
DRAFT

**PROPOSED WESTERN CANADA STUDY
ON
ANIMAL AND HUMAN HEALTH EFFECTS
ASSOCIATED WITH
EXPOSURE TO FLARE EMISSIONS**

February 24, 2000

**Prepared by an Ad-hoc
Multi-Government Steering Committee**

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EXECUTIVE SUMMARY

At the instruction of a number of Alberta Government Ministers an initiative was undertaken to develop a study plan to examine the potential effects of flare emissions on animal and human health. The study was to be comprehensive. Since health issues related to flaring are not unique to Alberta, other Western provinces, British Columbia, Saskatchewan and Manitoba, were to be invited to participate.

Based on this instruction, an Ad-hoc Multi-Government Steering Committee was formed with representatives from government agencies in British Columbia, Alberta, Saskatchewan and Manitoba. A proposed study plan has been developed by the Ad-hoc Steering Committee with scientific input and assistance from the Western College of Veterinary Medicine in Saskatoon, the Alberta Research Council, Alberta Health and Wellness, the University of Alberta, and the University of Calgary.

The proposed study plan has six research elements. These are:

- Ambient Air Quality Characterization Downwind of Flare Emissions (field study)
- Human Exposure and Health Risk Assessment (field study)
- Health Effects on Beef Cattle of Chronic Exposure to Flare Emissions (field study)
- Health Effects on Wildlife (Birds) of Chronic Exposure to Flare Emissions (field study).
- Reproductive Toxicology of Flare Emissions (lab study)
- Potential Biomarkers of Flare Emissions in Beef (lab and field study)

Collectively these studies would significantly advance our understanding of the potential impact of flare emissions on health. This increased understanding would help address public concerns surrounding this issue and assist in developing future policies and standards related to flaring. The estimated cost of these six studies is about \$16.2 million

An additional “optional” study element was considered. The “Effects on Dairy Cattle Health and Milk Production and Quality of Chronic Exposure to Flare Emissions (field study)”. It is the committee’s recommendation that the dairy cattle study element not be pursued.

A possible companion study involves work on flaring reduction and control technologies. Government involvement in, and support for, this aspect of flare research is being led by Alberta Innovation and Science. Government support in the order of \$1.6 million is being sought by industry. While not part of this study proposal, the committee supports research work directed at reducing and/or eliminating flaring and flare emissions.

The overall study proposal recommended by the Committee would include the six core research elements costing an estimated \$16.2 million. These estimates are based on integrating the study elements to the maximum extent possible which results in considerable efficiencies and dollar savings. Figure 1 provides an overview of each study element.

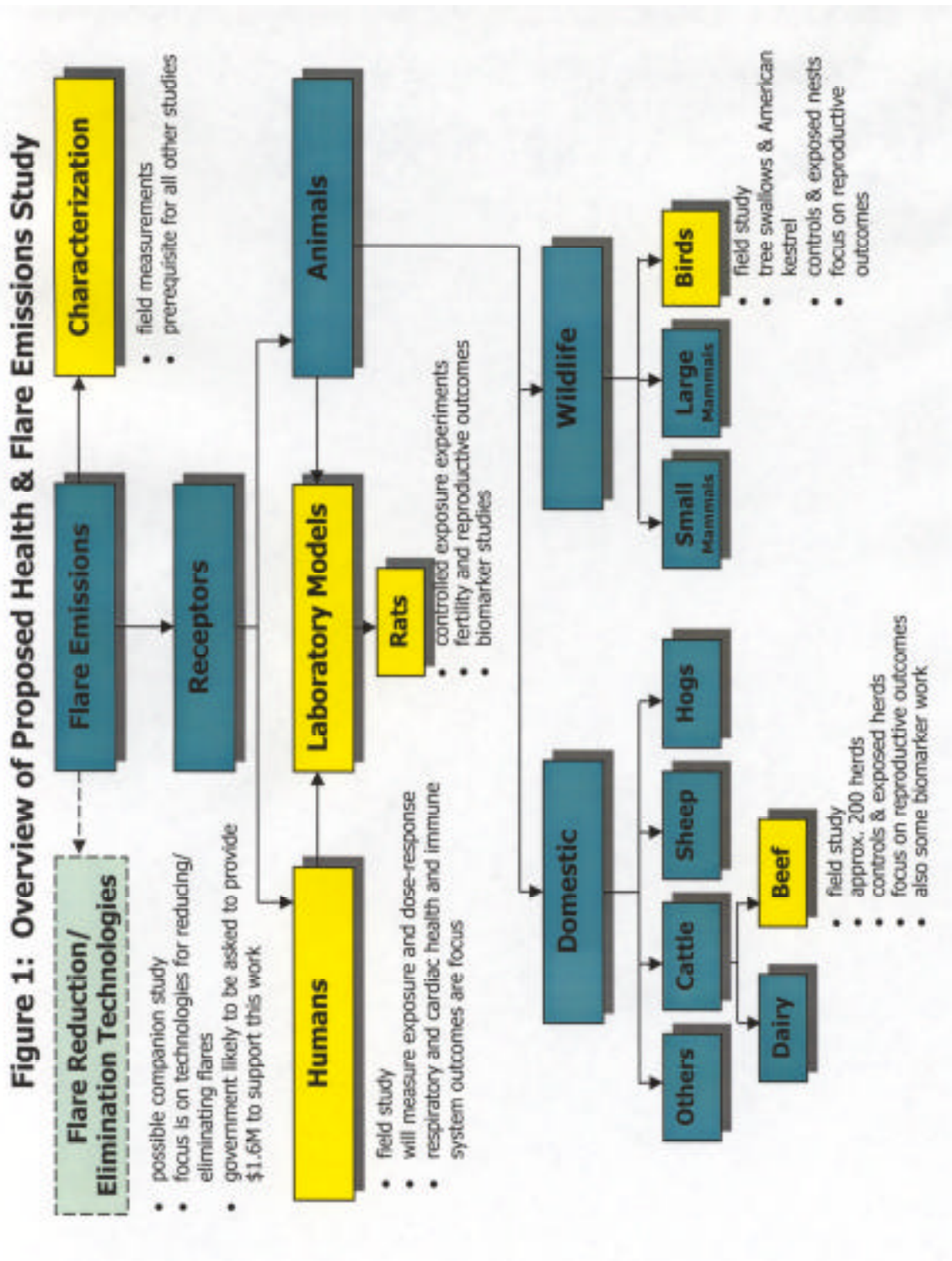
The December 14, 1999 draft Proposal was reviewed by the Co-Chairs of the Scientific Advisory Panel. They indicated that the research should be undertaken in two phases. Phase I would include the Ambient Air Quality Characterization, Human Exposure and Health Risk Assessment, Health Effects on Beef Cattle, and Health Effects on Wildlife (birds) research elements. Phase II would be the Reproductive Toxicology and Biomarker elements if the results of the Phase I research indicated that they were necessary.

