. The quantitative assessments of injury are confined to those resulting from SO_2 and NO_2 exposure since there is no evidence to believe that other emissions (with the possible exception of fluorides) will have measureable impact on local vegetation.

F6.1 366 m STACK WITH FLUE GAS DESULFURIZATION (FGD)

(a) Local Impact Assessment of SO_2/NO_2 Emissions

(i) Basis for Assessment

The detailed view of the ground level impingement of the generating station plume from a 366 m stack with FGD was obtained from the relevant ERT PEAK programme data, based upon 1-hour excursions greater than 255 µg SO_2/m^3, 3-hour excursions greater than 300 µg SO_2/m^3 and 24 hour excursions greater than 160 µg SO_2/m^3 (See Section F2.0).

While the detailed printouts were inspected to obtain an overall assessment of the pattern of SO_2 concentrations predicted to occur at a given site (as for example with the data for the uncontrolled emissions depicted for ERT receptor site 14 in Figure F5-1), attention has been focussed upon those sites at which 1-hour excursions above 450 µg/m^3, 3-hour averages above 300 µg/m^3 and 24-hour averages above 160 µg/m^3 SO_2 are predicted to occur during the period April 1 to October 31. Because of the importance of the magnitude of the predicted peak concentrations as well as their frequencies in causing injury to vegetation, isopleths of seasonal (April - October) peak concentrations as well as frequency isopleths were constructed, as described previously for the uncontrolled 366 m stack situation (Section F5.1(a)(iii)A.), together with maps depicting the annual situation for purposes of comparison.

These maps are presented in Figures F6-1 to F6-7. By overlaying the peak concentration and frequency isopleths for a given time of excursion, it is possible to determine precisely those receptor sites which the ERT modelling predicts will be exposed to elevated concentrations and the number of such events likely to occur during the season of vegetational growth.

Comparison of Figures F6-1 and F6-2 shows that the maximum 1-hour concentrations predicted for the April-October season are essentially those predicted for the complete year. Within the limits of the available data, much the same can be said for the 3-hour maxima, although four receptor sites to the southwest of the stack (sites 20, 21, 28, 29) no longer show maxima greater than 300 $\mu g/m^3$, as revealed in Figures F6-4 and F6-5. However, while the 24-hour maxima for the year are shown in Figure 6-7, there are no such maxima greater than 160 $\mu g/m^3$ predicted to occur between April 1 and October 31.

The predicted numbers of excursions greater than 450 $\mu g/m^3$ (1-hour) or 300 $\mu g/m^3$ (3-hour) during the April-October season are shown in Figures F6-3 and F6-6 respectively.

The similarities between the annual and seasonal 1-hour isopleths (Figures F6-1 and F6-2) provide corroboration of the situation described for uncontrolled emissions, in which comparable peak concentrations were predicted to occur during April-October and January-December (Section F5.1). Similarly, inspection of the 1-hour peak programme data for the FGD strategy also shows that approximately 60 percent of the seasonal excursions oc cur during daylight hours, and that, of these, approximately 20 percent occur in the hours immediately following sunrise. Hence these proportions of daylight and daybreak 1-hour excursions have been adopted routinely in the assessment of impact.

Figure F6-1

PREDICTED ANNUAL MAXIMUM 1-HOUR SO_2 CONCENTRATIONS (μg/m³) 366 m STACK WITH FGD

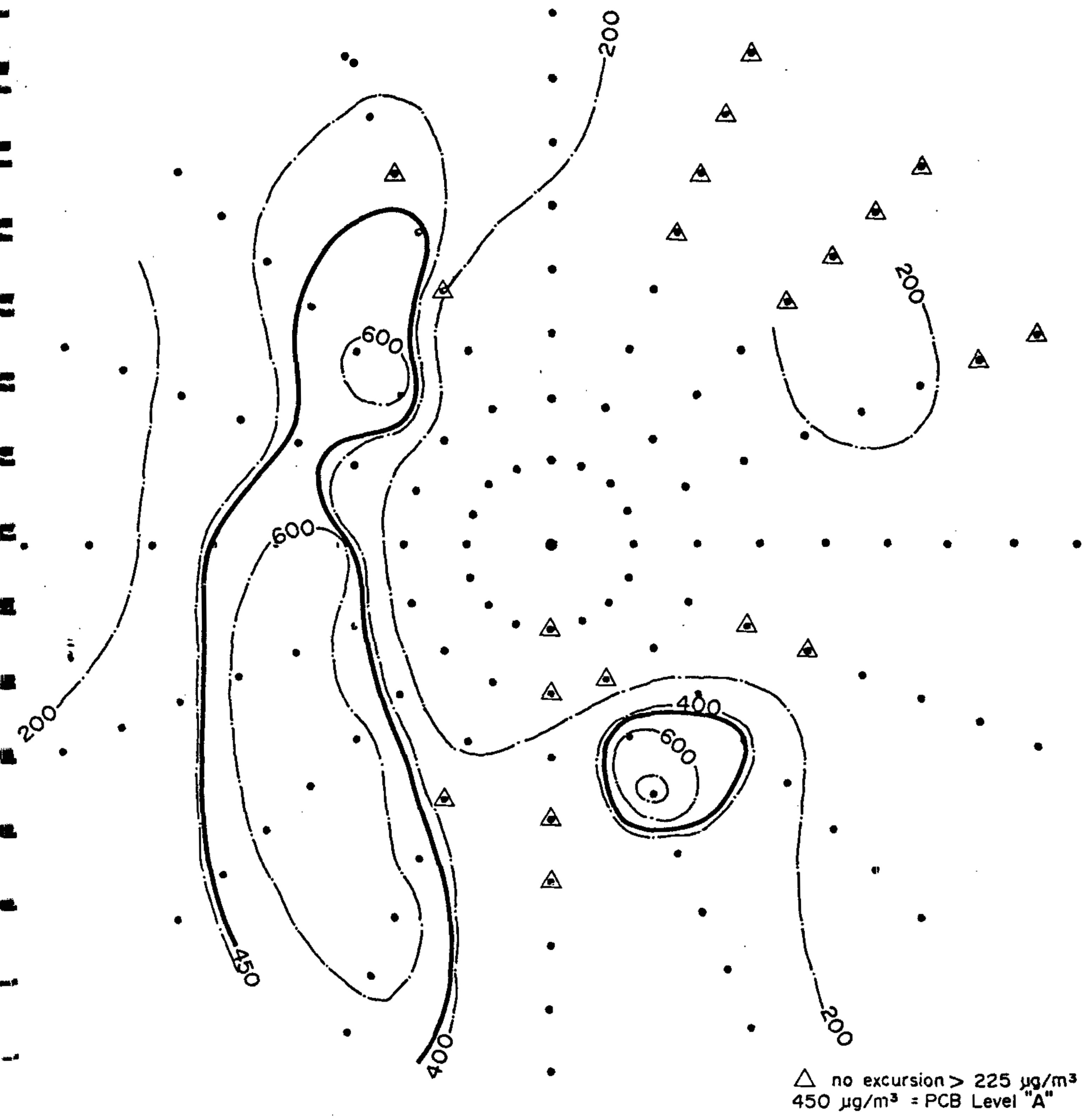


Figure F6-2

PREDICTED SEASONAL MAXIMUM 1-HOUR SO_2 CONCENTRATIONS (µg/m³) 366 m STACK WITH FGD

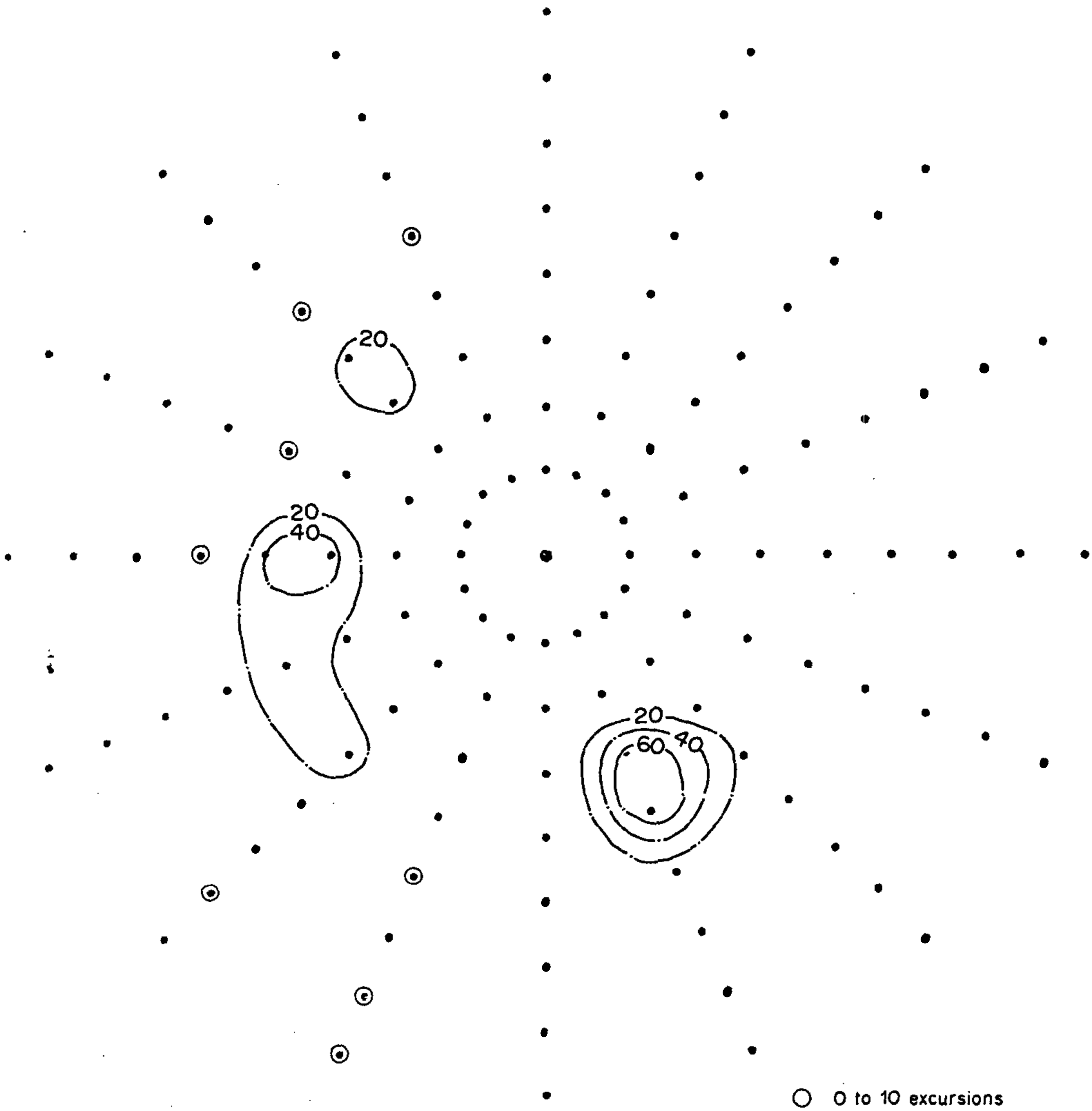


Figure F6-3

PREDICTED SEASONAL TOTALS
OF 1-HOUR SO_2 CONCENTRATIONS > 450 µg/m³
366 m STACK WITH FGD

Figure F6-4

PREDICTED ANNUAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS (µg/m³)
366m STACK WITH FGD

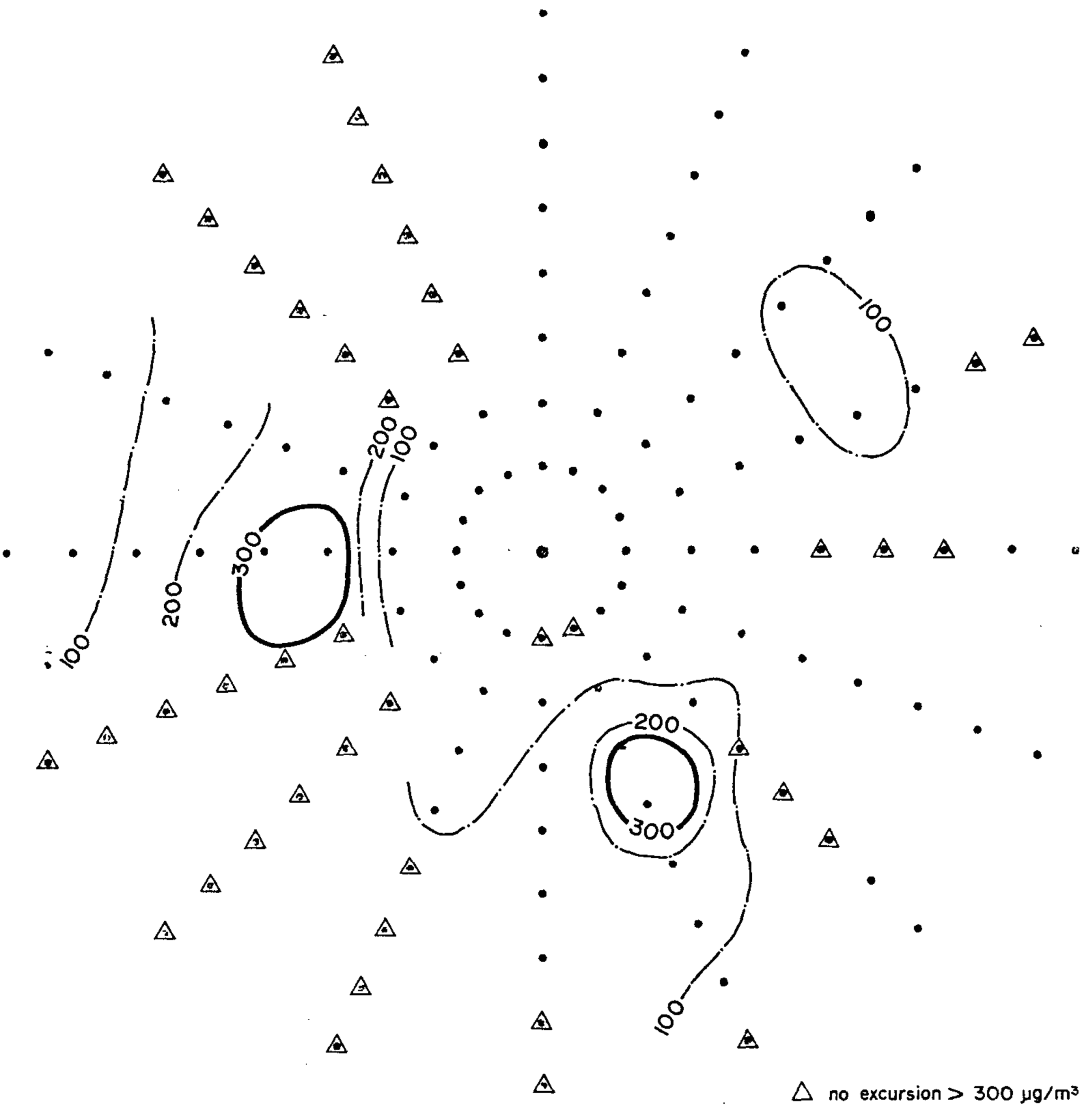


Figure F6-5

PREDICTED SEASONAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS (μg/m³)
366 m STACK WITH FGD

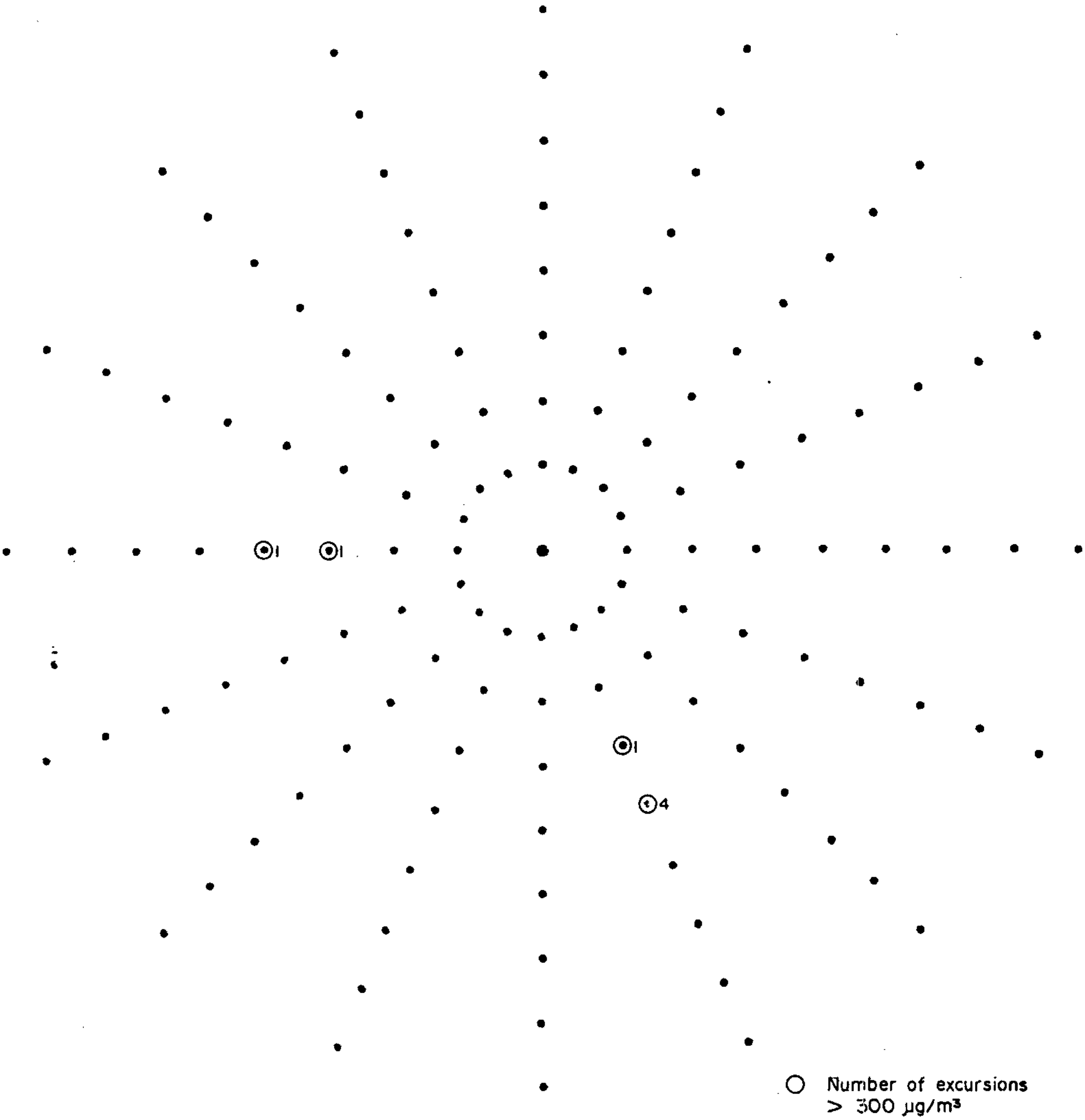


Figure F6-6

PREDICTED SEASONAL TOTALS
OF 3-HOUR SO_2 CONCENTRATIONS > 300 μg/m³
366 m STACK WITH FGD

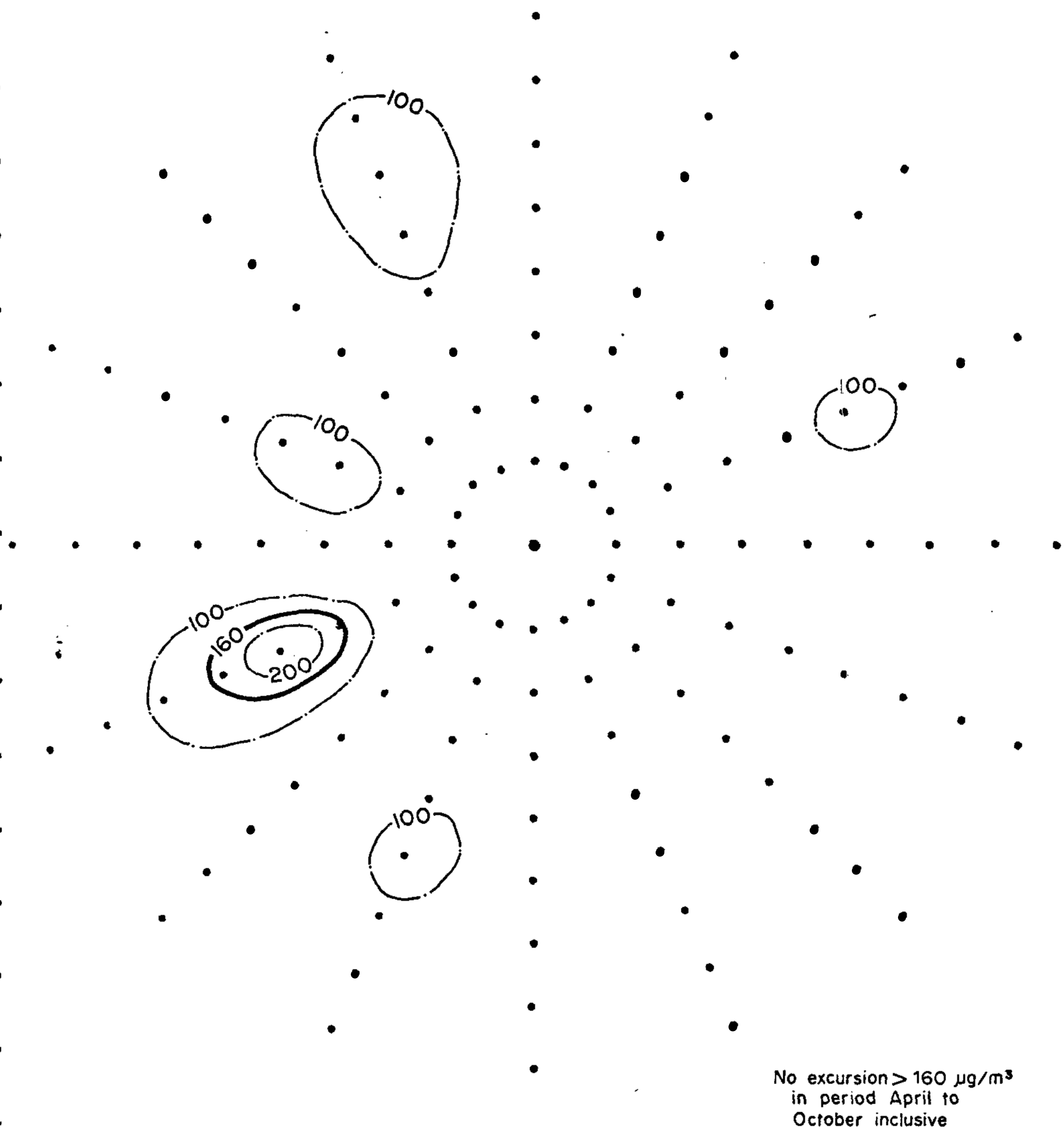


Figure F6-7

PREDICTED ANNUAL MAXIMUM 24-HOUR SO_2 CONCENTRATIONS (μg/m³) 366 m STACK WITH FGD

Unlike the 1-hour situation, in the case of 3-hour averages there are only 7 such predicted excursions 300 μg/m³ during the April-October season. Furthermore, of these only one is predicted to occur within daylight hours.

The low (<350 μg/m³) peak 3-hour averages revelaed by the ERT data indicate that such vegetation injury as may occur in most likely to be the result of 1-hour peaks. Hence injury has been assessed for the vegetation associated with sites 14, 20, 21, 22, 27, 28, 29, 35, 36, 37, 44, 51, 116, 123 and 124. These assessments are presented in Tables F6-1 to F6-16, and are derived in Section F5.4. Since relatively little injury is anticipated at any of these receptor sites, the information presented in Tables F6-1 to F6-16 does not list all of the species contributing 0.1 km or more to the plant cover associated with each site. Such detailed cover estimates are, however, included in the tables presented fully in Addendum A, and partly in the tables presented in Addendum A, and partly in the tables presented in connection with the 366 m stack/MCS and 244 m stack/MCS assessments in Sections F6.2 and F6.3, respectively. In the present assessment, no injury or possible growth stimulation is expected from site 13, 15, 16, 23, 53 and 61 and hence these are omitted from the tablulations.

The assessments of injury to natural vegetation are based upon the sensitivities listed in Tables F5-4 to F5-8. The assessments of injury to present or potential agricultural crops are based on the sensitivities listed in Table F5-9.

With regard to agricultural impact, Table F6-17 presents details of present and potential agricultural lands within the annular sectors associated with those receptor sites at which potentially injurious SO_2 levels may occur, i.e. sites 13, 14, 20, 23, 44, 52, 53 and 116. All except site 23 relate to exisitng cultivated lands.

In assessing impact on current agricultural crops, those crops listed in the Agricultural Report Table F5-1[104] as occurring within the local study

TABLE F6-1

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 14
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m^3	11	729
3-hr.>300 μg/m^3		
24-hr.>160 μg/m^3		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.2	0(+)
Poa pratensis	0.2	0(+)
Pleurozium schreberi	2.6	0

No injury expected to other species for which injury data are available. For detailed of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-26.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-2

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 20
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 $\mu g/m^3$	25	658
3-hr. >300 $\mu g/m^3$		
24-hr. ≥160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.2	0(+)
Pleurozium schreberi	2.6	0

No injury expected to other species for which injury data are available. For detailed of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-29.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-3

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 21
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	17	705
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix cascadensis	1.8	0(+)
Salix nivalis	2.0	0(+)
Pleurozium schreberi	4.3	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-30.