The costs of the four research components of Phase I are estimated at \$10.2 million. Study administrative costs include funding for a study manager, stakeholder advisory panels, peer reviewers, report publication, et cetera, and a Scientific Advisory Panel, are estimated at \$0.8 million. It should be noted that these costs are tentative and may change as study designs are further developed and finalized.

The study proposal outlines a study management structure involving a Steering Committee with a maximum of four government representatives from each of British Columbia, Alberta, Saskatchewan and Manitoba. In addition to the Steering Committee there would be a Stakeholder Advisory Panel, a Science Advisory Panel, and a Study Manager. The proposed study management structure is intended to ensure that the study is efficiently managed and has a high degree of both public and scientific credibility.

It is proposed that all of the field research elements of the study be conducted by the Western College of Veterinary Medicine (WCVM) i.e. the beef cattle and wildlife elements. It is proposed that the reproductive toxicology, biomarker, and ambient air monitoring research elements be either contracted to a private or institutional laboratory or conducted at the Alberta Research Council (ARC). Alberta Health and Wellness will manage the human health study element.

The comprehensive nature of the proposed study is such that study results of Phase I would not start to be available until the fall of 2002 or early 2003 assuming that detailed study planning begins in the fall of 1999. Results from all studies including Phase II and a synthesized final study report would not be available until late 2006.



OVERVIEW OF PROPOSED STUDY PLAN

1. Introduction

Western Canadian farmers and ranchers whose operations are located near gas plant flares or battery flares often ask questions or express concerns regarding the potential adverse impacts of flares on the health of their cattle and themselves. Flare design requirements have been assumed to be protective of animal and human health. Recent studies on flare emissions and animal health would indicate, however, that further studies are necessary to address these questions and concerns more definitely. Also, one of the main recommendations from animal health issue workshops held in Alberta in 1986 and 1996, is that additional research is needed to better understand the risk to cattle of volatile emissions from flaring and to determine whether current flaring practices, ambient guidelines and emission controls are adequate to protect cattle.

Solution gas flares are of particular concern because they are very numerous and often located in close proximity to livestock operations, farmsteads, and communities. It is proposed that these types of flares be the focus of this study initiative and throughout this proposal the term “flare” refers to solution gas flares¹. Solution gas flares are of two types; sour and sweet. Both types are common and it is proposed that possible impacts of both types of flares be addressed in this study. Flares, especially when operating inefficiently (calculations in Alberta show that under normal operating conditions flare efficiency can be as low as 66%), can also be the single largest source of a variety of volatile and semi-volatile (e.g. polycyclic aromatic hydrocarbons (PAHs)) compounds in an area.

Actions are being taken in some jurisdictions to eliminate or reduce flaring to the extent practical. This has resulted in questions regarding the need for a health – flaring issue study and suggestions that monies for such a study would be better spent on studying and developing strategies to better control or eliminate flare emissions. Efforts towards flare reduction and elimination need to continue as they are preventative measures. In this regard the Alberta Government has been approached to participate in the establishment of a flare reduction and control technology reduction facility. This type of initiative is considered to complement this study proposal.

While work on flare reduction/elimination is important, there is a need to assess more definitively and comprehensively the potential impact of flares on human and animal health and to address ongoing concerns and guide future regulatory measures related to flaring. In particular, greater scientific knowledge is required in order to understand the potential impacts of flare emissions both from a field and laboratory perspective. This knowledge will help to determine safe exposure levels under operating conditions encountered in field situations. Industry and government will then be better able to determine when and how adverse effects may occur and, if required, the degree of improvement in flare management needed to eliminate or minimize these adverse effects.

¹ Although solution gas flares are the proposed focus of this study initiative, it is recognized that flare emissions from gas plants and well testing may have to be considered in some of the herd study areas.

2. Purpose

The desired outcome of this initiative is scientifically sound data that indicates whether or not flares and flare emissions may be adversely impacting human, cattle, and wildlife health.

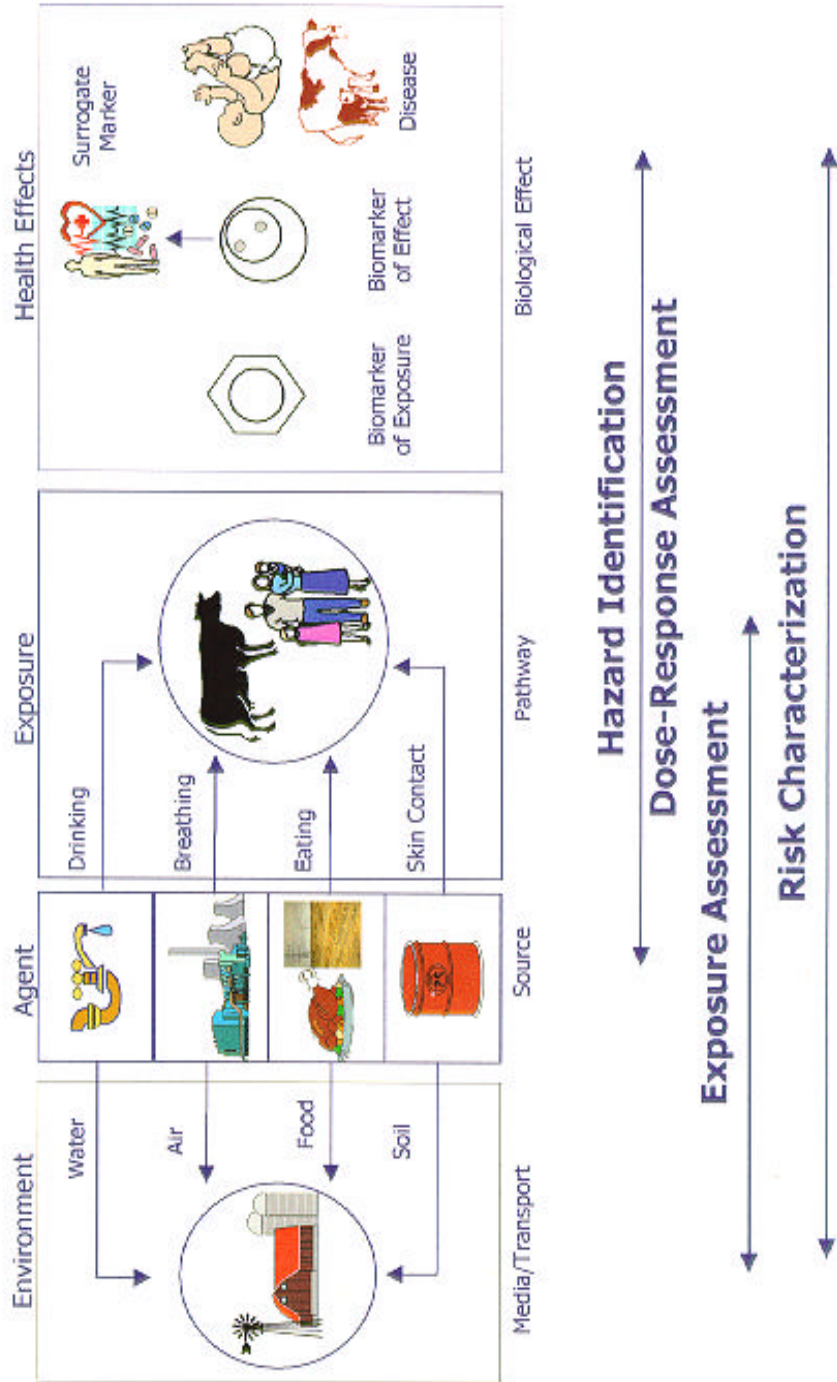
3. Criteria for Research Design

The following are proposed criteria for the design of a study related to flares and animal health impacts:

- i.) **Credible well coordinated science.** The study would build on existing knowledge and take a phased, synthesized and coordinated approach. The health risk assessment model shown in Figure 2 outlines the four general risk components that will be addressed by the research elements. The study would be done by reputable scientists and be subject to peer review. The work would be robust enough to distinguish the effects of flaring from other potential health stressors.

An initial review of the draft Proposal dated December 14, 1999 by the Co-Chairs of the Scientific Advisory Panel indicated that the research should be undertaken in two phases. The recommendation was that the Ambient Air Quality Characterization, Human Exposure and Health Risk Assessment, Health Effects on Beef Cattle, and Health Effects on Wildlife (birds) proceed as Phase I and that the reproductive toxicology and the biomarker studies should be deferred as Phase II until results are obtained from the components of Phase I.

Figure 2: Environmental Health Risk Assessment



- ii.) **Clear understanding of questions to be answered by the study.** The study would answer the following questions in two phases:

Phase I

- a) What types and classes of compounds are found in air downwind of flares?
- b) Is human health, cattle (beef) health, and/or wildlife (bird) health affected by the emissions from oil and gas flaring?
- c) Does oil and gas flaring as currently practiced affect cattle productivity (e.g. non-pregnancy, abortion, stillbirths, calf mortality, and calving interval)?

Phase II

- d) Are there biomarkers in animal tissue that can be used to measure exposure to flare emissions?
- e) What is the dose-response relationship between specific flare emissions and animal health outcomes?

- iii.) **Results owned by those who need to act.** Governments need to own the results and take appropriate actions based on these results. Industry and stakeholders are interested parties who may also need to act depending on the study findings. The appropriate interaction with stakeholders would occur as the study is planned and implemented.
- iv.) **Cost effective.** The study would be designed to obtain the desired outcomes in a cost-effective manner by integrating study elements to the maximum extent possible.
- v.) **Government leadership.** Governments as regulators of the oil and gas industry are expected to ensure activities, such as flaring, do not have short or long term environmental or health impacts. Governments are also expected to be able to answer questions regarding the safety and potential health impacts of flaring. It is therefore considered appropriate that Governments take a leadership role in this type of study and this is the proposed strategy. Industry and stakeholders would also be involved in the appropriate advisory capacity to ensure that issues are understood and there is buy-in to the study plan and study results.