(+) Possible beneficial effect of SO_2 on growth

TABLE F6- 4

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 22
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	11	606
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.1	0(+)
Salix cascadensis	1.1	0(+)
Salix nivalis	1.3	0(+)
Pleurozium schreberi	3.6	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-31.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-5

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 27
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	11	496
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.2	0(+)

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-34.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-6

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 28
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	31	696
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.3	1
Pleurozium schreberi	2.7	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-35.

TABLE F6- 7

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 29
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	18	631
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.3	0(+)
Salix cascadensis	3.4	0(+)
Salix nivalis	3.8	0(+)
Pleurozium schreberi	1.2	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-36.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-8

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 35
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.> 450 μg/m³	40	637
3-hr.> 300 μg/m³	1	338
24-hr.> 160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Salix sp.	0.1	1
Pleurozium schreberi	0.8	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-40.

TABLE F6-9

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON VEGETATION WITHIN RECEPTOR SECTOR 36 BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	48	696
3-hr.>300 $\mu g/m^3$	1	335
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.5	3
Pleurozium schreberi	5.0	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-41.

TABLE F6-10

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON VEGETATION WITHIN RECEPTOR SECTOR 37 BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m^3	7	489
3-hr.>300 μg/m^3		
24-hr.>160 μg/m^3		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.3	0(+)

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-42.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-11

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON VEGETATION WITHIN RECEPTOR SECTOR 44 BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	6	453
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Populus tremuloides	0.1	0(+)
Salix sp.	0.3	0(+)

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-45.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-12

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 51
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m³	21	637
3-hr. >300 μg/m³		
24-hr. >160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.4	0(+)

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-48.

(+) Possible beneficial effects of SO_2 on growth

TABLE F6-13

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 52
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	21	678
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Salix sp.	0.3	0(+)
Pleurozium schreberi	0.3	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-49.

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-14

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 55
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m^3	10	494
3-hr.>300 μg/m^3		
24-hr.>160 μg/m^3		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Poa pratensis	0.3	0(+)

No injury expected to species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-62.

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-15

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 123
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	60	637
3-hr.>300 $\mu g/m^3$	1	300
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Picea engelmannii	0.5	0(+)
Pinus contorta	6.8	0(+)
Pseudotsuga menziesii	0.2	0(+)
Alectoria jubata	2.4	0(+)
Pleurozium schreberi	1.6	0

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-63.

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-16

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 124
BASED ON THE 366 METRE STACK, FGD AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	72	825
3-hr.>300 $\mu g/m^3$	4	312
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.2	0(+)
Picea engelmannii	0.7	0(+)
Pinus contorta	1.6	0(+)
Pinus ponderosa	0.3	0(+)
Pseudotsuga menziesii	3.0	0(+)
Amelanchier alnifolia	1.5	0(±)
Salix sp.	0.1	8
Poa pratensis	0.2	2
Alectoria jubata	0.6	0
Drepanocladus uncinatus	0.1	0
Pleurozium schreberi	0.9	1

No injury expected to other species for which injury data are available. For details of species list and cover, see 366m stack/MCS assessment, Section F6.2, Table F6-64.

(+) Possible beneficial effects of SO_2 on growth.
(±) Indicates threshold for injury.

TABLE F6-17

EXISTING AND POTENTIAL AGRICULTURAL LAND DISTRIBUTION WITHIN RECEPTOR SECTORS IN WHICH SO_2/NO_2 IMPACT WOULD OCCUR FROM EMISSION FROM THE 366 M/FGD MODEL (AREAS IN KM_2)[a]

Site	Present Irrigation[b]	Potential Irrigation[c]	CLI Agricultural Land Capability[d]				
			Class 1	Class 2	Class 3	Class 4	Class 5
13	1.56	3.1	-	-		{ 3.22 2.53[e]	
14	0.06	0.8	-	-	-	0.30	5.22
20	-	n/a	-	-	-	-	-
23	-	n/a	-	-	-	-	-
44	-	n/a	-	-	-	-	-
52	-	n/a	-	-	-	-	-
53	-	n/a	-	-	-	-	-
116	-	0.52	-	-	-	2.47	

a all data received from Canadian Bio Resources Consultants Ltd.

b from Figure 4-9, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

c from Figure 5-1 , Hat Creek Detailed Environmental Studies, Agriculture Report[104]

d from Figure 4-7, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

e indicates that land is probably less suitable than indicated by CLI class, based on climate data (Figure 4-7 legend, Hat Creek Detailed Environmental Studies, Agriculture Report[104])

n/a inventory information not available

area have been assumed to be of general occurrence throughout the cultivated lands. However, alfalfa hay is the most common crop, with some plantings of grass-legume mixtures for hay or winter pasture, and a few plantings of annual cereals.

The major potential agricultural crops cited in the Agricultural Report are tomatoes (and other heat-loving crops), faba beans, potatoes, cabbage and corn, all of which could be grown in the Cache Creek - Ashcroft areas. The only proximate sites are 93 and 94. Corn is also depicted in the Agriculture Report, Figure 4-12, as a potential irrigated crop within Hat Creek Valley, but the area is close to the mine and generating station sites and is not expected to receive elevated levels of SO_2.

The lands identified in the Agriculture Report, Figure 4-7[104] as falling within Canada Land Inventory Classes 2 to 4 are for the most part Class 3 or Class 4. The most probable utilization of such land would be for hay production, if irrigated, or for reseeded range and grazing land.

Because of the alternatives between present and potential use for agriculture, the assessments of impact are presented individually for those sites at which injury or growth stimulation may occur. No effects are expected at sites 13, 23, 44 and 53. The assessment of the impact at the remaining sites are presented in Table F6-18.

(ii) Impact on Natural Vegetation

Inspection of Tables F6-1 to F6-16 indicates that the 366 m/FGD Air Quality Model is expected to give rise to some injury in receptor sites 28, 35, 36, and 124 for the average case predicted by ERT modelling.

The extent of injury in these sites is assessed in terms of annual impact and takes into account not only the probably impact of individual 1-, 3- and 24-hour average exposures, but also the consequences of repeated exposures throughout the growing season and the year, as discussed above Section F5.1(a)(iii)B.).

TABLE F6-18

POTENTIAL IMPACT OF SO_2 AND NO_x EMISSIONS
UPON EXISTING AND POTENTIAL AGRICULTURAL CROPS WITHIN SPECIFIC RECEPTOR SECTORS
BASED ON THE 366 M/FGD AIR QUALITY MODEL

Percent Injury

Crop Species	14	20	52	116
Medicago sativa	(+)	±0	±0	(+)
Trifolium hybridum	(+)	(+)	(+)	(+)
Bromus inermis	(+)	(+)	(+)	(+)
Lolium perenne	(+)	(+)	(+)	(+)
Phleum pratense	(±)	±0	±0	±0
Zea mays	(+)	(+)	(+)	(+)
Avena sativa	(+)	±0	±0	(+)

(+) Possible beneficial effect of SO on growth.

±0 Indicates threshold for injury.

It should be noted that several species in those sectors at which exposures are close to the injury threshold are listed as being possible beneficiaries of the SO_2 fumigations, as discussed above (Section F4.2; Figure F4-4). In addition, in several instances the dosage likely to be received is at the threshold of injury; i.e. is borderline between injury and possible benefit.

The lack of information about many of the species present poses additional problems in determining the overall impact of the predicted ground-level ambient concentrations. Thus, it is not possible to determine the nature of the ecological changes which would result. However, it is clear that, considering the average case situation alone, impact on *Salix sp.* would occur and would in turn probably lead to secondary impact on wildlife and gamebirds. Where *Salix* occurs in exposed locations, the impact within a single year may be relatively minor (except at site 124, Cornwall Peak), but would unquestionably lead to decline as a result of continuing stress.

No attempt has been made in this assessment to predict damage or economic loss. Furthermore, most of the assessments have required the exercise of judgment rather than measurement, particularly so since much of the injury expected will be of the chronic rather than the acute type, and, as has been pointed out previously, there is a dearth of quantitative information concerning chronic response. For purposes of quantitation, however, Tables F6-1 to F6-16 include information on the total cover of assessed species within each annular sector. While there is no simple method for deriving impact over a sector from knowlege of the probable injury to individual plants, an idea of the relative magnitude of the total impact on a given species can be obtained from the products of cover and injury.

(iii) Impact on Present and Potential Agriculture

In the context of the present and potential agricultural land (Table F6-17) and the diversity of agricultural crops suited to the Hat Creek region.

The assessments of impact presented in Table F6-18 relate to those species which are or might be grown on lands within specific receptor sites. They are all either annuals or perennials which are subject to one or more harvests annually. Hence the greater emphasis in terms of impact has been placed on exposures occurring during the growing season. Furthermore, the fact that they are all grown at lower elevations has been taken into account in making the assessments. As a result, the assessments suggest that there would be minimal negative impact, and that many crop species would possibly benefit from the predicted low-level exposures to SO_2, as has been shown for example to occur in alfalfa [94], perennial ryegrass[90] and corn[101]. Again, in some cases the effects of dosage will be borderline between injury and benefit.

(b) Regional Impact Assesement

The ERT regional projections for the uncontrolled emissions from a 366 m stack[1] are such that the predicted annual average concentrations of SO_2, NO, NO_2 and particulates are well below the thresholds of injury for veget-tion. The ERT modelling, however, does not provide information as to the occurrence of individual peak concentrations beyond the 25 km local zone of impact. Nevertheless, in the 366 m/FGD Air Quality Model, the 1-hour peaks greater than 450 $\mu g/m^3$ SO_2 appear to be confined to the local zone of impact, although there is uncertainty as to whether such peaks would occur in the SSW direction, i.e. beyond receptor site 16 (Figure F6-2). It appears therefore that no potentially injurious peak concentrations are likely to occur outside the local zone of impact. As a consequence, the impact of the 366 m/FGD system on the regional zone of impact is probably minimal, and may largely be related to marginal, if measurable, increases in growth.

Conversion products formed within the stack plume are similarly expected to result in low ambient concentrations of sulphate and nitrate which are unlikely to elicit any measurable response of vegetation within the 100 km radius regional zone of impact, regardless of whether the air contaminants impinge on the vegetation by dry or wet deposition, including acid rain.

F6.2 366 m STACK WITH METEOROLOGICAL CONTROL STRATEGY (MCS)

(a) Local Impact Assessment of SO_2 /NO_2 Emissions

The assessment of impact due to emissions of SO_2 and NO_2 from the 366 m/MCS systems within the local zone of impact has followed the same form as that for the FGD strategy. Below are presented sections on the basis for these particular assessments, the assessments themselves, and discussion of their significance to natural vegetation and to agriculture.

(i) Basis for Assessment

ERT PEAK programme data were again used as described for the 366 m/FGD strategy (Section F6.1) to prepare concentration and frequency distributions for 1-hour, 3-hour and 24-hour averaging times. The 1-hour predictions are presented in Figures F6-8 to F6-10, the 3-hour in Figures F6-11 to F6-13, and the 24 hour in Figures F6-14 to F6-16.

In the case of the 1-hour peak distributions, comparison of Figures F6-8 and F6-9 again shows that the maxima were essentially the same for each receptor site in the April-October season as for the whole year. With regard to the 3-hour averages, there were reductions in the maxima for sites 14, 15, 16, 20, 21, 22, 23, 27, 28, 29, 51, 52 and 61 as revealed by comparison of Figures F6-11 and F6-12.

Of the 1-hour excursions, inspection of the PEAK programme data again indicated that approximately 60 percent occurred during daylight hours and that 20 percent of these were at daybreak. In the case of the 3-hour averages, half of the 100 excursions occurred in daylight hours, with only 2 occurring at dawn.

In contrast, most of the 24-hour averages >160 $\mu g/m^3$ SO_2 occurred outside the April-October season with the result that sites 27, 18, 19, 43, 52, 61

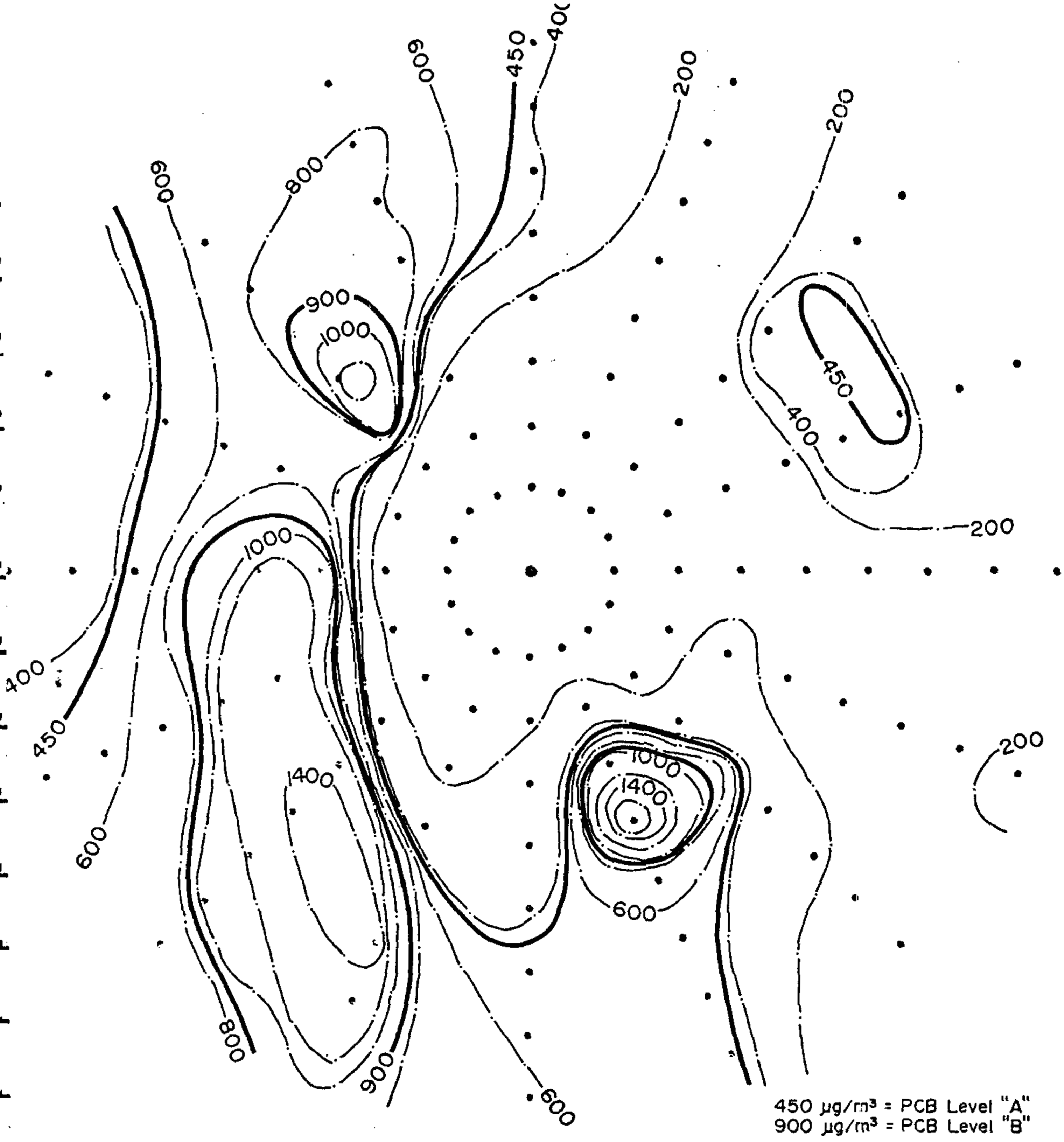


Figure F6-8

PREDICTED ANNUAL MAXIMUM 1-HOUR SO_2 CONCENTRATIONS (µg/m³) 366 m STACK WITH MCS

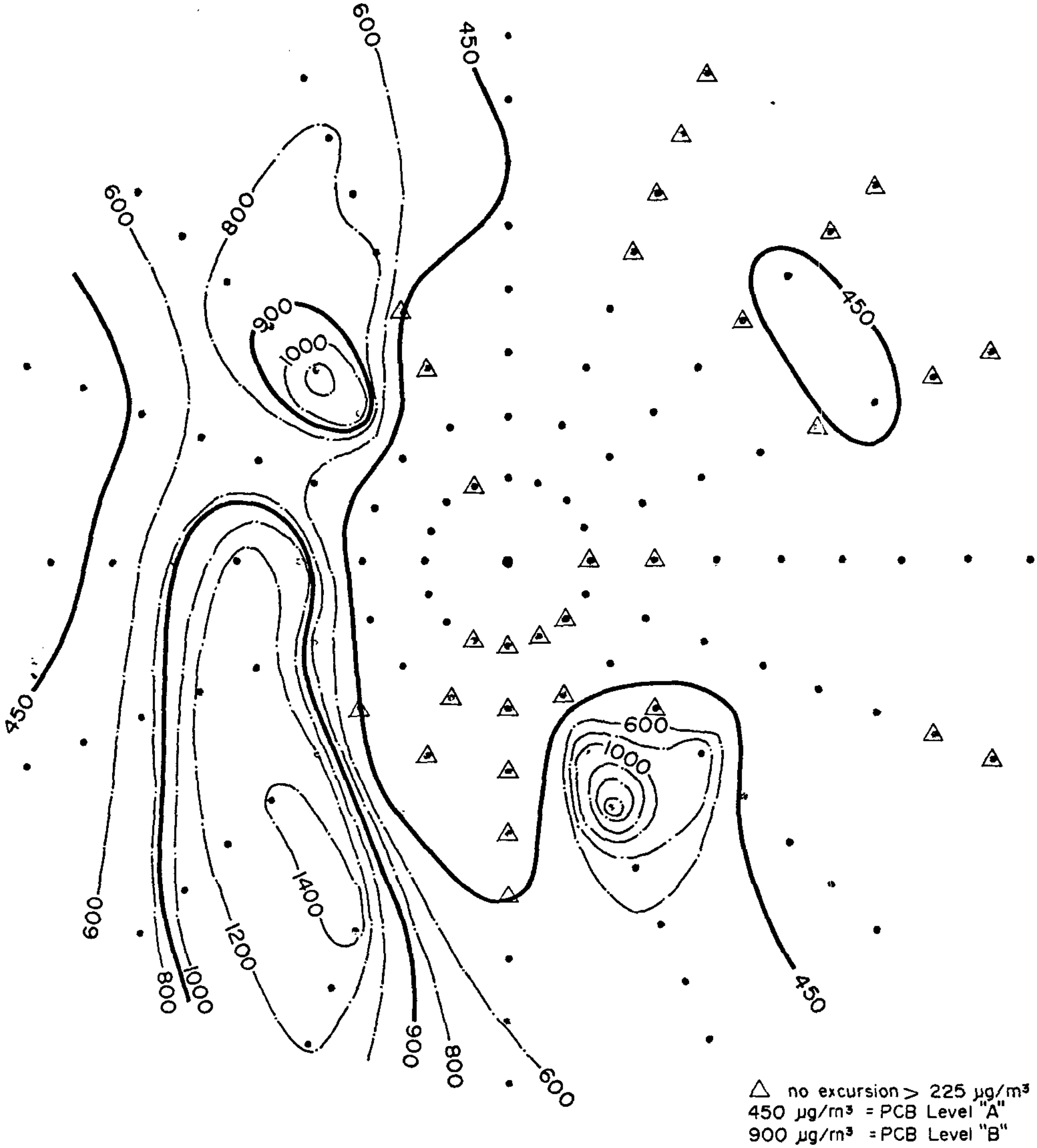


Figure F6-9

PREDICTED SEASONAL MAXIMUM
1-HOUR SO_2 CONCENTRATIONS (µg/m³)
366 m STACK WITH MCS

Figure F6-10

PREDICTED SEASONAL TOTALS
OF 1-HOUR SO_2 CONCENTRATIONS > 450 µg/m³
366m STACK WITH MCS

Figure F6-11

PREDICTED ANNUAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS ($\mu g/m^3$)
366 m STACK WITH MCS

Figure F6-12

PREDICTED SEASONAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS (µg/m³)
366 m STACK WITH MCS

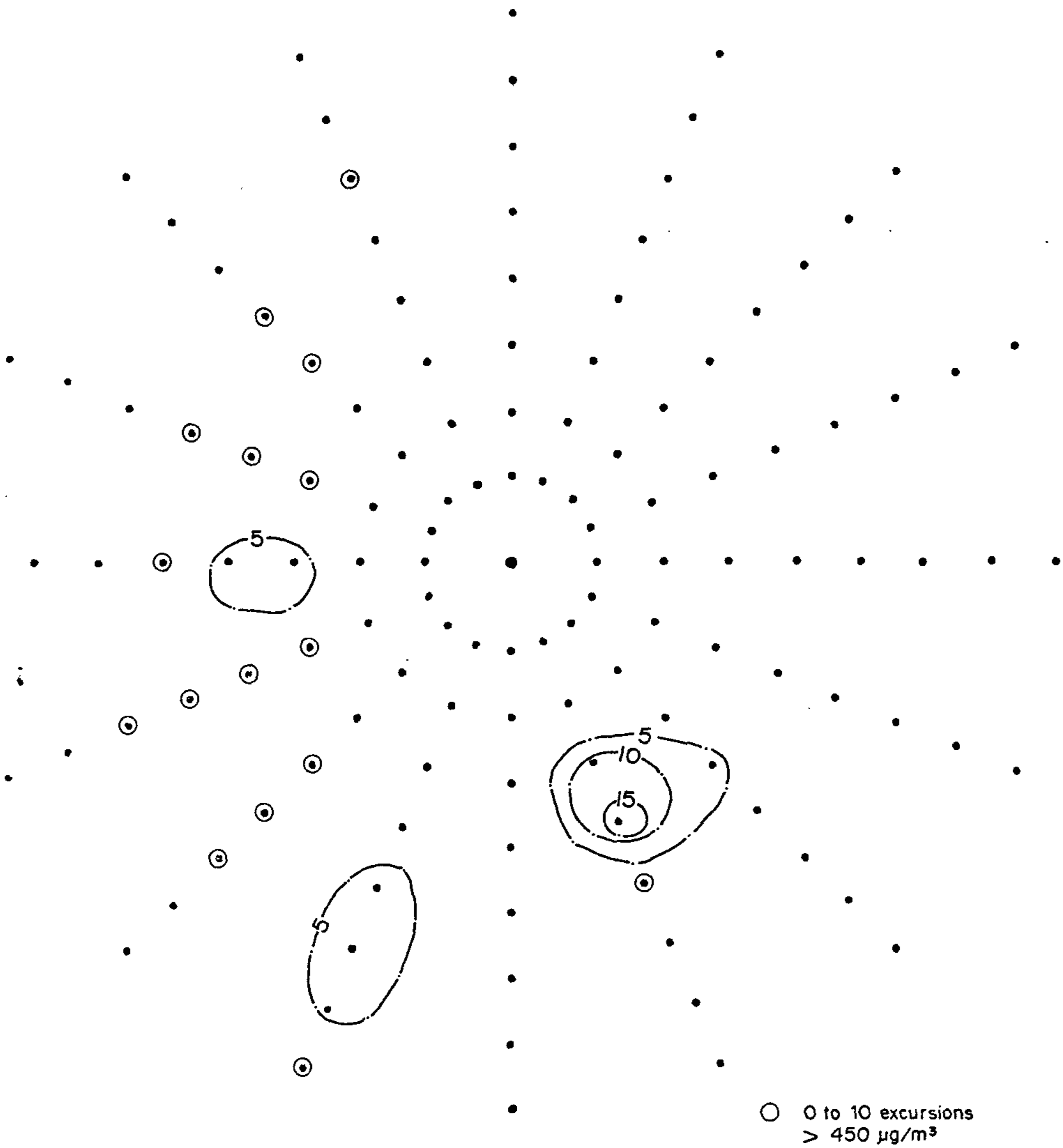


Figure F6-13

PREDICTED SEASONAL TOTALS
OF 3-HOUR SO_2 CONCENTRATIONS > 300 µg/m³
366 m STACK WITH MCS

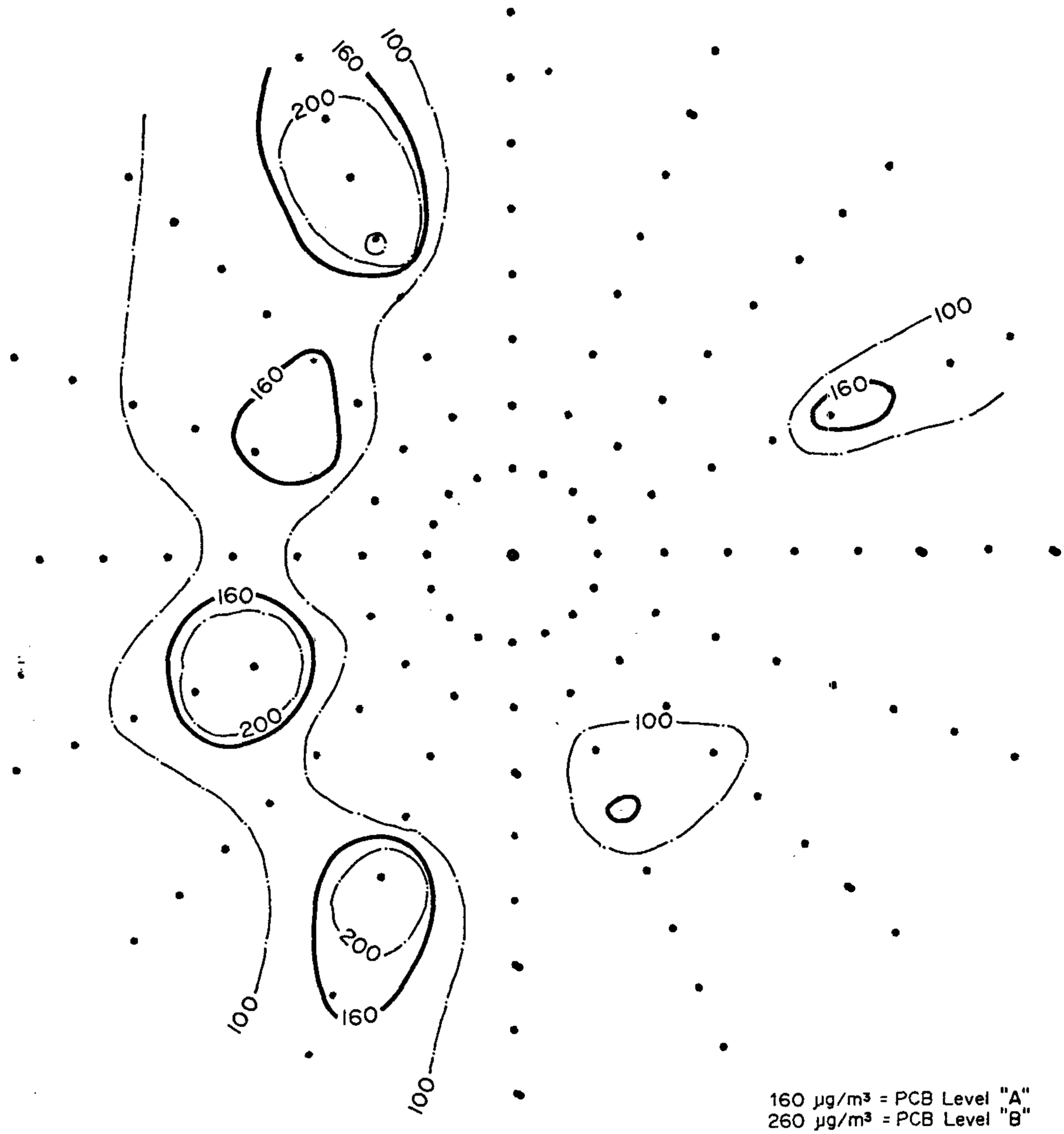


Figure F6-14

PREDICTED ANNUAL MAXIMUM
24-HOUR SO_2 CONCENTRATIONS (µg/m³)
366 m STACK WITH MCS

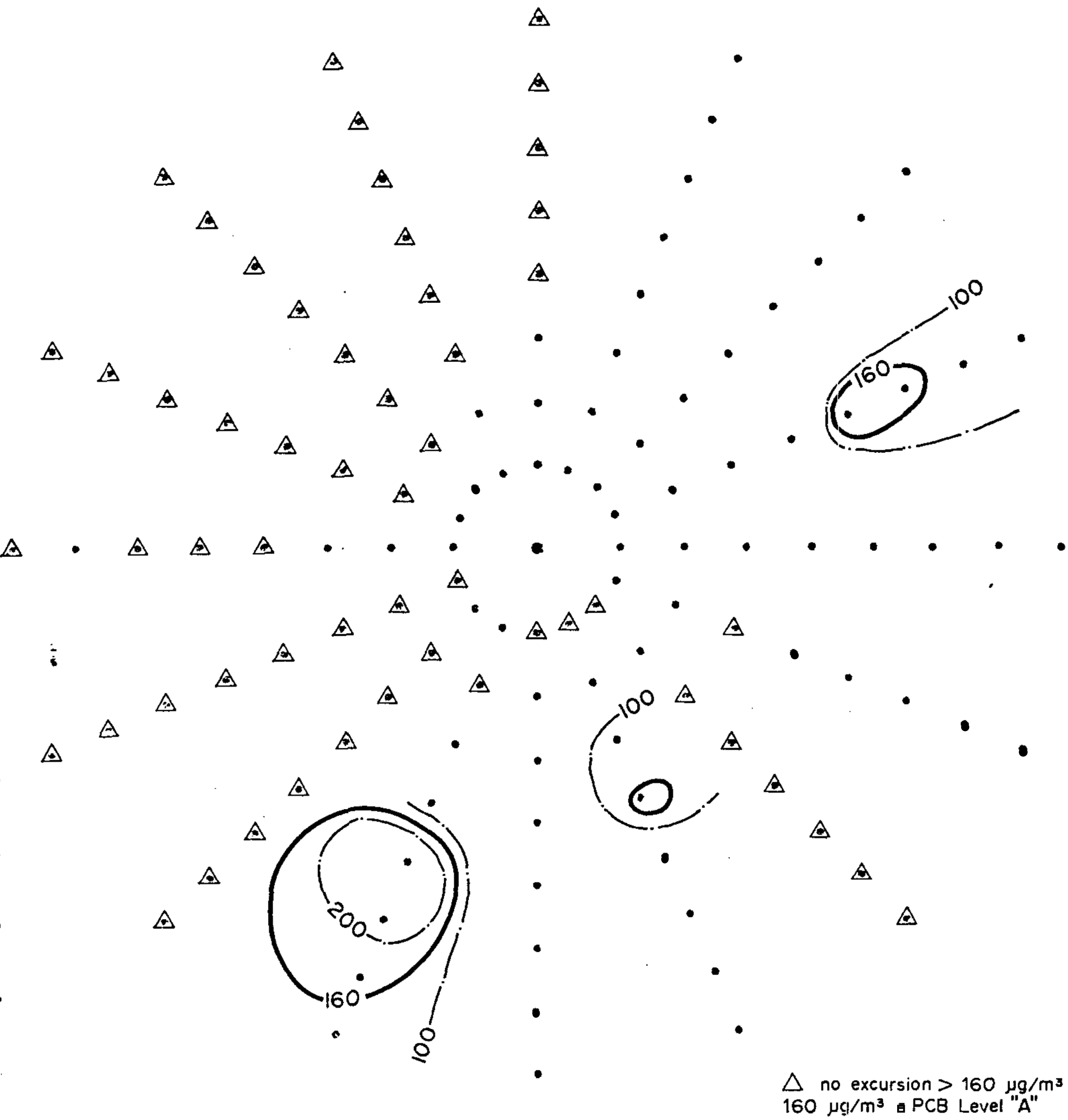


Figure F6-15

PREDICTED SEASONAL MAXIMUM
24-HOUR SO_2 CONCENTRATIONS (µg/m³)
366 m STACK WITH MCS

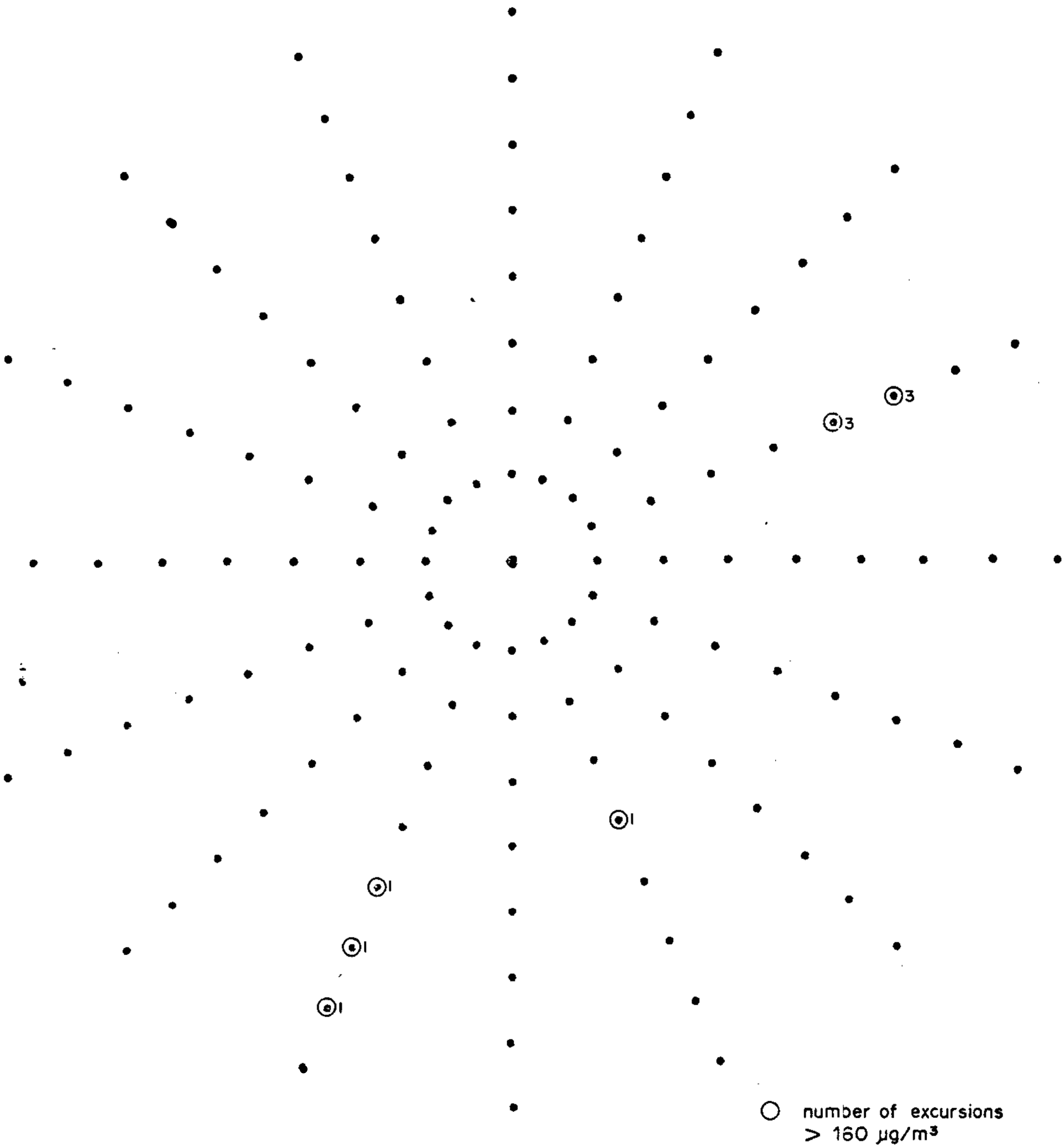


Figure F6-16

PREDICTED SEASONAL TOTALS OF 24-HOUR SO_2 CONCENTRATIONS > 160 $\mu g/m^3$ 366 m STACK WITH MCS

62, 63 and 63 do not show such averages in Figure F6-15 (cf. Figure F6-14). A total of 10 24-hour averages $\mu g/m^3$ SO_2 occur between April 1 and October 31, at sites 13, 14, 15, 93, 94 and 124.

Since appreciably more receptor sites are exposed in significant 1-hour, 3-hour aor 24-hour concentratons than in the case of the 366 m stack/FGD projections, the assessments of injury in the present 366 m stack/MCS situation have been undertaken for sites 8, 13, 14, 15, 16, 20, 21, 22, 23, 27, 28, 29, 30, 35, 36, 37, 43, 44, 45, 51, 52, 53, 54, 63, 64, 116, 123, 124 and 125. These assessments of injury, together with the estimates of cover for each species listed are presented in Tables F6-19 and F6-46. The criteria for inclusion of a species are those described in Section F5.1 (a)(iii). Complete cover estimates for all species prodiving 0.1 km cover within a receptor site are presented in Addendum A.

No assessment data are tablulated for sites 6, 7, 24, 31, 32, 38, 46, 55, 56, 61, 62, 64, 70, 86, 93, 94, 126, 127 and 128 since only possible beneficial effects (on those species for which assessment is feasible) appear likely.

Agricultural impact is again assessed in terms of both present and potential use. Table F6-47 presents details of present and potential agricultural lands within the receptor sectors in which potentially injurious SO_2/NO_2 levels may occur, i.e. sites 6, 13, 14, 20, 23, 34, 31, 32, 38, 43, 44, 45, 52, 53, 54, 55, 56, 63, 64, 70, 86, 93, 94, 116, 125, 127, and 128. Of these sectors, 13, 14, 20, 24, 44, 45, 52, 53, 55, 56, 93, 116 and 125 include lands currently under cultivation. The assessments of impact on agricultural crops are summarized in Table F6-48, for those receptor sectors in which injury is expected to occur. Thus, no specific data are presented for sectors 6, 24, 31, 32, 38, 45, 52, 53, 54, 55, 56, 63, 64, 70, 86, 93, 94, 126 and 127 and 128 since it seems likely that the effects, if any, in these sectors will probably be slightly beneficial.

TABLE F6-19

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 8
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	45	723
3-hr.>300 μg/m³	0	
24-hr.>160 μg/m³	0	

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.5	0(+)
Picea engelmannii	6.8	0(+)
Pinus contorta	5.8	0(+)
Pseudotsuga menziesii	1.3	0(+)
Arctostaphylos uva-ursi	1.9	0(+)
Juniperus communis	1.1	0(+)
Juniperus scopulorum	0.1	0(+)
Salix cascadensis	0.8	3
Salix nivalis	0.9	3
Shepherdia canadensis	1.4	?
Vaccinium scoparium	7.4	?
Agropyron spicatum	0.3	?
Calamagrostis purpurascens	0.5	?
Calamagrostis rubescens	6.3	?
Carex albo-nigrum	1.0	?
Poa grayana	0.8	?
Stipa occidentalis	0.1	0(+)
Trisetum spicatum	0.2	0(+)
Achillea millefolium	0.3	0(+)
Antennaria umbrinella	0.2	0(+)
Dryas octopetala	1.9	?
Equisetum arvense	0.1	0(+)
Equisetum scirpoides	0.2	0(+)
Fragaria glauca	1.8	?
Linnaea borealis	1.6	?

TABLE F6-19 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Lupinus lepidus	2.2	?
Pedicularis bracteosa	0.7	?
Phyllodoce empetriformis	0.9	?
Pyrola secunda	0.5	?
Alectoria fremontii	0.5	?
Alectoria jubtata	3.3	0
Alectoria saramentosa	1.7	?
Letharia vulpina	1.5	?
Peltigera aphthosa	0.8	?
Drepanocladus uncinatus	0.9	0
Pleurozium schreberi	3.1	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-20

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 13
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	71	943
3-hr.>300 $\mu g/m^3$	7	438
24-hr.>160 $\mu g/m^3$	1	208

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.1	1
Picea engelmannii	1.9	1
Pinus contorta	2.5	1
Pseudotsuga menziesii	2.0	1
Amelanchier alnifolia	0.2	1
Arctostaphylos uva-ursi	0.9	0(+)
Juniperus communis	0.5	0(+)
Salix sp.	0.2	14
Shepherdia canadensis	0.7	?
Vaccinium scoparium	1.9	?
Agropyron spicatum	0.4	?
Calamagrostis rubescens	5.3	?
Carex rostrata	0.2	?
Hordeum jubatum	1.0	?
Juncus balticus	0.7	?
Poa pratensis	0.5	3
Achillea millefolium	0.3	0(+)
Fragaria glauca	0.6	?
Linnaea borealis	0.6	?
Lupinus lepidus	0.5	?
Taraxacum officinale	0.2	0(+)
Alectoria jubata	1.3	0
Letharia vulpina	2.0	?
Drepanocladus uncinatus	0.2	0
Pleurozium schreberi	1.3	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-21

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 14
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	72	1565
3-hr.>300 $\mu g/m^3$	7	487
24-hr.>160 $\mu g/m^3$	1	214

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.4	4
Picea engelmannii	5.6	2
Pinus contorta	4.6	2
Pseudotsuga menziesii	1.8	2
Amelanchier alnifolia	0.1	2
Arctostaphylos uva-ursi	0.9	0(+)
Artemisia frigida	0.1	0(+)
Juniperus communis	0.8	0(+)
Salix sp.	0.2	28
Shepherdia canadensis	1.1	?
Vaccinium scoparium	9.5	?
Agropyron spicatum	0.4	?
Hordeum jubatum	0.4	?
Poa pratensis	0.2	7
Achillea millefolium	0.1	0(+)
Equisetum arvense	0.1	0(+)
Equisetum scirpoides	0.1	?
Fragaria glauca	1.2	?
Linnaea borealis	1.3	?
Lupinus lepidus	1.6	?
Phyllodoce empetriformis	0.7	?
Taraxacum officinale	0.1	0(+)
Alectoria jubata	2.7	1
Alectoria saramentosa	0.8	?
Letharia vulpina	2.0	?

TABLE F6-21 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Peltigera aphthosa	0.7	?
Drepanocladus uncinatus	0.8	0
Pleurozium schreberi	2.6	3

(+) Possible beneficial effect of SO_2 on growth.

(±) Indicates threshold for injury

TABLE F6-22

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 15
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 $\mu g/m^3$	73	1342
3-hr. >300 $\mu g/m^3$	5	407
24-hr. >160 $\mu g/m^3$	1	178

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.5	3
Picea engelmannii	6.0	2
Pinus contorta	5.1	2
Pseudotsuga menziesii	1.1	2
Arctostaphylos uva-ursi	1.7	0(+)
Juniperus communis	1.0	0(+)
Juniperus scopulorum	0.1	0(+)
Salix cascadensis	0.7	24
Salix nivalis	0.8	24
Shepherdia canadensis	1.2	?
Vaccinium scoparium	6.5	?
Agropyron spicatum	0.3	?
Calamagrostis rubescens	5.6	?
Carex albo-nigrum	0.9	?
Poa grayana	0.7	?
Stipa occidentalis	0.1	0(+)
Trisetum spicatum	0.2	0(+)
Achillea millefolium	2.3	0(+)
Dryas octopetala	1.7	?
Equisetum arvense	0.1	0(+)
Equisetum scirpoides	0.1	0(+)
Fragaria glauca	1.6	?
Linnaoa borealis	1.4	?
Lupinus lepidus	2.0	?

TABLE F6-22 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Pedicularis bracteosa	0.6	?
Phyllodoce empetriformis	0.8	?
Alectoria jubata	2.9	0
Alectoria saramentosa	1.5	?
Letharia vulpina	1.4	?
Peltigera aphthosa	0.7	?
Drepanocladus uncinatus	0.8	0
Pleurozium schreberi	2.7	3

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-23

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 16
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	50	1203
3-hr.>300 μg/m³	1	353
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.5	0(±)
Picea engelmannii	6.8	0(±)
Pinus contorta	5.8	0(±)
Pseudotsuga menziesii	1.3	0(±)
Arctostaphylos uva-ursi	1.9	0(+)
Juniperus communis	1.1	0(+)
Juniperus scopulorum	0.1	0(+)
Salix cascadensis	0.8	10
Salix nivalis	0.9	10
Shepherdia canadensis	1.4	?
Vaccinium scoparium	7.4	?
Agropyron spicatum	0.3	?
Calamagrostis purpurascens	0.5	?
Calamagrostis rubescens	6.3	?
Carex albo-nigrum	1.0	?
Poa grayana	0.8	?
Stipa occidentalis	0.1	0(+)
Trisetum spicatum	0.2	0(+)
Achillea millefolium	0.3	0(+)
Antennaria umbrinella	0.184	0(+)
Dryas octopetala	1.9	?
Equisetum arvense	0.1	0(+)
Equisetum scirpoides	0.2	0(+)
Frageris glauca	1.8	?
Linnaea borealis	1.6	?
Lupinus lepidus	2.2	?

TABLE F6-23 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Pedicularis bracteosa	0.7	?
Phyllodoce emperiformis	0.9	?
Pyrola secunda	0.5	?
Alectoria fremontii	0.5	?
Alectoria jubata	3.3	0
Alectoria saramentosa	1.7	?
Letharia vulpina	1.5	?
Peltigera aphthosa	0.8	?
Drepanocladus uncinatus	0.9	0
Pleurozium schreberi	3.1	1

(+) Possible beneficial effect of SO_2 on growth.

(±) Indicates threshold for injury.

TABLE F6-24

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 20
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	32	1219
3-hr.>300 $\mu g/m^3$	2	352
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.1	0(+)
Picea engelmannii	1.9	0(+)
Pinus contorta	5.5	0(+)
Pseudotsuga menziesii	1.9	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	1.1	0(+)
Juniperus communis	1.2	0(+)
Salix sp.	0.2	3
Shepherdia canadensis	1.4	?
Vaccinium scoparium	2.9	?
Agropyron spicatum	0.1	?
Calamagrostis rubescens	8.1	?
Carex rostrata	0.1	?
Achillea millefolium	0.1	0(+)
Fragaria glauca	0.8	?
Linnaea borealis	0.9	?
Lupinus lepidus	1.0	?
Alectoria fremontii	1.4	?
Alectoria jubata	2.3	0
Letharia vulpina	2.3	?
Peltigera aphthosa	0.6	?
Drepanocladus uncinatus	0.3	0
Pleurozium schreberi	2.2	0

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-25

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 21
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.> 450 μg/m³	32	1438
3-hr.>300 μg/m³	4	451
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km³)	Percent Injury
Abies lasiocarpa	0.7	0(+)
Picea engelmannii	6.7	0(+)
Pinus contorta	3.5	0(+)
Pinus albicaulis	0.2	?
Arctostaphylos uva-ursi	1.4	0(+)
Juniperus communis	0.8	0(+)
Salix cascadensis	1.9	5
Salix nivalis	2.0	5
Shepherdia canadensis	0.9	?
Vaccinium membranaceum	0.2	?
Vaccinium scoparium	5.0	?
Calamagrostis purpurascens	0.1	?
Calamagrostis rubescens	2.1	?
Carex albo-nigrum	0.4	?
Cornus canadensis	0.6	?
Equisetum arvense	0.2	0(+)
Equisetum scirpoides	0.2	0(+)
Fragaria glauca	1.4	?
Linnaea borealis	2.4	?
Lupinus lepidus	1.6	?
Pedicularis bracteosa	0.5	?
Thalictrum occidentalis	0.5	?
Alectoria fremontii	0.5	?
Alectoria jubata	3.3	0
Alectoria saramentosa	0.6	?

TABLE F6-25 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Peltigera aphthosa	0.9	?
Drepanocladus uncinatus	0.7	0
Pleurozium schreberi	4.3	1

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-26

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 22
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	33	1276
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.6	0(+)
Picea engelmannii	6.5	0(+)
Pinus albicaulis	0.2	?
Pinus contorta	1.7	0(+)
Pseudotsuga menziesii	0.4	0(+)
Arctostaphylos uva-ursi	1.6	0(+)
Artemisia frigida	0.1	0(+)
Juniperus communis	0.4	0(+)
Juniperus scopulorum	0.1	0(+)
Salix sp.	0.2	4
Salix cascadensis	1.2	4
Salix nivalis	1.4	4
Shepherdia canadensis	0.7	?
Vaccinium scoporium	4.9	?
Agropyron spicatum	0.3	?
Calamagrostis purpurascens	0.5	?
Calamagrostis rubescens	1.5	?
Carex albo-nigrum	1.2	?
Carex rostrata	0.1	?
Poa grayana	0.7	?
Stipa occidentalis	0.1	0(+)
Trisetum spicatum	0.1	0(+)
Achillea millefolium	0.3	0(+)
Antennaria alpina	0.1	0(+)
Antennaria umbrinella	0.2	0(+)

TABLE F6-26 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Dryas octopetala	2.0	?
Equisetum arvense	0.3	0(+)
Equisetum scirpoides	0.3	0(+)
Fragaria glauca	1.3	?
Linnaea borealis	2.1	?
Lupinus lepidus	1.1	?
Pedicularis bracteosa	0.6	?
Taraxacum officinale	0.1	0(+)
Alectoria jubata	0.6	0
Alectoria saramentosa	0.5	?
Peltigera aphthosa	0.7	?
Drepanocladus uncinatus	0.6	0
Pleurozium schreberi	3.7	0

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-27

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 23
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	30	1140
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.8	0(+)
Picea engelmannii	9.3	0(+)
Pinus albicaulis	0.1	?
Pinus contorta	2.7	0(+)
Pseudotsuga menziesii	1.5	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	1.6	0(+)
Juniperus communis	0.4	0(+)
Salix sp.	0.1	2
Salix cascadensis	1.1	2
Salix nivalis	1.2	2
Shepherdia canadensis	0.8	?
Vaccinium scoparium	7.3	?
Agropyron spicatum	0.1	?
Calamagrostis rubescens	3.3	?
Carex albo-nigrum	0.7	?
Poa grayana	0.6	?
Trisetum spicatum	0.2	0(+)
Achillea millefolium	0.2	0(+)
Antennaria umbrinella	0.1	0(+)
Cornus canadensis	0.5	?
Dryas octopetala	1.0	?
Equisetum arvense	0.3	0(+)
Equisetum scirpoides	0.3	0(+)
Fragaria glauca	1.7	?