4. Study Approach

The concept of a continuum from a source of contamination to the final health effect is a basic feature of all contemporary risk assessments. Determining the risk requires knowledge about the following fundamental components in the two phases:

- Source of contaminants;
- Transport of agents in the environment;
- Exposure of receptors to the contaminants of concern;

- Overt health effects.
- Dose received by exposed receptors;
- Early biological effects resulting from the dose; and

Collectively, studies designed using these components would significantly advance our understanding of the potential impact of flare emissions on animal and human health. This increased understanding would help address public concerns surrounding this issue and assist in developing future policies and standards related to flaring.

The study has been structured such that there are six research elements intended to address the following questions.

Phase I

What substances are found downwind of flares and what type of monitoring system(s) is best able to measure exposure to flare emissions?

What, if any, is the health risk to people living in close proximity to flares?

Do beef cattle exposed to sour or sweet gas flare emissions from oil and gas batteries have adverse health or reproductive outcomes relative to unexposed beef cattle?

Do sweet or sour gas flare emissions have any adverse effects on wildlife?

Phase II

What is the reproductive toxicology of certain sweet and sour solution gas flare emission substances?

Are there potential biomarkers that can be used to diagnose animal exposure to flare emissions and if so are there any potential human health implications of those impacts?

Collectively the Phase I and II research elements are considered to represent a thorough and comprehensive examination of the health issues related to flaring. It must be recognized that there are limitations in terms of definitively characterizing and measuring flare emission exposures, in terms of controlling and measuring confounding variables and in terms of measuring specific health outcomes.

A brief overview of the types of research studies that are being proposed to address these questions is as follows:

Phase I

- i) **Air Quality Studies** - Current measurements of ambient air quality downwind of sweet and sour flare stacks are insufficient to establish clearly the presence and concentrations of substances downwind of flares. There is a need for a significant increase in the amount of information so that the research teams can determine marker substances and the possibility of passive monitors for those marker substances. This would be done in all four provinces. In order to ensure a proper gradient of exposure when the field study begins, estimates of ambient concentrations need to be made from information about flare types, topography, and weather.
- ii) **Human Health Studies** – People living in close proximity to solution gas flares frequently voice concerns about the effects of these emissions on their health. In addition, a number of the chemicals identified in flare emissions are recognized as toxic to humans. The human risk assessment component will measure the exposure, dose, and response for humans living in close proximity to solution gas flares.
- iii) **Field cattle and wildlife (bird) studies** – Past cattle herd and epidemiological studies have suggested that there may be a negative association between flare emissions and certain reproductive outcomes in cattle. Further focused fieldwork is desirable to determine if these negative associations do exist and their magnitude. The best way to determine if emissions from normal oil and gas flaring activities are having a measurable affect on livestock production is to conduct this type of field study. In order to generate sufficient data for this type of assessment a large number of herds is required, e.g. 200. The focus of the work would be on beef cattle herds. Two bird species would be included to address the issue of the impact of flares on wildlife health and to take advantage of the exposure monitoring work that would be part of the beef cattle work. The bird species that would be studied have been used before as indicators of the possible effects of environmental contaminants and are considered a good sentinel wildlife species.

Phase II (Phase II initiation depends on results from Phase I)

- iv) **Toxicological testing** – Oil and gas flares generate a variety of substances. There is no or limited toxicological data on many of these substances. Also the toxicological effects of the mixture of substances found in flares are not known. To fully assess the actual and/or potential health effects of flare emissions on animals requires controlled toxicological testing. It is therefore proposed that toxicological testing of “cocktails” of flare emissions using laboratory animals be undertaken to develop a dose-response relationship between flare emissions and certain health outcomes. The focus would be on reproductive outcomes based on

previous cattle herd and epidemiological studies. While it is recognized that all the combinations of flare emissions that are encountered cannot be studied, a representative or “typical” mixture of flare emission compounds can be tested and the toxicological data collected extrapolated to expected responses in humans and other animals, e.g. cattle. This would help collaborate findings from the herd studies.

- v) **Biomarkers** –If present, biomarkers may be used to tell if exposure to flare emissions has occurred. This study element would try and identify possible flare emission exposure biomarkers in various animal tissues to aid in diagnosis. Certain biomarkers in beef tissues may also be of interest from both a health impact and beef quality standpoint if they are present in significant quantity. Impacts on beef quality may have important implications in terms of the marketability of beef products. It also has potential human health implications through the translocation of flare emission products to humans via animal products, e.g. beef. Laboratory and controlled field experiments are proposed to address the biomarker in tissues issue. Controlled experiments with exposures of laboratory animals (e.g. rats) and beef cattle would be conducted and tissue/organ/blood analysis conducted to determine possible biomarkers of flare emissions in beef and the health significance of these biomarkers. Samples will also be analysed from animals in the field study. The substances present in the muscle tissue is a function of many factors and for this reason the biomarker study will only involve comparing differences in biomarker levels between exposed and unexposed animals.

These research studies should, as comprehensively as is possible at this time, address what previous research has identified as key areas of uncertainty surrounding flare emissions and health. More details on the six research elements that are being proposed are outlined in Appendix I. A research element on dairy cattle was considered. The management of dairy herds is significantly different from the management of beef cattle. These differences include housing, reproduction control/manipulation, herd replacement practices, and feed sources. In general, dairy herd management practices add to the complexity of trying to assess the possible impacts of flare emissions on dairy herd productivity. Also, to achieve meaningful results the herd numbers required would be similar or larger than the number required for the beef cattle study. These factors combined with the fact that beef cattle can act as sentinel for all cattle led to the conclusion that including a dairy cattle component in the study proposal was not necessary and such a study component would not be cost effective.