TABLE F6-27 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Linnaea borealis	2.5	?
Lupinus lepidus	1.7	?
Pedicularis bracteosa	0.8	?
Phyllodoce empetriformis	0.6	?
Pyrola secunda	0.5	?
Thalictrum occidentalis	0.5	?
Alectoria jubata	2.7	0
Alectoria saramentosa	0.9	?
Letharia vulpina	1.4	?
Peltigera aphthosa	0.9	?
Drepanocladus uncinatus	1.0	0
Pleurozium schreberi	4.5	0

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-28

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 27
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m³	25	764
3-hr. >300 μg/m³	1	301
24-hr. >160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Picea engelmannii	0.8	0(+)
Pinus contorta	3.4	0(+)
Pseudotsuga menziesii	2.5	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.1	0(+)
Juniperus communis	0.7	0(+)
Salix sp.	0.2	1
Shepherdia canadensis	0.9	?
Vaccinium scoparium	1.5	?
Agropyron spicatum	0.2	?
Calamagrostis rubescens	7.2	?
Achillea millefolium	0.2	0(+)
Allium cernuum	0.2	?
Arnica latifolia	0.2	?
Cornus canadensis	0.2	?
Fragaria glauca	0.5	?
Linnaea borealis	0.4	?
Lupinus lepidus	0.6	?
Phyllodoce empetriformis	0.2	?
Pyrola secunda	0.2	?
Alectoria jubata	1.4	0
Letharia vulpina	2.1	?
Drepanocladus uncinatus	0.2	0
Pleurozium schreberi	1.0	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-29

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 28
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 $\mu g/m^3$	32	1309
3-hr. >300 $\mu g/m^3$	4	482
24-hr. >160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.4	0(+)
Picea engelmannii	5.4	0(+)
Pinus contorta	2.1	0(+)
Pinus ponderosa	0.1	0(+)
Pseudotsgua menziesii	1.1	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	0.6	0(+)
Juniperus communis	0.3	0(+)
Juniperus scopulorum	0.2	0(+)
Salix sp.	0.3	5
Shepherdia canadensis	0.6	?
Vaccinium scoparium	4.3	?
Agropyron spicatum	0.6	?
Calamagrostis rubescens	1.9	?
Carex rostrata	0.3	?
Achillea millefolium	0.2	0(+)
Equisetum arvense	0.2	0(+)
Equisetum scirpoides	0.2	0(+)
Fragaria glauca	0.9	?
Linnaea borealis	1.5	?
Lupinus lepidus	0.9	?
Alectoria jubata	1.7	0
Alectoria saramentosa	0.5	?
Letharia vulpina	6.7	?

TABLE F6-29 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Peltigera aphthosa	0.6	?
Drepanocladus uncinatus	0.6	0
Pleurozium schreberi	2.8	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-30

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 29
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	32	1306
3-hr.>300 $\mu g/m^3$	4	571
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury	
Abies lasiocarpa		0(±)	
Picea engelmannii		0(+)	
Pinus albicaulis		?	
Pinus contorta		0(+)	
Arctostaphylos uva-ursi		0(+)	
Juniperus communis		0(+)	
Salix sp.		5	
Salix cascadensis		5	
Salix nivalis		5	
Vaccinium scoparium		?	
Agropyron spicatum		?	
Calamagrostis rubescens		?	
Carex albo-nigrum		?	
Carex rostrata		?	
Festuca ovina		?	
Poa grayana		?	
Trisetum spicatum		0(+)	
Achillea millefolium		0(+)	
Antennaria roseus		0(+)	
Dryas octopetala		0	
Equisetum arvense		0(+)	
Eriogonum heracleoides		?	
Fragaria glauca		?	
Linnaea borealis		?	

TABLE F6-30 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Lupinus lepidus	1.9	?
Pedicularis bracteosa	0.6	?
Thalictrum occidentalis	0.6	?
Alectoria jubata	1.2	0
Drepanocladus uncinatus	0.5	0
Pleurozium schreberi	1.2	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-31

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 30
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	31	757
3-hr.>300 μg/m³	1	303
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.8	0(+)
Picea engelmannii	7.4	0(+)
Pinus contorta	2.0	0(+)
Pseudotsuga menziesii	2.1	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	1.3	0(+)
Juniperus communis	0.2	0(+)
Salix sp.	0.2	3
Shepherdia canadensis	0.9	?
Vaccinium scoparium	5.3	?
Agropyron spicatum	0.3	?
Calamagrostis purpurascens	0.3	?
Calamagrostis rubescens	4.6	?
Poa pratensis	0.4	0(+)
Stipa occidentalis	0.2	0(+)
Achillea millefolium	0.4	0(+)
Equisetum arvense	0.3	0(+)
Fragaria glauca	1.2	?
Linnaea borealis	2.8	?
Lupinus lepidus	1.0	?
Pyrola secunda	0.5	?
Taraxacum officinale	0.1	0(+)
Alectoria jubata	2.2	0
Alectoria saramentosa	0.6	?

TABLE F6-31 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Letharia vulpina	2.0	?
Peltigera aphthosa	0.8	?
Drepanocladus uncinatus	0.8	0
Pleurozium schreberi	3.9	0

(+) Possible beneficial effect of SO_2 on growth.

(±) Indicates threshold for injury.

TABLE F6-32

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON VEGETATION WITHIN RECEPTOR SECTOR 35 BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	39	1024
3-hr.>300 $\mu g/m^3$	6	570
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Picea engelmannii	0.6	0(+)
Pinus contorta	3.7	0(+)
Pseudotsuga menziesii	2.6	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.2	0(+)
Juniperus communis	0.8	0(+)
Salix sp.	0.2	6
Shepherdia canadensis	1.0	?
Vaccinium scoparium	1.5	?
Calamagrostis rubescens	8.0	?
Achillea millefolium	0.2	0(+)
Fragaria glauca	0.6	?
Lupinus lepidus	0.6	?
Alectoria jubata	1.5	0
Letharia vulpina	2.3	?
Peltigera aphthosa	0.3	?
Drepanocladus uncinatus	0.1	0
Pleurozium schreberi	0.8	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-33

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 36
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration	
		Average Case	Worst Case
1-hr.>450 μg/m³	46	1309	
3-hr.>300 μg/m³	6	646	
24-hr.>160 μg/m³			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.5	0(+)
Picea engelmannii	6.4	0(+)
Pinus contorta	3.2	0(+)
Arctostaphylos uva-ursi	0.1	0(+)
Juniperus communis	0.6	0(+)
Salix sp.	0.5	9
Shepherdia canadensis	0.9	?
Vaccinium scoparium	4.5	?
Calamagrostis rubescens	2.0	?
Carex aquatilis	0.1	?
Carex rostrata	0.5	?
Cornus canadensis	0.6	?
Equisetum arvense	0.4	0(+)
Fragaria glauca	0.9	?
Linnaea borealis	2.8	?
Lupinus lepidus	0.7	?
Alectoria fremontii	0.6	?
Alectoria jubata	2.4	0
Alectoria saramentosa	0.5	?
Drepanocladus uncinatus	0.6	0
Pleurozium schreberi	5.0	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-34

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 37
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr >450 μg/m³	44	941
3-hr.>300 μg/m³	3	449
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.7	0(+)
Picea engelmannii	7.8	0(+)
Pinus contorta	1.9	0(+)
Pseudotsuga menziesii	1.0	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	0.7	0(+)
Juniperus communis	0.3	0(+)
Juniperus scopulorum	0.2	0(+)
Salix sp.	0.4	4
Shepherdia canadensis	0.9	?
Vaccinium scoparium	4.7	?
Agropyron spicatum	0.5	?
Calamagrostis rubescens	2.0	?
Carex rostrata	0.3	?
Achillea millefolium	0.1	0(+)
Fragaria glauca	1.0	?
Linnaea borealis	3.2	?
Alectoria fremontii	0.6	?
Alectoria jubata	2.2	0
Letharia vulpina	0.8	?
Peltigera aphthosa	1.0	?
Drepanocladus uncinatus	0.7	0
Pleurozium schreberi	5.7	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-35

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 43
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration	
		Average Case	Worst Case
1-hr.>450 μg/m³	50	550	
3-hr.>300 μg/m³	4	320	
24-hr.>160 μg/m³			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.5	0(+)
Picea engelmannii	1.5	0(+)
Pinus contorta	0.3	0(+)
Pseudotsuga menziesii	3.2	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.2	0(+)
Salix sp.	0.2	6
Shepherdia canadensis	0.5	?
Vaccinium scoparium	0.6	?
Agropyron spicatum	0.6	?
Calamagrostis rubescens	6.0	?
Achillea millefolium	0.3	0(+)
Alectoria jubata	0.6	0
Letharia vulpina	3.0	?
Pleurozium schreberi	0.8	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-36

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 44
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m^3	50	783
3-hr.>300 μg/m^3	4	399
24-hr.>160 μg/m^3		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.4	0(+)
Picea engelmannii	4.1	0(+)
Pinus contorta	1.0	0(+)
Pinus ponderosa	0.2	0(+)
Pseudotsuga menziesii	2.0	0(+)
Arctostaphylos uva-ursi	0.8	0(+)
Juniperus communis	0.4	0(+)
Juniperus scopulorum	0.5	0(+)
Populus tremuloides	0.1	4
Salix sp.	0.4	5
Shepherdia canadensis	0.7	?
Vaccinium scoparium	2.5	?
Agropyron spicatum	1.0	?
Calamagrostis rubescens	1.4	?
Carex rostrata	0.3	?
Koeleria cristata	0.2	0(+)
Stipa richardsonii	0.1	0(+)
Achillea millefolium	0.1	0(+)
Antennaria roseus	0.1	0(+)
Equisetum arvense	0.2	0(+)
Fragaria glauca	0.6	?
Linnaea borealis	1.7	?
Alectoria jubata	1.2	0
Letharia vulpina	0.6	?
Peltigera aphthosa	0.5	?
Drepanocladus uncinatus	0.3	0
Pleurozium schreberi	3.0	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-37

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 45
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	50	664
3-hr.>300 $\mu g/m^3$	1	319
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.7	0(+)
Picea engelmannii	5.3	0(+)
Pinus contorta	1.2	0(+)
Pinus ponderosa	0.2	0(+)
Pseudotsuga menziesii	2.6	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.2	0(+)
Juniperus communis	0.3	0(+)
Juniperus scopulorum	0.2	0(+)
Salix sp.	0.2	2
Shepherdia canadensis	0.9	?
Vaccinium scoparium	3.0	?
Agropyron spicatum	0.9	?
Calamagrostis rubescens	5.0	?
Koeleria cristata	0.1	0(+)
Achillea millefolium	0.3	0(+)
Equisetum arvense	0.2	0(+)
Fragaria glauca	0.8	?
Linnaea borealis	2.1	?
Alectoria jubata	1.6	0
Letharia vulpina	2.4	?
Peltigera aphthosa	0.6	?
Drepanocladus uncinatus	0.4	0
Pleurozium schreberi	3.7	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-38

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 51
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	22	1024
3-hr.>300 μg/m³	2	346
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.4	0(+)
Picea engelmannii	0.6	0(+)
Pinus contorta	0.6	0(+)
Pseudotsuga menziesii	3.7	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.5	0(+)
Juniperus communis	0.1	0(+)
Rosa gymnocarpa	0.6	?
Salix sp.	0.4	2
Shepherdia canadensis	0.8	?
Vaccinium scoparium	0.6	?
Agropyron spicatum	0.2	?
Calamagrostis rubescens	1.0	?
Carex rostrata	0.2	?
Achillea millefolium	0.3	0(+)
Alectoria jubata	0.4	0
Letharia vulpina	3.6	?

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-39

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 52
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m³	25	1267
3-hr. >300 μg/m³	3	349
24-hr. >160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.2	0(+)
Picea engelmannii	1.4	0(+)
Pinus contorta	3.7	0(+)
Pinus ponderosa	0.1	0(+)
Pseudotsuga menziesii	3.0	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.2	0(+)
Juniperus communis	0.8	0(+)
Juniperus scopulorum	0.2	0(+)
Rhododendron albiflorum	2.1	?
Rosa gymnocarpa	0.6	?
Salix sp.	0.4	4
Shepherdia canadensis	2.8	?
Vaccinium membranaceum	0.3	?
Vaccinium scoparium	3.7	?
Agropyron spicatum	0.6	?
Calamagrostis rubescens	4.9	?
Carex rostrata	0.3	?
Trisetum spicatum	0.3	0(+)
Achillea millefolium	0.2	0(+)
Antennaria roseus	0.1	0(+)
Fragaria glauca	0.5	?
Linnaea borealis	1.0	?
Alectoria jubata	0.5	0
Letharia vulpina	3.2	?
Pleurozium schreberi	0.3	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-40

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 53
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	25	941
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.3	0+
Picea engelmannii	3.9	0+
Pinus contorta	4.6	0(+)
Pinus ponderosa	0.5	0(+)
Pseudotsuga menziesii	0.9	0(+)
Arctostaphylos uva-ursi	0.6	0(+)
Chrysothamnus nauseosus	0.2	0(+)
Juniperus communis	1.1	0(+)
Juniperus scopulorum	0.4	0(+)
Rhododendron albiflorum	1.1	?
Salix sp.	0.4	2
Shepherdia canadensis	1.7	?
Vaccinium membranaceum	0.2	?
Vaccinium scoparium	4.7	?
Agropyron spicatum	2.2	?
Calamagrostis rubescens	2.8	?
Carex rostrata	0.3	?
Koeleria cristata	0.2	0(+)
Trisetum spicatum	0.1	0(+)
Achillea millefolium	0.2	0(+)
Antennaria roseus	0.2	0(+)
Equisetum arvense	0.2	0(+)
Fragaria glauca	0.8	?
Linnaea borealis	2.0	?
Lupinus lepidus	0.5	?

TABLE F6-40 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Alectoria jubata	1.7	0
Alectoria saramentosa	0.3	?
Letharia vulpina	1.1	?
Drepanocladus uncinatus	0.4	0
Pleurozium schreberi	2.9	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-41

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 54
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	25	834
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.2	0(+)
Picea engelmannii	3.7	0(+)
Pinus contorta	3.1	0(+)
Pinus ponderosa	0.7	0(+)
Pseudotsuga menziesii	2.2	0(+)
Amelanchier alnifolia	0.1	0(+)
Artemisia frigida	0.2	0(+)
Artemisia tridentata	0.7	0(+)
Arctostaphylos uva-ursi	0.8	0(+)
Chrysothamnus nauseosus	0.3	0(+)
Juniperus communis	0.6	0(+)
Juniperus scopulorum	0.3	0(+)
Salix sp.	0.2	2
Shepherdia canadensis	0.8	?
Vaccinium scoparium	2.7	?
Agropyron spicatum	3.9	?
Calamagrostis rubescens	2.2	?
Hordeum jubatum	0.1	?
Koeleria cristata	0.3	0(+)
Poa pratensis	0.2	1
Achillea millefolium	0.5	0(+)
Antennaria roseus	0.3	0(+)
Balsamorhiza sagittata	0.5	?
Equisetum arvense	0.4	0(+)
Equisetum scirpoides	0.3	0(+)

TABLE F2-41 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Fragaria glauca	0.7	?
Linnaea borealis	1.1	?
Lupinus lepidus	0.7	?
Taraxacum officinale	0.1	0(+)
Alectoria jubata	1.8	0
Letharia vulpina	2.0	?
Peltigera aphthosa	0.2	?
Drepanocladus uncinatus	0.4	0
Pleurozium schreberi	2.2	1

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-42

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 63
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m³	20	894
3-hr. >300 μg/m³		
24-hr. >160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.3	0(+)
Picea engelmannii	5.0	0(+)
Pinus contorta	10.8	0(+)
Pseudotsuga menziesii	1.6	0(+)
Arctostaphylos uva-ursi	0.9	0(+)
Juniperus communis	2.0	0(+)
Rhododendron albiflorum	4.7	?
Rosa gymnocarpa	0.8	?
Salix sp.	0.3	2
Shepherdia canadensis	5.2	?
Vaccinium membranaceum	0.8	?
Vaccinium scoparium	11.2	?
Calamagrostis rubescens	5.2	?
Carex rostrata	0.3	?
Trisetum spicatum	0.7	0(+)
Arnica cordifolia	0.6	?
Equisetum arvense	0.1	0(+)
Fragaria glauca	1.4	?
Linnaea borealis	2.8	?
Lupinus lepidus	0.9	?
Pedicularis bracteosa	0.7	?
Thalictrum occidentalis	0.9	?
Alectoria fremontii	0.9	?
Alectoria jubata	1.9	0
Alectoria saramentosa	0.5	?

TABLE F6-42 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Letharia vulpina	3.3	?
Drepanocladus uncinatus	0.5	0
Pleurozium schreberi	1.8	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-43

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 116
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	52	865
3-hr.>300 $\mu g/m^3$	5	404
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Pinus ponderosa	0.7	0(+)
Pseudotsuga menziesii	3.1	0(±)
Amelanchier alnifolia	0.6	0(±)
Arctostaphylos uva-ursi	0.4	0(+)
Artemisia tridentata	2.0	0
Chrysothamnus nauseosus	0.6	0(+)
Juniperus communis	0.3	0(+)
Juniperus scopulorum	0.9	0(+)
Agropyron spicatum	4.7	?
Koeleria cristata	0.5	0(+)
Stipa comata	0.3	0(+)
Antennaria roseus	0.2	0(+)
Balsamorhiza sagittata	0.9	?
Letharia vulpina	0.7	?

(+) Possible beneficial effect of SO_2 on growth.
(±) Indicates threshold for injury

TABLE F6-44

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 123
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m³	60	1024
3-hr. >300 μg/m³	11	528
24-hr. >160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Picea engelmannii	0.5	0(±)
Pinus contorta	6.8	0(±)
Pseudotsuga menziesii	0.3	0(±)
Arctostaphylos uva-ursi	0.8	0(+)
Juniperus communis	1.5	0(+)
Shepherdia canadensis	1.5	?
Vaccinium scoparium	3.0	?
Calamagrostis rubescens	6.7	?
Fragaria glauca	0.7	?
Linnaea borealis	0.6	?
Lupinus lepidus	1.3	?
Phyllodoce empetriformis	0.5	?
Alectoria jubata	2.5	0
Alectoria saramentosa	0.6	?
Letharia vulpina	0.9	?
Peltigera aphthosa	0.5	?
Drepanocladus uncinatus	0.3	0
Pleurozium schreberi	1.7	1

(+) Possible beneficial effect of SO_2 on growth.
(±) Indicated threshold for injury

TABLE F6-45

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 124
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration.
1-hr.>450 $\mu g/m^2$	70	1644
3-hr.>300 $\mu g/m^2$	15	646
24-hr.>160 $\mu g/m^2$	1	159

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.2	4
Picea engelmannii	0.7	1
Pinus contorta	1.6	1
Pinus ponderosa	0.3	1
Pseudotsuga menziesii	3.1	2
Amelanchier alnifolia	0.4	2
Arctostaphylos uva-ursi	1.5	0(+)
Chrysothamnus nauseosus	0.2	0(+)
Juniperus communis	0.5	0(+)
Juniperus scopulorum	0.6	0(+)
Salix sp.	0.1	25
Shepherdia canadensis	0.6	?
Vaccinium scoparium	1.1	?
Agropyron spicatum	1.8	?
Calamagrostis rubescens	4.6	?
Koeleria cristata	0.3	0(+)
Poa pratensis	0.3	9
Stipa occidentalis	0.2	0(+)
Achillea millefolium	0.3	0(+)
Antennaria roseus	0.1	0(+)
Taraxacum officinale	0.1	0(+)
Alectoria jubata	0.6	0
Letharia vulpina	1.8	?
Drepanocladus uncinatus	0.2	0
Pleurozium schreberi	1.0	4

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-46

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 125
BASED ON THE 366 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr. >450 μg/m^3	62	718
3-hr. >300 μg/m^3	1	302
24-hr. >160 μg/m^3		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury	
Abies lasiocarpa	0.2	0	
Picea engelmannii	0.3	0(+)	
Pinus ponderosa	0.7	0(+)	
Pseudotsuga menziesii	5.3	0(+)	
Amelanchier alnifolia	0.8	0(+)	
Arctostaphylos uva-ursi	1.2	0(+)	
Artemisia tridentata	0.3	0(+)	
Chrysothamnus nauseosus	0.4	0(+)	
Juniperus communis	0.3	0(+)	
Juniperus scopulorum	0.9	0(+)	
Salix sp.	0.1	6	
Agropyron spicatum	3.7	?	
Calamagrostis rubescens	4.0	?	
Koeleria cristata	0.5	0(+)	
Poa pratensis	0.5	1	
Stipa occidentalis	0.1	0(+)	
Achillea millefolium	0.3	0(+)	
Antennaria roseus	0.7	0(+)	
Balsamorhiza sagittata	0.9	?	
Taraxacum officinale	0.1	0(+)	
Alectoria jubata	0.2	0	
Letharia vulpina	2.8	?	

(+) Possible beneficial effect of SO_2 on growth.
(±) Indicates threshold for injury

TABLE F6-47

EXISTING AND POTENTIAL AGRICULTURAL LAND DISTRIBUTION WITHIN RECEPTOR SECTORS IN WHICH SO_2/NO_2 IMPACTS WOULD OCCUR FROM EMISSIONS FROM THE 366 M/MCS AIR QUALITY MODEL (AREAS IN KM^2)[a]

Site	Present Irrigation[b]	Potential Irrigation[c]	CLI Agricultural Land Capability[d] Class 1	Class 2	Class 3	Class 4	Class 5
6	1.16	2.7	-	-	-	2.65	0.65
13	1.56	3.1	-	-	-	{ 3.22 2.53[e]	
14	0.06	0.8	-	-	-	0.30	5.22
20	-	n/a	-	-	-	-	-
23	-	n/a	-	-	-	-	-
24*	0.25	n/a	-	0.50	-	0.22	-
31	0.03	n/a	0.10	-	-	2.53	-
32*	-	n/a	-	-	-	-	-
38	-	n/a	-	-	-	-	-
43	0.33	n/a	-	-	2.51[e]	-	-
44	-	n/a	-	-	-	-	-
45	-	n/a	-	-	-	0.47	-
52	-	n/a	-	-	-	-	-
53	-	n/a	-	-	-	-	-
54	0.44	n/a	-	2.81	-	2.08	-
55	3.51	n/a	-	6.23	-	-	-
56*	1.31	n/a	-	2.08	-	-	-
63	-	n/a	-	-	0.75[e]	-	-
64*	-	n/a	-	-	-	-	-
70	-	n/a	-	-	3.80[e]	-	-
86	-	n/a	-	-	-	1.72	10.90
93	0.61	n/a	0.47	-	0.20	2.60	-
94	-	n/a	-	-	-	0.46	-
116	-	0.52	-	-	-	2.47	-
125	-	n/a	-	-	{ 0.79[e] 1.30	-	-
126	-	n/a	-	-	{ 1.00[e] 0.24	-	4.27
127	-	n/a	-	-	2.75	-	0.47
128*	-	n/a	-	-	0.76	-	-

a all data received from Canadian Bio Resources Consultants Ltd.

b from Figure 4-9, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

c from Figure 5-1, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

d from Figure 4-7, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

e indicates that land is probably less suitable than indicated by CLI class, based on climate data, Figure 4-7, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

* part of sector lies outside Local Study Area and was not in inventory

n/a inventory information not available

TABLE F6-48

POTENTIAL IMPACT OF SO_2 AND NO_x EMISSIONS
UPON EXISTING AND POTENTIAL AGRICUTURAL CROPS WITHIN SPECIFIC RECEPTOR SECTORS
BASED ON THE 366M/MCS AIR QUALITY MODEL

Percent Injury - Average Case

Receptor Sector

Crop Species	13	14	20	23	43	44	116	125
Medicago sativa	5	10	(+)	(+)	1	1	1	1
Trifolium hybridum	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Bromus inermis	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Lolium perenne	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Phleum pratense	6	11	(+)	(±)	3	2	3	3
Zea mays	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Avena sativa	5	11	(+)	(+)	2	2	2	2

(+) Possible beneficial effect of SO_2 on growth.

(±) Indicates threshold for injury

(ii) Impact on Natural Vegetation

From the estimates of injury presented in Tables F6-19 to F6-46, it is apparent that the 366 m/MCS Air Quality Model will give rise to considerably more widespread injury than that expected from the 366 m/FGD stragegy. Thus some injury to sensitive species is expected in sectors 8, 13, 14, 15, 16, 20, 21, 22, 23, 27, 28, 29, 30, 35, 36, 37, 43, 44, 45, 51, 52, 53, 54, 63, 116, 123, 124 and 125. The impact of of the projected SO_2/NO_2 emissions would probably be slightly beneficial to the vegetation in the remaining sectors investigated. Such benefits would also probably accrue to tolerant species within the sectors showing injury.

As in the case of the 366 m/FGD assessment, the extent of injury in the severely affected sectors in the Clear Range to the south and west, and on Cornwall Park to the south-east of the stack is assessed in terms of annual impact, which is of particular importance in terms of its consequences to the growth of the tree species present, and to shrubs such as *Salix* with their importance to wildlife and gamebirds.

Again, no attempt is made to present an assessment of economic loss or damage in these data, but the provision of information as to the extent of cover provided by the species injured by the SO_2/NO_2 emissions permits a semi-quantitative assessment of the magnitude of the impacts on different species.

(iii) Impact on Present and Potential Agriculture

The combination of the data on the extent and nature of agriculture lands (Table F6-47) and on the impact of the predicted SO_2/NO_2 emissions on the range of crop species which might be grown within specific receptor sectors (Table F6-48) permits an assessment of present and potential impact. From Table F6-48 it is apparent that the sectors likely to suffer the greatest amount on injury to crop species are those SSW of the stack, at the south end of the Hat Creek Valley, on the ground rising into the Clear Range.

It should be noted that no injury appears to be likely on present or potential crops in the Ashcroft-Cache Creek areas, growing at low elevations. If any SO_2 impact occurs in these areas, it appears probably that it will take the form of minor growth stimulations.

(b) Regional Impact Assessment

As in the case of the 366 m FGD strategy, the regional impact of the predicted SO_2/NO_2 emissions from the 366 m/MCS system is unlikely to involve measurable injury to vegetation. The only uncertainties concern the regions immediately surrounding the local zone of impact to the south and southwest, and to the northwest. In each of these directions the maximum 1-hour and 3-hour concentration distributions (Figures F6-9 and F6-12, respectively) run out beyond the 25 km radius of the local zone of impact, Hence the possibility exists of impact beyond the 25 km zone. In particular, a pattern of increasing numbers of excursions is seen in the southerly direction, through sites 6, 7 and 8. Similarly, high peak concentrations and frequencies appear possible in the SSW direction beyond site 16. Although the peak concentrations are somewhat less to the north-west, there is uncertainty as to the ground-level concentrations beyond sites 56 and 64, although in these directions the number of 1-hour peaks appears to be diminishing (Figure F6-10). Thus, there may be adverse effects on some species of the emissions under the 366 m/MCS strategy within the extended regional zone to the south. However, such effects of SO_2 and NO_2 as occur in other directions will probably be marginally beneficial in nature. Furthermore, there does not appear to be any reason to expect directly adverse effects on vegetation from the conversion products of the primary emissions from the 366 m generating station stack operating under MCS.

F6.3 244 m STACK WITH METEOROLOGICAL CONTROL STRATEGY (MCS)

The 244 m/MCS situation is one which cannot directly be compared with the strategies based upon a 366 m stack. No information as to the nature of the peaks and their distribution from an uncontrolled, base-load operation emitting through a 244 m stack is available, nor is regional zone of impact modelling for this reduced stack height. Hence the predictions from ERT's modelling of the local zone of impact have to be considered on their own merits. In the following sections, the same general format is followed as before, with assessments of impact being presented on natural vegetation and agriculture within both the local zone of impact, and the regional zone of impact.

(a) Local Impact Assessment

(i) Basis for Assessment

ERT PEAK programme data again provided the basis for preparing peak concentration and frequency distributions for 1-hour, 3-hour and 24-hour averaging times. The 1-hour predictions are presented in Figures F6-17 to F6-19, the 3-hour in Figures F6-20 to F6-22 and the 24-hour in Figures F6-23 to F6-25. In the case of the 1-hour peak distributions, comparison of Figures F6-17 and F6-18 shows that the peak distribution within the growing season is virtually unchanged from that predicted for the entire year.

Comparison between the 366 m and 244 m stack heights both operating under MCS (eg. Figures F6-8 and F6-17) illustrates clearly the greater extent of the impingement of peak SO_2 concentrations greater than 450 $\mu g/m^3$ as a consequence of the shorter stack height. Furthermore, the pattern of the total numbers of excursions above 450 $\mu g/m^3$ is markedly different in parts of the local zone of impact. Thus comparison of Figures F6-10 and F6-19 shows that the lower stack height results in a large increase in the numbers of such excursions SE, S, N and NE of the stack, such that the frequency of impingements on Cornwall Peak, for example, become overshadowed by those occurring at lower elevations of the Hat Creek Valley, immediately to the south of the stack. Particularly marked is the more than ten-fold increase in the frequency of ground-level fumigations predicted to occur due north of the stack and in

Figure F6-17

PREDICTED ANNUAL MAXIMUM 1-HOUR SO_2 CONCENTRATIONS (µg/m³) 244 m STACK WITH MCS

Figure F6-18

PREDICTED SEASONAL MAXIMUM
1-HOUR SO_2 CONCENTRATIONS (µg/m³)
244 m STACK WITH MCS

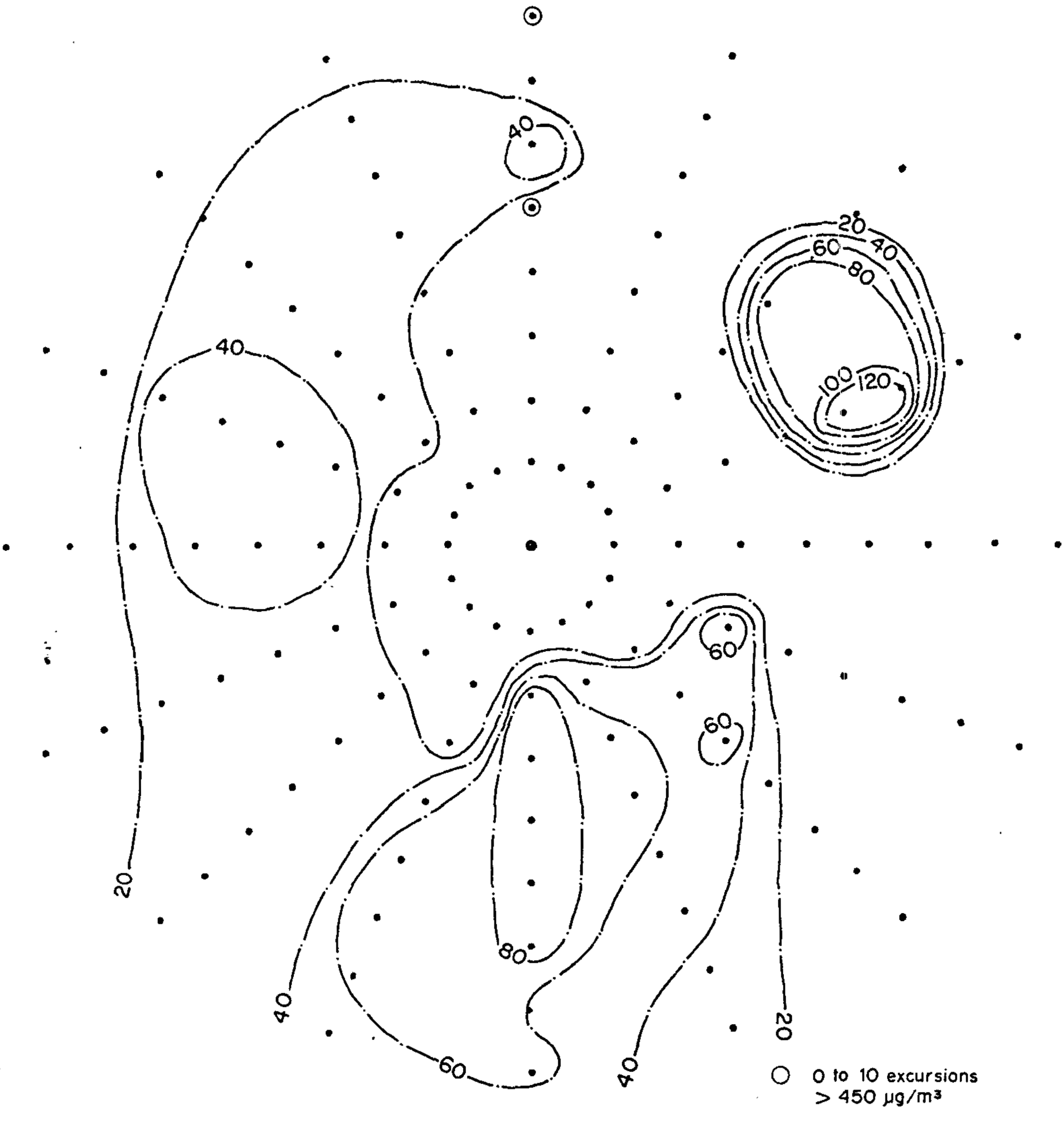


Figure F6-19

PREDICTED SEASONAL TOTALS
OF 1-HOUR SO_2 CONCENTRATIONS > 450 µg/m³
244m STACK WITH MCS

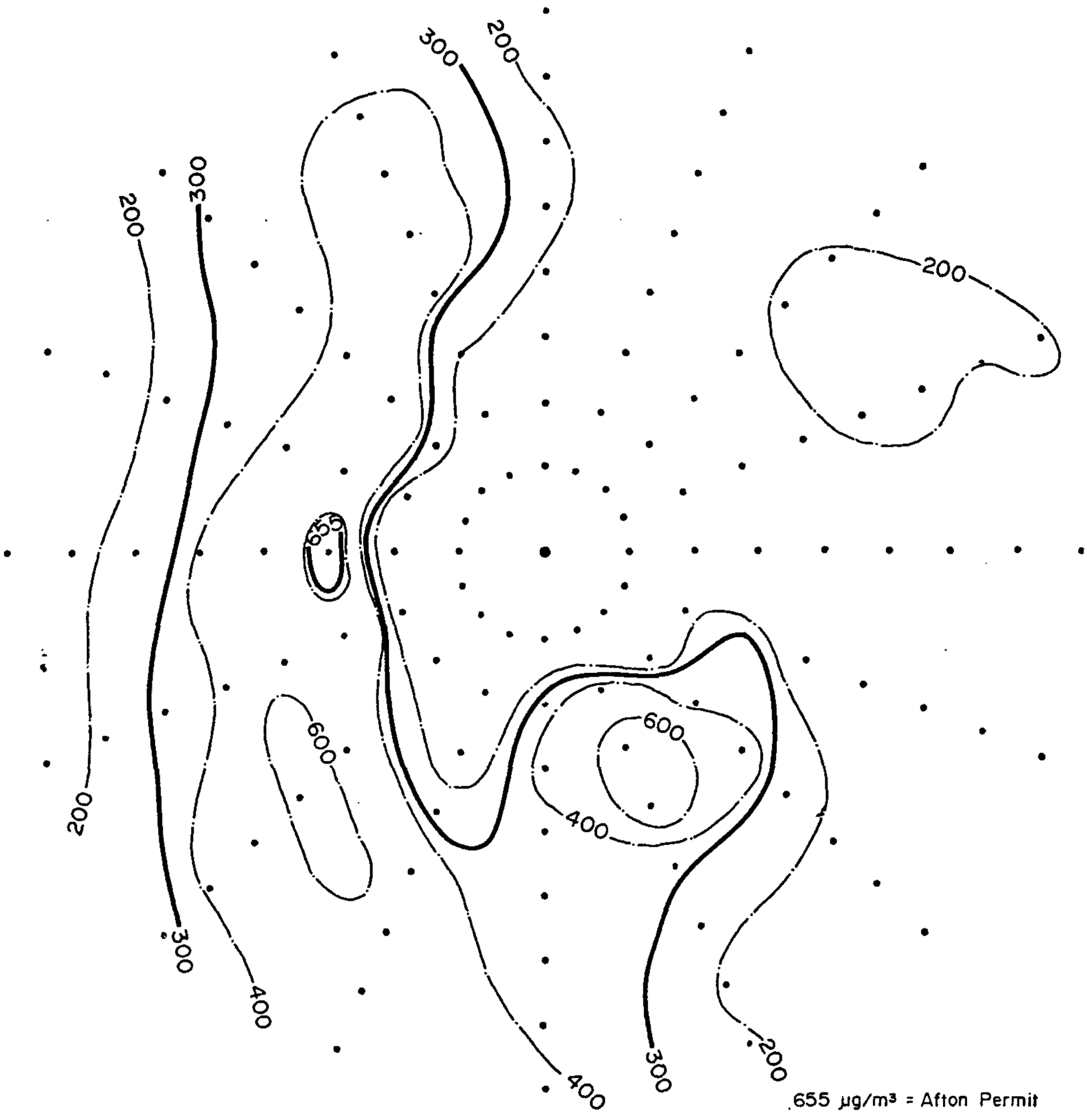


Figure F6-20

PREDICTED ANNUAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS (µg/m³)
366 m STACK WITH MCS

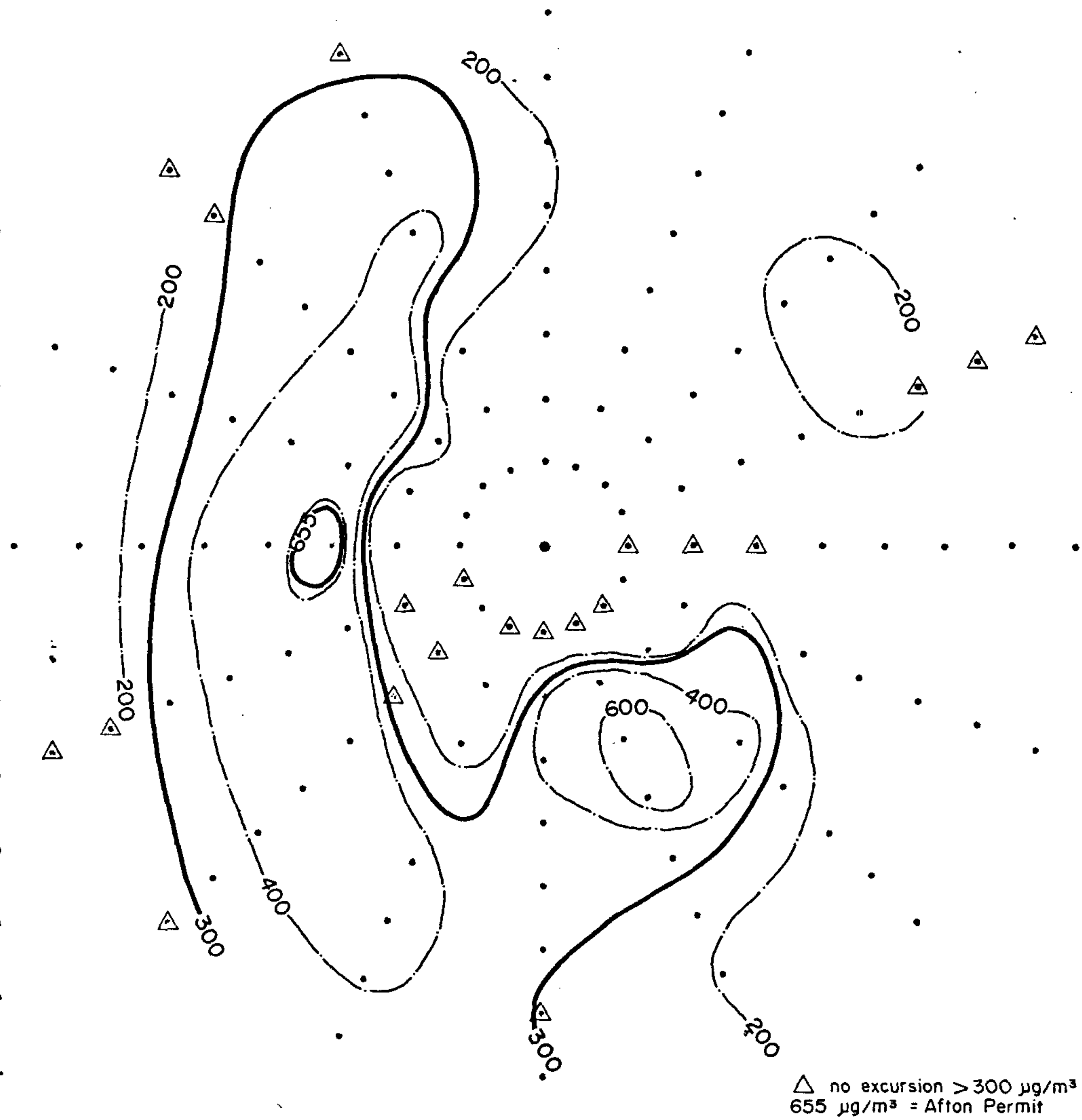


Figure F6-21

PREDICTED SEASONAL MAXIMUM
3-HOUR SO_2 CONCENTRATIONS (µg/m³)
244 m STACK WITH MCS

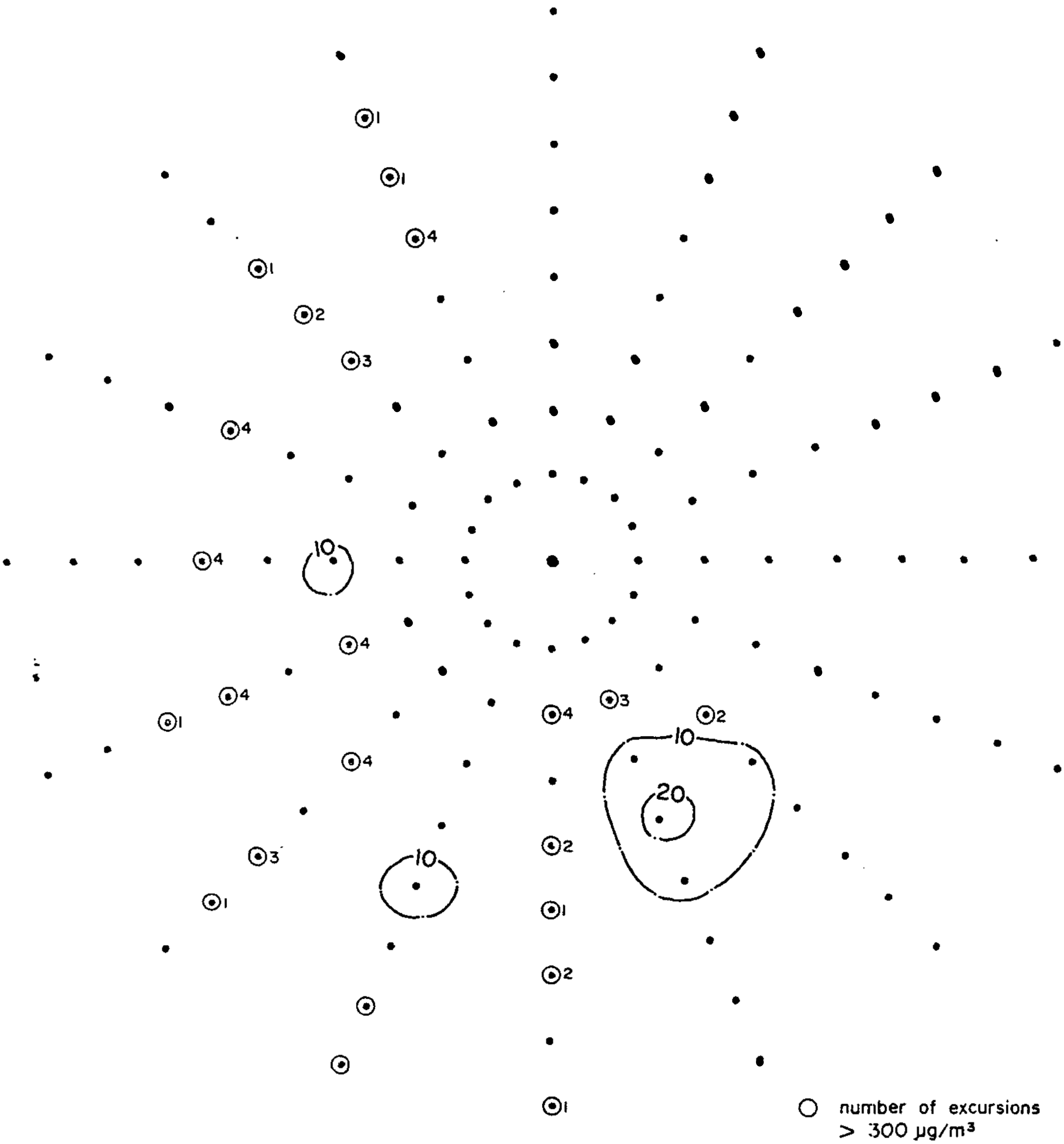


Figure F6-22

PREDICTED SEASONAL TOTALS
OF 3-HOUR SO_2 CONCENTRATIONS > 300 μg/m³
244m STACK WITH MCS

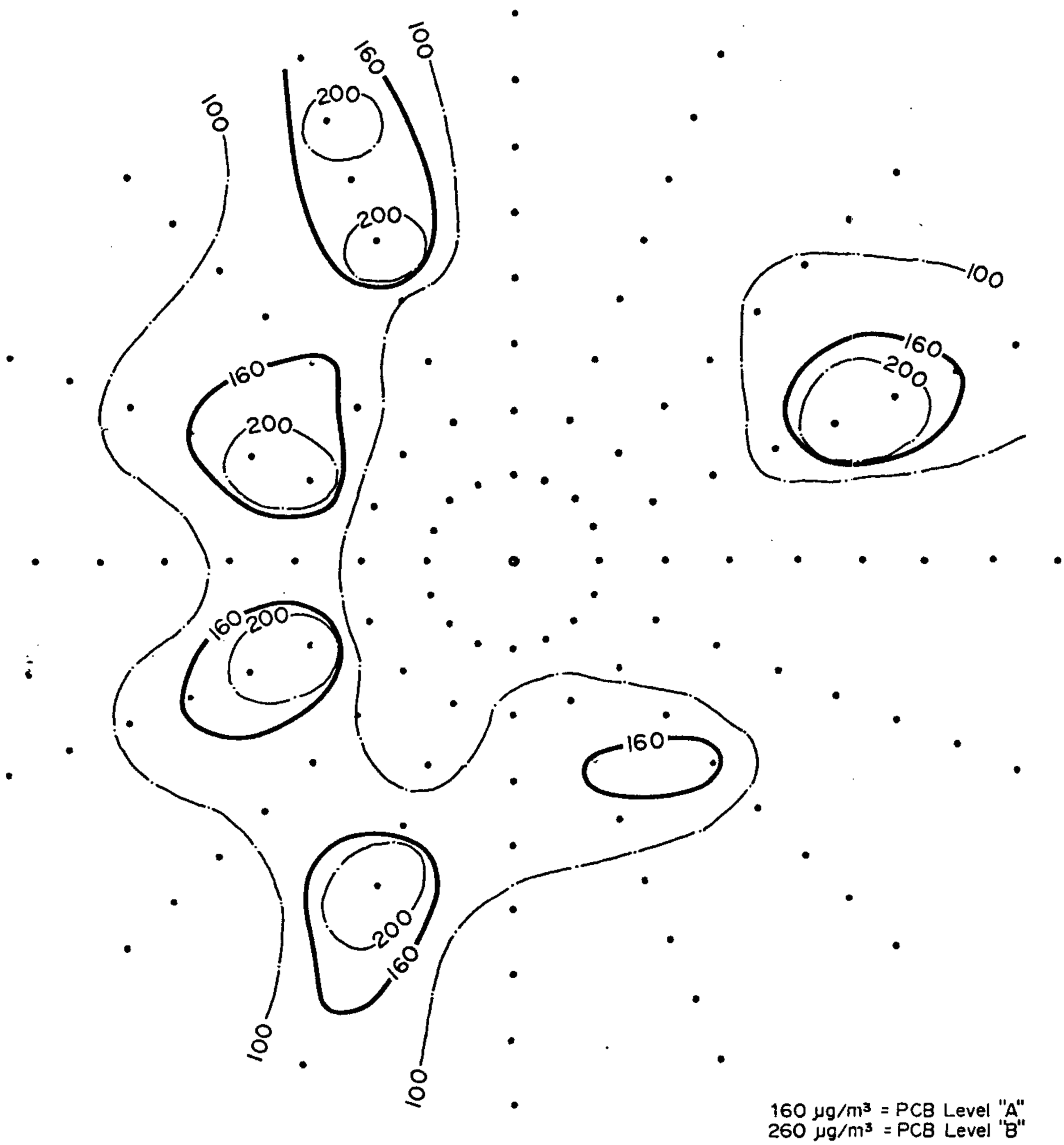
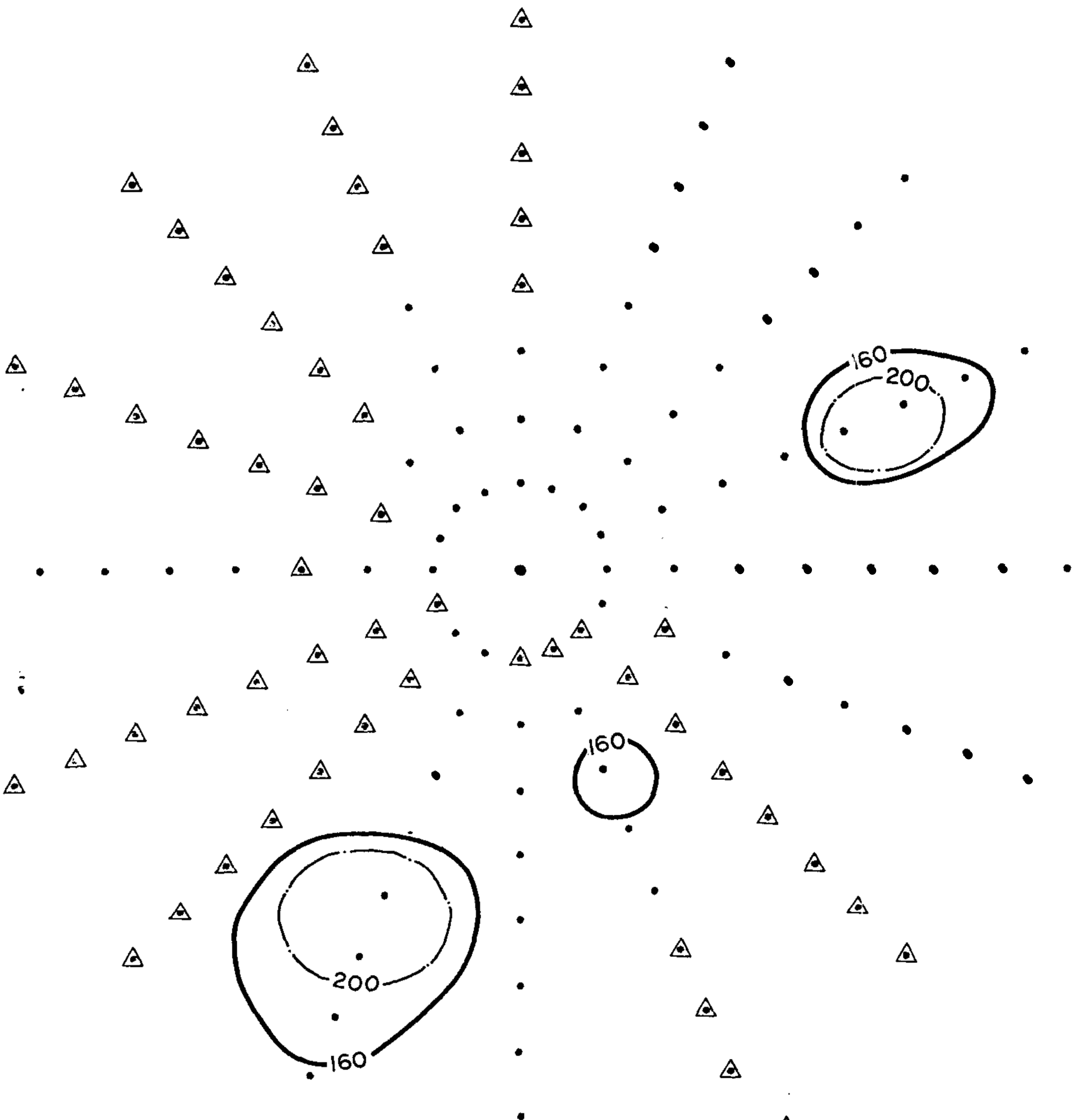