The draft Proposal dated December 14, 1999 was reviewed by the Co-Chairs of the Scientific Advisory Panel. They agreed that:

- The study proposal outlines a good general strategy to answer the study question on page 16.
- The ambient air quality characterization study is recognized as a very important component.

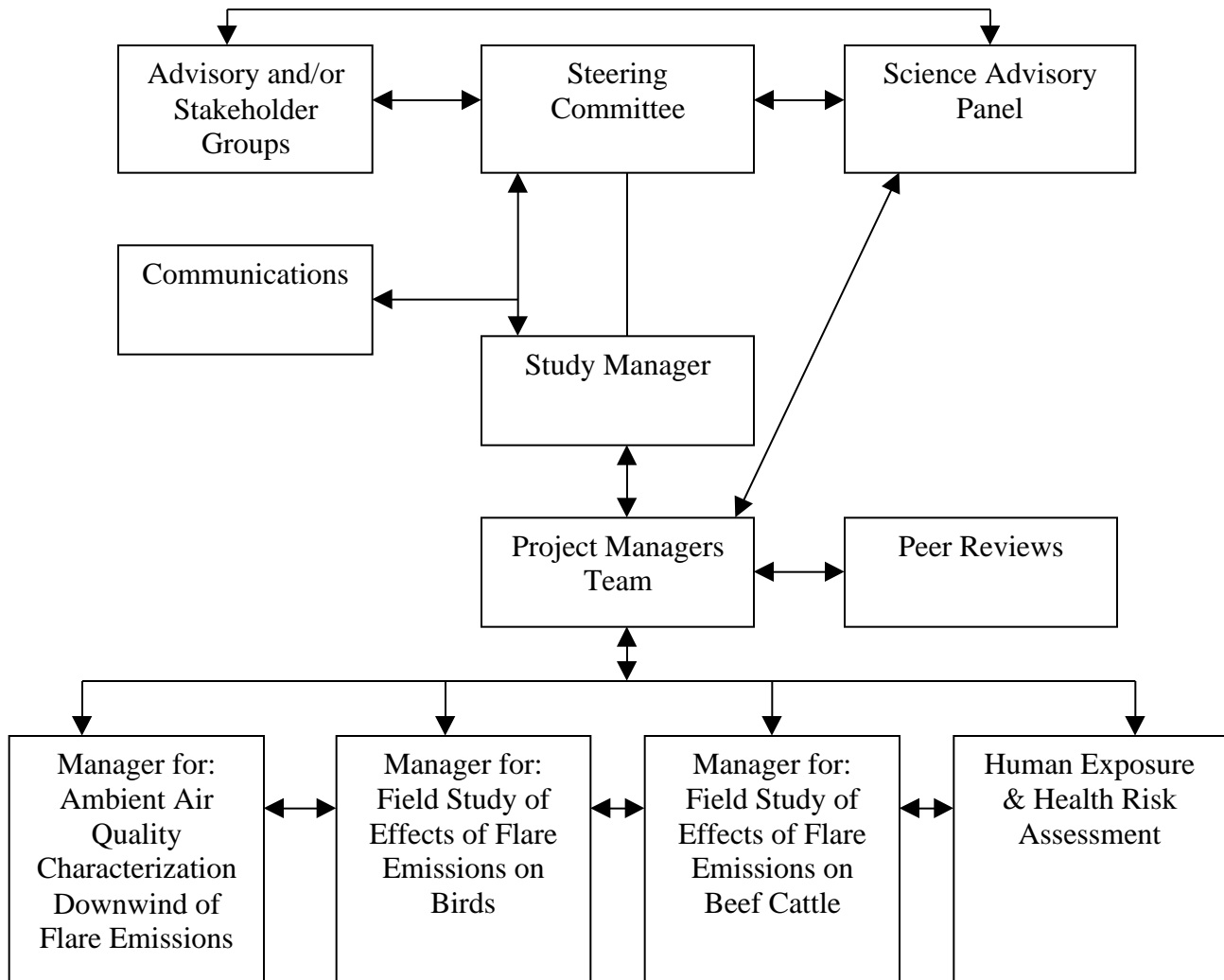
- The human health, animal health, and wildlife studies are necessary.
- The wildlife study is regarded as a cost-effective source of ambient exposure on a sensitive species that will add to the science of the study.
- The biomarker study and the reproductive toxicology study could be deferred until results are obtained from the herd study.

It should be noted that the proposed study approach and specific study elements need to be reviewed further with the Science Advisory Panel once it is established and also with stakeholders. It is expected that some changes will be made based on this input. However, the general scope and focus of the research is not expected to change.

5. Proposed Study Management Structure

The proposed management structure for Phase I of the study is outlined in Figure 3.

Figure 3: Proposed Study Phase I Management Structure



The following is a general overview of the key elements of the proposed Phase I study management structure.