Figure F6-23

PREDICTED ANNUAL MAXIMUM 24-HOUR SO_2 CONCENTRATIONS (µg/m³) 366m STACK WITH MCS



△ no excursion > 160 μg/m³
160 μg/m³ = PCB Level "A"

Figure F6-24

PREDICTED SEASONAL MAXIMUM
24-HOUR SO_2 CONCENTRATIONS (μg/m³)
244 m STACK WITH MCS

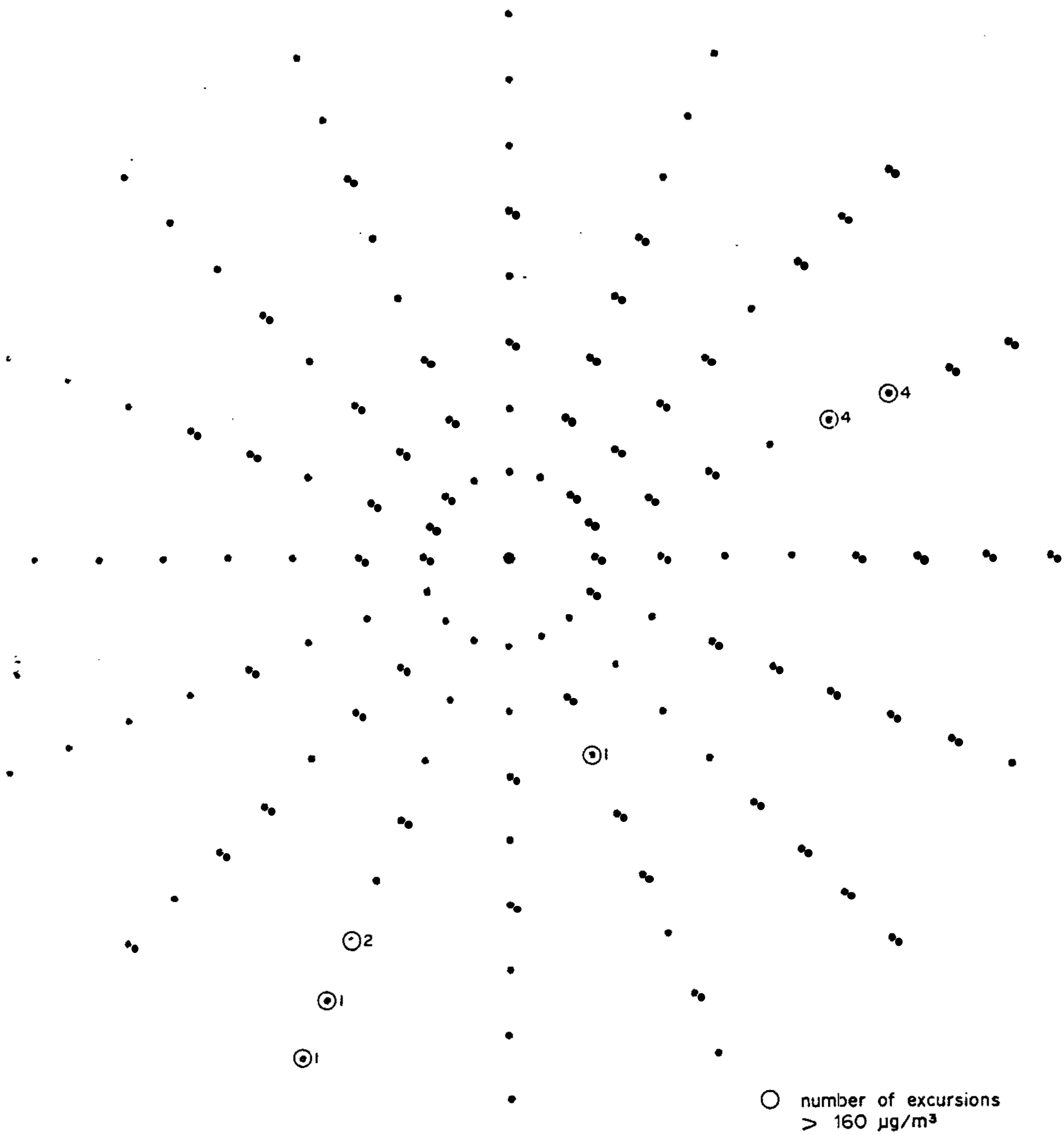


Figure F6-25

PREDICTED SEASONAL TOTALS
OF 24-HOUR SO_2 CONCENTRATIONS > 160 µg/m³
244 m STACK WITH MCS

the Arrowstone Hills to the north-east.

Comparisons between the 3-hour (e.g. Figures F6-12 and F6-21) and 24-hour (e.g. Figures F6-15 and F6-24) peak distributions similarly reveal the greater extent of ground-level fumigations from the 244 m stack.

In general the distributions of average concentrations resembled those found by inspection of the PEAK programme for the uncontrolled emissions, described in Section F5.1 (a)(iii)A. This is illustrated with regard to average maxima by the close similarities between Figures F6-17 and F6-18 for 1-hour maxima, and Figure F6-20 and F6-21 for 3-hour maxima. However, the 24-hour average concentrations to the west and north of the stack revealed in Figure F6-23 are absent from Figure F6-24 indicating that only those to the south and east occurred during the growing season.

Since the number of receptor sites exposed to significant 1-hour, 3-hour and 24-hour average concentrations of SO_2 and NO_2 is appreciably increased over the 366 m stack/MCS situation, the methodology used for reporting the 244 m stack/MCS assessment has been simplified to reduce the bulk of the data. Thus the comparisons of data from the two models for those sites which were assessed for the 366 m stack/MCS situation reveals that the cummulative doses for the 244 m stack are related to those from the 366 m stack by factors ranging from 0.9 to 2.8, as shown in Table F6-49. Furthermore the cummulative dose injury curves (Fig F5-2) used for the assessments of injury are essentially linear and all intercept the ordinate axis at approximately -5% injury. Hence each curve can be described by an equation:

$$I = k.d-5, \qquad (3)$$

Where I is percent injury, k is a constant for a particular species, and

TABLE F6-49

MULTIPLIER FACTORS FOR CUMULATIVE DOSES FROM 244M/MCS EMISSIONS BY COMPUTATION FROM 366 M/MCS DATA, FOR CERTAIN RECEPTOR SECTORS

Receptor Section	Factor	Reference Table
8	2.0	F6 - 19
13	1.1	F6 - 20
14	1.1	F5 - 21
15	1.1	F5 - 22
16	1.4	F5 - 23
20	1.3	F6 - 24
21	1.2	F6 - 25
22	1.2	F6 - 26
23	1.1	F6 - 27
28	1.6	F6 - 29
29	1.5	F6 - 30
30	0.9	F6 - 31
35	2.2	F6 - 32
36	1.6	F6 - 33
37	1.5	F6 - 34
43	1.2	F6 - 35
44	1.9	F6 - 36
45	2.0	F6 - 37
51	1.9	F6 - 38
52	1.3	F6 - 39
53	1.3	F6 - 40
54	1.2	F6 - 41
63	0.9	F6 - 42
116	2.2	F6 - 43
123	2.8	F6 - 44
124	1.6	F6 - 45
125	1.6	F6 - 46

d is cummulative dose. Equation (3) can be rearranged to

$$I + 5 = kd$$

The relationship between levels of injury caused by different doses is therefore given by

$$\frac{I_1 + 5}{I_2 + 5} = \frac{kd_1}{kd_2}, \text{ or } \frac{I_1 + 5}{I_2 + 5} = \frac{d_1}{d_2}, \qquad (4)$$

which is independent of species. Hence from a knowledge of the ratio between two doses and the injury caused by one, it is possible to use Equation (4) to calculate the injury caused by the other.

A sample of such computed injury levels is presented in Table F6-50 for a range of injury levels (such as those expected from fumigations of various species from 366 m stack emissions) and several dose ratios covering the range of those in Table F6-49, comparing the 366 and 244 m stack situations.

While the use of the factors of Table F6-49 together with the injury assessment of Tables F6-19 to F6-46 can thus provide assessments of the injury expected from the 244 m stack/MCS situation, such assessments are limited to those species at or above the injury threshold in Tables F6-19 to F6-46. For species below the injury threshold for the doses experienced in the 366 m stack situation, no injury can be computed for the 244 m stack emissions, even though the dose ratios for specific sectors may result in cummulative doses which would be sufficient to cause injury to such species. However, no assessments have been attempted in such cases, in order to reduce the tabulation of impact data to manageable proportions. One can nevertheless obtain an idea of the magnitudes of such injury, by analogy

TABLE F6-50

COMPARISON OF INJURY LEVELS CALCULATED FOR 244 M STACK/MCS FROM 366 M STACK/MCS DATA, BASED ON SELECTED DOSE RATIOS FROM TABLE F6-49, AND EQUATION (4)

Dose Ratio	I% (366 m stack) (arbitrary values)	I% (244 m stack) (calculated values)
0.9	0 i.e. (±)*	0 i.e. (+)*
	1	0.4
	5	4.0
	10	8.5
1.0	0 i.e. (±)	0 i.e. (±)
	1	1.0
	5	5.0
	10	10.0
1.1	0 i.e. (±)	0.5
	1	1.6
	5	6.0
	10	11.5
1.2	0 i.e. (±)	1.0
	1	2.2
	5	7.0
	10	13.0
1.5	0 i.e. (±)	2.5
	1	4.0
	5	10.0
	10	17.5
2.0	0 i.e. (±)	5.0
	1	7.0
	5	15.0
	10	25.0
2.8	0 i.e. (±)	9.0
	1	12.0
	5	23.0
	10	37.0

* (±) Indicates threshold for injury; (+) Indicates possible threshold effect as used in assessment tables.

with the injury levels expected to be revealed in sectors other than those covered by Tables F6-19 to F6-46. These sectors include 6, 7, 24, 27, 38, 46, 55, 70, 93, 94, 126 and 127, and specific assessments for these sectors are presented in Tables F6-51 to F6-64. Additional sectors in which measurable negative impact is likely from the 244 m stack emissions are 2, 3, 4, 5, 12, 19, 31, 32, 50, 56, 60, 64, 69, 72, 85, 107, 115, 117 and 122. However, no specific assessments are presented for these sites, although in general they are somewhat less than those in Tables F6-51 to F6-64, which in turn cover the same general range of impacts as those which can be computed by the methodology described above from the 366 m stack/MCS assessments.

With regard to agricultural impact, Table F6-65 summarizes the present and potential agricultural lands in receptor sectors which are predicted to receive elevated levels of SO_2/NO_2. Fourteen of the 35 sectors listed include current agricultural land. An additional 6 sectors may include current agricultural lands but are located beyond the limits of the detailed vegetational mapping information available. The assessemnts of impact on agricultural crops are presented in Table F6-66 for those sectors in which injury is expected to occur. Thus no specific data are presented for sectors 19, 24, 31, 32, 38, 50, 54, 54, 55, 56, 63, 64, 70, 72, 117, 127 and 128 within which the impact, if any, of emissions will probably take the form of marginal growth stimulation.

(ii) Impact on Natural Vegetation

The estimates of injury presented in Tables F6-51 and F6-64 and those derived from the factors in Tables F6-49 and F6-50 clearly indicate the greater impact on the emissions from the 244 m/MCS system when compared with those from the taller stack. Thus, some negative impact will be felt within sectors 2-8, 12-16, 2-024, 27-32, 35-38, 43-46, 51, 55, 70, 85, 86, 93, 94, 107, 115, 116, and 122-128. The magnitude for the injury to some species in some sectors

TABLE F6-51

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 6
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.> 450 μg/m³	95	599
3-hr.>300 μg/m³	3	319
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Picea engelmannii	0.7	0(±)
Pinus contorta	6.1	0(±)
Pinus ponderosa	0.2	0(±)
Pseudotsuga menziesii	3.9	1
Populus tremuloides	0.2	12
Amelanchier alnifolia	0.3	1
Arctostaphylos uva-ursi	2.1	0(+)
Juniperus communis	1.6	0(+)
Juniperus scopulorum	0.8	0(+)
Salix spp.	0.6	15
Vaccinium scoparium	2.5	?
Agropyron spicatum	1.0	?
Calamagrostis rubescens	10.7	?
Carex spp.	0.4	?
Hordeum jubatum	0.1	?
Poa pratensis	0.3	3
Achillea millefolium	0.5	0(+)
Antennaria spp.	0.1	?
Fragaria glauca	0.9	?
Lupinus lepidus	1.1	?
Linnaea borealis	0.5	?
Alectoria jubata	2.3	2
Alectoria saramentosa	0.5	?
Drepanocladus uncinatus	0.3	0
Letharia vulpina	3.3	?
Pleurozium schreberi	1.4	1

(+) Possible beneficial effect of SO_2 on growth
(±) Indicates threshold for injury

TABLE F6-52

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 7
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	53	596
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.1	0(+)
Picea engelmannii	1.9	0(+)
Pinus contorta	2.5	0(+)
Pseudotsuga menziesii	2.0	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	0.9	0(+)
Juniperus communis	0.5	0(+)
Salix spp.	0.2	4
Shepherdia canadensis	0.7	?
Vaccinium scoparium	1.9	?
Agropyron spicatum	0.4	?
Calamagrostis rubescens	5.3	?
Carex spp.	0.2	?
Hordeum jubatum	1.0	?
Poa pratensis	0.5	0(+)
Achillea millefolium	0.3	0(+)
Fragaria glauca	0.6	?
Lupinus lepidus	0.6	?
Linnaea borealis	0.6	?
Taraxacum officinale	0.2	0(+)
Alectoria jubata	1.3	0
Drepanocladus uncinatus	0.2	0
Letharia vulpina	2.0	?
Pleurozium schreberi	1.3	0

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-53

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 24
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	25	804
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.9	0(+)
Picea engelmannii	10.6	0(+)
Pinus albicaulis	0.1	?
Pinus contorta	3.1	0(+)
Pinus ponderosa	0	-
Pseudotsuga menziesii	1.7	0(+)
Amelanchier alnifolia	0.1	0(+)
Arctostaphylos uva-ursi	1.8	0(+)
Juniperus communis	0.5	0(+)
Salix spp.	0.1	2
Salix cascadensis	1.2	2
Salix nivalis	1.4	2
Shepherdia canadensis	1.0	?
Vaccinium scoparium	8.3	?
Agropyron spicatum	0.2	?
Calamagrostis rubescens	3.8	?
Carex spp.	0.8	?
Poa pratensis	0.1	1
Trisetum spicatum	0.2	0(+)
Achillea millefolium	0.3	0(+)
Antennaria	0.1	0(+)
Equisetum arvense	0.3	0(+)
Equisetum scirpoides	0.4	0(+)
Fragaria glauca	1.9	?
Lupinus lepidus	1.9	?

TABLE F6-53 (Continued)

Species	Total Cover Within Sector (km^2)	Percent Injury
Linnaea borealis	2.9	?
Alectoria jubata	3.1	0
Alectoria saramentosa	1.0	?
Drepanocladus uncinatus	1.1	0
Letharia vulpina	1.6	?
Pleurozium schreberi	5.1	0

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-54

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 27
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	25	1344
3-hr.>300 μg/m³	4	484
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Picea engelmannii	0.8	0(+)
Pinus contorta	3.4	0(+)
Pseudotsuga menziesii	2.5	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	1.1	0(+)
Juniperus communis	0.7	0(+)
Salix spp.	0.2	5
Shepherdia canadensis	0.9	?
Vaccinium scoparium	1.5	?
Agropyron spicatum	0.2	?
Calamagrostis rubescens	7.2	?
Achillea millefolium	0.2	0(+)
Fragaria glauca	0.5	?
Lupinus lepidus	0.6	?
Linnaea borealis	0.4	?
Alectoria jubata	1.4	0
Drepanocladus uncinatus	0.2	0
Letharia vulpina	2.1	?
Pleurozium schreberi	1.0	0

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-55

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 38
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration	
		Average Case	Worst Case
1-hr.>450 µg/m³	37	632	
3-hr.>300 µg/m³			
24-hr.>160 µg/m³			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km³)	Percent Injury
Abies lasiocarpa	0.5	0(+)
Picea engelmannii	3.6	0(+)
Pinus contorta	0.8	0(+)
Pinus ponderosa	0.6	0(+)
Pseudotsuga menziesii	5.4	0(+)
Populus tremuloides	0.2	2
Amelanchier alnifolia	0.7	0(+)
Arctostaphylos uva-ursi	1.6	0(+)
Juniperus communis	0.7	0(+)
Juniperus scopulorum	1.5	0(+)
Salix spp.	0.2	3
Shepherdia canadensis	0.1	?
Vaccinium scoparium	2.0	?
Agropyron spicatum	3.0	?
Calamagrostis rubescens	4.3	?
Antennaria roseus	0.3	0(+)
Equisetum arvense	0.2	0(+)
Fragaria glauca	0.6	?
Linnaea borealis	1.4	?
Alectoria jubata	1.1	0
Drepanocladus uncinatus	0.3	0
Letharia vulpina	2.8	?
Pleurozium schreberi	2.4	0

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-56

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 46
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration: Average Case	Maximum Expected Concentration: Worst Case
1-hr.>450 μg/m³	48		599
3-hr.>300 μg/m³			
24-hr.>160 μg/m³			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Abies lasiocarpa	0.8	0(+)
Picea engelmannii	5.1	0(+)
Pinus contorta	1.1	0(+)
Pinus ponderosa	0.4	0(+)
Pseudotsuga menziesii	4.0	0(+)
Amelanchier alnifolia	0.3	0(+)
Arctostaphylos uva-ursi	1.7	0(+)
Artemisia frigida	0.1	0(+)
Juniperus communis	0.2	0(+)
Juniperus scopulorum	0.2	0(+)
Rosa gymnocarpa	0.5	?
Salix spp.	0.3	5
Shepherdia canadensis	1.0	?
Vaccinium scoparium	2.8	?
Agropyron spicatum	2.2	?
Calamagrostis rubescens	7.6	?
Achillea millefolium	0.5	0(+)
Antennaria roseus	0.1	0(+)
Equisetum arvense	0.2	0(+)
Fragaria glauca	0.8	?
Lupinus lepidus	0.3	?
Linnaea borealis	1.9	?
Alectoria jubata	1.6	0
Drepanocladus uncinatus	0.4	0
Letharia vulpina	3.7	?
Pleurozium schreberi	3.4	0

(+) Possible beneficial effects of SO_2 on growth.

TABLE F6-57

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 55
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration: Average Case	Maximum Expected Concentration: Worst Case
1-hr.>450 μg/m³	25	843	
3-hr.>300 μg/m³			
24-hr.>160 μg/m³			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.3	0(+)
Picea Engelmannii	3.1	0(+)
Pinus contorta	0.9	0(+)
Pinus ponderosa	0.8	0(+)
Pseudotsuga menziesii	1.8	0(+)
Amelanchier alnifolia	0.2	0(+)
Arctostaphylos uva-ursi	0.3	0(+)
Artemisia frigida	0.2	0(+)
Artemesia tridentata	0.2	0(+)
Juniperus communis	0.2	0(+)
Juniperus scopulorum	0.4	0(+)
Salix spp.	0.2	1
Vaccinium scoparium	1.9	?
Agropyron spicatum	3.6	?
Calamagrostis rubescens	2.1	?
Poa pratensis	1.9	0(+)
Achillea millefolium	0.7	0(+)
Antennaria roseus	0.4	0(+)
Balsamorhiza sagitteta	0.6	?
Equisetum arvense	0.3	0(+)
Fragaria glauca	0.7	?
Linnaea borealis	1.3	?
Taraxacum officinale	0.4	0(+)
Alectoria jubata	0.9	0
Drepanocladus uncinatus	0.3	0
Letharia vulpina	1.2	?
Pleurozium schreberi	2.2	0

TABLE F6-58

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 70
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration	
		Average Case	Worst Case
1-hr.>450 μg/m^3	46		565
3-hr.>300 μg/m^3			
24-hr.>160 μg/m^3			

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Picea engelmannii	1.7	0(+)
Pinus contorta	0.8	0(+)
Pinus ponderosa	0.5	0(+)
Pseudotsuga menziesii	8.0	0(+)
Amelanchier alnifolia	0.8	0(+)
Arctostaphylos uva-ursi	2.6	0(+)
Juniperus communis	0.2	0(+)
Rosa gymnocarpa	0.8	?
Salix spp.	0.4	1
Shepherdia canadensis	0.8	?
Agropyron spicatum	2.1	?
Calamagrostis rubescens	11.2	?
Poa pratensis	0.2	0(+)
Achillea millefolium	0.5	0(+)
Allium cernuum	0.7	?
Antennaria roseus	0.2	0(+)
Balsomorhiza sagittata	0.6	?
Fragaria glauca	0.5	?
Lupinus lepidus	0	?
Linnaea borealis	0	?
Alectoria jubata	0.6	0
Letharia vulpina	6.2	?

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-59

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 86
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	92	514
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.1	1
Picea engelmannii	2.0	0(+)
Pinus contorta	4.4	0(+)
Pinus ponderosa	0.6	0(+)
Pseudotsuga menziesii	5.0	0(±)
Amelanchier alnifolia	0.6	0(±)
Arctostaphylos uva-ursi	1.8	0(+)
Juniperus communis	1.0	0(+)
Juniperus scopulorum	0.5	0(+)
Salix spp.	0.2	12
Shepherdia canadensis	1.3	?
Vaccinium scoparium	2.4	?
Agropyron spicatum	2.2	?
Calamagrostis rubescens	9.9	?
Achillea millefolium	0.3	0(+)
Antennaria roseus	0.1	0(+)
Fragaria glauca	0.8	?
Lupinus lepidus	0.8	?
Linnaea borealis	0.9	?
Alectoria jubata	2.0	0
Drepanocladus uncinatus	0.3	0
Letharia vulpina	4.1	?
Pleurozium schreberi	1.8	1

(+) Possible beneficial effect of SO_2 on growth.

(±) Indicates threshold for injury.

TABLE F6-60

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 93
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	126	596
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Pinus ponderosa	0.7	1
Pseudotsuga menziesii	2.8	2
Populus trichocarpa	0.1	2
Amelanchier alnifolia	0.4	2
Arctostaphylos uva-ursi	0.4	0(+)
Artemisia tridentata	2.8	0(+)
Chrysothamnus nauseosus	0.8	?
Juniperus communis	0.2	0(+)
Juniperus scopulorum	0.8	0(+)
Salix spp.	0.2	25
Agropyron spicatum	5.5	?
Antennaria roseus	0.2	0(+)
Balsamorhiza sagittata	0.8	?
Equisetum arvense	0.2	0(+)
Letharia vulpina	0.7	?

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-61

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 94
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	131	565
3-hr.>300 μg/m³		
24-hr.>160 μg/m³	4	251

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^2)	Percent Injury
Picea engelmannii	1.4	1
Pinus contorta	3.1	1
Pinus ponderosa	0.8	1
Pseudotsuga menziesii	2.0	1
Populus trichocarpa	0.1	1
Amelanchier alnifolia	0.3	1
Arctostaphylos uva-ursi	0.7	0(+)
Artemisia frigida	0.1	0(±)
Artemisia tridentata	1.6	0(+)
Chrysothamnus nauseosus	0.6	?
Juniperus communis	0.7	0(+)
Juniperus scopulorum	0.4	0(+)
Salix spp.	0.3	24
Shepherdia canadensis	0.8	?
Vaccinium scoparium	1.9	?
Agropyron spicatum	4.8	?
Calamagrostis rubescens	4.4	?
Achillea millefolium	0.3	0(+)
Antennaria roseus	0.2	0(+)
Balsamorhiza sagittata	0.6	?
Equisetum arvense	0.3	0(+)
Fragaria glauca	0.5	?
Lupinus lepidus	0.6	?
Linnaea borealis	0.7	?
Alectoria jubata	1.4	0
Drepanocladus uncinatus	0.2	0
Letharia vulpina	1.6	?
Pleurozium schreberi	1.5	3

(+) Possible beneficial effect of SO_2 on growth.
(±) Indicates threshold for injury.