- **Steering Committee** – The Steering Committee would plan, oversee, and supervise the study. The Committee would consist of government representatives only and each province could have a maximum of four representatives on the committee (this is to allow different government departments, e.g., health, environment, energy, agriculture, etc. to be represented). The study manager and Science Advisory Panel co-chairs would be ex-officio members of the committee.
- **Science Advisory Panel** – This would be a panel of world-class scientific experts to review proposals, progress, and final results.
- **Advisory and/or Stakeholder Groups** - Various groups may be called upon at the discretion of the Steering Committee. Funding partners would be invited to participate in a stakeholder advisory committee. The Clean Air Strategic Alliance Animal Health Working Group could be one of these groups.
- **Communications** - Communication on this project will be very crucial. At the initial stage of the study the Steering Committee would develop a communication strategy and plan.
- **Study Manager** - The manager for the study would be the person responsible for the overall management of the components of the study. Management would include administration, accounting, and supervision of project managers.
- **Peer Reviewers** - The peer reviewers would be university professors or other experts from various disciplines who are capable of reviewing specific aspects of the study components as they are developed.
- **Project Managers** – The exact project management structure at the research level is yet to be determined. There will be a project manager for each component of the study and there should be interaction between these managers. The Project Manager team may be formed to ensure that research efforts are coordinated and that preliminary findings are shared on a regular basis. Also, this team could be responsible for preparing a synthesis report of all work at the end of the study

6. Timelines

- Draft overall study plan and preliminary study budget prepared and reviewed by Ministers in February, 2000.
 - Approval received to proceed with study February, 2000.
 - Confirmation of funding in February, 2000.
 - A formal Steering Committee established by April, 2000.
 - A study manager/lead appointed by April 1, 2000.
 - A finalized study plan reflecting stakeholder input completed by March 31, 2000.
 - Contracts for undertaking the four research elements of the study will be in place by April 30, 2000.
 - The timelines (see Table 1) for completion of the various study components including preparation of preliminary study reports are estimated to be:
 - Phase I
 - i) Health Effects on Beef Cattle of Chronic Exposure to Flare Emissions – Spring 2004.
 - Phase II
 - ii) reproductive toxicology in lab animals – Spring 2005
 - iii) residues of flare emissions in beef – Spring 2006
 - A peer review consolidated report on Phase I study findings for stakeholder review will be completed by September 30, 2004.
 - A final stakeholder reviewed report on the Phase I study finding for Ministers will be completed by December 2004.
 - The proposed human health study will occur over a three to five year time frame.
- (Note: Timelines are tentative)**

7. Funding

The estimated base budget for Phase I of the study (i.e. the four core elements) is approximately \$10.19 million (note: an amount of \$2.5 million of this is in Alberta Health and Wellness budget submission for 2000 to 2005). An additional \$0.81 million is necessary for the study manager position, the Stakeholder Advisory Panel, other administrative costs, e.g. travel, printing, et cetera, and to cover costs associated with the Science Advisory Panel.

Table 1: Brief Description and Timelines for Study Components

Study Element	Brief Description	Study Outcomes	Cost	Start Date	Finish Date	Proposed Researchers
Phase I						
Ambient Air Quality Characterization	Field study measuring ambient air quality downwind of flare stacks where herds are located	<ol style="list-style-type: none"> 1. Which Substances 2. Marker Substances 3. Potential Exposure 4. tox. Information 5. herd exposure gradient 	\$.45M	3-00	3-01	Request for proposals
Human Exposure and Health Risk Assessment	Field study measuring exposure, dose, and response for humans living close to flares compared to a control population.	Respiratory and cardiac health, immune system function, and other biomarkers of effect.	\$2.5M	3-00	0-03/5	AHW. Centre for Toxicology, and University of Alberta
Health Effects on Beef Cattle of Chronic Exposure to Flare Emissions	Field study of exposed and control beef cattle herds from Man. To B.C. in relation to flaring.	Reproductive performance, general health assessments, and immune system function.	\$6.64 M	1-00	10-02	Western College of Veterinary Medicine and Toxicology Centre, University of Saskatchewan
Health Effects on Birds of Chronic Exposure to Flare Emissions	Field research in conjunction with cattle study.	Reproductive performance, general health, and immune system function.	\$0.6M	3-01	9-02	Western College of Veterinary Medicine, Toxicology Centre, and Canadian Cooperative Wildlife Health Centre
Phase II						
Reproductive Toxicology of Flare Emissions	Controlled laboratory study of the effects of flaring on rats.	Whether emissions have reproductive effects and dose-response data.	\$3.7M	10-02	10-05	Request for proposals
Potential Biomarkers of Flare Emissions Exposure	Laboratory study with rats to verify effects of biomarkers and apply results to cattle in field.	Analytical techniques, understanding biomarkers, levels in cattle, and health significance.	\$2.3M	10-02	10-06	Request for proposals

APPENDIX I

**SUMMARY OF THE
FIVE PROPOSED RESEARCH
ELEMENTS THAT CONSTITUTE
THE TOTAL STUDY PROPOSAL**

Introduction

Most health concerns related to flare emissions are associated with infertility/reproductive disorders, congenital defects, respiratory irritation, or immune system dysfunction leading to reduced reproduction and increased incidence of infectious diseases and poor performance.

The evidence for adverse effects in animals and humans from exposure to solution gas flare emissions remains largely anecdotal. Inhalational toxicology studies conducted in the U.S. using laboratory rats failed to demonstrate a link between chronic hydrogen sulfide (H₂S) exposure and adverse effects on rat fertility, or the health of offspring. However, flare emissions are comprised of more than 250 different compounds, some of which are potential endocrine disrupters (estrogen mimics), so the focus on H₂S alone may be misleading. In addition, humans, livestock, and wildlife species are exposed to a variety of chemical and environmental stressors in the field that may exacerbate or synergize the potential toxic effects of flare emissions. Field and laboratory studies are required to answer, with an acceptable degree of certainty, the question: “Are flare emissions adversely impacting human or animal health or livestock productivity, and what are safe levels of exposure?”

Recent epidemiological studies have shown potential associations between flare emissions and reduced reproductive performance in cattle on a local level, but investigations have not been of sufficient scope to distinguish potential exposure-related effects from the normal background incidence rate of the various diseases reported. The possibility that flare emissions have reproductive effects is also speculative because no reproductive toxicological studies have been done on the types of complex mixtures of compounds found in flares. With respect to biomarkers of flare emission compounds, no research or studies have been conducted.

To address these uncertainties five research study elements are proposed. One “optional” research study element to address wildlife health issues is also proposed to complement the research elements and increase the comprehensiveness and completeness the overall study. A brief overview of each of these studies follows.

STUDY PROPOSALS

A. “Ambient Air Quality Characterization Downwind of Flare Emissions”

The following is a brief description of the characterization proposal of ambient air quality.

Current measurements of ambient air quality downwind versus upwind of sweet and sour flare stacks are insufficient to establish clearly the presence and concentrations of substances downwind of flares. There is a need for a significant increase in the amount of information so that the research teams can determine marker substances and the possibility of passive monitors for those marker substances. This would be done in all four provinces. In order to ensure a proper gradient of exposure when the field study begins, estimates of ambient concentrations need to be made from information about flare types, topography, and weather.

Researchers: The characterization would be contracted through requests for proposals.

Approach: This would be a field study measuring substances at different distances downwind of sweet and sour flare stacks. Substances measured would include polycyclic aromatic hydrocarbons (PAHs), particulates, volatile organic compounds (VOCs) and sulphur compounds. The number and types of flare stacks monitored would be determined on the basis of potential herd exposure.

Duration One year.

Budget: \$450,000

Linkage: This element is linked to all the other research elements and is a pre-requisite for them. It would help answer the question of which marker substances to select and how they may be inexpensively monitored prior to commencing the field study..

Study Output:

- i) Presence and concentrations of substances downwind from sweet and sour flares.
- ii) The basis for the researchers to select marker substances.
- iii) An indication of the nature of animal and human exposure.
- iv) Detailed information required for the reproductive and residue toxicological studies.
- v) An expected exposure gradient for the selected herds.

B. “Human Exposure and Health Risk Assessment”

The following is a brief description of the research proposal for human health.

People living in close proximity to solution gas flares frequently voice concerns about the effects of these emissions on their health. In addition, a number of the chemicals identified in flare emissions are recognized toxins for humans. The human risk assessment component will measure the exposure, dose and response for humans living in close proximity to solution gas flares.

Researchers: The research would be conducted by Alberta Health and Wellness in association with the Centre for Toxicology and the University of Alberta.

Approach:

The concept of a continuum from source of contamination to the final health effect is a basic feature of all contemporary risk assessments. Determining the risk posed by environmental contaminants to human populations requires knowledge about the following fundamental components:

- Source of contaminants;
- Transport of agents in the environment;
- Exposure of individuals and communities to the contaminants of concern;
- Dose received by those exposed;
- Early biological effects resulting from the dose; and
- Overt health effects.

The output of each component in the chain of events serves as input for the next, and any lack of information on one component impairs our ability to make accurate assessments of the associated health risks. In order to ensure that adequate information is collected for an accurate assessment, the Total Exposure Assessment Method developed by the U.S. EPA will be used to guide the study protocol. The study will measure the exposure, dose and response for humans living in close proximity to solution gas flares and compare this with a control population. Objective measures of exposure, dose and health response for both an exposed and a control human population will be obtained to support the comparison. Health outcome measures will include respiratory and cardiac health, immune system function and other known biomarkers of effect. In addition, data on behavioral, lifestyle, social, economic and other confounding variables will be included.

- Duration:* The study would take place over a three to five year time frame to ensure, among other things, adequate characterization of potential seasonal variations.
- Budget:* \$2.5 million will be required for the human health component.
- Possible Linkages:* Owners and workers associated with the cattle health component could be incorporated into the sampling frame. The study could incorporate human biomarkers of exposure in parallel to the other core study of biomarkers.
- Study Output:*
- i) A comprehensive assessment of the level of exposure to solution gas flare emissions for humans including source characterization and quantification of the relative contribution of outdoor and indoor air to the total exposure.
 - ii) The dose associated with exposure to specific contaminants.
 - iii) A measure of the health risk associated with exposure.

C. “Health Effects on Beef Cattle of Chronic Exposure to Flare Emissions”

The following is a brief description of the research proposal for this study element.

- Researchers:* The research would be conducted by the Western College of Veterinary Medicine (WCVM) and the Toxicology Centre at the University of Saskatchewan.
- Approach:* Exposed and control beef cattle herds in British Columbia, Alberta, Saskatchewan and Manitoba would be studied (approximately 200 herds in total). The health outcome focuses would include:
- reproductive performance (including abortion, stillbirth, calf mortality, calving interval, and non-pregnancy),
 - general health assessments e.g., growth rate, and infectious disease incidence,
 - immune system function (including ELISA, delayed type hypersensitivity response, differential and total white cell counts, changes in leukocyte subpopulations, phagocytosis, alveolar macrophage function assays.
- Study sites would be chosen to include the entire range of sweet and sour solution gas (battery site) flaring exposures. Extensive exposure monitoring would be part of the study.
- Duration:* The study would cover one reproductive cycle from conception to weaning (Spring/Summer 2001 to fall of 2002).
- Budget:* \$6.64 million
- Possible Linkages:* The “optional” research element related to wildlife would be integrated into this study if it were decided to conduct this research element.
- Some work on flare emission biomarkers in beef could also be conducted as part of this research (This has not been scoped or budgeted).
- Study Output:*
- i) A comprehensive assessment of whether or not beef cattle exposed to sour or sweet solution gas flare emissions in actual field conditions are more likely to have adverse health or reproductive outcomes than unexposed animals.
 - ii) An assessment of the relationship (if any) between the magnitude and duration of flare emission exposure and any observed adverse animal health effects.