TABLE F6-62

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 126
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 $\mu g/m^3$	56	632
3-hr.>300 $\mu g/m^3$		
24-hr.>160 $\mu g/m^3$		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km^3)	Percent Injury
Picea engelmannii	1.3	0(+)
Pinus contorta	5.5	0(+)
Pinus ponderosa	0.3	0(+)
Pseudotsuga menziesii	3.9	0(+)
Amelanchier alnifolia	0.4	0(+)
Artostaphylos uva-ursi	1.9	0(+)
Artemisia frigida	0.1	0(+)
Juniperus communis	1.3	0(+)
Juniperus scopulorum	0.5	0(+)
Salix spp.	0.1	8
Shepherdia canadensis	1.5	?
Vaccinium scoparium	2.6	?
Agropyron spicatum	1.9	?
Calamagrostis rubescens	9.2	?
Hordeum jubatum	0.1	?
Poa pratensis	0.1	1
Achillea millefolium	0.3	0(+)
Antennaria roseus	0.1	0(+)
Fragaria glauca	0.8	?
Lupinus lepidus	1.0	?
Linnaea borealis	0.7	?
Taraxacum officinale	0.1	0(+)
Alectoria jubata	2.2	0
Alectoria sarmentosa	0.5	?
Drepanocladus uncinatus	0.3	0
Letharia vulpina	3.0	?
Pleurozium schreberi	1.7	1

(+) Possible beneficial effect of SO_2 on growth

TABLE F6-63

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON VEGETATION WITHIN RECEPTOR SECTOR 127 BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	32	543
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.3	0(+)
Picea engelmannii	0.8	0(+)
Pinus contorta	6.7	0(+)
Pinus ponderosa	0.4	0(+)
Pseudotsuga menziesii	4.5	0(+)
Amelanchier alnifolia	0.5	0(+)
Arctostaphylos uva-ursi	1.7	0(+)
Artemisia tridentata	0.5	0(+)
Juniperus communis	1.6	0(+)
Juniperus scopulorum	0.5	0(+)
Salix spp.	0.2	1
Shepherdia canadensis	1.7	?
Vaccinium scoparium	2.9	?
Agropyron spicatum	2.3	?
Calamagrostis rubescens	11.1	?
Hordeum jubatum	0.1	?
Poa pratensis	0.2	0(+)
Achillea millefolium	0.2	0(+)
Antennaria roseus	0.1	0(+)
Fragaria glauca	0.9	?
Lupinus lepidus	1.3	?
Linnaea borealis	0.6	?
Phyllodoce empetriformis	0.5	?
Alectoria jubata	2.6	0
Alectoria saramentosa	0.6	?
Drepanocladus uncinatus	0.3	0
Letharia vulpina	3.6	?
Pleurozium schreberi	1.6	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-64

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS
UPON VEGETATION WITHIN RECEPTOR SECTOR 128
BASED ON THE 244 METRE STACK, MCS AIR QUALITY MODEL

A) Number of Predicted Excursions and April - October Maxima

Standard	No. of Excursions	Maximum Expected Concentration
1-hr.>450 μg/m³	27	633
3-hr.>300 μg/m³		
24-hr.>160 μg/m³		

B) Assessment of Potential Injury to Significant Species

Species	Total Cover Within Sector (km²)	Percent Injury
Abies lasiocarpa	0.3	0(+)
Picea engelmannii	1.0	0(+)
Pinus contorta	7.6	0(+)
Pinus ponderosa	0.4	0(+)
Pseudotsuga menziesii	5.1	0(+)
Amelanchier alnifolia	0.6	0(+)
Arctostaphylos uva-ursi	1.9	0(+)
Artemisia frigida	0.1	0(+)
Artemisia tridentata	0.5	0(+)
Juniperus communis	1.9	0(+)
Juniperus scopulorum	0.6	0(+)
Salix spp.	0.2	1
Salix cascadensis	1.9	1
Shepherdia canadensis	1.9	?
Vaccinium scoparium	3.3	?
Agropyron spicatum	2.6	?
Calamagrostis rubescens	12.6	?
Hordeum jubatum	0.1	?
Poa pratensis	0.2	0(+)
Achillea millefolium	0.3	0(+)
Antennaria roseus	0.1	0(+)
Balsamorhiza sagittata	0.6	?
Equisetum arvense	0	0(+)
Linnaea borealis	0.6	?
Alectoria jubata	3.05	0
Alectoria saramentosa	0.64	?
Drepanocladus uncinatus	0.3	0
Letharia vulpina	4.1	?
Pleurozium schreberi	1.8	0

(+) Possible beneficial effect of SO_2 on growth.

TABLE F6-65

EXISTING AND POTENTIAL AGRICULTURAL LAND DISTRIBUTION WITHIN RECEPTOR SECTORS IN WHICH SO_2/NO_2 IMPACTS WOULD OCCUR FROM EMISSIONS FROM THE 244 M/MCS AIR QUALITY MODEL (AREAS IN KM^2)[a]

			CLI Agricultural Land Capability[d]				
Site	Present Irrigation[b]	Potential Irrigation[c]	Class 1	Class 2	Class 3	Class 4	Class 5
5	0.64	2.0	-	-	-	1.43	-
6	1.16	2.7	-	-	-	2.65	0.65
12	1.49	4.0	-	-	-	(3.74 / 1.12 e	
13	1.56	3.1	-	-	-	3.22 / 2.53 e	
14	0.06	0.8	-	-	-	0.30	5.22
19	-	1.5	-	-	-	0.10	1.20
20	-	n/a	-	-	-	-	-
23	-	n/a	-	-	-	-	-
24*	0.25	n/a	-	0.50	-	0.22	-
31	0.03	n/a	0.10	-	-	2.53	-
32*	-	n/a	-	-	-	-	-
38	-	n/a	-	-	-	-	-
43	0.33	n/a	-	-	2.51 e	-	-
44	-	n/a	-	-	-	-	-
45	-	n/a	-	-	-	0.47	-
50	-	n/a	-	-	0.05	-	-
52	-	n/a	-	-	-	-	-
53	-	n/a	-	-	-	-	-
54	0.44	n/a	-	2.81	-	2.08	-
55	3.51	n/a	-	6.23	-	-	-
56*	1.31	n/a	-	2.08	-	-	-
63	-	n/a	-	-	0.75 e	-	-
64*	-	n/a	-	-	-	-	-
70	-	n/a	-	-	3.80 e	-	-
85	0.42	n/a	-	-	-	9.25	0.20
86	-	n/a	-	-	-	1.72	10.90
93	0.61	n/a	0.47	-	0.20	2.60	-
94	-	n/a	-	-	-	0.46	-
107	-	n/a	-	-	-	-	-
116	-	0.52	-	-	-	2.47	-
117	0.82	5.71	0.10	-	8.00	0.58	0.25
125	-	n/a	-	-	(0.79 / 1.30 e	-	-
126	-	n/a	-	-	(1.00 / 0.24 e	-	4.27
127	-	n/a	-	-	2.75	-	0.47
128	-	n/a	-	-	0.76	-	-

a all data received from Canadian Bio Resources Consultants Ltd.

b from Figure 4-9, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

c from Figure 5-1, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

d from Figure 4-7, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

e indicates that land is probably less suitable than indicated by CLI class, based on climate data, Figure 4-7 legend, Hat Creek Detailed Environmental Studies, Agriculture Report[104]

* part of sector lies outside Local Study Area and was not in inventory

n/a inventory information not available.

TABLE F6-66

POTENTIAL IMPACT OF SO_2 AND NO_2 EMISSIONS UPON EXISTING AND POTENTIAL AGRICULTURAL CROPS

WITHIN SPECIFIC RECEPTOR SECTORS BASED ON THE 244 M/MCS AIR QUALITY MODEL

	5	6	12	13	14	20	23	43	44	45	52	85	86	93	94	107	116	125	126
Average Case:																			
Medicago sativa	2	2	(+)	4	10	1	(+)	2	3	2	1	3	3	7	7	1	6	3	1
Trifolium hybridum	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	2+	(+)	(+)	(+)	(+)	(+)	(+)
Bromus inermis	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	2+	(+)	(+)	(+)	(+)	(+)	1
Lolium perenne	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Phleum pratense	3	5	(+)	5	12	1	(+)	3	(4)	3	1	4	4	9	9	1	8	4	2
Zea mays	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Avena sativa	2	5	(+)	5	11	1	(+)	2	3	2	1	3	3	8	8	1	7	3	1
Lycopersicon esculeutum	-	-	-	-	-	-	-	-	-	-	-	-	-	9	7	1	7	-	-
Solarum tulerosum	-	-	-	-	-	-	-	-	-	-	-	-	-	9	7	1	7	-	-
Vicia faba	-	-	-	-	-	-	-	-	-	-	-	-	-	(+)	(±)	4	(±)	-	-

is appreciable. For example, trees and shrubs such as *Abies, Pseudotsuga* and *Salix* will unquestionably suffer serious decline in the Cornwall Hills, along the eastern slopes of the Clear Range and on the southern slopes of the Pavilion Range, with chronic injury appearing on *Pseudotsuga, Pinus ponderosa* and *Salix* on the southwestern slopes of the Arrowstone Hills.

As in the case of the 366 m stack models, some species would probably benefit from SO_2/NO_2 fumigations in sectors within which sensitive species would be severely adversely affected. Furthermore, in some sectors the effects, if any, of the emissions would probably be marginally beneficial to all species.

The magnitudes of the impacts assessed in the 244 m/MCS case are derived from assessment of both acute and chronic injury. There are sufficient numbers of 1-hour exposures to SO_2 concentrations greater than 1310 $\mu g/m^3$ in fourteen sectors and concentrations greater than 655 $\mu g/m^3$ in twenty-four others to result in acute injury to sensitive individuals and species. Furthermore, the high numbers of 1-hour exposures to SO_2 concentrations in the range 450 to 655 $\mu g/m^3$ occurring in some sectors will probably induce chronic injury in sensitive species, in spite of the fact that the maximum predicted annual average SO_2 concentration within the local zone of impact is less than 10 $\mu g/m^3$.

(iii) Impact on Present and Potential Agriculture

The assessment of agricultural impact derives from the extent and nature of the agricultural lands, presented in Table F6-65 and the effects of SO_2/NO_2 emissions presented in Table F6-66. From the latter, it is apparent that impact will be marginal in sectors 12, 20, 23, 52, 107 and 126. Of particular note is the greater impact on agricultural land in the south end of the Hat Creek valley itself (sectors 5, 6, 13, 14 and 20) from the 244 m/MCS strategy than from either strategy employing a 366 m stack. In addition, the lower stack results in elevated levels to the northeast and southeast which would result in injury to crops at the upper elevations of agricultural land to the west of Ashcroft and to the east of Cache Creek. Since it is in these areas that tomatoes, potatoes and faba beans have been listed in the Agricultural Report as potential crops[104], assessments of injury to these crop species have been included in Table F6-66 for the relevant sectors.

(b) Regional Impact Assessment

The ERT predictions for regional air quality from the 244 m/MCS system are such that there is no reason to expect significant injury to vegetation within the outer parts of the regional zone of impact. However, as was noted in the case of the 366 m/MCS situation, uncertainties exist around the local zone of impact. In the present case, there is still more reason for uncertainty because of the patterns of peak concentration predicted for the local zone as one progressed outwards along several axes. For example, inspection of Figure F6-17 clearly shows that peak 1-hour SO_2 concentrations greater than 600 $\mu g/m^3$ may occur S, SW, NW, NNW and SSE of the stack (beyond receptor sites 8, 24, 56, 64 and 128 respectively) while in the SSW direction peaks up to 1200 $\mu g/m^3$ may occur, beyond receptor site 16. Hence, injurious effects may occur beyond the local zone of impact along these axes. However, because of the discontinuity between the local and regional modelling, it is impossible to make any definitive statements as to the magnitude of such effects. All that can be said is that for the more distant sites in the regional zone of impact, the effects, if any, of the generating station emissions are likely to be marginally beneficial.

F7.0 ASSESSMENT OF IMPACTS OF COOLING TOWER EMISSIONS ON VEGETATION

As pointed out previously (Section F5.2), there is a lack of information as to the effects of salt aerosols from cooling tower drift on plants. Those studies which have been reported in the available literature are confined to thermal generating stations employing (at least in part) saline water for cooling purposes. Hence a major component of the salt aerosols generated are relatively rich in Na^+ and Cl^- ions. The Thompson River water to be used for the Hat Creek project has an entirely different composition[3]. Nevertheless, the deposition rates predicted by the ERT models for the various cooling tower options[3] suggest that minor adverse effects of vegetation are almost certain within three km of the towers, and that some effects may occur at greater distances. However, it is not possible to offer any quantitative estimates of the magnitude of these impacts in the absence of specific information as to the effects of aerosols of the composition expected from Thompson River water on those species which occur within the locality of the cooling towers. Indeed, it is possible that, because of the content of Ca^{++} and $SO_4^=$ ions expected to be present, aerosol deposition might result in nutrional benefits to local vegetation.

Finally, it should be pointed out that the generating station stack and cooling tower plumes may interact. The primary consequence of such interaction would be the exposure of vegetation to SO_2/NO_2 mixtures in conditions of high humidity, in which case the impact of the gaseous emissions would be enhanced as a result of greater uptake. It is also possible that aerosol/gas interactions could occur on such occasions. However, there appears to be no information available as to the consequences of such interactions to vegetation.

F8.0 CONCLUSIONS

F8.1 EFFECTS OF GENERATING STATION EMISSIONS ON VEGETATION

The effects of the generating station emissions on natural and agricultural vegetation have been assessed for each of the three emissions control options: 366 m stack with FGD, 366 m stack with MCS, and 244 m stack with MCS. Summary conclusions for each option are presented below, but in terms of comparative impact, they can be ranked in the following order of increasing injury to vegetation:

366m/FGD < 366m/MCS < 244 m/MCS

In general, it should be observed that the primary reason for the greater impact of the two options involving MCS is the result of the larger numbers of potentially injurious 1-hour concentrations of SO_2/NO_2 permitted by MCS based upon the projected 3-hour 655 $\mu g/m^3$ SO_2 standard.

The ERT modelling of the local and regional zones of impact is subject to increasing discontinuity at the junction of the two zones (25 km from the stack) in the above sequence of emission control options, such that there is greater likelihood of injury to vegetation beyond the 25 km limit of the local model in the case of the 244 m/MCS option.

(a) 366 m Stack/FGD Air Quality Model

This model provides the least adverse impact on vegetation within the Hat Creek region. The injury which is predicted to occur is essentially confined to the upper elevations of Cornwall Peak, with minor injury on the Clear Range west of the stack. The injury is largely expected to be chronic in nature, resulting from repeated fumigations with SO_2 and NO_2. The acute injury threshold of sensitive species may be exceeded from time to time. Injury on Cornwall Peak may be increased as a consequence of simultaneous impingement of the generating station stack and cooling tower plumes.

No significant injury is expected to occur to important tree species, although individual trees may be adversely affected on Cornwall Peak.

Measurable injury is however expected to shrubs such as *Salix* and such injury may adversely affect the food supply of wildlife such as moose and gamebirds. No estimates of the impact on important range grasses are possible in the absence of species-specific data on dose-response for these species. Some chronic injury to lichens and mosses is to be expected in the sectors along the eastern slopes of the Clear Range and around Cornwall Peak subjected to repeated fumigations.

Agricultural impact (other than possibly on rangeland grass species) is expected to be of minor importance.

In general, the negative impacts are likely to affect few species in few locations. On the other hand, there is reason to believe that in many locations, some benefit may accrue to many species from the uptake of SO_2, NO_2 and additional CO_2, although this effect is not quantifiable.

No significant adverse effects on the vegetation of the surrounding region are anticipated.

While these assessments are based upon a single year's operation of the generating station, continued operation over several years might result in negative effects on some of the important tree species in the Cornwall Hills, as a consequence of fumigations in the winter months. Similarly, cumulative injury to sensitive shrubs would almost certainly lead to their progressive decline, and perhaps their ultimate disappearance.

(b) 366 m Stack/MCS Air Quality Model

This option results in greater exposures of vegetation to SO_2 and NO_2 than that utilizing FGD. As a consequence, the degree of injury predicted to occur within specific receptor sectors and the number of receptor sites affected are both increased. In general, the comparison of the two 366 m stack models indicates greater likelihood of injury to all vegetation types from the MCS option, with the major area of impact again being Cornwall Peak and significant injury also occurring on the southern end of the Clear Range. There is a greater risk of injury to important species in these locations, much of it resulting from the increased numbers of 1-hour exposures to elevated SO_2 and NO_2 levels. In contrast to the FGD model, in the case of the MCS strategy a greater proportion of injury is likely to be of the acute type, although greater chronic injury will also occur.

In addition to greater specific injury, the ecological impact of the MCS strategy would be greater than FGD, as would be the agricultural impact. In the latter case measurable injury to forage species is expected to occur on the agricultural lands within the southern Hat Creek Valley on the slopes of the Clear Range, with minor injury extending through Marble Canyon to the northwest and to the eastern slopes of the Cornwall Hills.

Again there appears to be no reason to expect adverse effects of generating station emissions on vegetation beyond the local zone within the regional zone of impact. The possible exception is in the directions of S and SSW of the stack where it appears that significant peak SO_2 concentrations might occur. However, for the most part the effects of gaseous emissions within the regional zone of impact would probably be beneficial rather than injurious.

Greater concern should be noted with regard to possible interactions between the stack and cooling tower plumes on Cornwall Peak, because of the greater emissions of SO_2 and NO_2 than from the FGD strategy.

As in the case of the FGD strategy, continued operation of the generating station over several years will result in cumulative injury on the Clear Range and the Cornwall Hills. This is likely to cause significant reduction in tree growth, and the decline and disappearance of individual plants of sensitive shrub species. Lichen cover would probably also be reduced. All these effects would be expected to result in discernible changes in species composition and diversity.

(c) 244 Stack with MCS Air Quality Model

This option can only be assessed in absolute terms since no other than 244 m stack configuration data are available. However, the potential adverse impacts for this option are unquestionably the greatest of the three options under study. The lower stack height would result in phytotoxic ground-level concentrations of SO_2 and NO_2 over a much wider area than either of the 366 m stack options, and in high concentrations in many of those sectors adversely affected by the 366 m stack emissions. There is good reason to believe that some measurable adverse effects would occur beyond the limits of the local zone of impact, particularly to the south and and west.

The impingement of gaseous emissions would measurably injure important tree and shrub species to the southeast, south, southwest, west and northwest of the stack. In addition, some injury to these species would be expected to the northeast in the Arrowstone Hills.

The impact on agriculture would not only adversely affect forage production within the Hat Creek Valley, but would also be expected to injure potential crops such as tomatoes, potatoes and faba beans if grown at higher elevations around Ashcroft and Cache Creek, to the east and southeast.

In general, the injury to vegetation which is predicted would be of both acute and chronic types. Increased acute injury is anticipated from the repeated doses of elevated SO_2/NO_2 levels although individual doses may be only close to the acute injury thresholds for individual species. Such cumulative injury would have serious ecological consequences in that the levels of injury predicted for some species, e.g. *Salix* would lead to their rapid decline, resulting either in denudation of the affected terrain or at least in changes in species composition and in the distribution of plant cover, which would become more and more pronounced during the subsequent years of operation of the generating station.

(d) General Remarks with Regard to Generating Station Emissions

In the assessments of impact, greatest attention has been paid to SO_2 and NO_2 . The only other constituents of these emissions which may be injurious to vegetation are floorides. However, the expected concentrations of gaseous and particulate fluorides are such that no acute injury is anticipated. On the other hand, since fluorides are cumulative toxicants, chronic injury might well occur in some species, particularly perennials, including the important conifers, and the perennial range grasses, over time. Such injury would be additional to that assessed in this report, and would be expected to increase in magnitude according to the sequence: 366 m/FGD < 366m/MCS. < 244 m/MCS. No assessment has been made in this report of the known secondary impact of fluoride accumulations on livestock and wildlife.

The major impacts on tree species particularly in the MCS situations would affect growth and productivity and be translatable into economic loss with regard to timber production.

The extent of the assessments of effects on vegetation of value to livestock and wildlife is quite variable. Completely lacking are assessments of impact on important range grasses, because, in the absence of any information on the dose-response characteristics of those species of importance to Hat Creek, it is impossible to predict with any meaningful accuracy the impact on these species. This weakness is clear indication of additional studies which are required in order to provide a better assessment of impact. The same concerns may also be expressed with regard to other indigenous species which have been excluded from the assessment, and which may be of particular importance to wildlife and gamebirds and for ethnobotanical reasons, e.g. *Cornus stolonifera, Rosa gymnocarpa, Shepherdia canadensis, Symphoricarpos albus, Vaccinium spp., Linnaea borealis,* and several lichens and mosses. In terms of damage to native vegetation and to agricultural crops, an approximation of the economic significance can be obtained by assuming that the assessed levels of injury constitute loss of production during the calendar year.

F8.2 EFFECTS OF COOLING TOWER EMISSIONS ON VEGETATION

Cooling tower emissions are expected to have minimal adverse effects on vegetation. Such effects would largely occur in close proximity to the cooling towers and would result from salt deposition from aerosols. Increased local humidities may enhance the impact of the generating station emissions where the plumes from both sources overlap.

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ADDENDUM A
VEGETATION COVER TABLES