D. “Health Effects on Birds of Chronic Exposure to Flare Emissions”

From a general environmental protection assessment standpoint, it would be desirable to select some sensitive wildlife species and determine if these species are being impacted by exposure to flare emissions. Selecting sensitive wildlife species for study also increases the ability to extrapolate results of the study to other species.

The following is a brief description of the research proposal for this study element.

Researchers: The research would be conducted by the Western College of Veterinary Medicine, the Toxicology Centre and the Canadian Cooperative Wildlife Health Centre.

Approach: Tree swallows and American kestrels would be studied in selected flare exposed and control sites. These species have been selected for the following reasons:

- They are native species that are likely to be found near most of the cattle study sites.
- They can be encouraged to nest in specific locations facilitating monitoring and sampling.
- They are higher level consumers, e.g., insects, and in the case of kestrels, insects and small mammals. Their exposure to lipophilic flare emission substances may be higher than primary feeders, e.g., cattle, rodents, et cetera.
- They have small home ranges which reduces variability in exposure estimates.
- They have high metabolic and respiratory rates and are usually more sensitive to inhaled toxicants than mammals making them a potential sensitive indicator of possible impacts on other wildlife.
- There is research experience with using these species as indicators of environmental contaminant effects.

The health outcome focuses of the research would include:

- Reproductive (including clutch size, egg mass, hatching success, fledgling success, and breeding dates)
- General health e.g., growth rates, incidence of infectious disease.
- Immune system function/competence (similar to those for the beef cattle study)
- Others e.g., hepatic P₄₅₀, microsomal enzymes, and residues of selected contaminants in egg yolks

Data would be collected over two successive breeding seasons. Study sites would be selected to cover the entire range of sweet and sour solution gas flaring exposures. The exposure monitoring done as part of the cattle study would provide all the exposure monitoring for this research element.

Duration:

The study would cover two successive breeding seasons.

Budget:

Approximately \$.6 million

Possible Linkages:

This would be a nested study within the beef cattle study to take advantage of the exposure monitoring that is part of that study. The study links to the beef cattle and toxicological research elements in that it may increase our insight into potential toxicological mechanisms operating in cattle.

Study Output:

- i) An indication of whether or not sensitive wildlife species are being impacted by flare emissions.
- ii) Possible identification of sensitive and specific biological markers of solution gas exposure that could be used for future monitoring operations.

E. “Reproductive Toxicology of Flare Emissions”

Previous researchers have identified the desirability of conducting reproductive toxicological testing on flare emissions. Such testing would help determine whether or not exposure to certain mixtures of flare emission compounds can have reproductive effects and if so what are the effects and at what levels do they occur. Reproductive effects are often cited by producers as an impact of flare emissions and epidemiological studies have identified possible associations between flare emission and adverse reproductive outcomes in cattle.

The following is a brief description of the research proposal for this study element.

<i>Researcher:</i>	Either the Alberta Research Council (ARC) or a private/contract laboratory or research institute.
<i>Approach:</i>	This would be a laboratory study using purebred rats. The industrial standard OECD Guidelines for testing the reproductive toxicology of chemicals would be followed. The effects of both sweet and sour solution gas flare emissions on the fertility and toxicity in the parental generation of rats, and on birth defects and fertility in the offspring generation would be measured. For each flare emission type (i.e. sweet solution gas and sour solution gas), there would be a control and a high to low gradient of exposure.
<i>Duration:</i>	3 years
<i>Budget:</i>	\$3.7 million
<i>Linkage:</i>	This research has linkages to all the other research elements. It would help answer the question of whether or not exposure to flare emissions can have, or would be expected to have, reproductive implications (note: This type of toxicological data could also be extrapolated to possible human health risks/impacts from flare emissions).
<i>Study Output:</i>	<ol style="list-style-type: none">i) Reliable data on whether or not certain mixtures of flare emission compounds have fertility/reproductive effects on animals and the type/nature of these effects.ii) Dose – response data for any fertility/reproductive effects that are measured.

F. “Study on Potential Biomarkers of Flare Emissions Exposure”

It would be desirable to determine if biomarkers for flare emission exposure can be established in animal tissue. This information would assist in the diagnosis of exposure and allow determination of the potential of emissions from flares to translocate into animals used for human food. This has potential human implications and product marketability / perception implications.

The following is a brief description of the research proposed for this study element.

<i>Researcher:</i>	Either the Alberta Research Council (ARC) or a private/contract laboratory or research institute.
<i>Approach:</i>	The research would have three components. The first would be laboratory exposure experiments with rats to develop and verify analytical methods and a chemical translocation model. The second would be controlled exposure of cattle to various concentrations of flare emissions and periodic blood and tissue/fat analysis. The third element would be exposing cattle to flare emissions in an actual field situation and comparing tissue/organ biomarkers to those of a control herd. An assessment of the health and product quality implications of any biomarker levels measured would be undertaken.
<i>Duration:</i>	4 years
<i>Budget:</i>	\$2.3 million
<i>Linkages:</i>	If conducted in conjunction with the reproductive toxicology work the cost of this research would be reduced to approximately \$1.7 million due to savings in capital investment and manpower. This study element might be enhanced if the beef cattle field study element were to also include a residues element. This possibility will be pursued as study plans are further developed and finalized.
<i>Study Output:</i>	<ol style="list-style-type: none">i) Analytical techniques for measuring flare emission biomarkers in tissue and blood.ii) An understanding of behavior and fate of flare emissions in biological organisms.iii) The identification of biomarkers that could be used to estimate the exposure of animals to flare emissions.iv) The level of flare emission biomarkers in various tissues/organs in beef cattle under different exposure conditions.v) An assessment of the health significance of the tissue biomarkers measured.