ADDENDUM A

ESTIMATED TREE AND SHRUB COVER IN SELECTED RECEPTOR SECTORS

	336m MCS																																													
	366m FGO																																													
TREES	13	14	15	20	21	22	23	27	28	29	35	36	37	44	51	52	116	123	124	6	7	8	16	24	30	31	32	38	43	45	46	53	54	55	56	61	62	63	64	70	86	93	94	125	126	127	128
Abies lasiocarpa	0.1	0.4	0.5	0.1	0.7	0.6	0.8	*	0.4	0.5		0.5	0.7	0.4	0.4	0.2			0.2		0.5	0.5	0.5	0.9	0.8	0.8	0.9	0.5	0.5	0.7	0.8	0.3	0.2	0.3	0.3		0.1	0.3	0.3		0.1		*	0.2	*	0.3	0.3
Picea engelmannii	1.9	5.6	6.0	1.9	6.7	6.5	9.3	0.8	5.4	4.3	0.6	6.4	7.8	4.1	0.6	1.4		0.5	0.7	0.7	6.0	6.8	6.8	10.6	7.4	9.3	10.6	3.6	1.5	5.3	5.1	3.9	3.7	3.1	3.6	1.8	2.7	4.9	5.6	1.7	2.0		1.4	0.3	1.3	0.8	1.0
Pinus albicaulis			*		0.2	0.1	0.1			0.3											*	*	*	0.1	2.0	0.1	0.1			1.2																	
Pinus contorta	2.5	4.6	5.1	5.5	3.5	1.7	2.7	3.4	2.1	1.2	3.7	3.2	1.9	1.0	0.6	3.7		6.8	1.6	6.1	5.1	5.8	5.8	3.1		2.7	3.1	0.8	0.3	0.2	1.1	4.6	3.1	0.9	1.0	8.0	6.9	10.8	12.2	0.8	4.4		3.1		5.5	6.7	7.6
Pinus ponderosa	*							*	0.1				*	0.2		0.1	0.7		0.3	0.2								0.6	*		0.4	0.5	0.7	0.8	0.9		0.3			0.5	0.6	0.7	0.8	0.7	0.3	0.4	0.4
Pseudotsuga menziesii	2.0	1.8	1.1	1.9	*	0.4	1.5	2.5	1.1		2.6	*	1.0	2.0	3.7	3.0	3.1	0.3	3.1	3.9	1.1	1.3	1.3	1.7	2.1	1.5	1.7	5.4	3.2	2.7	4.0	0.9		1.8	2.0	2.6	2.5	1.6	1.8	8.0	5.0	2.8	2.0	5.3	3.9	4.5	5.1
Populus tremuloides														0.1		*				0.2								0.2		*		*	2.2	*	*							*	*				
Populus trichocarpa																																		*	*							0.1	0.1				
SHRUBS	13	14	15	20	21	22	23	37	38	29	35	36	37	44	51	52	116	123	124	6	7	8	16	24	30	31	32	38	43	45	46	53	54	55	56	61	62	63	64	70	86	93	94	125	126	127	128
Alnus incana	*	0.1	0.2	0.2	*			0.2	*		0.2	*						0.3	*	0.3	0.2	0.2	0.2									*	0.1				*	*	*		0.2		1.0		0.3	0.3	0.4
Alnus rubra																																	*	0.1	0.1							0.2	0.3			2.9	3.3
Amelanchier alnifolia	0.2	0.1	*	0.1		*	0.1	0.2	1.4		0.2		0.1	*	0.2	0.2	0.6	0.8	0.4	0.3	*	*	*	0.1	0.1	0.1	0.1	0.7	0.2	0.2	0.3	*	0.1	0.2	0.2	*	0.2			0.8	0.6	0.6	0.3	0.8	0.4	0.5	0.6
Arctostaphylos uva-ursi	0.9	0.9	1.7	1.1	1.4	1.6	1.6	1.1	0.6	2.4	1.2	0.1	0.7	0.7	1.5	1.2	0.4	*	1.5	2.1	1.7	1.9	1.9	1.8	1.3	1.6	1.8	1.6	1.2	1.2	1.7	0.6	0.8	0.3	0.4	1.8	0.9	0.9	1.0	2.6	1.8	0.4	0.7	1.2	1.9	1.7	1.9
Artemisia frigida	*	0.1	*		*	0.1	*		*	*			*	*					*	*	*	*	*	*	*	*	*		*	*	0.1	*	0.2	0.2	0.2						*	*	0.1	*	0.1	*	0.1
Artemisia tridentata																	2.0																0.7	0.2	0.2							2.8	1.6	0.3		0.5	0.5
Betula glandulosa	*			*	*	*		*	*	*		*	*	*	*	*				*												*		*	*			*	*			*	*				
Cassiope mertensiana	*	0.1	0.2		*	*	0.2		*	0.1									*		0.2	0.2	0.2	0.2	0.1	0.2	0.2						*				*	*									
Chrysothamnus nauseosus	*	*						*	*				*	*		*	0.6		0.2	0.1								0.3	*	*	0.1	0.2	0.3	0.1	0.3		0.1		*	0.2	0.2	0.8	0.5	0.4	0.2	0.3	0.3
Cornus stolonifera																																	0.1	0.1	0.2							0.3	0.3				
Juniperus communis	0.5	0.8	1.0	1.2	0.8	0.4	0.4	0.7	0.3	0.5	0.8	0.6	0.3	0.4	0.1	0.8	0.3	1.5	0.5	1.6	1.0	1.1	1.1	0.5	0.2	0.4	0.5	0.7	*	0.3	0.2	1.0	0.6	0.2	0.2	1.5	1.8	2.0	2.3	0.2	1.0	0.2	0.7	0.3	1.3	1.6	1.9
Juniperus scopulorum	*		0.1		*	0.5	*	*	0.2	*			0.2	0.5		0.2	0.9	*	0.6	0.8	0.1	0.1	0.1	*	*	*	*	1.5	*	0.2	0.2	0.4	0.3	0.4	0.4		0.3			*	0.5	0.8	0.4	0.9	0.5	0.5	0.6
Kalmia microphylla	*			*	0.1	*		*	*	*		*	*	*	*	*				*												*						*	*								
Lonicera involucrata	*	0.1	0.1	*	0.3	0.3	0.3	*	0.2	0.1		0.3	0.4	0.2	*	*				*	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.2	*	0.2	0.2	0.2	0.1	0.2	0.2		*	1.0	1.0		*		*		*		
Rhododendron albiflorum															0.4	2.1																1.1				4.5	4.0	4.7	5.3								
Ribes lacustre														0.1		*				0.1								0.2		*		*	0.2	*	*							*	*				
Rosa gymnocarpa	0.3	0.2	0.1	0.2		*	0.2	0.3	*		0.3		0.1	0.2	0.6	0.6			0.2	0.5	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.5	0.3	0.2	0.3	0.4	0.8	0.7	0.8	0.9	0.8	0.5	*	0.2	0.3	0.3	0.3	0.4
Rosa nutkana														*		*				*								*		*		*	*	*	*							*	*				
Rubus idaeus																																	*														
Salix sp.	0.2	0.2	*	0.2	*	0.2	0.1	0.2	0.3	0.3	0.2	0.5	0.4	0.4	0.4	0.4			0.1	0.6	*	*	*	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.2	0.2	0.2	*		0.3	0.3	0.4	0.2	0.2	0.4	0.1	0.1	0.2	0.2
Salix cascadensis			0.7	1.4	1.8	1.2	1.1			3.5											0.7	0.8	0.8	1.2		1.1	1.2																				
Salix nivalis			0.8		2.1	1.4	1.2			3.8											0.8	0.9	0.9	1.4		1.2	1.4																				
Shepherdia canadensis	0.7	1.1	1.2		0.9	0.7	0.8	0.9	0.6	0.2	1.0	0.9	0.9	0.7	0.8	2.8		1.5	0.6		1.2	1.4	1.4	1.0	0.9	0.8	1.0	0.9	0.5	0.9	1.0	1.7	0.9	0.2	0.2	4.7	4.4	5.2	5.9	0.8	1.3		0.8	0.3	1.5	1.7	1.9
Spiraea betulifolia														0.2		*				0.2										*		0.1															
Spiraea douglasii	*			*	*	*		*	*			*	*	*	*	*				*												*						*	*								
Symphoricarpus albus																																		*	*							*	*				
Vaccinium membranaceum	*			*	0.2											0.3																0.2				0.8	0.7	0.8	0.9								
Vaccinium scoparium	1.9	5.5	6.5	2.9	6.0	4.9	7.3	1.5	4.3	4.8	1.5	4.5	4.7	2.5	0.6	3.7		3.0	1.1	2.5	6.5	7.4	7.4	8.3	5.3	7.3	8.3	2.0	0.6	3.0	2.8	4.7	2.7	1.9	2.1	7.5	8.4	11.2	12.7		2.4	*	1.9		2.5		

* Species which provide 2.5 percent cover within specific associations, but which provide · 0.1 km^2 cover within annular sector.

ADDENDUM A

ESTIMATED GRAMINACEOUS VEGETATION COVER IN SELECTED RECEPTOR SECTORS

	366m FGD																		
	13	14	15	20	21	22	23	27	28	29	35	36	37	44	51	52	116	123	124
Agropyron spicatum	0.4	0.4	0.3	0.1	*	0.3	0.1	0.2	0.6	0.1			0.5	1.0	0.2	0.6	4.7	*	1.8
Agrostis alba	0.4	0.1																	
Bromis inermis																			
Calamagrostis purpurascens			0.4		0.1	0.5	0.2		0.2	0.2			0.2					0.1	0.4
Calamagrostis rubescens	5.3	0.1	5.6	8.1	2.1	1.5	3.3	7.2	1.9	0.3	8.0	2.0	2.0	1.4	1.0	4.9		6.7	4.6
Carex sp.	*			*	*	*		*	*	*		*	*	*	*	*			
Carex aquatilis	*			*	*	*		*	*	*		0.1	*	*	*	*			
Carex albo-nigra			0.9		0.4	1.2	0.7		*	1.2			*					*	*
Carex pyrenaica	*			*	*	*		*	*	*		*	*	*	*	*			
Carex rossiana	0.2	*		0.1	*	0.1			0.2	0.3		0.5	0.3	0.3	0.2	0.2			
Distichlis stricta	0.4	0.1																	
Eleocharis palustris	*	*																	
Eriophorum viridiarinatum	*			*	*	*		*	*	*		0.1	*	*	*	*			
Festuca ovina			0.3		0.2	0.4	0.2		*	0.6			*					*	0.1
Festuca scabrella	*	*												*					
Hordeum jubatum	1.0	0.5												*					
Juncus balticus	0.7	0.2																	
Juncus tenuis	*						*												*
Koeleria cristata	*	*					*	*	*				*	0.2		*	0.5		0.3
Luzula parvifolia								*	*				*			*	0.3		0.1
Poa alpina			0.2		0.1	0.3	0.2			0.3									
Poa grayana	*	0.2	0.7		0.3	0.7	0.6		*	0.8			*					*	0.1
Poa interior														*		*			
Poa pratensis	0.5	0.2					*							*					0.3
Poa sandbergii																	0.2		
Poa scabrella	*						*												*
Sporobolus cryptandrus																	0.3		
Stipa comata	*						*										0.3		*
Stipa occidentalis	*	*	0.1		*	0.1	*		*	*			*	*				*	0.2
Stipa richardsonii	*	*					*							0.1					*
Trisetum spicatum	*		0.2		*	0.1	0.2		*	0.1					*	0.3			

	6	7	8	16	24	30	31	32	38	43	45	46	53	54	55	56	61	62	63	64	70	86	93	94	125	126	127	128
Agropyron spicatum	1.0	0.3	0.3	0.3	0.2	0.3	0.1	0.2	3.0	0.6	0.9	2.2	2.2	4.0	3.6	4.1		1.1			2.1	2.2	5.5	4.8	3.7	1.9	2.3	2.6
Agrostis alba															*	*							*	*				
Bromis inermis															*	*							*	*				
Calamagrostis purpurascens	*	0.4	0.5	0.5	0.3	0.3	0.2	0.3			*	0.1			0.1	0.1										0.3		
Calamagrostis rubescens	10.7	5.6	6.3	6.3	3.8	4.6	3.3	3.8	4.3	6.0	5.0	7.6	2.8	2.2	2.1	2.4	5.4	4.5	5.2	5.9	11.2	9.9		4.4	4.0	9.2	11.1	12.6
Carex sp.	*												*						*	*								
Carex aquatilis	*												*						*	*								
Carex albo-nigra	*	0.9	1.0	1.0	0.8	*	0.7	0.8			*	*			*	*										*		
Carex pyrenaica	*												*						*	*								
Carex rossiana	0.4												0.3		*	*			0.3	0.3			*	*				
Distichlis stricta																												
Eleocharis palustris																												
Eriophorum viridiarinatum	*												*						*	*								
Festuca ovina	*	0.3	0.4	0.4	0.3	*	0.2	0.3			*	*			*	*										*		
Festuca scabrella	*									*	*	0.1	0.1	0.2	0.2	0.2							*	0.2	*	*	*	*
Hordeum jubatum	0.1									*	*			0.1	*	*							*	*	*	0.1	0.1	0.1
Juncus balticus																												
Juncus tenuis					*	*	*	*							0.4	0.4				*					*			
Koeleria cristata	0.2				*	*	*	*	0.5	*	1.0	0.2	0.2	0.3	0.6	0.6		0.2			0.3	0.2	0.5	0.4	0.5	0.3	0.3	0.4
Luzula parvifolia									0.3					*	*	*		0.1			0.2	0.1	0.2	*	0.3	0.1	0.2	0.2
Poa alpina		0.2	0.2	0.2	0.2		0.2	0.2																				
Poa grayana	*	0.7	0.8	0.8	0.7	0.2	0.6	0.7			*	*		*	*	*		*	0.1	0.1						*		
Poa interior	*								*		*		*		*	*							*	*				
Poa pratensis	0.3				0.1	0.4	*	0.1		*	*			0.2	1.9	2.2					0.2		*	*	0.4	0.1	0.2	0.2
Poa sandbergii																						*	0.3	0.2	*		*	*
Poa scabrella					*	*	*	*							0.1	0.1					*				*			
Sporobolus cryptandrus																							0.5	0.3	*		*	*
Stipa comata					*	*	*	*							0.1	0.1					*	*	0.5		*		*	*
Stipa occidentalis	*	0.1	0.1	0.1	*	0.2	*	*		*	*	*		*	0.5						*		*	*	0.1	0.1	*	*
Stipa richardsonii	*				*	*	*	*		*	0.1	0.2	0.2	0.5	0.8						*		*		0.1	*	*	*
Trisetum spicatum		0.2	0.2	0.2	0.2		0.2	0.2					0.1	*			0.6	1.9	0.7	0.7								

* Species which provide > 2.5 percent cover within specific associations, but which provide $< 0.1\ km^2$ cover within annular sector.

ADDENDUM A

ESTIMATED HERBACEOUS VEGETATION COVER IN SELECTED RECEPTOR SECTORS

	366m MCS																																													
	366m FCD																																													
Species	13	14	15	20	21	22	23	27	28	29	35	36	37	44	51	52	116	123	124	6	7	8	16	24	30	31	32	38	43	45	46	53	54	55	56	61	62	63	64	70	88	93	94	125	126	127	128
Achillea millefolium	0.3	0.1	0.3	0.1	*	0.3	0.2	0.2	0.2	0.1	0.2	*	0.1	0.1	0.3	0.2		*	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.2	0.3	*	0.3	0.3	0.5	0.2	0.5	0.7	0.8	*		*	*	0.5	0.3	*	0.3	0.3	0.3	0.2	0.3
Actaea rubra																																	*														
Anemone multifida	*		0.1		0.1	0.2	0.1		*	0.2								*	0.1	*	0.1	0.2	0.2	0.1	0.1	0.1	0.1			*	*			0.2	0.2					*	*	*		*	*		
Allium cernuum	0.2	0.3	0.1	0.2		*	0.2	0.2			0.3		*	*	0.4	0.2			0.2	0.3	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4		0.2	0.1	0.1	0.1				0.7	0.4	*	*	0.2	0.2	0.3	0.3
Antennaria alpina			*		*	0.1	*		*	*			*					*	*	*	*	*	*	*	*	*	*			*	*			*	*										*		
Antennaria rosea	*		*		*	*	*	*	*	0.2			*	0.1		0.1	0.2		0.1	0.1	*	*	*	*	*	*	*	0.3	*	*	0.1	0.2	0.3	0.4	0.5		*			0.2	0.1	0.2	0.2	0.7	0.1	0.1	0.1
Antennaria umbrinella			0.2			0.2	0.1			*											0.2	0.2	0.2	0.1		0.1	0.1																				
Arenaria capillaris			0.4		*	0.5	0.2		*	0.2			*					*		*	0.4	0.5	0.5	0.5	*	0.2	0.3				*			*	*										*		
Arnica cordifolia															*	0.3																0.1				0.6	1.9	0.6	0.7								
Arnica latifolia	0.2	0.3	0.4	0.3	0.4	0.1	0.2	0.2	0.1	0.3	0.2	*						0.3	0.1	0.3	0.4	0.4	0.4	0.2	0.1	0.2	0.2					*	0.1				0.1	0.2	0.2		0.7		0.1		0.3	0.3	0.4
Arnica rydbergii			*			0.1	*			*											*	*	*	*		*	*																				
Astragalus miser				*										*			0.1			*									*	*	*	*		0.1	0.1							0.2	0.2	*		*	
Balsamorhiza sagittata	*	*						*	0.1				*	0.1		0.1	0.9		0.4	0.2								0.8	*	0.1	0.3	0.3	0.5	0.4	0.7		0.3			0.6	0.4	0.8	0.6	0.9	0.5	0.5	0.6
Castilleja miniata			*		*	*	*			0.2											*	*	*	*		*	*																				
Centaurea diffusa																																									*	*					
Cerastium arvense			0.1		*	0.1	*		*	*			*					*	*	*	0.1	0.1	0.1	*	*	*	*			*	*			*	*												
Claytonia lanceolata	*																		*						*									0.2	0.2					*				*			
Crepis atrabarba																																									*	*					
Cornus canadensis	0.2	0.4	0.4	0.4	0.6	0.4	0.5	0.2	0.3	0.1	0.2	0.6	0.4	0.3		*		0.4	*	0.3	0.4	0.5	0.5	0.6	0.4	0.5	0.6	0.3	*	0.6	0.4	0.4	0.3	0.3	0.3		0.1	0.3	0.3		0.3		0.3		0.4	0.4	0.5
Dryas octopetala			1.7		*	2.0	1.0			1.1											1.7	1.9	1.9	1.2		1.0	1.2																				
Erigeron compositus	*	*												*					*	*					*				*	*			*	0.1	0.1							*	*	*	*	*	*
Erigeron linearis																	0.2																									0.3	0.2	*		*	*
Eriogonum heracleoides	*		*		*		*			0.2				*		*			*	*	*	*	*	*	*	*	*	*		*		*		0.1	0.1					*				*			
Eriogonum pyrolifolium			*			0.1	*			*												*	*	*		*	*																				
Equisetum arvense	*	0.1	0.1	*	0.1	0.1	0.3	*	0.2	0.2		0.4		0.3	*	*				*	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.2	*	0.2	0.2	0.2	0.4	0.3	0.3		*	0.1	0.2		*	0.2	0.3		*		
Equisetum scirpoides		0.1	0.1		0.2	0.3	0.3	*	0.2	*											0.1	0.2	0.2	0.4			0.4						0.3	*	*							*	*				
Fragaria glauca	0.6	1.2	1.6	0.8	1.1	1.3	1.7	0.5	0.9	1.3	0.6	0.9	1.0	0.6	0.4	0.5		0.7	0.4	0.9	1.6	1.8	1.6	1.9	1.2	1.7	1.9	0.6	0.4	0.8	0.8	0.8	0.7	0.7	0.8	0.8	1.0	1.5	1.6	0.5	0.8		0.5	0.2	0.8	0.9	1.0
Geum macrophyllum	*		0.2	*	*	*		*	*	0.1		0.2	0.1	*	*	*				0.2												0.1						0.1	0.1								
Geum triflorum	*	*		*	*	0.2	0.1	*	0.1	0.1			0.1	*		*	0.2	*	0.3	*	0.2	0.3	0.3	0.1	0.2	0.1	0.1	0.2	*	*	*		0.1	0.5	0.6		*			0.2	0.1	0.2	*	0.3	0.3	0.2	0.2
Haplopappus lyallii			*			0.1	*			*											*	*	*	*		*	*																				
Heracleum lanatum	*	0.1	0.1	*	0.1	0.3	0.3	*	0.2	*			0.4	0.2		*					0.1	0.2	0.2	0.4	0.3	0.3	0.4	0.2	*	0.3	0.3	0.2	0.1	0.2	0.2		*	0.1	0.1		*		*		*		
Heuchera cylindrica	*													*		*			*	0.1					*			0.1		*		*		0.1	0.1					*				*			
Linnaea borealis	0.6	1.3	1.4	1.0	2.4	2.1	2.5	0.4	1.5	0.7		2.4	3.2	1.7	0.1	1.0		0.6	0.1	0.5	1.4	1.8	1.6	2.9	2.8	2.5	2.9	1.4	0.4	2.1	1.9	2.0	1.1	1.3	1.4	1.9	2.1	2.8	3.2		0.9		0.7		0.7	0.6	0.6
Lithospermum ruderale	*								*				*			*	0.3		0.1	*								0.2	*	0.1	0.2	0.2	0.4	0.4	0.4		0.1			0.2	0.1	0.2	0.4	0.3	0.3	0.2	0.2
Lupinus lepidus	0.6	1.6	2.0	1.0	1.6	1.1	1.7	0.6	0.9	1.0		0.7	0.5	0.2	0.4	*		1.5		1.1	2.0	2.2	2.2	1.9	1.0	1.7	1.9	0.2	*	0.3	0.3	0.5	0.7	0.2	0.2		0.5	0.9	1.0		0.8		0.6		1.0	1.2	1.8
Lomatium macrocarpum																																									*	*					
Opuntia fragilis																	0.1																*	*	*						*	*	0.1	*		*	*
Osmorhiza chilensis																																		*	*							*	*				
Oxytropis campestris			*							*											*	*	*																								
Pedicularis bracteosa	0.1	0.4	0.6	*	0.5	0.6	0.8	*	0.4	0.6		0.3	0.3	0.2	*	0.2			*		0.6	0.7	0.7	0.9	0.5	0.8	0.9	0.1	*	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.5	0.7	0.8		*	*	0.1		*		
Pedicularis racemosa															*	0.2																*				0.8	0.3	0.4	0.4								
Penstemon fruticosus														0.2		*				0.2								0.3		*		0.1															
Penstemon procerus			*		*	*	*			0.2											*	*	*	*		*	*																				
Petasites frigidus	*			*	*	*		*	*	*		*	*	*		*				*												*		*				*	*			*	*				
Potentilla diversifolia	*		0.2		*	0.3	0.2														0.3	0.3	0.3	0.2	*	0.2	0.2							0.1	0.1					*				*			
Phacelia sericea			*			0.1	*			*											*	*	*	*		*	*																				
Phyllodoce empetriformis	0.2	0.7	0.8	0.4	0.3	0.2	0.6	0.2	0.4	0.4	0.3	0.1						0.5	0.2		0.8	0.5	0.9	0.6	0.4	0.6	0.6					0.1	0.3				0.2	0.1	0.1		0.3		0.2		0.4	0.5	0.4
Pyrola secunda	0.2	0.4	0.5	0.3	0.5	0.4	0.5	0.2	0.3	0.2	0.2	0.5	0.5	0.2		*		0.2	0.5	0.3	0.1	0.5	0.5	0.4	0.5	0.5	0.4	0.2	*	0.1	0.3	0.3	0.5	0.1	0.2		0.1	0.3	0.3		0.3		*		0.3	0.3	
Salsola kali																																									*	*					
Saxifraga bronchialis			0.2			0.2	0.1			*											0.2	0.2	0.2	0.1		0.1	0.1																				
Sedum lanceolatum			0.1		0.2	0.2	0.1			0.4												0.2	0.2	0.2		0.2	0.2																				
Solidago spathulifolia														*														*	*	0.2	0.2	0.3	0.3	0.3								0.2				
Streptopus amplexifolius																																	*													
Taraxacum officinale	0.2	0.1	*		*	0.1	*		*				*	*				*	0.1	*	*	*	*	*	0.1	*	*		*	*	*		0.1	0.4	0.5					*		*	*	0.1	0.1	*	*
Thalictrum occidentale	*	0.2	0.3	*	0.5	0.4	0.5	*	0.2	0.6		0.3	0.3	0.2	*	0.4			*		0.3	0.4	0.4	0.5	0.6	0.5	0.5	0.1	*	0.2	0.2	0.3	0.1		0.2	0.8	0.7	0.9	1.0		*	*	0.1		*		
Trifolium repens																																		*	*							*	*				
Trollius laxus	*	0.2	0.2		*	*	0.1		0.1	0.1									*		0.2	0.2	0.2	0.1	0.1	0.1	0.1										*	*	0.1								
Valeriana sitchensis	*	0.1	0.1	*	0.2	0.2	0.3	*	0.2	*		0.3	0.3	0.2		*					0.1	0.1	0.1	0.3	0.2	0.3	0.3	0.1	*	0.2	0.2	0.1	*	0.1	0.1		*	*	*		*				*		

* Species which provide < 1.5 percent cover within specific associations, but which provide < 0.1 km² cover within annular sector

ADDENDUM A

ESTIMATED COVER OF NON-VASCULAR PLANTS IN SELECTED RECEPTOR SECTORS

	366m NCS																																														
	366 m FGD																																														
	13	14	15	20	21	22	23	27	28	29	35	36	37	44	51	52	116	123	124	6	7	8	16	24	30	31	32	38	43	45	46	53	54	55	56	61	62	63	64	70	86	93	94	125	126	127	128
LICHENS																																															
Alectoria fremontii	0.2	0.4	0.4	1.4	0.5	0.4	0.5	0.2	0.3	0.1	0.2	0.6	0.6	0.3	*	0.2		0.5	0.1	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.3	*	0.4	0.4	0.4	0.3	0.2	0.3	0.4	0.5	0.9	1.0		0.4		0.3		0.4	0.5	0.5
Alectoria jubata	1.3	2.7	2.9	2.3	3.3	0.6	2.7	1.4	1.7	1.2	1.5	2.3	2.2	1.2	0.4	0.5		2.5	0.6	2.3	2.9	3.3	3.3	3.1	2.2	2.7	3.1	1.1	0.6	1.6	1.6	1.7	1.8	0.9	1.1	0.5	1.2	1.9	2.2	0.6	2.0		1.4	0.2	2.2	2.6	3.0
Alectoria sarmentosa	0.3	0.8	1.4	0.5	0.6	0.5	0.9	0.3	0.5	0.5	0.3	0.5	0.4	0.2		*		0.6	0.2	0.5	1.5	1.7	1.7	1.0	0.6	0.8	0.9	0.2	*	0.3	0.3	0.3	0.5	0.2	0.2		0.3	0.5	0.6		0.4		0.3		0.5	0.6	0.6
Letharia vulpina	2.0	2.0	1.4	2.3	0.2	0.4	1.4	2.1	0.7		2.3		0.8	0.6	3.6	3.2	0.8	0.9	1.8	3.3	1.4	1.5	1.5	1.6	2.0	1.4	1.6	2.8	3.0	2.4	3.7	1.1	2.0	1.2	1.3	4.0	3.1	3.3	3.8	6.2	4.1	0.7	1.6	2.8	3.0	3.6	4.1
Peltigera aphthosa	0.3	0.7	0.7	0.6	0.9	0.7	0.9	0.3	0.6	0.3	0.3	0.3	1.0	0.5				0.5	*	0.5	0.7	0.8	0.8	1.1	0.8	0.9	1.1	0.4	0.1	0.6	0.6	0.1	0.2				0.1	0.2	0.2		*		0.2		0.4	0.5	0.6
Peltigera canina																																	*														
MOSSES																																															
Abietinella abietina														*		*				0.1								0.1		*		*															
Aulacomnium palustre																																	0.3														
Brachythecium sp.																																	*	*	*							*	*				
Drepanocladus uncinatus	0.2	0.8	0.8	0.3	0.7	0.6	1.0	0.2	0.6	0.5	0.1	0.6	0.7	0.3		*		0.3	0.2	0.3	0.8	0.9	0.9	1.1	0.8	1.0	1.1	0.3	*	0.4	0.4	0.4	0.4	0.3	0.3		0.2	0.5	0.5		0.3		0.2		0.3	0.3	0.3
Hylocomium splendens																																	0.1														
Hypnum revolutum														*		*				*								*		*		*															
Pleurozium schreberi	1.3	2.6	2.7	2.2	4.3	3.7	4.5	1.0	2.8	1.2	0.8	5.0	5.7	3.0		0.3		1.7	1.0	1.4	2.7	3.1	3.1	5.1	3.9	4.5	5.1	2.4	0.8	3.7	3.4	2.9	2.2	2.2	2.5		0.8	1.8	2.0		1.8		1.5		1.7	1.6	1.8
Sphagnum sp.	*			*	*	*		*	*	*		0.1	*	*	*	*				0.1												*						*	*								
Tomenthypnum nitens	*			*	*	*		*	*	*		0.1	*	*	*	*				0.1												*						*	*								
Tortula ruralis																																									0.1	*					

* Species which provide > 2.5 percent cover within specific associations, but which provide < 0.1 km^2 cover within annular sector.